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Conservation action implementation, funding, and population trends of birds listed on the Endangered Species Act

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ABSTRACT

Current rates of species endangerment and extinction are unprecedented in modern times. Conservation efforts aim to slow down, stop, and reverse threats to species and thus the current loss of biodiversity. However, the extinction risk to species continues to rise. Thus far, research has examined the efficiency and the effectiveness of conservation actions individually, yet, the full suite of implemented conservation actions should be considered. We assessed all implemented conservation actions for avian species listed under the Endangered Species Act (ESA) in the United States. Using data available through the US Fish and Wildlife Service (USFWS) we assessed the relationships between conservation actions implemented, population trends, and financial expenditures for all listed species each year between 1996 and 2013. We found positive associations between the amount of funding allocated for a species and their population trend. Implementation of the conservation actions habitat protection and educational awareness were positively associated with annual funding for a species. Our results highlight the disparity in conservation action implementation and resource allocation between ESA listed species on the mainland and on islands in the USA. Together these results and the cause and effect relationships they suggest could provide a pathway toward more effective conservation programs.

1. Introduction

The number of species threatened with extinction is higher than at any other time in recent history (Barnosky et al., 2011, Pimm et al., 2014). Conservation biologists attempt to stop loss of biodiversity through conservation actions, such as habitat protection, education and awareness, *ex-situ* programs, removing invasive species, and legislation (Salafsky et al., 2008). Such conservation efforts have delivered numerous successes in which species have been brought back from the brink of extinction. Between 1994 and 2004, conservation efforts likely prevented at least 16 avian species from going extinct (Butchart et al., 2006, Rodrigues et al., 2006). The Endangered Species Act in the United States of America and subsequent conservation actions implemented after species were listed as threatened or endangered is thought to have protected 227 species from extinction (Schwartz 2008). In addition, conservation efforts have had a substantial impact on overall trends in extinction risk as measured by the Red List Index, reducing the declining trajectory of 20% of threatened mammal and bird species (Hoffmann et al., 2010).

Available resources for conservation are currently insufficient to confront expanding threats (Miller et al., 2002, McCarthy et al., 2012, Restani and Marzluff, 2001, 2002), so it is important for practitioners to understand the factors that predispose conservation actions toward success. To date there has been little analysis of influences on the results of these conservation actions (Chapman et al., 2014). In the United States, the Endangered Species Act (ESA) was enacted to reverse the declining population trends of endangered species. The U.S. Fish and Wildlife Service (USFWS) creates a recovery plan with specific actions assigned to aid the recovery of each endangered and threatened species. In addition, they provide 5-year reviews on the progress of the conservation of each listed species. Together these reports provide information about both the conservation actions recommended and implemented, and the population trends of species listed under the ESA. Previous research has focused on the effectiveness of the Endangered Species Act and found that recovery of some species has been associated with the amount of funding, the length time on the act, the type of recovery plan, and implementation of critical habitat (see Gibbs and Currie, 2012)., In this paper we focus on the implementation of specific conservation actions to assess their effectiveness and their association with funding. We apply four specific research questions to the available information:

1. Are the recommended conservation actions being implemented?
2. Which conservation actions in place are positively correlated with increasing population trends?
3. Is there a relationship between conservation action implementation and the amount of money spent on conservation actions?

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4. Is there a relationship between the amount of money spent and population recovery?

Birds are an excellent study group to investigate such questions within the context of the ESA as they are easily studied and identifiable, and there are large networks of researchers studying birds and compiling information about their conservation status. Due to these networks of researchers generally there is more available information for birds than other taxa, which can help inform conservation decisions as well as assess the impact of conservation actions.

2. Methods

Information on avian species identity, recovery plan, 5-year reviews, and conservation expenditures were all found on publically available USFWS websites, http://www.fws.gov/info/databases2.html. Recommended conservation actions were found in the recovery plan for each listed species and sorted into the following categories; enforce regulations, population monitoring, habitat restoration (including habitat maintenance), habitat protection, invasive species control (competitors and predators, including native as well as nonnative species), *Ex-situ*, reintroduction, education, legislation, and research (after Salafsky et al., 2008). The USFWS ROAR database has information on all implemented conservation actions at 5-year intervals from 1995 through 2013. We used these data to identify in which year each conservation action was implemented for each species (https://ecos.fws.gov/roar/pub/ConfigureRecActionReport.do?path=ROAR%20Custom%20Queries.Public%20Actions%20AdHoc). Where data were available for multiple populations of a listed species we summed the population information so that the analysis would be at the level of the listing unit, not sub-populations within the listing unit.

Population level information was collected from the 5-year review for each listed species, including the number of individuals and the number of populations, as well as the year. All data were transformed to the number of individuals for each species, for example for species reported in number of breeding pairs rather than number of individuals, we multiplied breeding pairs times two. The amount of money spent on the conservation of each species in a given year was collected from the USFWS ESA library, http://www.fws.gov/endangered/esa-library/. The total amount of money spent for a species in a year was used and averaged based on the available data from 1996 to 2013.

Species were categorized as living on continents, 35 species, or islands, 51 species, because species on continents and islands often face different threats and require different conservation strategies. Island species included all ESA listed avian species on both oceanic islands, such as Puerto Rico and Hawaii, and continental islands, such as the Channel Islands in California. Four species were excluded from the analysis because USFWS listed them as exempt from recovery or extinct (see Appendix 1 for a list of all listed species and those not included in this study). While some other species are thought to be extinct since their listing, specifically some Hawaiian species (see Eliphick et al. (2010) for a full list), some of those species are included in this study because they had recovery plans, conservation actions were implemented for them, and they were not listed as exempt from recovery.

We used t-tests to compare the total number of conservation actions recommended and the number implemented for all species, the number of conservation actions implemented for species on islands and the continental US, and the number of conservation actions implemented for endangered and threatened species. We used paired t-tests to determine if the number of conservation actions recommended differed from the number implemented for each class of conservation action, for endangered species, for threatened species, for continental species, and for island species. For the paired t-tests of classes of conservation actions, to reduce the possibility of false positive results from multiple tests we used a Bonferroni correction factor and adjusted the alpha value from 0.05 to 0.0125.

To determine which conservation actions were associated with increasing or decreasing population trends we first conducted linear regression on the available population data from the USFWS for each species to determine the population trend of each species; two species had fewer than 3 years of available population data and were not included. Based on these results each species was labeled as having an increasing, stable, or decreasing population (see supplement for population trend regression results for each species). We used an information theoretic approach to select the best multiple regression logistic model for the binary response of population trend (increase or decrease), starting with a full model that included all implemented conservation actions, as well as total funding, and landmass. In our initial model, population trend was the binary response variable while conservation action implementation, yes or no for each species, and landmass type, island or mainland, inhabited by a species were the predictor variables. We then used forward and reverse stepwise AIC model selection to choose the best model from all possible subsets (step function R stats package version 2.15.3).

To examine the relationships between average annual funding and the implementation of each management action we used binomial general linear models (GLMs) with annual funding, log transformed, as a predictor, and implementation of each conservation action as a response. We used a GLM to predict number of actions implemented as well as which actions were implemented as a function of total funding. Finally, we used a binomial GLM to regress population trend against total funding, annual funding, plan year, landmass type, and the number of years a species was funded. Total funding was log transformed to meet assumptions of a normal distribution. All statistical analyses were performed in R statistical software version 2.15.3.

3. Results

Overall there were more conservation actions recommended, 6.6 ± s.e. 0.05, than implemented, 5.0 ± s.e. 0.07 (T-ratio = 4.2, DF = 86, $P < 0.0001$). Species listed as endangered and living on islands had significantly more conservation actions recommended than implemented while continental species and threatened species did not. These differences were significant for the following conservation actions and circumstances: monitoring, invasive species control, education, habitat protection, reintroduction, and *ex-situ* conservation (see Table 1 for statistical results; Fig. 1). However, significantly more actions were implemented than recommended for enforcing regulations for continental species, and for implementing new legislation for island species.

There were significantly more conservation actions implemented for continental than island species, 7.1 ± s.e 0.53 and 5.7 ± s.e. 0.44, respectively, (T-ratio = 2.07, DF = 84, $P = 0.04$), but there was no significant difference between threatened and endangered species in number of conservation actions implemented. There was more habitat protection (T-Ratio = 2.78, DF = 84, $P = 0.0067$) and habitat restoration (T-Ratio = 3.17, DF = 84, $P = 0.001$) implemented for continental species than species on islands, but none of the conservation actions were implemented differently for threatened and endangered species.

Sixteen continental and ten island species had increasing population trends, while eighteen continental and forty species on islands had declining populations. Species on islands were significantly more likely to have decreasing population trends than continental species (ChiSquare Pearson = 6.13, $P = 0.013$). Population trend was not associated with any specific conservation actions.

On average more money was spent per year for species in the continental U.S. than species on islands (T-Ratio = 4.6, DF = 82, $P < 0.0001$), with $2,908,615 (s.e. ±$433,906) spent on average per year for continental species (median $1,334,335), and $293,164 (s.e. ±$357,808) spent on average per year for island species (median $125,733). There was no significant difference in the amount of money spent annually between endangered and threatened species. The five species that received the most money on average, red-cockaded woodpecker,

Table 1
The conservation action categories assessed in this study along with the number of actions that were recommended and implemented. Conservation actions were further split into categories of species that were listed as endangered or threatened and species that inhabit islands or continents. Statistical results in these categories are the results of paired t-tests of the recommended and implemented conservation actions in each row.

Conservation action	Recommend	Implement	Endangered	Threatened	Island	Continent
Monitor	82	64	t-ratio = −3.33, DF = 74, P = 0.001	P = 0.08	t-ratio = −3.47, df = 51, P = 0.001	P = 0.09
Habitat protection	75	58	t-ratio = −3.01, DF = 51, P = 0.002	P = 0.09	t-ratio = −2.58, DF = 51, P = 0.01	P = 0.09
Invasive species control	69	39	t-ratio = −6.31, df = 72, P < 0.001	P = 0.67	t-ratio = −5.33, DF = 51, P = <0.001	t-ratio = −2.09, DF = 34, P = 0.04
Reintroduction	44	27	t-ratio = −2.29, DF = 72, P = 0.03	t-ratio = −2.28, DF = 13, P = 0.04	P = 0.09	t-ratio = −2.76, df = 34, P = 0.009
Ex-situ	47	29	t-ratio = −4.53, DF = 72, P < 0.001	P = 1	t-ratio = −4.76, DF = 51, P = <0.001	P = 0.42
Education	74	57	t-ratio = −2.82, DF = 72, P = 0.006	P = 0.16	t-ratio = −2.52, DF = 51, P = 0.01	P = 0.08
Legislation	15	24	t-ratio = 2.36, DF = 72, P = 0.02	P = 0.5	t-ratio = 2.39, DF = 51, P = 0.02	P = 0.48
Enforce rules	24	46	t-ratio = 2.67, DF = 72, P = 0.01	t-ratio = 2.46, DF = 13, P = 0.03	P = 0.24	t-ratio = 4.43, DF = 34, P = <0.001

southwestern willow flycatcher, northern spotted owl, piping plover, and least tern interior population, received 47% of average annual expenditures. There was a significant positive relationship between annual funding and implementation of habitat protection (z = 2.280, DF = 78, *P* = 0.022) and education (z = 2.292, DF = 78, *P* = 0.021) (Fig. 2). There was a significant relationship between total funding and population trend, though the amount of variance explained was small (z = 2.349, DF = 82, *P* = 0.018, pseudoR^2 = 0.07; Fig. 3a), and between annual funding and population trend (z = 2.304, *P* = 0.021, R^2 = 0.11; Fig. 3b), with more funding associated with increasing population trend in both cases.

4. Discussion

Our assessment of the relationships between recommended and implemented conservation actions, funding, and population trends of threatened and endangered species found positive associations between the amount of funding allocated for a species and its population

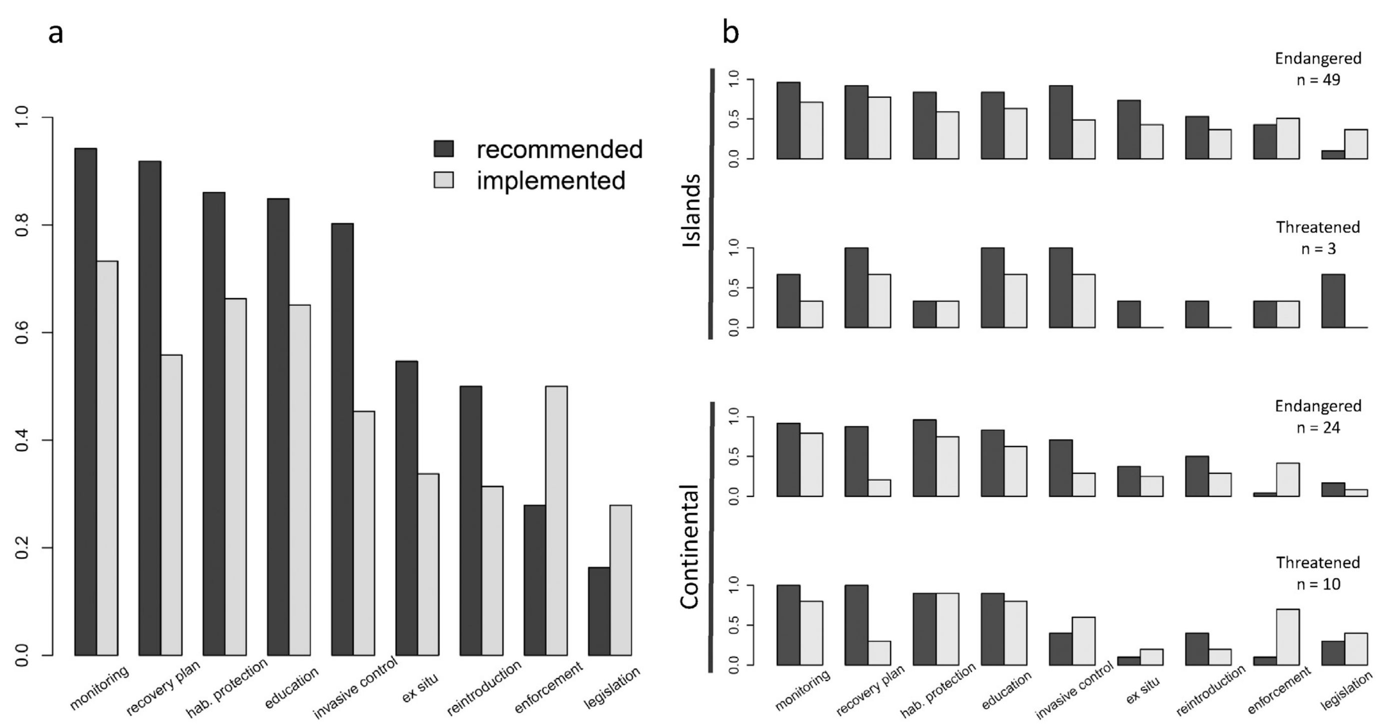

Fig. 1. a) Comparison of the proportions of recommended and implemented conservation actions from 86 ESA listed avian species. b) Comparison of the proportions of recommended (dark bars) and implemented (light bars) conservation actions from 86 species recovery programs. Programs are separated by island *versus* continental species, and threatened *versus* endangered species.

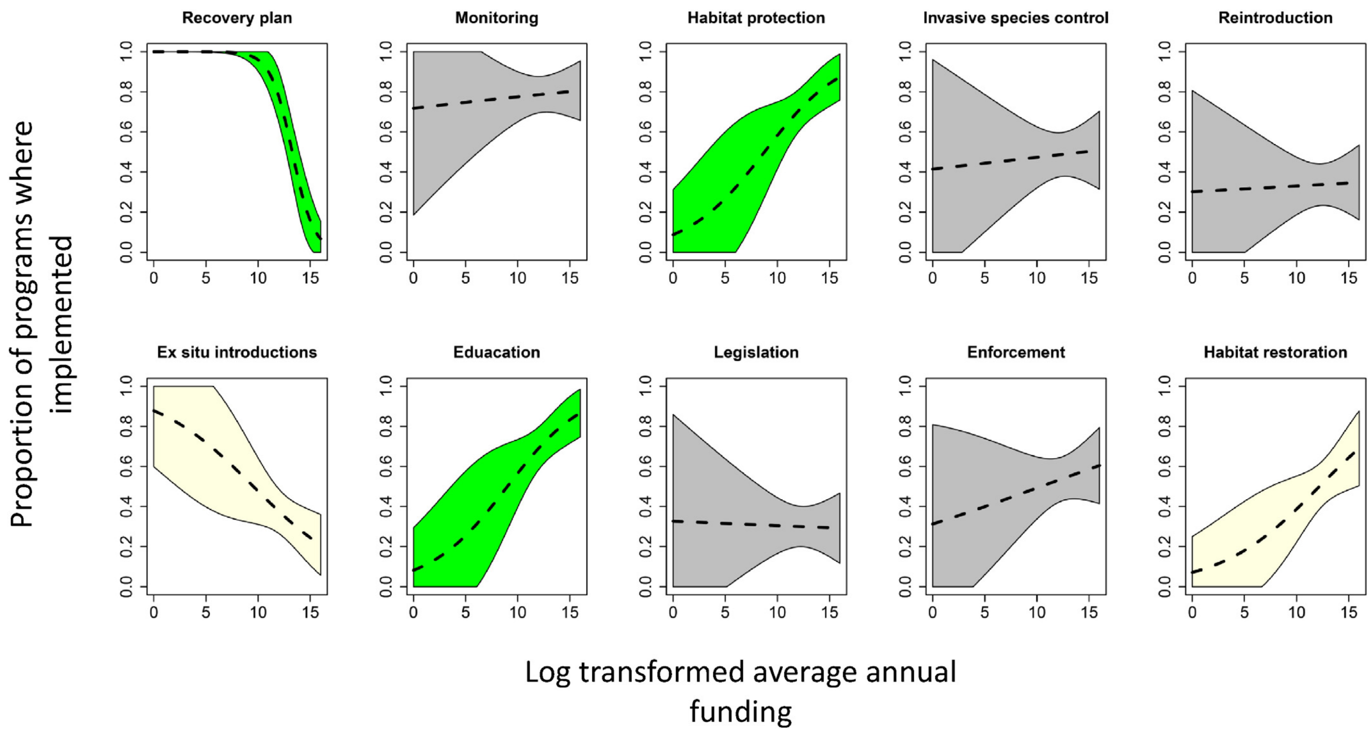

Fig. 2. Relationship between conservation action implementation and average annual funding. The dotted line is the model fit, the polygon is the 95% confidence envelope and polygon color indicates model significance (green for $p < 0.05$, yellow for $0.05 < p < 0.10$, and gray for $p > 0.1$).

trend. In addition, implementation of habitat protection and educational awareness were positively associated with annual funding for a species, suggesting that these are especially expensive activities, or are more likely to be undertaken when more funding is available. Our results also highlight the disparity in conservation action implementation and resource allocation between ESA listed species on the mainland and on islands in the U.S. Taken together these results have implications for increased efficiency in terms of the conservation of threatened and endangered species and should improve the effectiveness of future conservation efforts.

Positive population trends for ESA listed avian species were associated with the total and average annual amount of funding that a species received, but not with any specific classes of conservation actions. Miller et al. (2002) and Gibbs and Currie (2012) also found a positive association between annual funding and increasing population trends, although funding did not explain a large amount of variance, which is true in our study as well. While we found no specific classes of conservation actions associated with positive population trends, larger amounts of spending on a particular species could reflect a greater diversity of conservation actions implemented for those species.

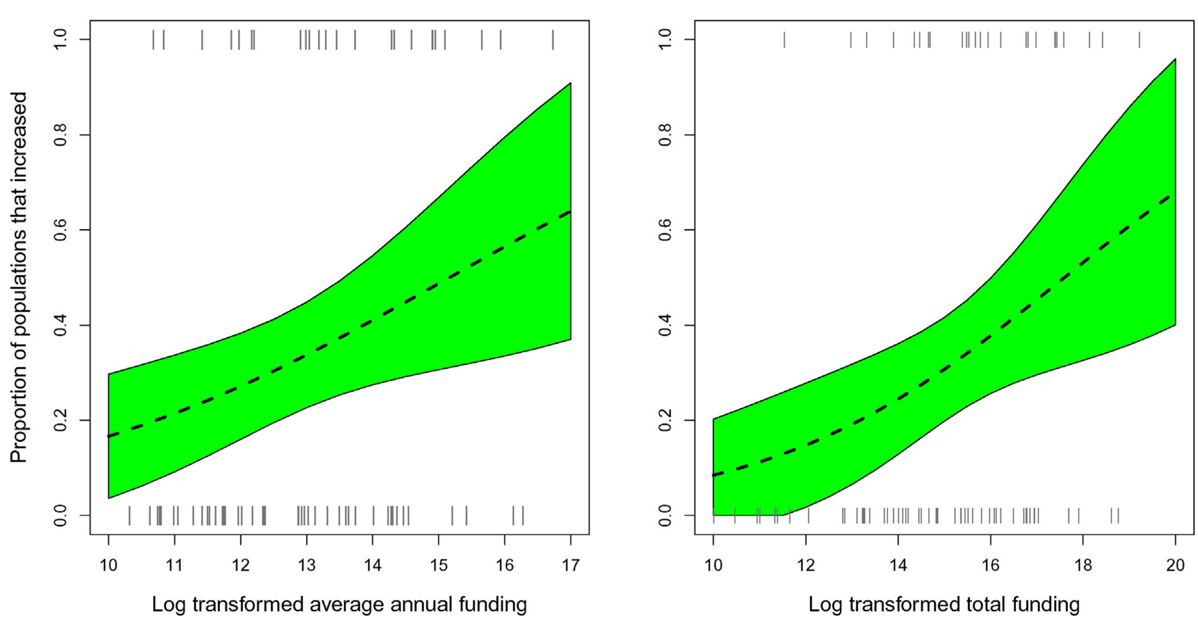

Fig. 3. Proportion of species with increasing population trends as a function of a) average annual expenditures and b) total expenditures.

Potentially interactions between various implemented conservation actions, such as invasive species control and *ex-situ* conservation, could have synergistic effects that help species recover when one class of action on its own might not be enough to promote population recovery. In contrast, a study of globally threatened bird species found correlations between positive population trends and the conservation actions reintroduction, *ex-situ*, invasive species control, education, and legislation (Luther et al. in review). Potentially the discrepancy between the analyses of threatened bird species around the world and ESA listed avian species arises from a smaller sample size for ESA listed birds, or a lack of good population trend data for ESA listed species (Gibbs and Currie, 2012). In other studies of ESA listed species positive population trends have been shown to be associated with the length of time a species has been listed, having a species specific recovery plan, as well as the degree of habitat protection (Taylor et al., 2005, Gibbs and Currie, 2012).

The conservation actions habitat protection and educational awareness were positively associated with the amount of funding a species received, consequently there could be an important nexus between these actions and increasing population trends. Habitat protection is an important component of species conservation and specific habitat conservation plans are developed for many ESA listed species. In fact, Restani and Marzluff (2001, 2002) found that ESA listed birds with increasing population trends had lands purchased for protection more often than birds with declining population trends. The conservation actions habitat protection and habitat restoration were implemented more frequently for continental than island species, which could increase exposure to threats for island species. Potentially, more habitat protection for mainland species than island species could result from larger range sizes, more real estate available to buy/protect, or more money/effort available for species on the mainland. However, given the high number of endangered species on islands, more protected areas could result in the conservation of more species (Kier et al., 2009, Reed et al., 2012).

Allocated funding per species per year was drastically different between mainland and island species (Restani and Marzluff, 2001, 2002, Leonard, 2008). Given the association between annual funding and population trends (Gibbs and Currie, 2012), funding could be a factor that contributes to the differences in population trends between island and continental species. The disparity in funding could result from a number of political, logistical, or biological factors, for example on islands many species tend to be under the umbrella of one organizational unit, as opposed to separate programs for each species on the mainland. Restani and Marzluff (2001, 2002) found that between 1992 and 1995 a small number of continental bird species with wide distributions, high recovery potential and captive breeding programs received most of the money for endangered species each year, while 10 of the 12 species that received the least spending were on islands. While the exact species receiving the most and the least funding has changed since 1995 we found that the trend of wide ranging continental species receiving the most funding while island species received the least has persisted (see Appendix 1 for funding for each species). In addition, there are a higher percentage of listed species on islands, which could make it difficult politically to provide the same amount of funding per species (Leonard, 2009). There is also a greater percentage of species on islands with multispecies recovery plans than on the mainland and species with their own dedicated recovery plan are more likely to have positive population trends than species included in multispecies plans (Taylor et al., 2005). However, these relationships are correlational and other interpretations exist. For example, it may be that conservation issues are more often intractable on islands, such that little can be done to halt population declines and thus little money is spent on some species (see below).

We found a greater likelihood for island species to have declining population trends (Trevino et al., 2007). Most likely many of the population trend differences result from key biological differences and the larger impact of threats to species on islands and continental landmasses (Scott et al., 1986, Pratt, 2009). Most avian extinctions in the last few centuries have been on islands (Clavero and Garcia-Berthou, 2005). Island species might be more susceptible to population declines and extinction than continental species because they were closer to extinction when they were listed, threats have had a more significant impact on islands, island populations were initially smaller, island populations receive less funding to combat threats, or they receive fewer conservation actions (Pratt, 2009). Invasive species have been a leading cause of extinction for native species on islands (Clavero and Garcia-Berthou 2005). Fortunately, eradicating invasive species is an increasingly successful conservation action, although usually on small rather than large islands (Howald et al., 2007; Kraus and Duffy, 2009; Veitch et al., 2011). However, we found no difference in implementation of invasive species control between islands and continents, or relationship of implementation of invasive species control to population trends, perhaps because most of the ESA listed birds are on large islands where invasive species control has been less successful compared to smaller islands.

A closer look at the implementation of specific classes of conservation actions and their effects on population trends could improve the timing and effectiveness of conservation action implementation as well as help prevent more species from being lost. One potential avenue is to look at the alignment between threats and implemented conservation actions to see if closer alignment might result in increased population trends. The relationships that we found between landmass type on which species live and expenditures on those species and population trends were correlative and as such are subject to multiple interpretations. Where possible we substantiated our interpretations with similar findings in other papers but more work needs to be done to tease apart these relationships if we are to truly improve the efficiency and effectiveness of endangered species conservation.

The data used in this article is in Appendix 1. We will also deposit the data on Dr. Luther's website. http://mason.gmu.edu/~dluther/Luther_Lab.html. Supplementary data associated with this article can be found in the online version, at http://dx.doi.org/10.1016/j.biocon.2016.03.019.

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