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A Policy Analysis of the Endangered Species Act

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ABSTRACT

The goal of this thesis was to identify and analyze common characteristics that are shared by recovering species listed in the Endangered Species Act (ESA). NatureServe population data was used to determine which listed species were recovering, and a logistic regression analysis was performed to identify which aspects of the ESA most contribute to recovery. Of the 747 species tested, only 24% had a population that was stable or improving. Time listed and classification group were found to significantly influence recovery, and recovery plan presence and critical habitat designation also increase the odds of recovery. The analysis found no relationship between species recovery and average annual funding, and species listed as “threatened” were just as likely to be recovering as those listed as “endangered”.

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INTRODUCTION

The Endangered Species Act (ESA) has been the key piece of wildlife protection policy in the United States for nearly five decades. Passed into law in 1973, the ESA was not the first law regarding wildlife in the United States but it was, and remains, the most expansive. Administered by the US Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS), it currently protects more than 1,400 endangered and threatened plant and animal species. When the ESA was passed, it was a universally supported act of legislation. It received only 12 votes against in the House and Senate combined. However, this was likely the peak of the act's popularity. The Tellico Dam project quickly drew attention to the act's wide-ranging authority, and it has had a variety of detractors ever since. Many of those detractors oppose the ESA's overarching authority. They claim that the act infringes on private property rights, and that no act should be able to tell someone what to do with their land, no matter what kind of plants and animals inhabit it (Czech and Borkhataria 2001, Runion 2011). Some landowners have gone so far as to modify their land to prevent it from being habitat for a listed species (Bean 1998, Lueck and Michael, 2003, Michael 2000). Others claim that the act is a waste of money, and that the millions spent every year on species recovery and protection should be spent on "more important" ventures, and that protection of critical habitat for endangered and threatened species hinders economic growth and takes away land that could be used for other means (Lingley 2013, Runion 2011, Shogren 1998).

Another point of contention is the ESA's general effectiveness. Many people believe that the act cannot justify its exorbitant funding due to its failure to achieve its goals (Runion 2011). Congressmen routinely call for the removal of the law, often citing the poor species recovery rate as the primary reason (Lingley 2013). The ESA has also lost the support of some environmentalists, who believe the act does not do enough for wildlife conservation (Alagona 2013). While they respect the ESA's work in preventing the extinction of many species, they do not believe it has done enough to help species populations recovery, and they are convinced the evidence is on their side (Alagona 2013, Scheer and Moss 2012). The recovery numbers can be quite damning: 1,766 species have been listed under the ESA at some point; only 96 of those species have been delisted. Out of those 96 delistings, only 65 were due to species recovery, with the remaining delistings being due to extinction or an error in the original data. Using these numbers, the recovery rate is under 4%, which is difficult to consider successful. However, there is more to the ESA than simply delistings. The FWS releases a recovery report to Congress every 2 years which contains data on the recovery status of every species listed. These numbers may describe a clearer picture of how the ESA is performing, and can help us determine more accurately if the ESA is indeed failing or succeeding. Previous studies have used these reports to analyze the ESA effectiveness, with varying results (Male and Bean 2005, Schwartz 2008, Taylor et al. 2005). Taylor et al. (2005) found that time listed, critical habitat designation and recovery plans all positively affected species recovery. Male and Bean (2005) also found that time listed was a critical factor in recovery, but they found no correlation between recovery and critical habitat.

Considering the debate around the ESA, and the difficulty of determining its effectiveness, this study conducted a policy analysis of the ESA. A policy analysis is a study or evaluation of an existing or potential policy, with the goal of determining the appropriate course of action. Policy analysis are being used more frequently to shape existing policy, often using quantitative studies such as cost/benefit analysis to determine a future course of action (Daniell et al. 2016). In this case, I analyzed the ESA to determine if it is having a noticeable effect on the recovery of endangered species. Using data from the FWS and the NatureServe Explore database (NatureServe 2021), I analyzed the effectiveness of several variables including time since first listed, existence of a recovery plan, designation of critical habitat, and money spent towards recovery. The results of this analysis can help determine if the ESA is an effective way to combat species extinction, and if the money spent towards it is providing the desired benefit.

OBJECTIVES

There are two goals for this study:

1. Identify and describe variables associated with the ESA, then determine which of these variables are associated with the recovery of endangered species.
2. Identify shortcomings, knowledge gaps, and areas of improvement that could improve the potential for recovery of listed species under the ESA.

HISTORICAL BACKGROUND

This section examines the history of laws protecting wildlife species in the United States. The predecessors of the ESA and how they shaped wildlife policy in the United States are first examined, followed by the history of the ESA itself, including how it was passed, its amendments, and the various controversies surrounding it that have shaped the way it is viewed and enforced today.

Prior to the 20th century, the United States had few laws regarding wildlife. There were barely any regulations preventing the killing of wildlife, and those that did exist were only on the state level (Peterson 1999). The first federal law did not come until the early twentieth century, when Congress passed the Lacey Act. Intended to combat illegal hunting, the Lacey Act outlawed “interstate traffic in birds and other animals illegally killed in their State of origin” (Lacey Act of 1900). The Act makes it a federal crime to traffic illegally killed or captured animals, both intentionally and unintentionally. This includes taking animals from one state to another, taking them from marine areas to the states, and importing them from other countries. The original act did not include fish in its protections, so in 1926 Congress passed the Black Bass Act to account for this absence (Black Bass Act of 1926). The Lacey Act has seen several amendments. A 1981 amendment combined the Lacey Act and the Black Bass Act into one in order to more efficiently combat a growing illegal wildlife trade (Littell 1992). Its most recent amendment in 2008 added more plants and plant products to its list of protections. These new protections help combat illegal logging, and prevent the importation of invasive species (Doub 2013).

In 1916, the United States signed a treaty with Great Britain to protect all migratory birds within the borders of the two countries and their territories (which at the time included Canada as a British Territory). To enact this treaty, in 1918 Congress passed the Migratory Bird Treaty Act. The Act forbids killing, possessing, or trading all migratory birds, and it put in place a hunting season for game birds. In 1936, the United States signed a similar treaty with Mexico that was added to the Migratory Bird Treaty Act, and treaties with Japan and Russia were added in the 1970s. Today, the Migratory Bird Treaty Act continues to protect all migratory birds that enter the United States. It allows for the prosecution of anyone who has killed or is in possession of a migratory bird (Migratory Bird Treaty Act of 1918). Until recently, it also protected migratory birds from incidental take. These protections meant that any person or company that unintentionally harmed or killed a migratory bird could be prosecuted as well. This part of the law was used to prosecute fossil fuel companies, loggers, electric companies, and wind farms, and is very similar to Section 7 of the ESA (Doub 2013). In 2017, these incidental take protections were removed from the Migratory Bird Treaty Act.

In 1940, Congress passed the Bald Eagle Protection Act. Intended to prevent the extinction of the national symbol of the United States, the Bald Eagle Protection Act was in a way a precursor to the ESA. The act outlaws all killing and trapping of bald eagles, and also prohibits the take of their eggs or nest. This law was the first to mention protection of a species from “take,” with the definition of the term very similar to the definition in the ESA. Unlike the ESA, the Bald Eagle Protection Act does not allow the right of private action, meaning no private entity can sue on behalf of the species under the act (Bald Eagle Protection Act of 1940).

By the 1960s, a growing environmental movement called for stronger, more comprehensive wildlife protection laws. The first step towards this came in 1964, with the passing of the Wilderness Act. This act created the National Wilderness Preservation System, a network of 54 wild areas to be left in a natural state and with a minimum amount of management. The land was to be closed to all development, including timber harvest, mining, and roads (Wilderness Act of 1964). Originally totaling 9.1 million acres, the system now contains more than 111 million acres of wilderness area. While not specifically created for endangered species, these wilderness areas contain critical habitat for hundreds of species listed under the ESA. It also showed a willingness for Congress to set aside valuable land, and potential economic gains, in order to protect natural areas.

The Endangered Species Preservation Act soon followed in 1966. This was the first major law passed with the specific intention of protecting endangered species. As with most first attempts, this act was not very successful (Littell 1992, Peterson 1999). It prevented the taking of endangered species on federal land, but it had no power to protect species on private land. The act also stated that species were to be protected whenever it was “practical” (Endangered Species Preservation Act of 1966). This vagueness allowed for the protection of endangered species only when it was convenient for the agency (Littell 1992). In an attempt to increase its effectiveness, the act was amended in 1969 with the Endangered Species Conservation Act. This amendment increased federal involvement in wildlife protection and expanded its protection to include some international species (Endangered Species Conservation Act of 1969). Despite this amendment, the Department of the Interior still lacked to power to make a significant difference in the recovery of endangered species, and both acts, the Endangered Species Preservation Act and the Endangered Species Conservation Act, were eventually repealed upon the passing of the ESA in 1973. While ultimately unsuccessful, the Endangered Species Preservation Act and the Endangered Species Conservation Act did make a few important contributions to endangered species protection. The 1966 Endangered Species Preservation Act created the first federally-protected endangered species list, containing 72 species, many of which are still listed today. It also provided much needed funding that went towards research into these species. The 1969 Endangered Species Conservation Act brought about the idea of recovery plans, now an important part of the ESA (Shogren 1998).

Despite the legislative work done in the 1960s, the existence of a legal tool for wildlife conservation was still limited, and public outcry was not diminishing. Further action seemed necessary, and so in 1973 the Endangered Species Act (ESA) was passed by Congress. The bill was remarkably popular, unanimously approved by the Senate and approved in the House by a vote of 390 to 12. That popularity would not last very long, for Congress did not realize the power of the legislation that it had passed. The Tellico Dam controversy in Tennessee would bring the power of the ESA to light, and would greatly decrease the popularity of the act.

The Tellico Dam was a project being built by the Tennessee Valley Authority in the Little Tennessee River. When completed, it would stop the flow of the river, and generate electricity for the surrounding area. The project began in 1967, before the Endangered Species Act, and before any endangered species were known to inhabit the area. The dam was controversial before wildlife even came into play. The locals were having their land claimed by imminent domain, and they enlisted the help of environmental groups to help fight the dam (Roman 2011). In 1973, Dr. David Etnier of the University of Tennessee, who was due to testify as an environmental witness in the Tellico case, discovered a species of fish that was believed to only inhabit in the Little Tennessee River (Murchison 2007). This fish was the snail darter (*Percina tanasi*). A petition to list the species under the ESA was sent to the FWS, and the fish was listed as endangered in November of 1975. This listing meant it was now eligible for protections under the ESA, and opponents of the Tellico Dam argued that the damming of the river constituted a "take" of the snail darter. The battle between the dam and the darter drew national attention, and initially the court ruled that the dam should be completed, despite the fact that it would likely wipe out an entire species (Roman 2011). However, the decision was reversed by the Sixth Circuit, with the declaration that the ESA had the duty and authority to stop the dam construction. The court also stated that no economic cost could compare to the loss of a species, setting a controversial precedent (*Tennessee Valley Authority (TVA) v. Hill*, 1978).

Prior to the *TVA v. Hill* ruling, a Senate subcommittee had approved the completion of the Tellico Dam and had appropriated $9.7 million to the project (Roman 2011). The ruling against the dam upset Congress, and in response they amended the ESA in 1978. This new amendment allowed for exemptions from

ESA regulations in government projects or other cases similar to the Tellico Dam (Littell 1992). A committee formed in order to analyze all cases and grant exemptions when they saw fit. The Tellico Dam project was not granted an exemption by this committee, though the dam would later be completed by Congressional order. Another significant part of this amendment was the requirement of critical habitat. Critical habitat had been an optional tool to use when protecting species, but this amendment made it a requirement to be designated for every species as soon as the species is listed. However, economic factors also had to be considered when designating critical habitat, meaning that not every decision could be based strictly on science, which was contrary to the original intent of the ESA (Doub 2013).

The next two amendments to the ESA basically undid the 1978 amendment. In 1979, the language in Section 7 was changed to ensure that no federal government actions jeopardized the existence of any species (Littell 1992). This would keep exemptions from being given to projects similar to the Tellico Dam. The 1982 amendment eliminated the requirement that economics be considered in the designation of critical habitat and the listing of species. The act was back to making habitat rulings based strictly on science, and it was also easier to list species now that economics no longer had to be considered. The wave of amendments from 78 to 82 were considered a net gain by the supporters of the

ESA. In 1988, the act was amended once again. The FWS was now required to submit biannual reports to Congress on all listed species, and was also required to monitor species that were candidates for listing and that had been delisted within the previous five years. This amendment made it easier to judge the effectiveness of the ESA, since more recovery information would be made publicly available, and it was the last major amendment to the law. Various court rulings have set precedents on the authority of the act, such as the rulings on the spotted owl controversy (see discussion below), but there have been no major changes to the act itself. Some changes to the way threatened species are protected and how species are delisted were proposed by the Trump administration (Friedman 2019), but as of the time of this writing they have yet to take effect.

The ESA remains the most powerful piece of wildlife legislation in the United States. It has seen the number of species under its protection go from 137 species in 1973 to 2,534 domestic and 641 foreign species in 2021. It is currently administered by the U.S. Fish and Wildlife Service (FWS) and the NOAA National Marine Fisheries Service (NMFS), and the Secretary of the Interior has final say on all species listings, delistings, and critical habitat designations. The FWS administers the protections of the terrestrial and freshwater species, while the NMFS are responsible for the marine wildlife. The ESA's primary power in helping the recovery of a species is protecting it from take. In this context, *take* is defined in section 7 of the ESA as “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct.” (Endangered Species Act of 1973). These protections apply not only to the species but to the species habitat as well. They apply to both public and private land and violation of these rules is punishable in a court of law. These protections apply only to those species that are listed as endangered; species listed as threatened have less stringent protections and each species protections are tailored to its needs (Endangered Species Act of 1973).

The process of adding a species to the ESA list is both tedious and time-consuming. A petition must be made to have the species listed and the listing must be approved by the Secretary of the Interior. As soon as a species is officially listed, its protection from take begins, and the FWS begins the process of developing a recovery plan for the new species. These recovery plans, written by biologists familiar with the species, are meant to describe the necessary steps for the species to recover to the point that it no longer needs protection. The ESA requires that all species have a recovery plan, but the process for creating these plans is slow and the requirement is not always upheld. Upon the implementation of a recovery plan, a critical habitat is then designated for the species. These areas are supposed to be essential for the recovery of the species that inhabits it and are protected from any destruction or development. Like recovery plans, this designation is also required under the ESA but only a small percentage of species have actually received this requirement (10% according to Taylor et al. 2005).

TERMS

This section examines the different terms of the ESA with more detail, specifically their function and how they have evolved over time.

Recovery Plans

The FWS develops and implements recovery plans for all listed species. These plans are developed by those with a vast knowledge of the species, through a public or private agency (Endangered Species Act of 1973). These plans lay out the species basic information, its primary habitat, and its conservation needs. They then provide measurable goals that, when met, would signal species recovery and would allow for its delisting (Boersma et al. 2001). Finally, they estimate the time required for these goals to be met and the expected cost associated with them. These plans are mandatory for all species, and a report on the progress of these plans is to be provided to Congress every two years (Malcom and Li 2018).

Not all recovery plans are created equal. Some plans take much longer to create and are much more complex due to the nature of the species. Other plans are much simpler, especially for those species where there is limited data. A more recent trend has seen the increase in multispecies plans. These plans are often implemented when multiple species inhabit the same area or ecosystem (Boersma et al. 2001, Hoesktra et al. 2002).

These plans are developed by experts with an advanced knowledge of the species, and are periodically reviewed and updated. Unfortunately, despite the ESA's mandate, not every species has a recovery plan. As of 2019 approximately 75% of US listed species had recovery plans (ECOS 2021). The reasons for absence vary, but the fact remains that over 400 species are missing an important tool that can aid in their recovery.

Critical Habitat

Critical habitat is designated for each species after it has been listed. The designated land can include currently occupied habitat, previously occupied habitat, and habitat that was not previously occupied but is deemed suitable for that species. It includes all of the food, water, shelter, and space that a species needs to survive and recover (Endangered Species Act of 1973). Unlike the listing of a species, the designation of critical habitat can take economic factors into account. If it is determined that some areas are too important economically, their designation as critical habitat will be withheld, provided that their exclusion would not result in the extinction of the species (Plantinga et al. 2014). To help make this decision, two analyses are produced. One analyzes the economics of the region assuming no critical habitat is designated, the other conducts the analysis assuming critical habitat designation. The two are then sent to the Secretary of the Interior whom decides whether or not to approve the critical habitat designation. If the difference between the two analyses is too large, then the Secretary may choose to withhold the designation. This is the only point under the protection process at which economics are allowed to be considered in regards to species recovery (Shogren 1998, Lueck and Michael 2003).

Any action taken by a public or private agency affecting a species' critical habitat is subject to a consultation. This can also include action taken outside of the critical habitat area if that action will have an effect on the area. These consultations, administered by the FWS or NMFS, ensures that there is no destruction or modification to the critical habitat that is detrimental to the species. (Endangered Species Act of 1973).

Species Listing

There are two ways to start the listing process for a species: 1) it can be nominated for listing by the FWS or NMFS, or 2) an individual or organization may petition to have it listed (Shogren 1998). Ultimately, the decision to place a species on the list falls to the Secretary of the Interior. The Secretary can list a species as long as it falls into one of five categories: (1) there is present or threatened destruction of its habitat; (2) there is an overutilization for commercial, recreational, scientific, or educational purposes; (3) there are extreme losses due to disease or predation; (4) there is an inadequacy of existing laws to protect the species; (5) there are “other natural or man-made factors affecting its existent” (Endangered Species Act of 1973). If the FWS deems that a species is worthy of listing, a notice of intent is published, announcing the reasons for listing and asking for public comment on the issue. A final listing determination must be made within one year of the publication of the notice. The final listing decision must be based solely on the scientific and commercial data available (Wilcove et al. 1993). A species can be listed as either endangered or threatened. An endangered species is “any species which is in danger of extinction throughout all or a significant portion of its range”, while a threatened species is “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range” (Endangered Species Act of 1973).

Many critics of the ESA say that, despite the large number of species that have been added to the list over the years, there are still many more species without much needed protection. Both the International Union for Conservation of Nature (IUCN) Red List and the NatureServe database have twice as many endangered species designations as the ESA (Harris et al. 2012, Wilcove and Master 2005). Of course, these lists do not have to deal with the bureaucratic and political hurdles required by the ESA. Despite the ESA’s insistence of only using the science when designating a species, there is room for subjectivity in the process (Wilcove and Master 2005). The amount of new species that are listed appears to be affected by the political party controlling the executive branch (Stinchcombe 2000). The number of new listings plummeted under the Bush Administration, with only 60 between 2001 and 2008. They rebounded well under Obama, with 390 new listings over the next 8 years, only to take another drastic dip under the current administration, with only 17 between 2017-2019 under the Trump administration (ECOS 2021).

Delisting

If the FWS finds that a species is showing significant recovery and its population has rebounded, it may be a candidate for delisting (ESA Section 4). In order for it to be delisted, it must have met its recovery goals laid out for it in its recovery plan. The process is similar to the listing process. First, the FWS or NMFS conducts a recovery assessment to determine if indeed its population has improved and if it can maintain its population if its protections are removed (U.S. Fish and Wildlife Service 2011). If the assessment is favorable, then its delisting will be proposed in the Federal Register and the opinions of the public and experts in the field will be gathered. If all remains favorable, then the delisting may be completed. The process is the same when downgrading a species from Endangered to Threatened (Doub 2013).

Once a species is delisted, its population is monitored for a minimum of five years in order to ensure that no unforeseen threats occur and its population remains stable. If problems arise, then the species may be relisted. The delisting process has been used much less than its listing counterpart. Since 1973, only 90 species have been delisted, of which only 58 have been due to species recovery. The remaining 32 delistings were because a species was originally listed in error or the species went extinct (ECOS.FWS.gov). These numbers are a cause of great debate among the conservation community, as they are used by some to argue against the ESA being an effective law (Lingley 2013).

Take

Every species listed on the endangered species list is protected from take. As defined by the ESA, *take* means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct" (Endangered Species Act of 1973). These protections are very broad, and have proven to be very controversial. This definition can and has been interpreted many different ways over the years, and it has been the subject of many court cases.

This definition of take was challenged in Hawaii in 1981, when environmental groups sued the state to stop the grazing of sheep and goats. The environmentalists argued that the grazing was damaging the habitat of the palila

(*Loxioides bailleui*), and that this constituted a taking under the ESA. The court sided in favor of the environmental groups, ruling that the habitat destruction did count as “take” and that the law mandated that the government step in and prevent the grazing. The court cited that the word “harm” within the “take” definition could include indirect harm caused by habitat destruction (*Palila v. Hawaii Department of Land and Natural Resources*, 1981). In response to this ruling, the Secretary proposed to amend the ESA’s definition of “harm”, but the proposal received much negative feedback, and was abandoned for a more moderate definition. The new definition stated that habitat modification alone was not enough to be considered take, but actual harm to the species caused by the modification must occur before action is taken (Littell 1992).

In 1988, in *Sierra Club v. Lyng*, the court ruled that US Forest Service clear-cutting was causing “harm” to the red-cockaded woodpecker (*Leuconotopicus borealis*). The ruling stated that “harm” does not require proof of death. It also ruled that failing to act to protect a species can also be considered “take” (*Sierra Club v. Lyng*, 1988). In 1989, the court ruled that the continued registration under the Environmental Protection Agency of a pesticide known to cause harm to listed species also counted as “take” under the ESA (*Defenders of Wildlife v Administrator, Environmental Protection Agency* 1989).

While these early cases helped shape the definition of “take”, two cases in 1995 involving the Northern Spotted Owl (*Strix occidentalis caurina*) brought the “take” argument into the eye of the general public. In *Forest Conservation Council v. Rosboro Lumber Co*., the court ruled that the building of a logging road would constitute as a “taking” of the Northern Spotted Owl. It stated that evidence of past injury was not required to prove “harm”, and that the potential for future injury was enough to be considered “harm” (*Forest Conservation Council v. Rosboro Lumber Co*., 1995). In a second spotted owl case, the court upheld the past ruling that habitat modification could be considered “take”, even if there is no proof that this modification will lead to species killings (*Babbit v. Sweet Home Chapter of Communities for a Great Oregon*, 1995).

In 1999, the FWS released a new definition of “harm”. The new definition is as follows:

NMFS interprets the term ‘‘harm’’ as an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding or sheltering.

The stated purpose of the release of this definition was not to change the law, but to clarify it. It was a direct response to the growing number of cases about the definition of “take”, and *Babbit v. Sweet Home* was referenced in the release. Despite this updated definition, the phrase continues to be a topic of controversy to this day, and faces new court challenges annually (Doub 2013).

JUSTIFICATION

Several studies have tackled this subject previously. Taylor et al. (2005) used logistic regression to test several variables against population trend. They used FWS recovery reports to congress over a 14-year period as their source of population trend data, and their data set included 1095 species. They found that time listed, existence of recovery plans, and critical habitat significantly affected recovery. They also found that species listed as “threatened” were more likely to be recovering than those listed as “endangered” (Taylor et al. 2005). Male and Bean (2005) published a similar study. These authors also used the FWS recovery reports to congress, and included all listed species in their dataset. They found that time listed strongly correlated with recovery, and that taxonomic class and annual funding also affected population trend. Having critical habitat defined did not correlate with recovery (Male and Bean 2005).

Suckling (2006) analyzed the endangered species in the northeastern United States. This study had a smaller sample size (n=56) but took a more detailed approach to the population trend number. They used recovery plans, previous studies, and census data to acquire population trend. In the study, 93%

of species populations were stable or increasing. They also found that the average expected recovery time for each species is 42 years (Suckling 2006).

Luther et al. (2016) analyzed how funding is distributed amongst listed species, and if it correlates with recovery. They found that funding did correlate with recovery, and that there was no difference in funding between species listed as “threatened” or “endangered” (Luther et al. 2016). Luther and Gentry (2019) analyzed funding amongst all listed vertebrates, and also looked at recovery rates of listed species. They used 5-year status reviews of each individual species to gather their population trend data, and they found that 30% of species were stable or improving. They found that funding rates did not differ between taxonomic class, and that funding did not correlate with species population trend (Luther and Gentry 2019).

These previous studies have found that time listed is highly correlated with recovery, and a species is most likely to be recovering when it has been listed for at least 14 years (Male and Bean 2005). It has been 16 years since the last study that analyzed all listed species (Male and Bean 2005, Taylor et al. 2005). The 1990s saw a huge wave of newly listed species, with 728 species added to the ESA between 1990 and 2000. Most of these new species have not been listed long enough to be showing recovery at the time of the previous analysis. Thus, the purpose of this study was to use current data sources available to describe the different variables considered by the ESA for the recovery of endangered species and determine which of those factors most contribute to the recovery of species. This analysis included all of the species listed under the ESA as opposed to one specific group (Luther and Gentry 2019) or area (Suckling 2006). This analysis included 9 independent variables, more than previous studies have included, and also used a different data source for the recovery data. Previous studies (Male and Bean 2005, Taylor et al. 2005) used the FWS Recovery Reports to Congress for their recovery data. These recovery reports formally provided a “population trend status” for each listed species, but this data is no longer being provided by the FWS. As an alternative I used the NatureServe Explorer database to obtain my recovery data (NatureServe 2021). By expanding the dataset and the number of variables tested, and by utilizing a database with a wide variety of data sources, we can get a more complete analysis of the ESA.

METHODS

The success of the ESA should not be measured by the number of delisted species (Suckling et al. 2012). It takes time for a species to recover to the point of delisting, and 80% of species have not been listed long enough to have recovered based on expectations detailed in species recovery plans (Suckling et al. 2012). An alternative approach is to look at population trends (increasing or decreasing abundance) during the period the species has been listed. Many studies have used this method to judge the success of the ESA (Male and Bean 2005, Suckling 2006, Suckling et al. 2012, Taylor et al. 2005). These studies obtained their species population data directly from the FWS biannual *Recovery Report to Congress*. In these reports, a species status was presented as either improving, stable, or declining. Beginning in 2011, the species recovery status was removed from the FWS biannual reports, with the FWS citing a “common misuse of information” as the reason for the removal (U.S. Fish and Wildlife Service 2012).

Because this recovery status is no longer available, the data used in this analysis was collected from the NatureServe database (NatureServe 2021). NatureServe uses a wide variety of sources to obtain their data. NatureServe has a network of more than eighty programs spread throughout the western hemisphere, and each program has experts in the field collecting data on species and ecosystems. NatureServe also gathers data from outside sources as well, including the FWS. NatureServe updates the dataset regularly, which results in the species profiles being updated as soon as new information is obtained. Each individual species profile is well referenced, and the sources can be found at the bottom of each species profile page. The NatureServe dataset that I used for species recovery status is the “Short-term trend” status. This status is determined by examining population data and trends over the past 10-20 years. The data for this status is acquired from a variety of sources, depending upon the species. The status categorizes species as improving, stable, declining, or unknown.

Only species present in the United States were included in the analysis. Foreign species listed under the ESA do not receive the same protections as species native to the United States, and including them in the study would skew the results. A population status was assigned to every U.S. species listed under the ESA using the NatureServe Explorer website. The status used in the analysis can be found in the individual species page under the subheading “Short-term trend”. All sources used to acquire that status are cited in this section. The status was coded with a “0” representing a population trend that is still declining, and a “1” representing a population that is improving or stabilized.

Not every species has a short-term trend status. Some species have too little information available to make an accurate status available. For example, the Point Arena mountain beaver (*Aplodontia rufa nigra*) has an “unknown” trend status as there are no available sources for this data. Species such as this were excluded from the analysis, as the lack of information makes them impossible to analyze accurately.

I selected the following variables for analysis:

- Designation of Critical Habitat: as discussed earlier, every species is supposed to have one or more areas designated as critical habitat. Past studies have found only 10% of species have designated critical habitat (Taylor et al. 2005). Data on this variable was obtained from the FWS Environmental Conservation Online System (ECOS, ecos.fws.gov) database, the primary source of all information that the FWS has gathered on all listed, delisted, and proposed for listing species. Coded as “yes” for when the species has designated critical habitat or “no” for when the species does not have designated critical habitat.
- Recovery Plan: the ESA requires every listed species to have a recovery plan; however, only 75% of listed species had a recovery plan in 2018 (Malcom and Li 2018). Information on this variable was gathered from the ECOS online database and from the 2015-16 FWS Recovery Report to

Congress (the most recent recovery report available as of November 2020). Coded as “yes” when the species has a recovery plan or “no” when the species does not have a recovery plan.

- Time listed: this variable describes the length of time a species has been listed. Previous studies have found this to be one of the most important variables for predicting recovery (Male and Bean 2005, Taylor et al. 2005). Information on this variable was collected from the 2015-16 Recovery Report to Congress.
- Threatened or Endangered: each listed species is designated as either threatened or endangered. Endangered species have slightly more protections provided to them under the ESA. Information on this variable was gathered from the ECOS online database and from the 2015-16 FWS Recovery Report to Congress (the most recent recovery report available as of November 2020).
- Species or Subspecies: the ESA has both species and subspecies/variants listed under its protection. This variable was included in the analysis to test for differences in the recovery trend between species and subspecies/variants, assuming that subspecies/variants may have the advantage of rescue effect from translocation of individuals of a different subspecies. For example, the Florida panther (*Puma concolor couguar*) is an endangered subspecies endemic to the Florida peninsula

and geographically separated from the rest of the range of the mountain lion s (*P. concolor*). Wildlife managers have attempted to increase the population of the Florida panther by relocating mountain lions from Texas and breeding them with Florida panthers (Roman 2011). This is a management technique that can only be used when managing subspecies or variants. The data for this variable was taken from the NatureServe Explorer database. Coded as “Subspecies” when the plant or animal is categorized as a subspecies or a variant, coded as “Species” when the plant or animal is categorized as a species.

- Range Size: this variable was included in the analysis to test whether historic range size has any effect on species recovery. The NatureServe Explorer database was used to gather this data, under the subheading “range extent”. This number is an approximation based on studies and other data available. The data is normally presented in a range, i.e. 100-250 square km. In the dataset, the highest number was recorded (i.e. 250 sq. km) because this number represents the maximum range size available for the species. This number represents the maximum extent of the historic range of the species, not the current range. Many species have a current inhabited area much smaller than their historic range.
- Funding: every dollar spent towards the ESA is designated towards a specific species or subspecies and recorded in the annual FWS

Expenditure Reports to Congress. All money spent at the federal, state, and local level is recorded, and it allowed to test whether money spent has any effect on species recovery. data on this variable was obtained from the FWS Expenditure reports to congress. The "Species Total" column in the Expenditure Report is the total amount spent on that species by all government agencies that year. In order to account for variability, the reports from 2015, 2016, and 2017 (the three most recent reports available) were compiled and an average yearly expenditure for each species was calculated. For example, for the red-cockaded woodpecker the 2015 species total was $28,091,150, the 2016 species total was $15,769,327, and the 2017 species total was $25,032,102. The value used in the dataset will be $22,964,193, an average of the previous 3 years spending.

- Species classification group: The FWS breaks down listed species into different classification groups. There are 11 groups represented in this study: mammals (M), birds (B), fish (F), reptiles (R), amphibians (A), clams (C), crustaceans (Cr), arachnids (Ar), insects (I), snails (S), and plants (P). Only 1 listed arachnid had available trend data, so it was included in the insect class, leaving 10 tested groups.
- Region: the FWS divides the United States into 8 administrative regions (Figure 1). Every listed species has a designated region that is in charge

of monitoring the species and planning its recovery. A species' designated region is always the region that its primary habitat is located, although some species have large enough ranges that they can occur in more than one region. For species that do inhabit multiple regions, the region where they are most commonly found was the region used in the dataset. The species' region can be obtained from the individual species' page at ecos.fws.gov.

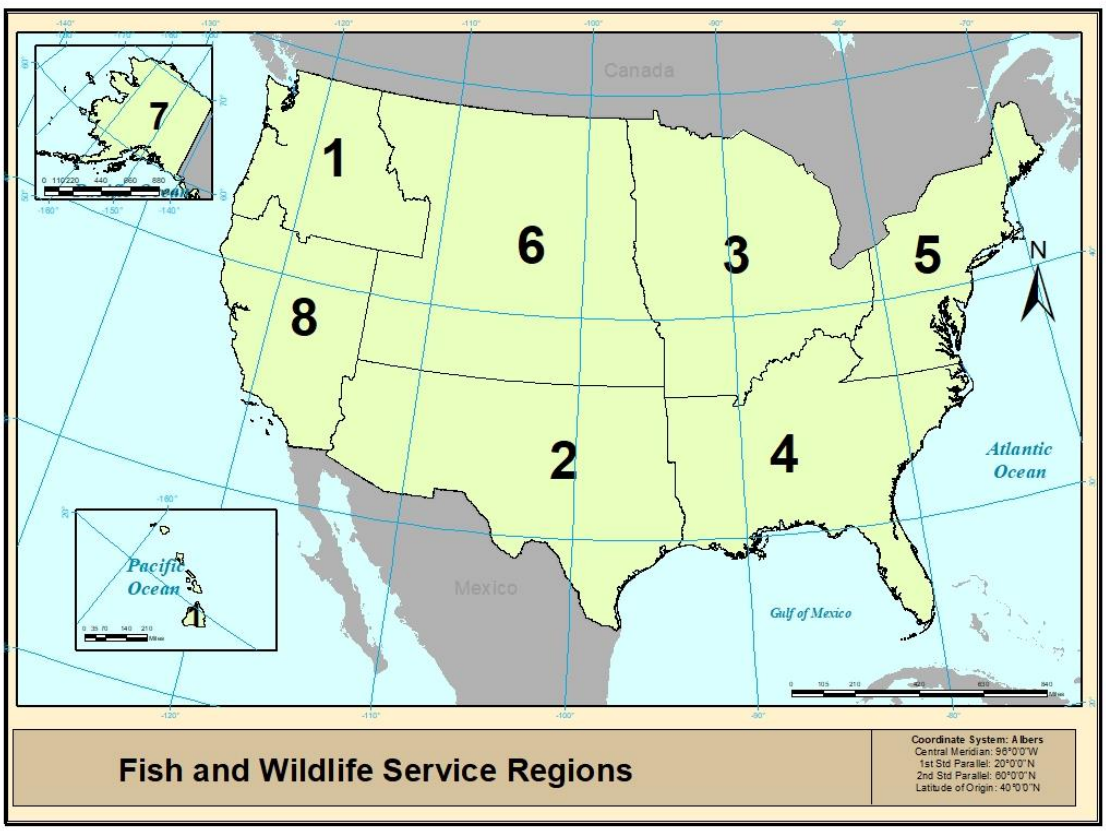

Figure 1. Administrative regions of the Fish and Wildlife Service (fws.gov)

All the data for these variables was compiled in a dataset created and stored in a Microsoft Excel spreadsheet. The SAS procedures MEANS and FREQ (Stokes et al. 2000) were used to describe the different variables. I used logistic regression similar to Taylor et al. (2005). Logistic regression is used when the dependent variable is nominal and contains two possible outcomes. Logistic regression is a form of statistical modeling that is often approximate for categorical outcome variable. It describes the relationship between a categorical response variable and a set of explanatory variables, and most often the response variable is dichotomous (yes or no). Logistic regression does not require key assumptions such as linearity, normality, and equal variance, but it does require data independence, little multicollinearity, and a relatively large dataset (Stokes et al. 2000). My data does not have issue of independence, and the size of my dataset is sufficient.

The response variable, recovery status, is in the format of 0/1 (Y=0 if a negative (declining) state of a population was true, and Y=1, otherwise), and therefore was analyzed using the following logistic model:

$$\text{logit}(\pi) = \log\left(\frac{\pi}{1-\pi}\right) = \alpha + \beta' x$$

where x is a vector of explanatory variables design matrix, which includes both categorical and continuous various, $\pi(=\Pr(Y = 1|x))$ is the response probability to be modeled, α is the intercept parameter, and β is the vector of regression slopes. The SAS procedure LOGISTIC (Stokes et al. 2000) was used to run the model. In its first step all predictors were included (referred to as the full model) and then in its subsequent step, the stepwise selection method (slentry = 0.25, slstay = 0.25) was used to select the final model. Effects of the predictors which were not included in the model were considered as not significant. For the selected model, model assumptions were checked using residual plots and overdispersion was adjusted using the option of PEARSON. The interactions between predictors were not considered. Testing interaction among predictors, while possible, is statistically impractical for a model of this size. The significance of the model parameter estimates was tested using the method of the Wald chi-square test, and their odds ($=\frac{\pi}{1-\pi}$) estimates were calculated by exponentiating the estimate. The estimate statement was used to estimate probabilities.

The SAS procedure GLM was used to test the effects of Groups, Region, Listing, Plan, Habitat, and their two-way interactions on funding. Similar to predicting recovery, a stepwise procedure was used to develop the final model. The assumptions (normality, equal variance, and independence) of the selected model were checked by plotting the residual plots. Collinearity among model predictors was checked using variance inflation factor (VIF); all variables had a VIF < 10.

RESULTS

Data was collected for 1,462 species. This included all listed individual species and subspecies in the United States, but did not include distinct population segments (DPS). Some species have listings for only a distinct segment of their population. For example, the Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) has five different DPS listed as endangered under the ESA. In circumstances such as this, the species would only be counted once, as I could not find the proper data for each distinct population segment.

Tables 1-7 and figures 2 and 3 display the summary statistics of the data gathered for all listed species. Table 1 summarizes how the different classification groups compare to one another. ‘Total Listings’ is the number of species or subspecies belonging to each group that are listed. ‘Percentage of Total’ is how the number of listings in each group compare to the total amount of listings. ‘Yearly Funding per Species’ is the average annual funding that a species in the classification group receives. ‘Average Time Listed’ is the average amount of time that a species within the classification group has been listed. Plants represent the largest classification group, with 60% of the total. Mammals receive the highest annual funding, with arachnids receiving the lowest. Birds have the highest average time listed, with snails and insects having the lowest.

Table 1. Breakdown of funding, time listed, and total listings across classification groups. Data is for all listed species.

Group	Total Listings	% of Total	Yearly Funding per Species	Average Time Listed
Mammals	67	5%	$ 1,266,208	33 years
Birds	85	6%	$ 1,143,905	41 years
Fish	115	8%	$ 1,201,688	34 years
Reptiles	29	2%	$ 748,131	35 years
Amphibians	31	2%	$ 419,228	23 years
Clams	90	6%	$ 122,437	27 years
Snails	49	3%	$ 52,979	21 years
Crustaceans	27	2%	$ 150,167	25 years
Insects	78	5%	$ 163,243	21 years
Arachnids	12	1%	$ 27,029	24 years
Vertebrates	327	22%	$ 1,086,627	35 years
Invertebrates	256	18%	$ 120,176	24 years
Animals	583	40%	$ 664,872	30 years
Plants	879	60%	$ 46,854	24 years
Total	1462	100%	$ 289,938	27 years

Table 2 summarizes how the different classification groups compare to one another. ‘Subspecies Percentage’ is the number of listings in each group that are considered a subspecies or variant. ‘Have Critical Habitat’ is the number of listings in each group that have had critical habitat designated. ‘Have Recovery Plan’ is the number of listings in each group that have a recovery plan. ‘Listed as

Threatened’ is the number of listings in each group that are listed as ‘Threatened’ instead of ‘Endangered’. Mammals have the highest amount of subspecies listed, and crustaceans do not have any listed subspecies. Arachnids have both the highest critical habitat designation rate and the highest recovery plan rate. Reptiles have the highest percentage of ‘threatened’ listings, and arachnids do not have any.

Table 2. Breakdown of critical habitat, recovery plan, species/subspecies, and endangered/threatened variables across classification groups. Data is for all listed species.

Group	Subspecies %	Have Critical Habitat	Have Recovery Plan	Listed as Threatened
Mammals	69%	36%	73%	24%
Birds	35%	29%	86%	16%
Fish	18%	57%	84%	36%
Reptiles	38%	48%	83%	55%
Amphibians	13%	65%	61%	45%
Clams	10%	43%	79%	16%
Snails	6%	33%	61%	27%
Crustaceans	0%	52%	67%	15%
Insects	40%	53%	53%	18%
Arachnids	0%	67%	100%	0%
Vertebrates	34%	46%	80%	31%
Invertebrates	17%	46%	67%	18%
Animals	27%	46%	74%	25%
Plants	16%	49%	75%	18%
Total	20%	48%	75%	21%

Table 3 compares the statistics of the different FWS Region (see Figure 1 for the locations of each region). ‘Area’ is the total land area in millions of acres that each region contains. ‘Total Listings’ is the number of listed species or subspecies within the region. ‘Percentage of Total’ is how the number of listings in each region compare to the total amount of listings. ‘Yearly Funding per Species’ is the average annual funding that a species or subspecies within that region receives. ‘Average Time Listed’ is the average time that a species or subspecies within that region has been listed. Region 7 is the largest region, but it has the fewest number of listings. Listings within Region 6 receive the highest average annual funding. Listings in Region 7 have the highest average time listed.

Table 3. Funding, time listed, and total listings compared between FWS regions. Data is for all listed species.

FWS Region	**Area (millions of acres)**	**Total Listings**	**% of Total**	**Yearly Funding per Species**	**Average Time Listed**
1	90.9	521	36%	$ 121,786	22
2	59.8	159	11%	$ 352,898	30
3	33.5	43	3%	$ 702,563	27
4	31.5	355	24%	$ 212,972	29
5	22.1	41	3%	$ 116,128	30
6	142.2	57	4%	$ 1,995,732	30
7	235.9	6	<1%	$ 867,543	37
8	110.1	280	19%	$ 276,977	29

Table 4 compares the statistics of the different FWS Region (see Figure 1 for the locations of each region). ‘Total Listings’ is the number of listed species or subspecies that have the largest portion of their range within that region. ‘Subspecies %’ is the number of listings in each region that are considered a subspecies or variant. ‘Have Critical Habitat’ is the number of listings in each region that have had critical habitat designated. ‘Have Recovery Plan’ is the number of listings in each region that have a recovery plan. ‘Listed as Threatened’ is the number of listings in each region that are listed as ‘Threatened’ instead of ‘Endangered’. Region 8 has the highest percentage of subspecies among its listings. Region 1 has by far the highest critical habitat designation rate, while Regions 4 and 5 have the highest recovery plan rate. Region 7 has the highest percentage of species listed as ‘threatened’, while Region 1 has a ‘threatened’ designation rate well below every other region.

Table 4. Critical habitat, recovery plan, species/subspecies, and threatened/endangered variables compared across FWS regions. Data is for all listed species.

Region	Total Listings	Subspecies %	Have Critical Habitat	Have Recovery Plan	Listed as Threatened
1	521	14%	71%	67%	8%
2	159	22%	48%	74%	23%
3	43	16%	14%	74%	35%
4	355	15%	29%	84%	26%
5	41	20%	22%	85%	39%
6	57	14%	35%	75%	47%
7	6	17%	33%	50%	50%
8	280	39%	40%	76%	26%

Table 5 compares the statistics of various lengths of time species or subspecies have been listed. ‘Total Listings’ is the total number of species or subspecies that have been listed for the specific amount of time. ‘% of Total’ is how the number of listings in each category compare to the total amount of listings. ‘Yearly Funding per Species’ is the average annual funding from the past three expenditure reports (2015-2017) that a species or subspecies within each category receives. Only 16% of species or subspecies have been listed for more than 40 years. Average annual funding is greater for species or subspecies that have been listed longer.

Table 5. Total listings and annual funding compared to time listed. Data is for all listed species.

Time Listed	Total Listings	% of Total	Yearly Funding per Species
<10 years	216	15%	$ 174,276
≥10 years	1246	85%	$ 308,176
≥20 years	1148	79%	$ 326,138
≥30 years	524	36%	$ 537,424
≥40 years	238	16%	$ 754,265

Table 6 compares the statistics of various lengths of time species or subspecies have been listed. 'Total Listings' is the number of listed species or subspecies that have the largest portion of their range within that category. 'Subspecies %' is the number of listings in each category that are considered a subspecies or variant. 'Have Critical Habitat' is the number of listings in each category that have had critical habitat designated. 'Have Recovery Plan' is the number of listings in each category that have a recovery plan. 'Listed as Threatened' is the number of listings in each category that are listed as 'Threatened' instead of 'Endangered'. Subspecies percentage is greatest among the oldest listings. Critical habitat designation rate is highest among those listings that have occurred within the last ten years, while recovery plan rate is extremely low for recent listings. Species listed as threatened are fairly evenly distributed across the different categories.

Table 6. Critical habitat, recovery plan, species/subspecies and threatened/endangered variables compared to time listed. Data is for all listed species.

Time Listed	Total Listings	Subspecies %	Have Critical Habitat	Have Recovery Plan	Listed as Threatened
<10 years	216	19%	69%	2%	24%
≥10 years	1246	20%	44%	87%	20%
≥20 years	1148	21%	40%	93%	21%
≥30 years	524	27%	22%	97%	27%
≥40 years	238	34%	22%	96%	24%

Figure 2 displays how funding compares between different classification groups. The figure shows the percentage of listings in each group that receive greater than $1 million in average annual funding. Figure 2 shows that less than 5% of total listings receive greater than $1 million annually, while nearly 20% of vertebrates receive that amount. Plants are not included in the graph because no listed plants receive more than $1 million in annual funding.

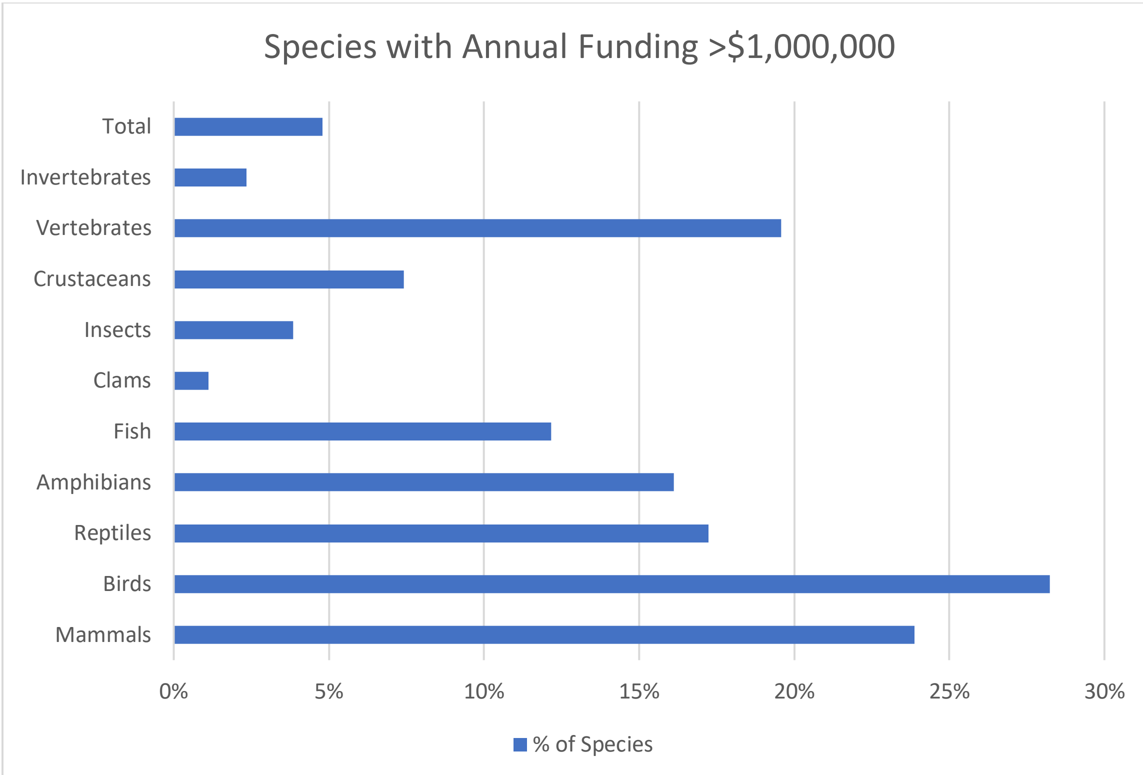

Figure 2. A graph displaying the number of species in each classification group with more than $1 million in average annual funding. Data is for all listed species.

Figure 3 displays how funding compares between classification groups. The figure shows the percentage of listings in each group that receive less than $10,000 in annual funding. More than 50% of listed snails and 40% of listed arachnids receive less than $10,000 in annual funding. Meanwhile, only 5% of listed mammals receive such a small amount of annual funding. Figures 2 and 3 are very useful when shown together, as they display the unequal distribution of annual funding very effectively.

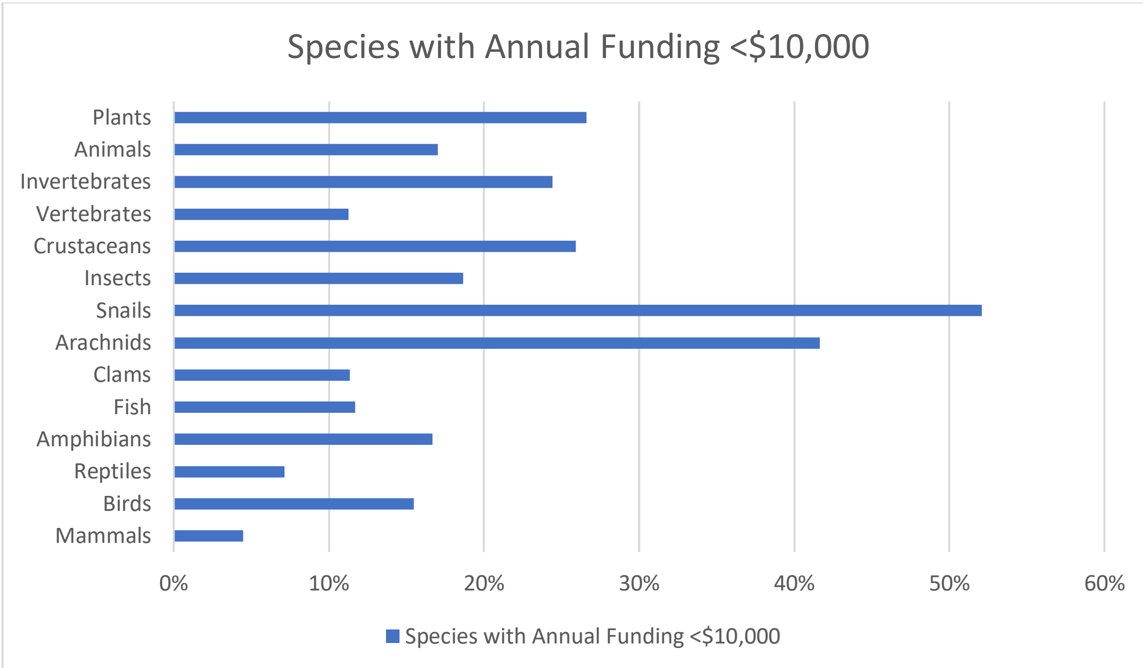

Figure 3. A graph displaying the number of species in each classification group with an average annual funding less than $10,000. Data is for all listed species.

Table 7 displays how range extent compares between different classification groups. 98% of listed snails have a range extent less than 1,000 km^2, while only 20% of listed reptiles have a range extent that small. 33% of listed birds have a range extent greater than 200,000 km^2, while no listed snails or arachnids have a range extent of that magnitude.

Table 7. Range extent and total listings compared to each classification group. Data is for all listed species with range data available.

Group	Total Listings	Range Extent <1,000 km^2	Range extent >200,000 km^2
Mammals	67	43%	33%
Birds	85	58%	25%
Fish	115	49%	14%
Reptiles	29	20%	35%
Amphibians	31	48%	19%
Clams	90	62%	8%
Snails	49	98%	0%
Crustaceans	27	83%	4%
Insects	78	77%	10%
Arachnids	12	91%	0%
Vertebrates	327	48%	23%
Invertebrates	256	77%	6%
Animals	583	61%	15%
Plants	879	75%	6%
Total	1462	70%	10%

A total of 747 listed species had recovery trend data available, and only 694 had all variables used in modeling their effect on species recovery. Only 165 of the species tested had a population that was either stable or improving, and the remaining 529 species were showing population decline. Tables 8 and 9 present a summary for all the predictors.

Table 8 displays the summary statistics for the continuous variables. The average annual funding per species was $420,269.50, with the highest funding for a listed species being nearly $18 million. The average time listed was 27.7 years, and the average range size per listing was about 170,000 square kilometers.

Table 8. Summary statistics for the continuous variables. Data represents the 694 listed species and subspecies that have data available for all the tested variables.

Variable	Mean	Std Dev	Min	Max
Funding (dollars)	$420,269.5	$1,491,449	$375	$17,856,204
Time (years)	27.76037	14.29825	1	53
Range (km^2)	169383	594,357.2	100	2,500,000

Table 9 displays the breakdown of the response variable and the binary predictors. 'Recovery' is the response variable, with '0' representing declining populations and '1' representing improving or stable populations. 'Habitat' is the critical habitat designation variable, with '1' meaning critical habitat has been designated. 'Plan' is the recovery plan variable, with '1' meaning a recovery plan has been created. 'Species' is the species/subspecies variable, with '0' meaning a listing is a subspecies or variant and '1' meaning a listing is a species. 'Listing' is the threatened/endangered variable, with ‘0’ representing a ‘threatened’ listing and ‘1’ representing an ‘endangered’ listing.

Table 9. Summary statistics for the binary predictors. Data represents the 694 listed species and subspecies that have data available for all the tested variables.

Variable	% of the total	
	0	1
Recovery	75.77	24.23
Habitat	56.63	43.37
Plan	28.92	71.08
Species	22.62	77.38
Listing	25.84	74.16

Table 10 displays how the selected species are distributed across the nominal predictors. 32% of all species were located in Region 4, and an additional 22% were in Region 8. Region 7 had the fewest species, with <1% of those tested. Amphibians (A) made up 3%, birds (B) 8%, clams (C) 12%, fish (F) 12%, insects 7%, mammals (M) 7%, plants (P) 40%, snails (S) 5%, reptiles (R) 3%, and crustaceans (Cr) 2%. Figure 4 provides a visual breakdown of selected species by Region.

Table 10. Summary statistics for the classification group and FWS region variables. Data represents the 694 listed species and subspecies that have data available for all the tested variables.

Group	A	B	C	F	I	M	P	S	R	Cr
% of Total	3.08	8.3	11.91	12.72	6.83	7.1	40.16	5.35	2.8	1.7
Region	1	2	3	4	5	6	7	8		
% of Total	19.41	12.32	4.95	31.86	3.75	4.55	0.67	22.49		

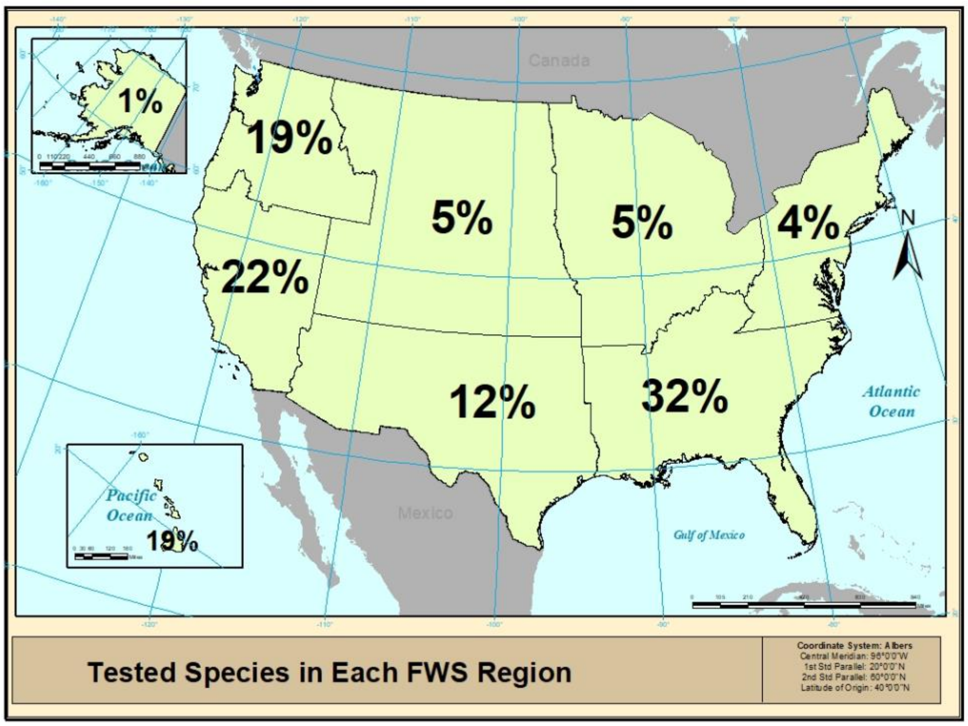

Figure 4. A map displaying the breakdown of tested species per FWS region. Data represents the 694 listed species and subspecies that have data available for all the tested variables.

Classification group (P <.001) and time since listing (P = .0016) had significant effects on the species recovery trend, while all other predictors were not statistically significant (table 11). Overall the full model was significantly (P = .0010) better than the model with only the intercept. Results of logistic regression on all predictors are presented in Table 11.

Table 11. Logistic regression results of the full model. The 'Effect' column contains the nine independent variables tested in the model. The 'Pr > ChiSq' column represents the effect the independent variable had on the response variable (recovery); any number below .05 indicates a significant effect on the response variable.

Type 3 Analysis of Effects			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
Group	9	35.2528	<.0001
Habitat	1	2.4401	0.1183
Time	1	9.9713	0.0016
Species	1	0.6200	0.4311
Funding	1	0.4097	0.5221
Range	1	0.4684	0.4937
Plan	1	1.6047	0.2052
Listing	1	0.1038	0.7473
Region	7	4.1899	0.7577

The final model was selected using a stepwise procedure (Table 12). Based on the criteria slentry=0.25 and slstay=0.25, only four predictors remained in the model, taxa (p <.001), time (p = .0006), habitat (p = .0834), and plan (p = .2122).

Table 12. Logistic regression results for the final model. The 'Effect' column contains the nine independent variables tested in the model. The 'Pr > ChiSq' column represents the effect the independent variable had on the response variable (recovery); any number below .05 indicates a significant effect on the response variable.

Type 3 Analysis of Effects			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
Group	9	41.1278	<.0001
Habitat	1	2.9976	0.0834
Time	1	11.7729	0.0006
Plan	1	1.5566	0.2122

Table 13 lists the odds ratio estimates. Plants was used as the comparison classification group. Plants were 89% more likely to have Trend=1 than clams, and 500% less likely to have Trend=1 than crustaceans. The odds of having Trend =1 when habitat=1 was 1.51 times as large as the odds for habitat=0, and the corresponding value for plan (1 vs 0) was 1.51 times. Also, with every 1-year increase in time, the odds of having Trend=1 increased by 3.9%.

Table 13. Odds ratio estimates for predictors in the final model. Odds ratios estimate the difference in effect on recovery between two variables. The 'Effect' column contains the two variables that are being compared, and the 'Point Estimate' column contains the estimated increase or decrease in likelihood of recovery.

Odds Ratio Estimates			
Effect	**Point Estimate**	**95% Wald Confidence Limits**	
Amphibians vs Plants	3.753	1.448	9.725
Birds vs Plants	3.320	1.660	6.638
Clams vs Plants	0.117	0.027	0.498
Fish vs Plants	2.026	1.066	3.849
Insects vs Plants	1.640	0.743	3.619
Mammals vs Plants	2.955	1.479	5.903
Snails vs Plants	1.441	0.585	3.546
Reptiles vs Plants	0.690	0.181	2.639
Crustaceans vs Plants	6.059	1.891	19.407
Habitat 1 vs 0	1.509	0.947	2.403
Time (1-year increase)	1.039	1.017	1.062
Plan 1 vs 0	1.512	0.790	2.893

Figures 5 and 6 represent the changes in probability following the change in a predictor while keeping the others constant. Clearly the probability of trend=1 increased with time. Much higher probability was observed for habitat=1 than habitat=0 and this became more diverged when time increases; recovery plan behaved in a similar manner. There were differences in probability among the classification groups; for group 3 (C), the probability was low (plants 10 times as likely to be recovering as clams). For group 10 (Cr), the probability was the highest (crustaceans 5 times as likely to be recovering as plants). All group probabilities increased over time at varying rates.

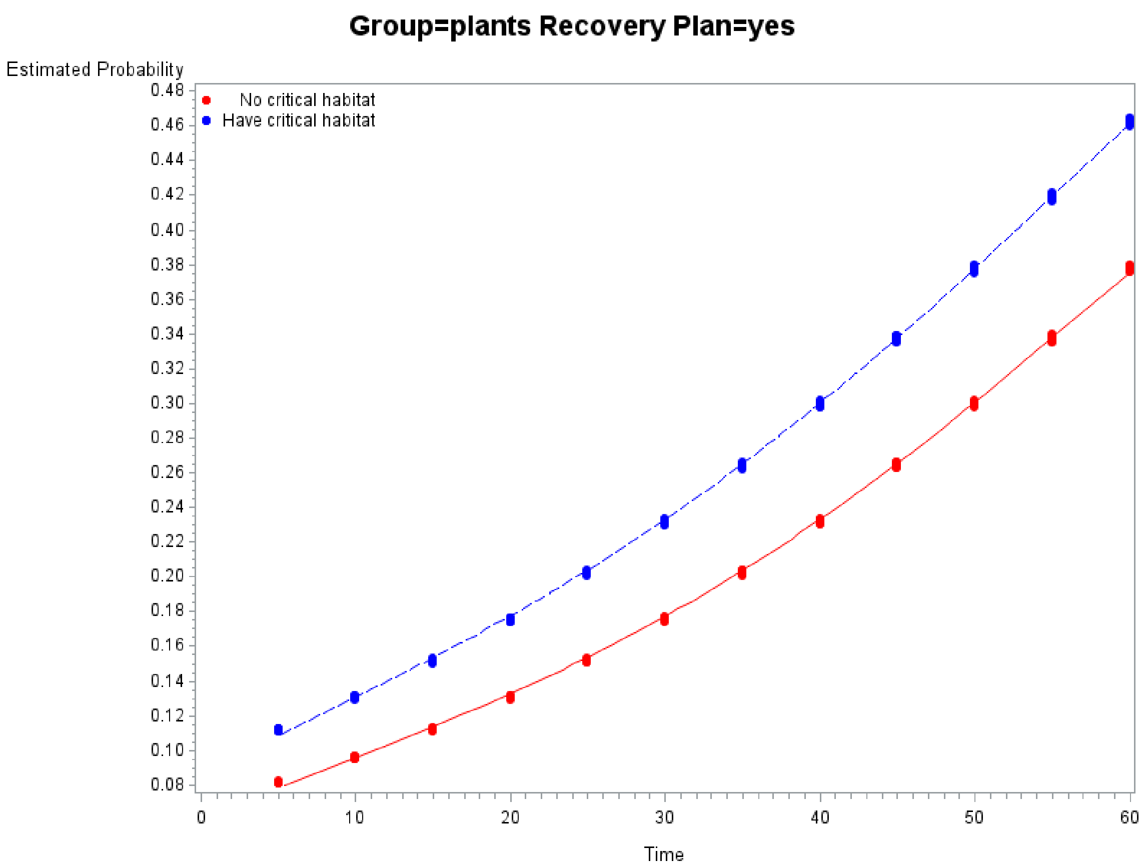

Figure 5. Displays the recovery probability of plants that have a recovery plan. The x-axis represents time listed, and the y-axis represents recovery probability. The blue line represents listings with designated critical habitat, and the red line represents listings without critical habitat. Plants were used because they were the classification group with the largest sample size.

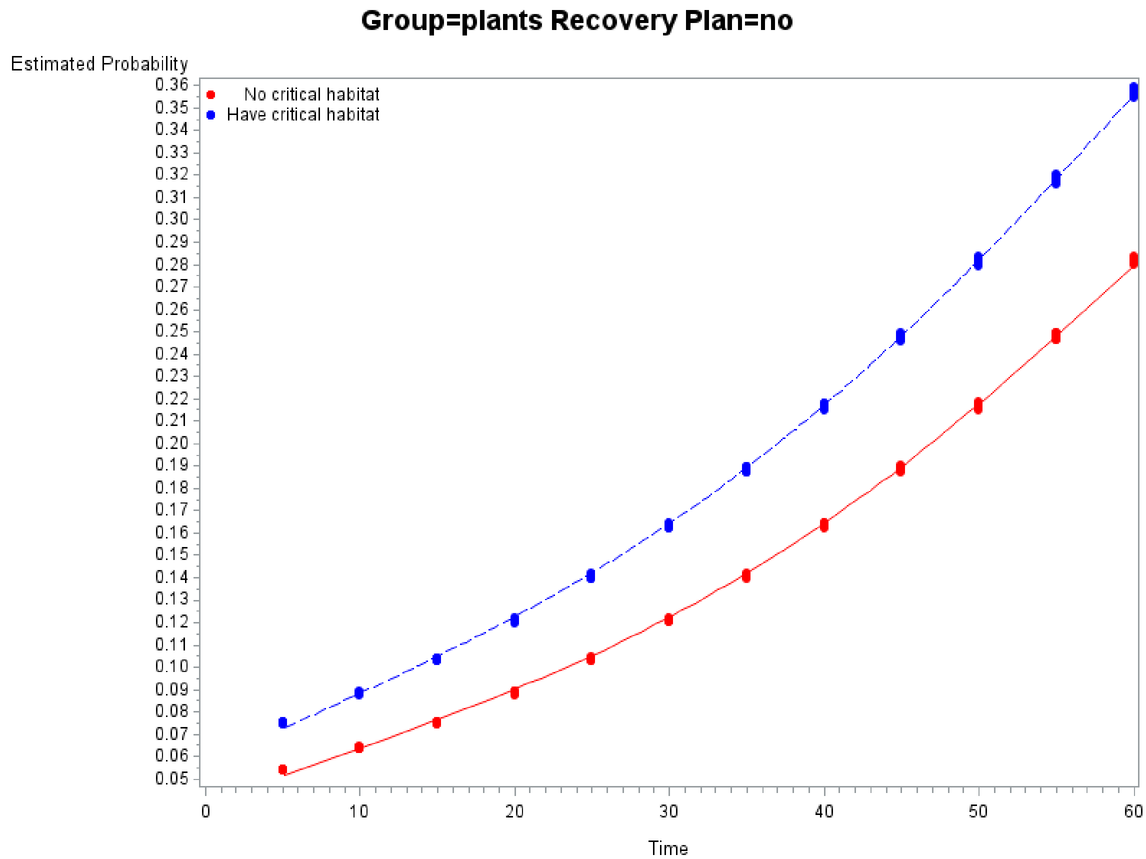

Figure 6. Displays the probability of plants without a recovery plan. The x-axis represents time listed, and the y-axis represents recovery probability. The blue line represents listings with designated critical habitat, and the red line represents listings without critical habitat. Plants were used because they were the classification group with the largest sample size.

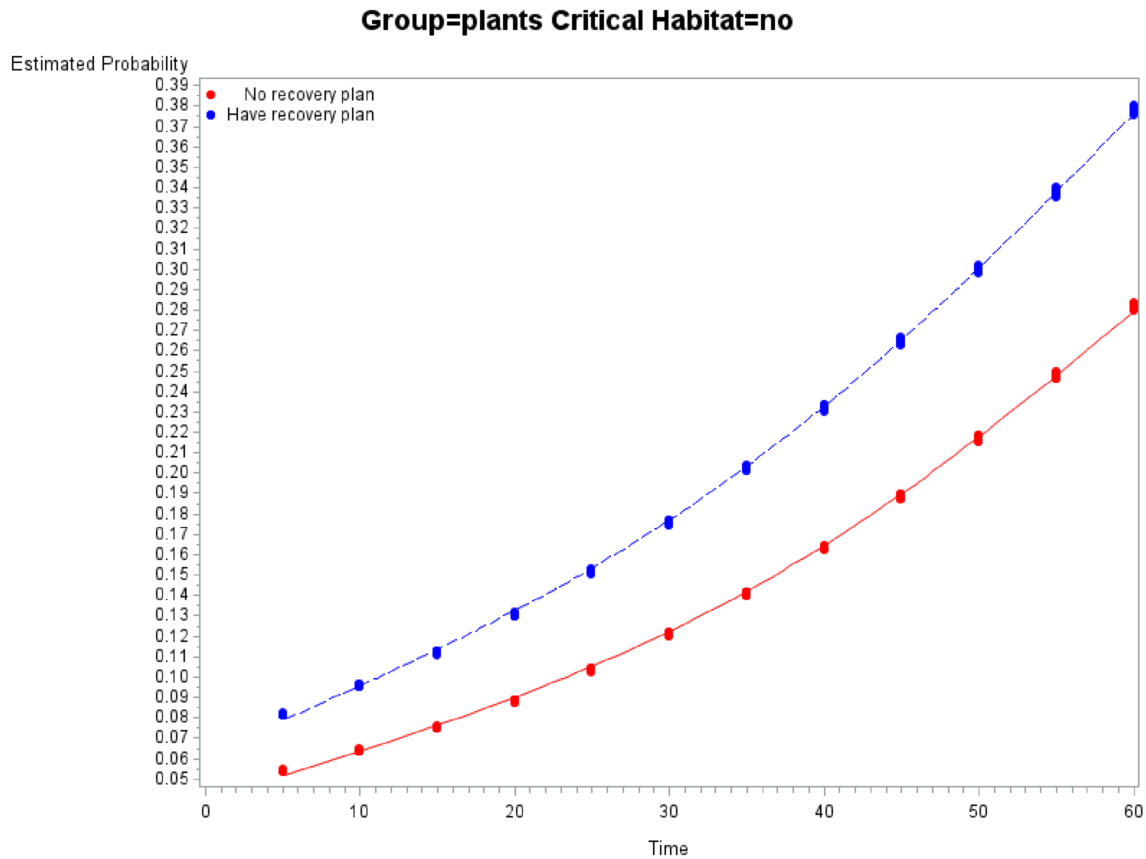

Figure 7. Displays the recovery probability of plants that do not have critical habitat. The x-axis represents time listed, and the y-axis represents recovery probability. The blue line represents all listings with recovery plans, and the red line all listings without recovery plans. Plants were used because they were the classification group with the largest sample size.

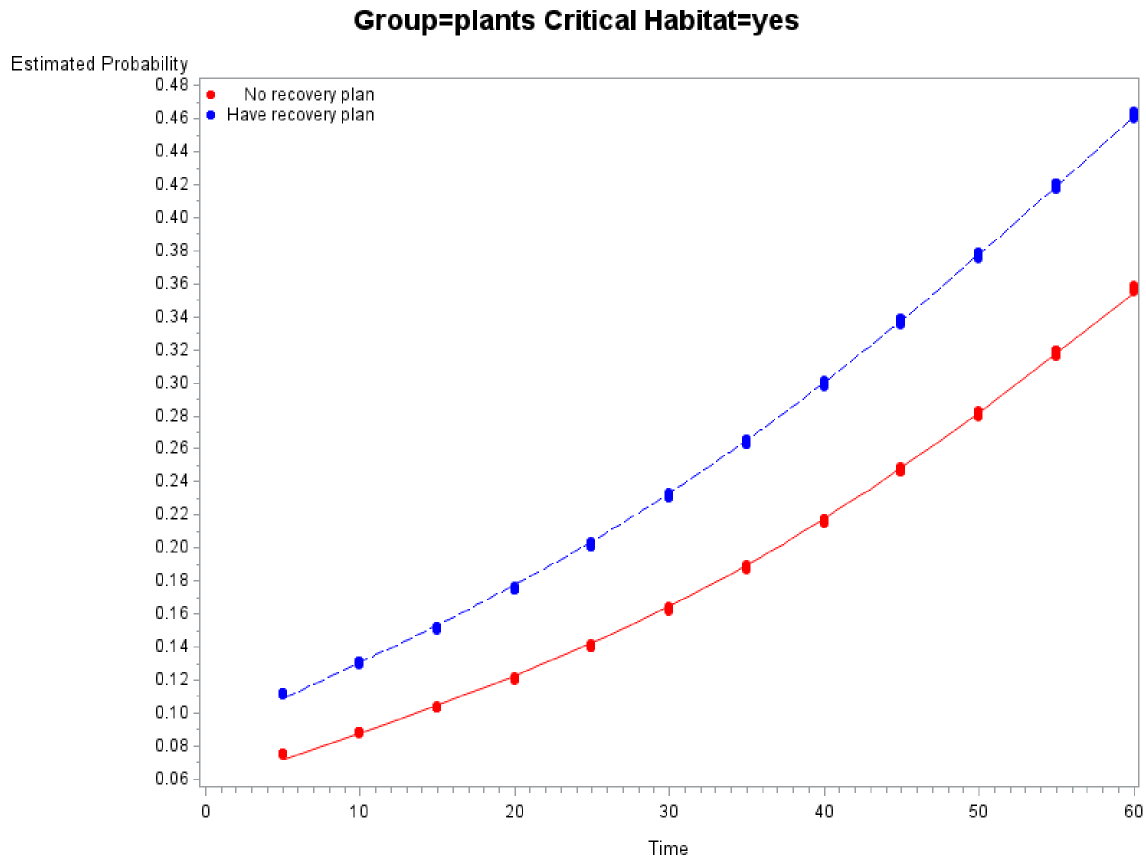

Figure 8. Displays the recovery probability of plants that do not have critical habitat. The x-axis represents time listed, and the y-axis represents recovery probability. The blue line represents all listings with recovery plans, and the red line all listings without recovery plans. Plants were used because they were the classification group with the largest sample size.

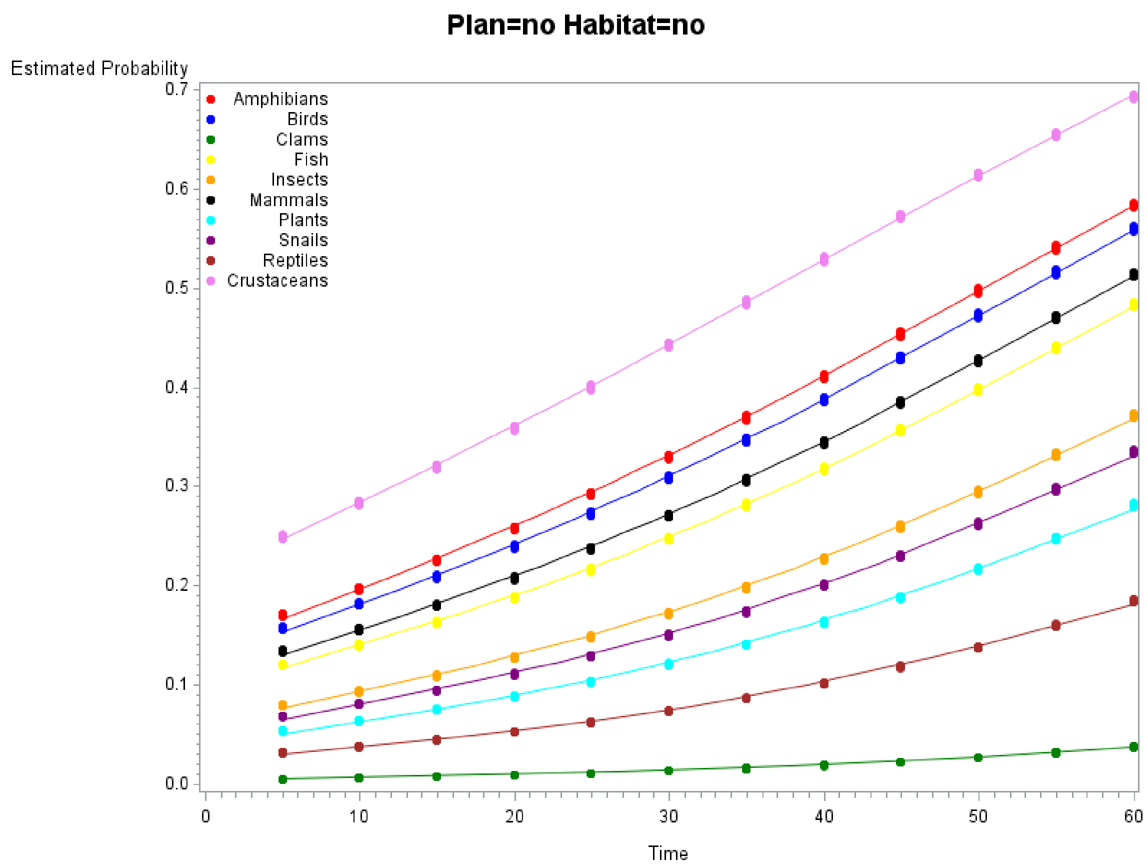

Figure 9. Displays the results when no recovery plan or critical habitat is present. The x-axis represents the amount of time listed and the y-axis represents probability of recovery.

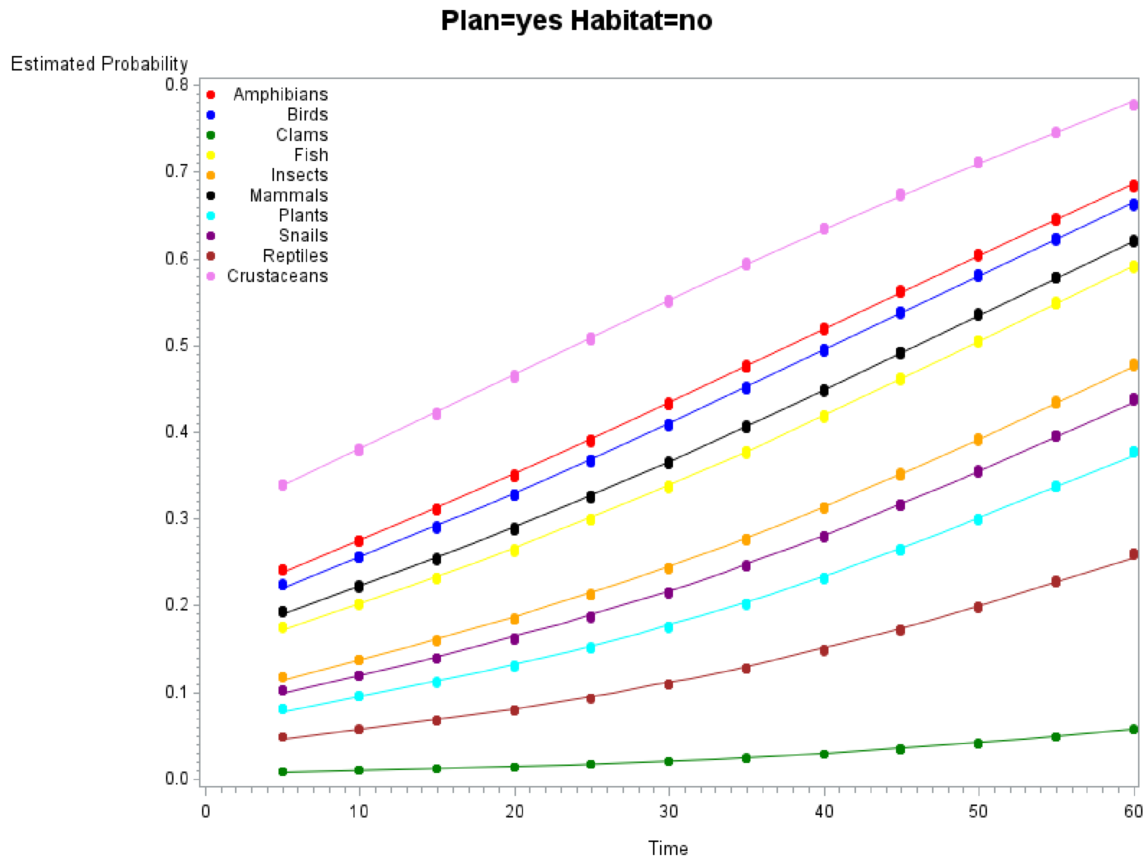

Figure 10. Displays the results when recovery plan is present with no critical habitat. The x-axis represents the amount of time listed and the y-axis represents probability of recovery.

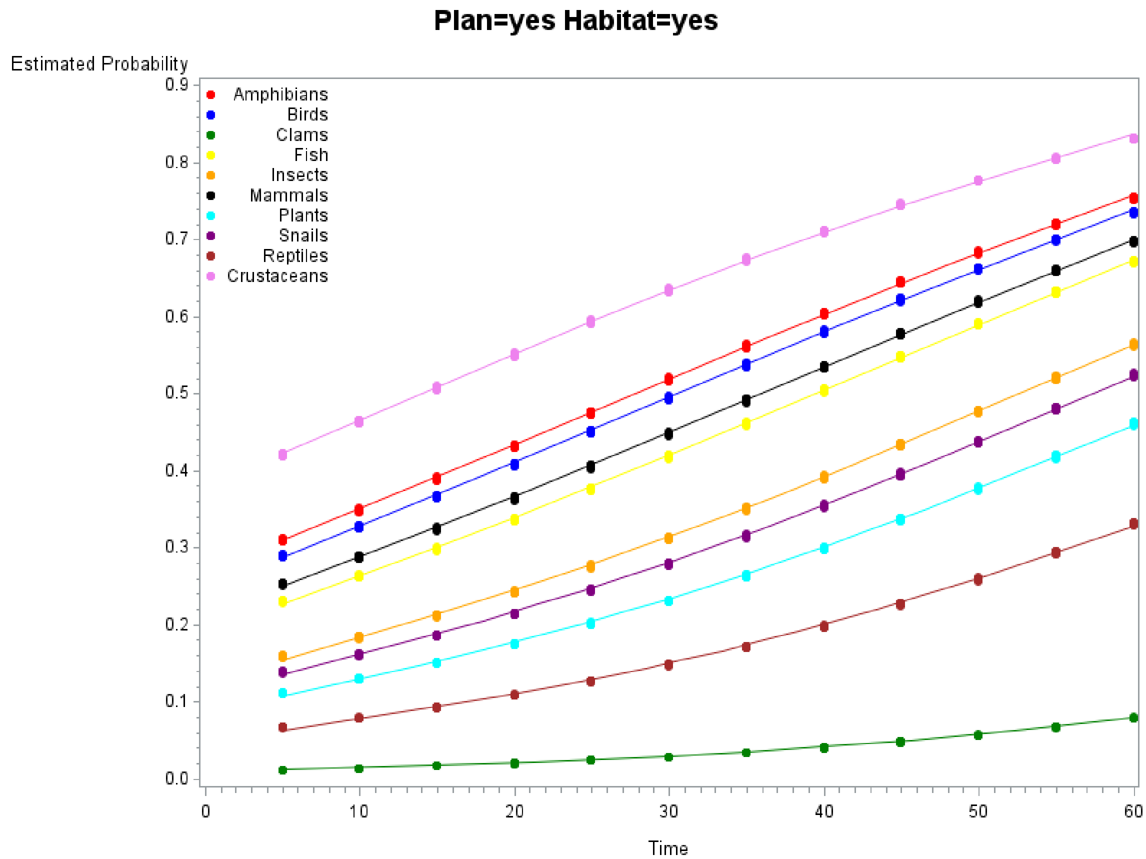

Figure 11. Displays the results when both a recovery plan and critical habitat are present. The x-axis represents the amount of time listed and the y-axis represents probability of recovery.

The GLM procedure outlined the relationship between funding and its predictors. The results show that differences in funding varied significantly with group, region, and habitat, while effects of plan and listing were insignificant.

Table 14 displays the complete results of the GLM procedure. Interactions had no effect (p-value) and were therefore not included in the final table.

Table 14. Complete results of the GLM procedure outlining the relationship between funding and its predictors.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Group	9	1.8239147E14	2.0265719E13	10.70	<.0001
Region	7	6.1747686E13	8.8210979E12	4.66	<.0001
Listing	1	1.6424119E12	1.6424119E12	0.87	0.3520
Plan	1	2.7542816E12	2.7542816E12	1.45	0.2282
Habitat	1	1.407871E13	1.407871E13	7.44	0.0066

DISCUSSION

Species recovery was found to be lower than expected. Out of the 747 species with population data available, only 165 had a population that was no longer declining (22%). About half of the listed species had population data available, and it's probable that those without data are much more likely to be declining, meaning the true recovery rate of all listed species could be even lower. These numbers are significantly lower than those found by previous studies. Male and Bean (2005) found that 52% of species were no longer declining, and Suckling (2006) found that number to be 93%. However, this study found numbers more similar to those found by Luther and Gentry (2019), who found that only 30% of species were no longer declining. These disparities in results could be due to the age of the previous studies, or it could be due to the difference in data sources.

The analysis found that designated critical habitat increases the odds of recovery. Previous studies have been split on this issue, with the value of critical habitat being up for debate. Taylor et al. (2005) found that critical habitat significantly effects recovery, while Male and Bean (2005) found that it has no correlation. Forty-three percent of tested species have designated critical habitat, and 47% of the total listed species. Time listed has a significant ($P \leq 0.05$) relationship with recovery, with species being more likely to recover the longer they are listed. Many previous studies have also come to this conclusion (Taylor et al 2003, Male and Bean 2005, Suckling 2006). The average time listed of recovering species is 35 years, while those that are not recovering have an average time listed of 26 years. The model found that for every year a species is listed, its odds of recovery increase 3%. Recovery plans were found to also increase the odds of recovery slightly, and funding and listing classification were found to not have an effect, which contradicts the findings of previous studies (Taylor et al 2005, Male and Bean 2005). My funding data only included the past three years of expenditures, which could explain the discrepancy from previous studies. A more detailed analysis focused on funding across a greater time period might yield different results. Range size, FWS region, and species/subspecies classification also had no effect on recovery.

The analysis found significant variation in recovery across classification groups. Vertebrates are 2.8 times more likely to be recovering than invertebrates, and 2.3 times more likely to be recovering than plants. As a whole, animals are much more likely to be recovering than plants (Figure 12). The reasons for these differences are difficult to determine. Funding does differ greatly between classes, but as mentioned earlier, funding does not correlate with recovery.

There are two possibilities that seemed to reasonably explain this discrepancy. First, in the early years of the ESA the only species to be listed were vertebrates. It was not until later that invertebrates and plants were placed under ESA protection. As we have learned, species are more likely to recover over time, and this head start that vertebrates received might be reflected in these results. Suckling (2006) found that the average expected recovery time for a species is 42 years, and most invertebrates have not been listed nearly that long. Second, vertebrates receive more support from the general public than invertebrates and plants, and therefore are more likely to be listed quickly. The listing process is arduous, and there is a backlog of species that are struggling that have not yet been listed (Wilcove and Master 2005). These popular vertebrates that are listed quickly have a better chance of recovery, while invertebrates and plants are not listed until their numbers are extremely low and chance of recovery looks bleak.

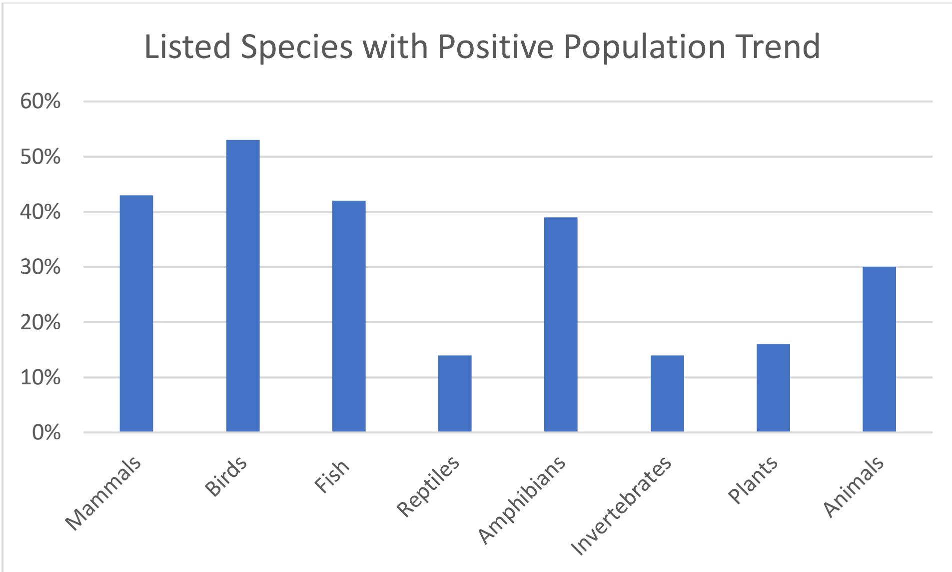

Figure 12. Graph displaying listed species with improving population trend broken down by classification group.

Previous studies have found that species listed as "threatened" are more likely to be recovering than those listed as "endangered" (Taylor et al. 2005). However, the data showed no difference between the two listing classifications. Out of the 1,462 domestic species listed, only 305 are listed as threatened, and there was no increase in recovery among species listed as threatened. The model also found that despite the added level of protection given to "endangered" species, the amount of funding received is not significantly different to that of the "threatened" species.

As mentioned previously, funding is not evenly distributed across classification groups. The model found that mammals, birds, and fish receive decidedly more funding than species in other classes. Table 1 shows that average funding for vertebrates is over $1,000,000, while invertebrate funding is $120,000 and plants is only $46,000 annually.

The average annual total spending from 2015-2017 was $417,221,000 for all domestic species. Of that total, 44% was used on 14 species, all of which were fish, mammals, or birds. The funding discrepancy was astronomical even between species in the same class. The pallid sturgeon (*Scaphirhynchus albus*) received nearly $44,000,000 annually across 2015-2017, while the San Marcos gambusia (*Gambusia georgei*) was only given $1,033 annually. These species with large annual budgets are those that are well known by the public, and they are used as a way to spread awareness of the work the ESA does. Their consistence presence in the news puts pressure on the FWS to recover the species, and therefore they receive an unequal distribution of funds. The grizzly bear (*Ursus arctos horribilis*), the red-cockaded woodpecker (*Picoides borealis*), and the northern spotted owl (*Strix occidentalis caurina*) are all excellent examples. These big-budget species are an important part of the ESA, and while their exorbitant expenditures are not entirely unwarranted, it does leave many lesser known species underfunded.

Critical habitat was found to be a significant predictor of funding, along with taxonomic class and region. Species with critical habitat have an average annual funding of $512,379, while species without average $455,127 in annual funding. This funding discrepancy makes sense, and it could explain why critical habitat designation remains below 50% for all listed species. The difference in funding among regions is a little harder to explain, but upon closer examination it can be concluded that this discrepancy is caused by a few big-budget species that receive an inordinate amount of funding and skew the data. The model found no difference in funding between species listed “endangered” and “threatened” (which confirms the results found by Luther et al. 2016), and recovery plan presence also had no correlation.

The analysis found that critical habitat frequency differed across regions. Regions 3, 4, and 5 had lower rates of critical habitat designation than other regions. To explain this, I used USGS data to determine how much public land existed in each region (NGDA 2017), and then compared these numbers to my critical habitat numbers. Public land, which consist of all state- and federally-owned land, is much more common in the less densely-populated states of the west. Figure 13 displays how public land is distributed between regions. This data showed a strong correlation between public land critical habitat (Figure 14). The regions with the lowest critical habitat designation rate (Regions 3, 4, and 5) also have the least public land, with the 3 of them combing for only 12% of the nation's total public land.

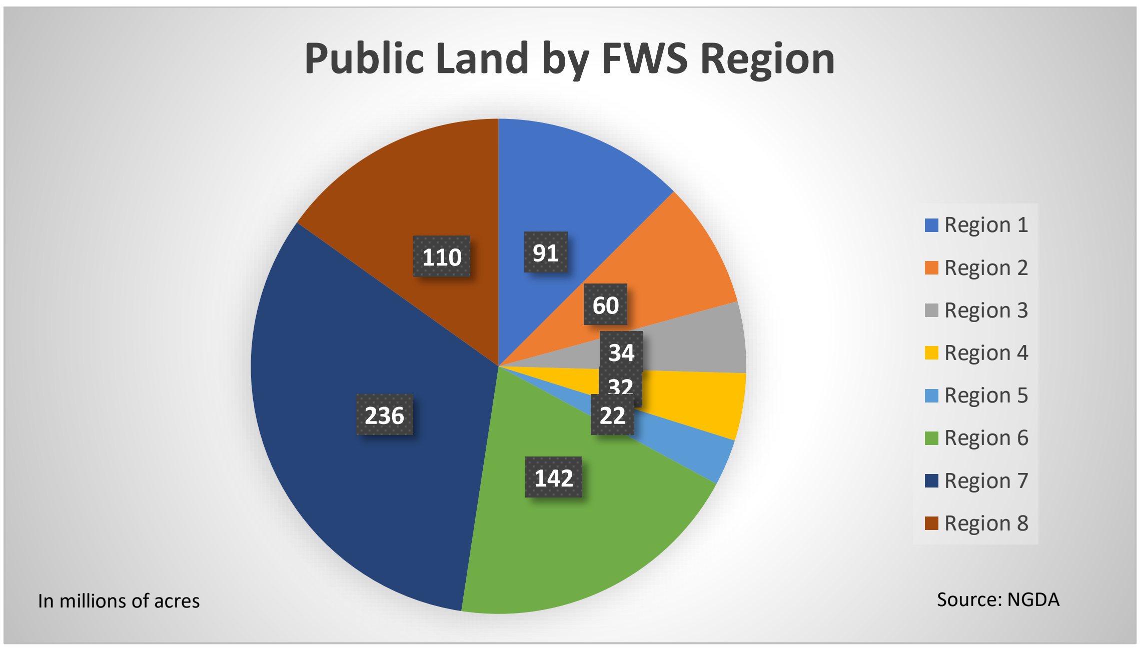

Figure 13. Chart displaying how all of the public land in the United States is divided among the FWS regions.

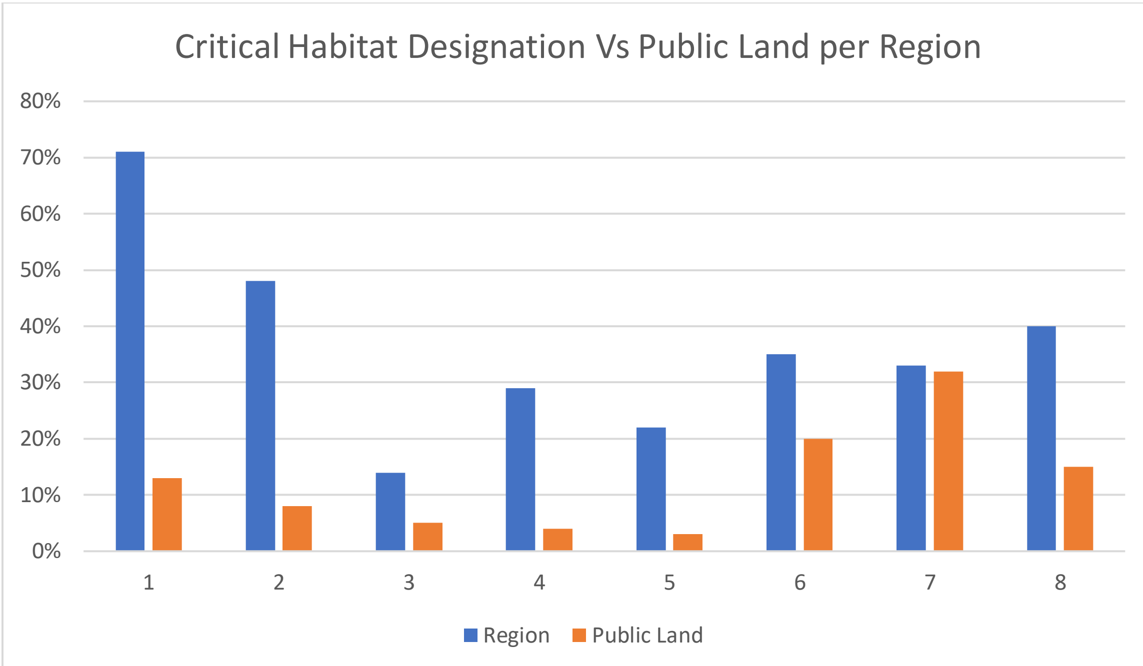

Figure 14. Graph displaying rate of critical habitat designation compared to amount of public land in each FWS region.

CONCLUSIONS

The first objective of this study was to identify what variables contribute to species recovery. Out of the 9 variables tested, only 2 were found to significantly ($P \leq 0.05$) effect recovery. Recovery was dependent on classification group, with vertebrates being more likely to recover than plants and invertebrates. Birds had the highest rate of recovery, and were the only classification group with a recovery rate above fifty percent. Recovery was also dependent upon time listed. Many previous studies have also found time to be a critical variable (Taylor et al. 2005, Male and Bean 2005, Suckling 2006). There is a nine-year difference between the average time listed for recovering species and the average time listed for declining species, and the model found that the odds of recovery increase three percent for every year a species is listed.

Although critical habitat was found to be a statistically significant ($P \leq 0.05$) variable, it did increase the odds of recovery. Forty-eight percent of all listed species have been designated critical habitat, and critical habitat designation is even across classification group.

Seventy-five percent of listed species have a recovery plan, including 87% of species listed longer than 10 years, and recovery plans were found to not increase funding. Recovery plans were found to increase the odds of recovery slightly, although this relationship was not statistically significant based on my model. There was no statistical relationship between listing classification and recovery. Threatened species were found to be just as likely to be recovering as endangered species, which is contrary to the findings of previous studies (Taylor et al. 2005, Male and Bean 2005). No difference in recovery was found between species and subspecies or variants. Range extent was found to have no effect on recovery, and FWS region also had no effect. Annual funding was found to be unevenly distributed, with vertebrates receiving significantly more funding than invertebrates and plants. However, the model found that funding was an insignificant variable, and it has no effect on recovery.

The second objective of this study was to identify areas the ESA could improve upon. The easiest fix for the ESA is to increase the critical habitat designation rate. Critical habitat was found to be a significant predictor of recovery, but only forty-eight percent of all listed species have been designated critical habitat. Critical habitat for all species is an unrealistic goal, but increasing the designation rate to even seventy-five percent could make a huge difference and should help more species recover. The biggest obstacle to this is funding. Designating critical habitat for a species does require an increase in funding, and the data showed that species with critical habitat use on average $57,000 more in funding per year than species without. Based on these numbers, increasing critical habitat designation rate to 75% of listed species would require an additional $22 million in annual funding.

Classification group was found to be a big predictor of recovery, with vertebrates showing greater recovery rate than plants and invertebrates. It is difficult to determine the cause of this discrepancy. Critical habitat is evenly distributed over classification groups. Funding is skewed heavily towards vertebrates, but the model found that funding does not affect recovery. Time listed is a likely factor, as vertebrates have been listed much longer on average than invertebrates and plants.

The data shows that the best way to increase species recovery is to wait. Time listed is the most effective predictor of recovery, and many species have not been listed long enough to show positive results. Suckling (2006) found that the average expected time to recovery is 42 years, yet only 16% of species have been listed for 40 years or more. According to those numbers, most species have not even been listed long enough to be showing recovery, and the 24% recovery rate is actually higher than expected.

These findings support the idea that patience and attentiveness are the two attributes that the FWS needs to deploy when managing the ESA. The recovery process is a slow one, and it can take several decades before a species begins to show signs of recovery. The likelihood of recovery can be increased by fulfilling the obligations of the ESA and designating critical habitat to every species. The good news is that rate of critical habitat designation has greatly increased recently. In the last 10 years, 74% of newly listed species have been designated critical habitat, up from 42% across the previous 40 years. This is a significant step in the right direction, and shows that the FWS has similar data that confirms the effectiveness of critical habitat. This also suggests that this recent rise in critical habitat designation should lead to an increase in species recovery, but it could be a decade or more before this increase is noticed. The best way to increase recovery among listed species is to further increase critical habitat rate, give more attention to invertebrates and plants, and to be patient. Populations do improve over time, and many species have not been listed long enough to be showing improvement. The Endangered Species Act is working, but it takes time to undo decades of population decline.

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VITA

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