DOES LISTING STATUS MATTER? QUANTIFICATION OF THREATS FACING THREATENED AND ENDANGERED SPECIES LISTED UNDER THE US ENDANGERED SPECIES ACT

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Abstract

With species increasingly becoming imperiled due to anthropogenic activities, conservation practitioners are tasked with determining conservation priorities in order to make the best use of limited resources. One way of setting these priorities is to categorize species based on their risk of extinction. The United States' Endangered Species Act (ESA) has two listing statuses for imperiled species: Threatened or Endangered. For six broad-scale threats, we investigated whether there is a difference in the number and types of threats impacting Threatened and Endangered species at the time of their listing. We found that they were both faced by a similar number of threats at their time of their listing. The only broad-scale threat that impacted Endangered species more than Threatened species was demographic stochasticity. We further examined demographic stochasticity by breaking it down into finer-scale threats. We found four finer-scale demographic stochasticity threats (few individuals in one population, few individuals in multiple populations, lack of reproduction, and genetic loss) to be strong predictors of Endangered status. The similarities in the number and types of broad-scale threats faced by Threatened and Endangered species suggest that changes recently made to the ESA may be detrimental to the recovery efforts of future Threatened species.

Introduction

With extinctions occurring at an alarming rate worldwide (Barnosky et al. 2011, Pimm et al. 2014, Ceballos et al. 2015), conservation practitioners are tasked with defining levels of endangerment in order to classify and conserve imperiled species. In the United States, the primary legislation to prevent biodiversity loss is the Endangered Species Act (ESA). The ESA has two categories of imperiled species: Threatened, "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (ESA sec. 3(20)), and Endangered, "any species which is in danger of extinction throughout all or a significant portion of its range" (ESA sec.3(6)). The key distinction between these two categories is the time frame of impending extinction. Also, an Endangered species likely has fewer individuals and/or populations than a Threatened species (Neel et al. 2012) and it may face threats of greater immediacy (USFWS 2010). The United States Fish and Wildlife Service (USFWS) had intended for these categories to be flexible so that conservationists were not restricted to one-size-fits-all criteria when determining the listing status that best represents a species' condition (USFWS 2010). However, multiple studies (e.g., Rohlf 1991, Harris et al. 2012) have criticized the definitions of Threatened and Endangered as being too vague, subjective, and prone to non-scientific influence.

A species' Threatened or Endangered listing status determines how many regulations are enacted to protect the species. One of these differences is with Section 9 of the ESA, which provides an array of protections to both the species and its habitat. All of these protections go into effect automatically for species listed as Endangered; however, for Threatened species it is up to the Secretary of the Interior (USFWS) or Commerce (National Marine Fisheries Service, NMFS) to grant some or all of these protections to the species. Another major ESA protection is found within Section 4. Through much of the ESA's history, it was illegal to "take" ("harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct" (ESA sec. 3(19))) any Threatened or Endangered animal species. This was not the case for protected plant species; their protections came from state law and regulations on the federal lands where they occur (Evans et al. 2016). In 1995, the "harm" aspect of this "take" definition was clarified as including any "act which actually kills or injures wildlife" including "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering", thereby protecting both the animal and its habitat (50 CFR § 17.3). However, a recent change to the ESA (USFWS 2019) removed the "take" protection from animal species that would be newly listed as Threatened unless a special rule is provided.

To the best of our knowledge, few studies have examined the association between a species' listing status and the threats it faces. Ducatez and Shine (2017) found that the more critical the listing status of IUCN-listed vertebrates, the more threats the species had. Additionally, they identified specific threats within each taxa that were more likely to impact individuals with increasing listing status (Ducatez and Shine 2017). Conversely, when Greenville et al. (2020) analyzed IUCN-listed vertebrates at the global scale with a network analysis, they did not find a connection between the species' IUCN status and the number or types of threats that impact them. On a national scale, Venter et al. (2006) found that the number of threats faced by species protected by Canada's Species at Risk Act increased with increasing level of endangerment. This limited evidence is inconclusive as to whether a species' listing status is related to the degree to which it is impacted by threats.

The objective of this project was to elucidate differences between Threatened and Endangered species beyond those described in their ESA definitions. To do so, we will: (1) determine whether there is a difference in the number of threats facing Threatened and Endangered species at the time of their listing, (2) determine whether Threatened and Endangered species are faced by the same general threats (i.e., broad-scale threats), and (3) for the general threats which impact one listing status more than the other, discern finer-scale threats where Threatened and Endangered species differ. Based on their definitions, we would expect a Threatened species to be faced by fewer threats at its time of listing than an Endangered species. Because species with fewer individuals remaining (i.e., Endangered species; Neel et al. 2012) are more vulnerable to demographic consequences (Lande 1988), we also predict that Endangered species are more likely to be impacted by threats relating to demographic stochasticity. By identifying these distinctions between Threatened and Endangered species, we can determine whether the current differences in regulatory protections are appropriate, or if Threatened and Endangered species need to be treated more similarly so they are both afforded the ability to successfully recover from the ESA.

Methods

1. Threatened and Endangered Species Analyzed

Our analysis included every species in the United States, its territories, and its territorial waters that the USFWS or the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) listed as "Threatened" or "Endangered" under the ESA between 1975 and 2020. We excluded species listed prior to 1975 because those listing decisions did not include information on the threats facing the species. We included species that were delisted due to recovery or extinction. Consistent with the ESA's definition of "species" (ESA section 3(16)), each Distinct Population Segment (DPS) was treated as its own species. The resulting sample size was 1569 species.

2. Threat data collection

Leu et al. (2019) had previously quantified the number of threats facing Threatened and Endangered species at the time of their listing for six overarching categories: habitat modification, overutilization, pollution, species-species interactions, environmental stochasticity, and demographic stochasticity. Using the same methods as Leu et al. (2019), we updated this dataset by collecting data for species listed between 2018 and 2020. Using this database, we compared both the number and type of threats facing a species at their time of listing between species categorized as Threatened versus Endangered.

Based on this analysis, only the demographic stochasticity threat type differed between Threatened and Endangered species (see Results). We broke this threat into more specific categories so that we could further evaluate differences between Threatened and Endangered species. In order to collect the threat data at a finer resolution, we reviewed each species' Final Rule listing document. All threat language for demographic stochasticity was pulled from the "Summary of Factors Affecting the Species" section in each listing document. From this section, we extracted "threat language" only if a threat was specified as actively impacting the species at the time of their listing.

We classified threats pertaining to demographic stochasticity into ten threat categories (Table 1). We defined these categories on the basis of initial reviews of Final Rule listing documents, searches of our database of collected threat language, and reviews of previous work (e.g., Wilcove et al., 1998; Evans et al., 2016; Leu et al., 2019).

Table 1. Demographic stochasticity threats were classified on the basis of threats described in ESA listing documents.

Threat
Few individuals, one population
Few individuals, multiple populations
Few populations
Isolation
Reduced range
Lack of reproduction
Inbreeding
Genetic loss
Biological limitations
Not in the wild

3. Statistical analysis

Our first objective was to determine whether the number of threats at time of listing differed between Threatened and Endangered species. We used a generalized linear mixed effect model (GLMER; lme4 package version 1.1-23; Bates et al., 2015) to relate Threatened or

Endangered status to the number of threats at time of listing. The response variable was binary (Threatened [value = 0] or Endangered status [value = 1]), so we used a binomial error structure with a logit link. Because Leu et al. (2019) had previously found that the number of threats at time of listing related to the year of listing, we included year as a random factor. We also included taxa and region (both as delineated by the USFWS and NMFS) as random factors because species that are more closely related or that are found in a similar geographic location are more likely facing similar threats. Bolker et al. (2008) suggested a minimum of ten "samples" (species) per category in each random factor for a robust model. Three taxa (Cephalopods, Conifers and Cycads, and Lichens), two USFWS regions (7 and 10), and thirteen years (1975, 1981, 1983, 2003, 2004, 2005, 2007, 2008, 2009, 2017, 2018, 2019, and 2020) did not reach this threshold and were therefore omitted from the analyses. This reduced our sample size from 1569 to 1487 Threatened and Endangered species. We used Akaike information criterion (AICc; Burnham and Anderson, 2002) to compare the model of threats at time of listing to a null model.

Our second and third objectives were to compare the types of broad- and fine-scale threats faced by Threatened and Endangered species at their time of listing. We first compared univariate GLMER models for each of six broad threat types (with taxa, region, and year of listing as random factors and a binomial error structure as stated above) to a null model. Univariate models were carried forward to a global model if they performed better than the null model. All predictor variables included in the global model were compared with the dredge function in the MuMIn package (version 1.43.17; Barton, 2020). We model averaged final parameter estimates and associated variance across all candidate models and assessed the importance of a given variable on the basis of AICc weights (Burnham and Anderson, 2002). We used this approach for both the broad-scale analysis of threat categories from Leu et al. (2019) and analysis of the fine-scale demographic stochasticity threats.

All analyses were done in R (version 3.6.2; R Core Team, 2019). We used the DHARMa package (version 0.3.3.0; Hartig, 2020) to ensure that residuals were properly distributed for the mixed models.

Results

1. Distribution of Threatened and Endangered Species

Of the 1569 species considered in our study, 75% (1170 species) were listed as Endangered. There was notable variation in the proportion of species listed as Threatened or Endangered across years of listing, taxa, and regions. Among the years in which more than ten species were listed, the range of listings was 40% Endangered (1977 & 2014) to 96% Endangered (2010). Taxa had a similarly extensive range, with 100% of corals listed as Threatened and 100% of arachnids listed as Endangered. Among the regions with adequate sample sizes, the range was 30% Endangered species in Region 9 and 91% Endangered species in Region 1. The ranges reported here reflect all listed species considered in our analysis; however, we omitted 83 species due to small sample sizes of species in certain years, taxa, and regions. While this may result in slight deviations from the percentages reported here, the omissions represent only 5% of our total sample size. Of the 1487 species that were analyzed, the proportion listed as Endangered was still 75% (1122 species).

2. Comparison of number of threats at time of listing

We found that Threatened and Endangered species were listed with a similar number of threats (Figure 1). The null model had a lower AICc (1413.94) than the model including number of threats as a predictor (1415.29), indicating that there was no difference in the number of threats facing Threatened and Endangered species at the time of their listing.

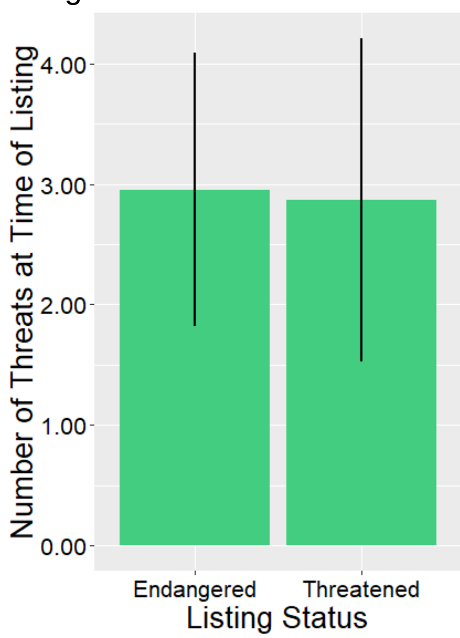

Figure 1. Average number (+/- 1 SD) of threats at time of listing did not differ between Endangered and Threatened species.

3. Comparison of threat types at time of listing

We found that demographic stochasticity was 1.9 times (95% CI 1.4-2.6) more likely to impact an Endangered species than a Threatened species. Of the six threat types analyzed, only demographic stochasticity performed better than the null model by > 2 AICc. Habitat modification, overutilization, pollution, species-species interactions, and environmental stochasticity threats were all as likely to impact Threatened species as Endangered species. Because there were no other variables worth considering, we did not construct a global model or use model averaging for this set of threats.

4. Comparison of demographic stochastic threats

Of the ten demographic stochastic threats, we found five to be predictors of Endangered status: few individuals in one population, few individuals in multiple populations, lack of reproduction, genetic loss, and few populations. These threats were between 4.2 times (few individuals in one population; 95% CI 2.3-7.6) and 1.1 times (few populations; 95% CI 0.7-1.8) more likely to impact Endangered than Threatened species (Table 2). We excluded the "not in the wild" threat category as only 17 species (1.1%) were listed with this threat. Isolation, reduced range, and biological limitations performed within 2 AICc of or were worse than the null model.

Table 2. Odds that a given threat will impact an Endangered species.

Threat	Odds	Confidence interval
Few individuals, one population	4.2	2.3 – 7.6
Few individuals, multiple populations	2.2	1.6 – 3.0
Lack of reproduction	2.1	1.1 – 3.9
Genetic loss	1.7	1.1 – 2.6
Inbreeding	1.6	0.8 – 3.2
Few populations	1.1	0.7 – 1.8

Discussion

Both Threatened and Endangered species faced a similar number of threats at the time of their listing (Figure 1). Of the six potential threats where these two listing categories could differ, the only one which impacts Endangered species more than Threatened species was demographic stochasticity. We found that habitat modification, overutilization, pollution, species-species interactions, or environmental stochasticity were as likely of a threat to Endangered as Threatened species. Further, only four of the nine demographic stochasticity threats we evaluated (few individuals in one population, few individuals in multiple populations, lack of reproduction, and genetic loss) were suitable predictors of Endangered status.

Despite differences in scale, taxonomic composition, and analysis, our findings support those of Greenville et al. (2020) in that both the number and types of threats facing species did not vary based on listing status. The contrary patterns identified by Ducatez and Shine (2017), that number of threats increased with listing status and that several broad-scale threats were more likely to impact species with higher listing statuses, were not seen among ESA-protected species. Similarly, species protected by the ESA differed from those protected by Canada's Species at Risk Act in that the Canadian species also displayed an increasing trend between listing status and the number of threats (Venter et al. 2006). Despite our research, there is still disagreement on how the number and type of threats relate to different listing statuses.

We found that the only differences in threats between Threatened and Endangered species related to demographic stochasticity. It has previously been found that Endangered species were listed with fewer individuals and populations remaining compared to Threatened species (Neel et al. 2012). As published in the literature, species with fewer individuals remaining in the wild are more susceptible to threats relating to demographic stochasticity, such as inbreeding, genetic loss, and the Allee effect (Lande 1988). Despite numerous criticisms that the definitions of Threatened and Endangered are too vague and subjective, leaving the USFWS and NMFS susceptible to lawsuits (Rohlf 1991, De Grammont and Cuarón 2006, D'Elia and McCarthy 2010, Harris et al. 2012, Regan et al. 2013, Waples et al. 2013), these listing statuses appear to be applied consistently to listed species. If they were not, differences in demographic stochastic threats (such as few individuals in one or multiple populations) would not have been as pronounced between the two groups. In this respect, the definitions of Threatened and Endangered also appear to provide an accurate assessment of extinction risk; the fewer and smaller the populations, the more likely extinction is (Pimm et al. 1988, O'Grady et al. 2004a).

Extinction risk is the most commonly used basis of listing categories, and several studies (O'Grady et al. 2004a, O'Grady et al. 2004b, De Grammont and Cuarón 2006) have verified that it is the best metric to use. In this respect, the ESA is consistent with the majority of endangered species lists. However, the ESA's criteria is far less quantitative than that of most other lists, and it has been frequently suggested for the USFWS and NMFS to implement more specific thresholds (De Grammont and Cuarón 2006, D'Elia and McCarthy 2010, Harris et al. 2012, Regan et al. 2013). However, this study confirms that Threatened and Endangered categories are being applied more consistently than is commonly believed.

Of the nine demographic stochastic threats we analyzed, three were equally as likely to impact Threatened species as Endangered species: biological limitations, isolation, and reduced range. It was unexpected that reduced range was not a predictor of Endangered status, as it is widely regarded as a strong method of predicting extinction risk (Newsome et al. 2020, Staude et al. 2020). A potential explanation for this result is that our definition of “reduced range” encompassed both ranges that have been reduced from a historical larger size due to anthropogenic activities and ranges which had always been small, such single islands, pools, or caves. A species that has always existed in a small range may not have lost individuals to the same degree as a species whose dwindling habitat has become unable to support the populations it once had; the former may be listed as Threatened while the latter may be Endangered. Because the documents did not always distinguish between these two forms of small range, we were unable to be more specific with our definition. We do not believe the inclusion of DPS as species impact this result; while approximately twice as many DPS were listed as Threatened than Endangered, they constitute 75 of our 1487 species and are therefore unlikely to have a strong influence on our results.

The second demographic stochastic threat which did not differ between the two listing statuses was isolation, which includes fragmentation of populations and individuals. While this is another commonly used indicator of extinction vulnerability, Fahrig (2003) found that habitat fragmentation was as likely to have positive effects on biodiversity as negative effects, and that its overall impact was weaker than that of having a reduced range. This uncertainty could explain why this threat did not impact Endangered species more than Threatened species.

The final demographic stochasticity threat which did not impact one listing status over the other was biological limitations - traits such as low fecundity, species which take a long time to reach maturity, or other life history traits which are cause for concern. O’Grady et al. (2004a) found that reduced range, fragmentation, and “biological limitations” (generation length, fecundity, etc.) were not strong predictors of extinction risk. They suggested that while population size and trend are correlated with other demographic factors, these two relate the strongest to a species’ viability and will therefore stand out in explaining extinction risk (O’Grady et al. 2004a).

Notably, we did not see a difference in the degree to which Threatened and Endangered species are impacted by five major threat types: habitat modification, overutilization, pollution, species-species interactions, and environmental stochasticity. Of these threats, habitat modification has historically had the greatest impact on Threatened & Endangered species and has a 91% probability of being included in today’s listing decisions (Leu et al. 2019). Because Threatened species are just as likely as Endangered species to be faced by this pervasive threat, we did not find biological justification for the recent changes made to the ESA (USFWS 2019) by the Trump administration. A species is more likely to be recovering the longer it has been protected from take (Taylor et al. 2005, Haines et al. 2021), including actions which “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct” (ESA sec. 3(19)) and take of its habitat. By revoking these automatic protections, species listed as Threatened are now vulnerable to habitat modification and overutilization in the absence of a special rule.

The objective of the ESA is to recover species such that they no longer require the ESA's protection. However, the Trump administration's changes undermine its ability to do so for Threatened species (SCBNA 2018). If not afforded adequate protections, Threatened species may need to be up-listed to Endangered. Not only would the species then be in a more dire condition, but it would also require additional regulations which many had hoped to avoid. While species listed as Threatened after September 2019 can still have protections from take if the USFWS or NMFS publish a special rule, there are concerns that these agencies do not have the resources necessary to write these reports for every species which would need them (TWS 2018). Because the USFWS' funding priorities are in litigation rather than the listing and maintenance of Threatened and Endangered species (Waples et al. 2013), it seems unlikely that additional resources will become available to make this possible. This extra step required for designating Threatened species' protections also leaves them vulnerable to the influence of non-scientific interests (SCBNA 2018).

Our findings demonstrate that the categories of Threatened and Endangered are consistently being applied to the species protected by the ESA. The definitions, although nebulous, are suitable and therefore do not require modification. However, there is substantial overlap between Threatened and Endangered species in terms of both the number and types of threats they face. The ESA has proven itself an effective tool in mitigating biodiversity loss in the United States; species recovery has been increasing relative to species listings (Haines et al., 2021). The ESA has recovered 51 species as of January 2021 (ECOS; ecos.fws.gov) and has prevented the extinction of 97% of the species that are still listed (Evans et al. 2016). However, for the act to operate as originally intended, any amendments made to the ESA should be agreed upon by the scientists and conservation practitioners who implement this law. Maintaining the ESA as it was originally intended will allow it to continue to effectively protect the country's most vulnerable species.

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