Conservation Biology

Research Note

Use of standardized methods to improve extinction-risk classification

Caitlin C. Mothes ,* Stephanie L. Clements, Dishane K. Hewavithana, Hunter J. Howell, Aaron S. David , † Nicole D. Leventhal, and Christopher A. Searcy

Department of Biology, University of Miami, 1301 Memorial Drive, Coral Gables, FL 33146, U.S.A.

Abstract: Standardized classification methods based on quantifiable risk metrics are critical for evaluating extinction threats because they increase objectivity, consistency, and transparency of listing decisions. Yet, in the United States, neither federal nor state agencies use standardized methods for listing species for legal protection, which could put listing decisions at odds with the magnitude of the risk. We used a recently developed set of quantitative risk metrics for California herpetofauna as a case study to highlight discrepancies in listing decisions made without standardized methods. We also combined such quantitative metrics with classification tree analysis to attempt to increase the transparency of previous listing decisions by identifying the criteria that had inherently been given the most weight. Federally listed herpetofauna in California scored significantly higher on the risk-metric spectrum than those not federally listed, whereas state-listed species did not score any higher than species that were not state listed. Based on classification trees, state endemism was the most important predictor of listing status at the state level and distribution trend (decline in a species' range size) and population trend (decline in a species' abundance at localized sites) were the most important predictors at the federal level. Our results emphasize the need for governing bodies to adopt standardized methods for assessing conservation risk that are based on quantitative criteria. Such methods allow decision makers to identify criteria inherently given the most weight in determining listing status, thus increasing the transparency of previous listing decisions, and produce an unbiased comparison of conservation threat across all species to promote consistency, efficiency, and effectiveness of the listing process.

Keywords: classification trees, conservation priority, listing criteria, listing decisions, quantitative risk metrics, risk assessment, threatened species

Uso de Métodos Estandarizados para Mejorar la Clasificación del Riesgo de Extinción

Resumen: Los métodos estandarizados de clasificación basados en medidas cuantificables del riesgo de extinción son sumamente importantes para evaluar las amenazas de extinción ya que incrementan la objetividad, consistencia y transparencia de las decisiones de listado. Aún así, en los Estados Unidos, ni las agencias federales ni las estatales usan métodos estandarizados para enlistar a las especies para su protección legal, lo que podría poner en discrepancia a las decisiones de listado con la magnitud del riesgo. Usamos un conjunto de medidas cuantitativas del riesgo, desarrollado recientemente para la herpetofauna de California, como un estudio de caso que nos permitiera resaltar las discrepancias en las decisiones de listado hechas sin métodos estandarizados. También combinamos dichas medidas cuantitativas con un análisis de árbol de clasificación para intentar incrementar la transparencia de las decisiones de listado previas al identificar los criterios a los cuales se les había otorgado mayor peso inherentemente. La herpetofauna de California que se encontraba enlistada a nivel federal tuvo un puntaje significativamente más alto en el espectro de la medida del riesgo que aquellas especies que no estaban enlistadas, mientras que las especies enlistadas a nivel estatal no tuvieron un puntaje más alto que aquellas especies que no estaban enlistadas a nivel estatal. Con base en los árboles de clasificación, el endemismo estatal fue el

*email ccmothes@miami.edu

†Current address: USDA-ARS Invasive Plant Research Laboratory, 3225 College Avenue, Fort Lauderdale, FL 33314, U.S.A.

__Article impact statement__: Using standardized, quantitative methods to assess extinction risk can improve listing decisions by increasing consistency and transparency

Paper submitted May 3, 2019; revised manuscript accepted September 19, 2019.

DOI: 10.1111/cobi.13421

indicador más importante del estado de listado a nivel estatal y tanto la tendencia de distribución (declinación del tamaño de la extensión de una especie) y como la tendencia poblacional (declinación de la abundancia de una especie en sitios localizados) fueron los indicadores más importantes a nivel federal. Nuestros resultados enfatizan la necesidad que tienen los cuerpos de gobierno de adoptar los métodos estandarizados que están basados en criterios cuantitativos para la evaluación del riesgo de conservación. Dichos métodos permiten que quienes toman las decisiones identifiquen los criterios a los cuales se les otorga inherentemente el mayor peso al determinar el estado de listado, lo que incrementa la transparencia de las decisiones previas de listado, y produce una comparación sin sesgos de la amenaza de conservación en todas las especies para promover la regularidad, eficiencia y efectividad de los procesos de listado.

Palabras Clave: árbol de clasificación, criterios de listado, decisiones de listado, especies amenazadas, evaluación del riesgo, medidas cuantitativas del riesgo, prioridad de conservación

摘要: 基于定量风险指标的标准化分类方法可以提高濒危物种名录确定的客观性、一致性和透明度, 因而对评估物种的灭绝风险十分重要。然而, 在美国, 无论是联邦机构还是州立机构, 都没有使用标准化方法来确定法律保护的濒危物种, 这可能会导致濒危物种名录决策与物种面临的灭绝风险程度不相一致。我们以最近开发的一套美国加州爬行动物区系定量风险指标为例, 展示了标准化方法的使用与否在濒危物种名录确定中产生的差异。我们还将这些定量指标与分类树分析相结合, 试图通过找出之前的确定方法中占权重最大的指标来增加决策的透明度。被联邦政府列入名录的加州爬行动物的风险指标谱得分明显高于那些没有列入名录的物种, 而州政府列入名录的物种得分却并不比没有列入的物种高。分类树结果还显示, 州级濒危等级最重要的预测因子为州级特有性, 而在联邦一级最重要的预测因子则是分布趋势 (物种分布范围的缩小) 和种群趋势 (局部地区物种丰度的下降) 。我们的研究结果突出表明管理机构应采用基于定量指标的标准化方法来评估保护风险。这些方法可以帮助决策者找到濒危等级确定中最重要的指标, 从而增加已有确定方法的透明度, 还可以通过公正地比较所有物种面临的保护威胁, 以提升濒危物种名录确定过程中的一致性、效率和效果。【翻译: 胡怡思; 审校: 聂永刚】

关键词: 分类树, 保护优先性, 濒危物种名录标准, 濒危物种名录决策, 风险评估, 受胁迫物种, 定量风险指标

Introduction

The Anthropocene epoch is characterized by unprecedented rates of biodiversity loss worldwide (Crutzen & Stoermer 2000). Protecting imperiled species from negative anthropogenic impacts is a crucial step toward preserving the biodiversity that currently persists (Barnosky et al. 2011; Dirzo et al. 2014). Imperiled species lists that classify species' conservation status are valuable tools that aid in policy decisions by directing conservation prioritization (de Grammont & Cuarón 2006; Rodrigues et al. 2006). An important aspect of producing imperiled species lists and subsequent legal protection is having a standardized categorization system with risk criteria, particularly those that minimize subjective elements. Doing so increases consistency and transparency of definitions and designations (de Grammont & Cuarón 2006). The most widely accepted method for classifying conservation risk has been developed by the International Union for Conservation of Nature (IUCN), and many nations have adopted the IUCN classification as the basis for their wildlife protection (de Grammont & Cuarón 2006; Mace et al. 2008).

However, such quantitative categorization systems are not currently used in the United States. Rather, the federal government has developed its own system for listing imperiled species, which are protected under the Endangered Species Act (ESA), arguably the world's most powerful biodiversity conservation law (Bean & Rowland 1997; Schwartz 2008). Decisions to list species as threatened or endangered are based "solely on the basis of the best scientific and commercial data available" (ESA Sec 4[b][1][A]) and consider threats to a species' habitat or range, overutilization of the species, disease or predation threats, lack of existing regulatory mechanisms, and other natural or anthropogenic factors affecting the species' continued existence (ESA Sec 4[a][1]). In addition to federal protection, most states have their own statewide legal protection of imperiled species and their own categories, such as species of special concern (SSC) (i.e., species that do not necessarily fit the criteria that warrant legal protection, but may qualify in the future). Listing decisions at the state and federal levels are not based on standardized methods to estimate extinction risk, but instead rely on highly subjective definitions of what warrants legal listing (Waples et al. 2007). Although studies have encouraged the administering state and federal bodies to adopt a set of standardized, quantitative criteria on which to base listing decisions (DeMaster et al. 2004; Regan et al. 2009), they have yet to do so.

California has one of the most comprehensive statewide imperiled species acts, the California Endangered Species Act (CESA), which is modeled after the U.S. ESA and administered by the California Department of Fish and Wildlife (CDFW) (George & Snape III 2010). California also produces extensive SSC lists, including Thomson et al. (2016), which recently updated status assessments for amphibian and reptile SSC. Although most previous SSC documents were based primarily on expert opinion, Thomson et al. (2016) formalized their listing criteria by developing a set of 8 quantitative risk metrics that describe the extent to which a species is threatened by extinction. By standardizing the criteria for listing, the new classification provides increased transparency, facilitates feedback on scoring, and enhances the ability of CDFW and other agencies to replicate the process in the future.

Although Thomson et al. (2016) provided status assessments for SSC (including taxa that are federally listed), they did not assess amphibian and reptile species already protected under the CESA. We used their quantitative risk metrics to assess these species and then examined the accuracy and consistency of state and federal listing decisions by comparing species' risk scores with their listing status. Using the herpetofauna of California as a case study, our goal was to highlight the potential discrepancies in listing decisions made without using standardized methods and emphasize the need for governing bodies to adopt such methods.

Methods

Classifying State-Listed Species

Thomson et al.'s (2016) method assigned a risk score based on 8 risk metrics (Table 1). The scores for each category range from 0 (low risk) to either 10 or 25 (high risk). More weight is placed on documented declines in either distribution or population size and less weight is placed on potential concerns, such as life history characteristics that increase environmental sensitivity or projected impacts from climate change and other anthropogenic factors. Although there is some subjectivity in choosing these metrics and their relative weights, it is one of the few listing assessment approaches based on standardized criteria.

Table 1. Species risk metrics and risk-scoring descriptions developed by Thomson et al. (2016).

Risk metric	*Criterion*	*Score*	*Maximum score*
Range size (% of California occupied)	small (<10%)	10	10
	medium (10-50%)	5	
	large (>50%)	0	
Distribution trend	severely reduced (>80%)	20	25
	greatly reduced (>40–80%)	15	
	moderately reduced (20–40%)	10	
	slightly reduced (<20%) or suspected declines	5	
	stable (~0% reduced) or increasing	0	
	additional 5 points if negative trend is ongoing	+5	
Population concentration or migration	vulnerable life stages present	10	10
	no vulnerable life stages present	0	
Endemism (% of entire range in California)	100% (endemic)	10	10
	>66–99%	7	
	33–66%	3	
	<33%	0	
Ecological tolerance	narrow ecological specialist on a rare resource	10	10
	narrow ecological specialist on a common resource	7	
	moderate ecological specialist	3	
	broad ecological tolerance	0	
Population trend	severe declines (>80% reduced)	20	25
	great declines (>40–80% reduced)	15	
	moderate declines (20–40% reduced)	10	
	slight (<20% reduced) or suspected declines	5	
	stable (~0% reduced) or increasing	0	
	additional 5 points if declines are ongoing	+5	
Vulnerability to climate change	highly sensitive	10	10
	moderately sensitive	7	
	slightly sensitive	3	
	unlikely to be sensitive	0	
Projected impacts (of threats over the next 20 years)	serious	10	10
	moderate	7	
	slight	3	
	no substantial impact	0	
Total possible			110

After assigning a score for each individual risk metric, the species is given a final risk score, which is the total score (sum of the scores given for all of the risk metrics) divided by the total possible (maximum value that could be assigned based on available data). If a certain risk metric is lacking in data for a given species, then it is classified as not available and is omitted from the final risk-score calculations. Thomson et al. (2016) used the final risk scores to assign 1 of 3 listing prioritizations for the SSC: priority 1 (top priority), priority 2 (medium priority), and priority 3 (lowest priority).

Thomson et al. (2016) used their method to calculate risk scores for candidate SSC herpetofauna in California and published their assessments for 45 taxa (species or subspecies). These assessments excluded all taxa already listed under the CESA because this set of taxa already had a separate state conservation designation. We used Thomson et al.'s (2016) method to calculate conservation risk for the 22 reptile and amphibian taxa that are listed as either threatened ($n = 16$) or endangered ($n = 6$) under the CESA. To be as consistent as possible with the assessment methods used in Thomson et al. (2016), we used peer-reviewed literature as our primary source of information for assigning risk scores to each state-listed species. We also used agency reports documenting the information that justified listing (Supporting Information).

Statistical Analyses

Within our sample of 67 species, we first tested for overall differences in risk scores between listed and unlisted species at the federal and state levels with Student's t tests. The same method was used to compare risk scores between reptiles and amphibians considering the entire data set and only California state-listed species. Next, we investigated differences in risk scores between CA state-listed species and each of the 3 priority levels of SSC with a 1-way analysis of variance followed by Tukey's multiple comparison test.

We also identified which risk metrics best predicted listing status, since governing bodies do not explicitly state how such risk metrics are weighted during the listing process. We used classification and regression tree analysis because of its robustness to unbalanced data sets (De'ath & Fabricus 2000) and past model performance (Bland et al. 2015). We modeled the decisions to list a species at the state and federal levels with risk scores as the independent variables. All 8 risk metrics were used after ensuring there were no significant correlations among metrics. All statistical analyses were conducted in R version 3.5.0 (R Core Team 2018), and classification models were run with the rpart package version 4.1 (Therneau & Atkinson 2018).

Results

The risk scores (total score/total possible) for the California state-listed species ranged from 38% to 97% (mean 64%). Species state-listed as endangered had significantly higher scores than species state-listed as threatened ($t = 2.46$, df $= 20$, $p = 0.023$). Among all assessed species, federally listed species had significantly higher risk scores than nonfederally listed species ($t = 5.78$, df $= 65$, $p < 0.001$), but state-listed species did not differ in mean risk score from nonstate-listed species ($t = 1.11$, df $= 65$, $p = 0.27$) (Fig. 1). When we separated the SSC by listing priority, listing status was related to risk score ($F_{3,60} = 10.76$, $p < 0.001$), but state-listed species fell between priority 1 and 2 species and only scored significantly higher than priority 3 species (Fig. 1). Amphibians had higher risk scores than reptiles ($t = 3.32$, df $= 65$, $p = 0.001$) across the full data set. However, within the CA state-listed species there was no difference in mean risk score between amphibians and reptiles ($t = 0.37$, df $= 20$, $p = 0.71$).

For the state classification tree, endemism was the most important variable defining state listing status, such that listed species had higher endemism scores than unlisted species. Distribution trend and population trend were the most important variables defining federal listing status; scores for listed species were higher than scores for unlisted species (Fig. 2). The misclassification rate was relatively low for both models: 18% for state listing and 19% for federal listing.

Discussion

Previous arguments for using standardized classification methods emphasize their ability to increase objectivity, transparency, and consistency of listing decisions (de Grammont & Cuarón 2006; Mace et al. 2008). Applying a set of objective quantitative risk metrics and classification tree analyses to California's imperiled herpetofauna had 2 main outcomes that reemphasize the importance of making standardized conservation threat assessments. First, it allowed us to determine which risk factors have inherently been given the most weight during previous listing decisions, thereby increasing transparency of those previous decisions. Second, it pointed out inconsistencies, such as risk scores for state-listed species being no different from nonstate-listed species. This highlights the need for more consistent listing decisions.

Our classification tree analysis offers greater transparency to the factors underlying listing decisions, revealing which listing criteria are inherently given the most weight by USFWS and CDFW, neither of which apply an explicit listing method. At the state level, state endemism was the most important variable in determining listing status. This approach seems reasonable because state

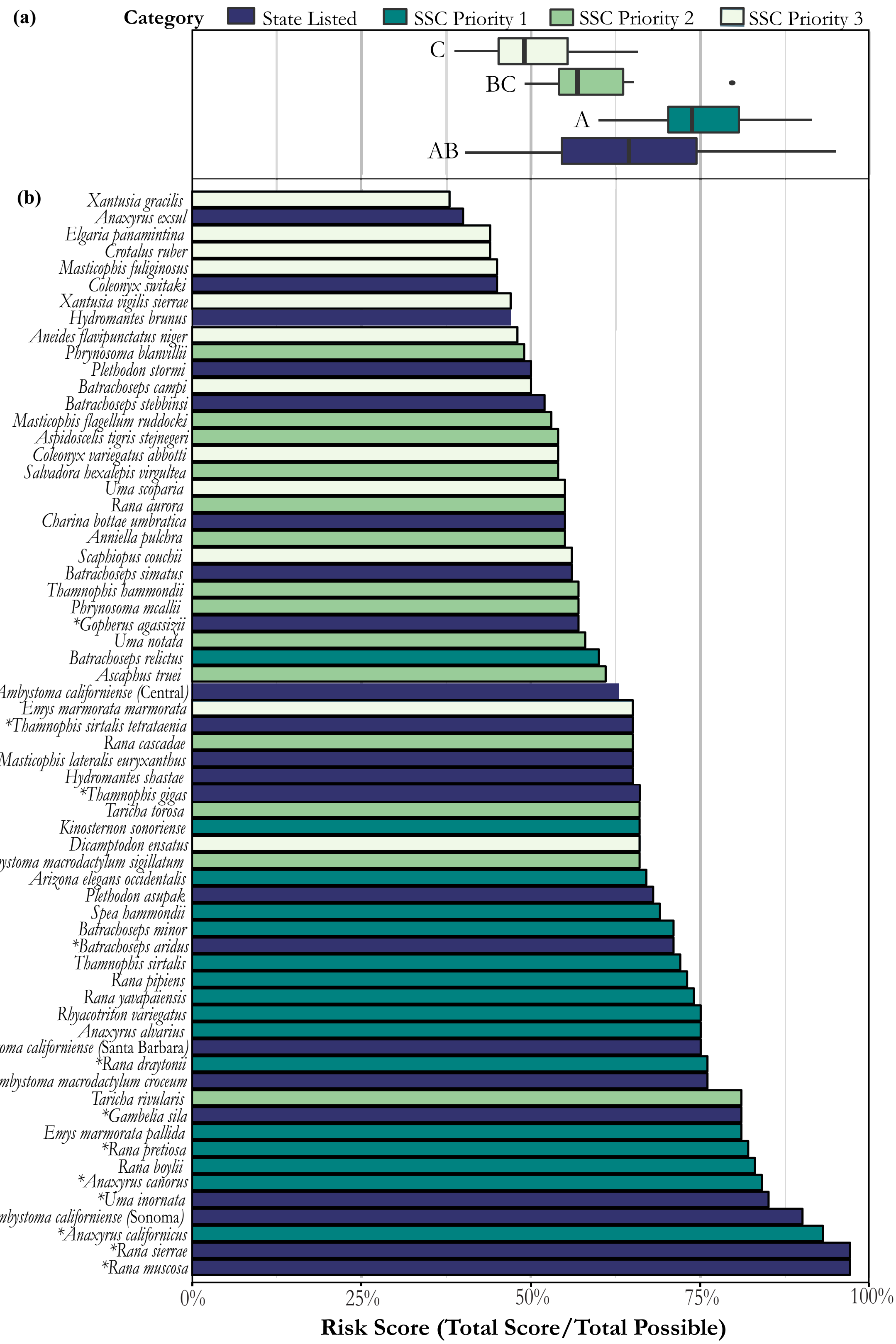

Figure 1. (a) Risk scores for California reptile and amphibian state-listed species and species of special concern priority 1, 2, and 3. (different letters denote significant differences between individual categories; overall state- and nonstate-listed species did not differ significantly [p = 0.34]) and (b) individual risk scores for all species assessed (, federally listed species, which scored significantly higher than nonfederally listed species [p < 0.001]).*

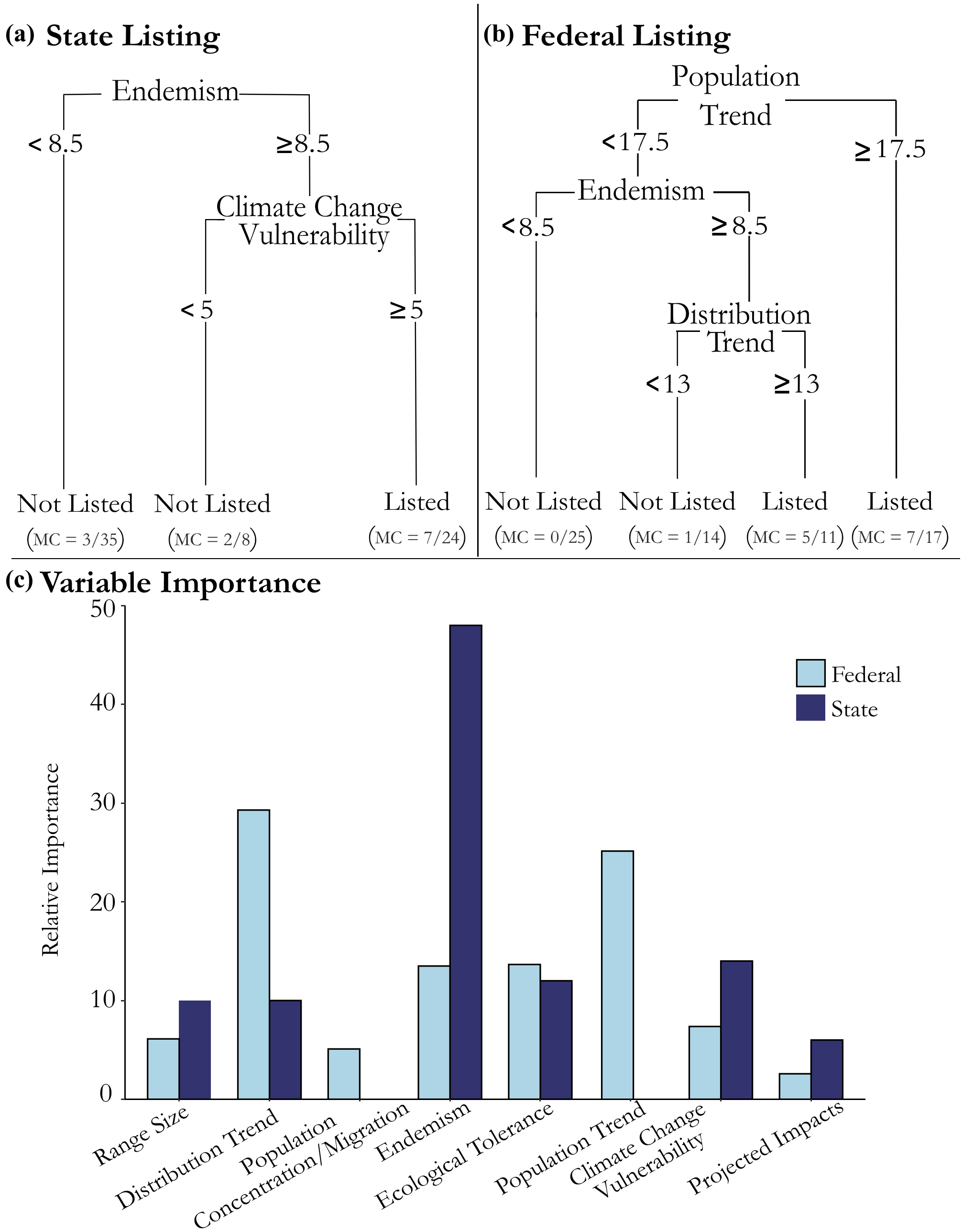

Figure 2. Classification trees describing listed versus unlisted reptile and amphibian species at the (a) state (California) and (b) federal level (misclassification rates [MC] in parentheses for each terminal node; numbers on branches, species' risk scores for risk metric indicated) and (c) relative importance of each risk metric inherent in the state and federal listing process.

endemic species are a unique piece of the state's natural heritage that cannot be protected anywhere else. Thus, states may wish to prioritize these species for both biological and public-relations reasons. In terms of conservation-related species attributes, the public is most receptive to endemism (Meuser et al. 2009); therefore, state endemic species may be most likely to promote local conservation interest. At the federal level, the most important variables describing listing status were distribution trend and population trend. This indicates agreement between federal listing decisions and Thomson et al.'s (2016) method, which gave the highest weight to these 2 metrics. Previous simulation studies indicate that among the risk metrics we considered, population trend should be the most predictive of true extinction probability (O'Grady et al. 2004), and population and distribution trend were the most correlated of all variables examined.

The finding that risk metric scores were no higher for state-listed species than for unlisted species suggests there may be inconsistencies in the decision-making process. Our methods suggest 2 ways to promote consistency of listing decisions. We identified the factors that were inherently given the most weight in previous listing decisions. Thus, one option would be to apply the same set of factors consistently to all future listing decisions. Currently, this would result in 7 unlisted species that should be reconsidered for listing according to our classification tree analysis. If we reclassified all species according to the best-fit classification tree, mean risk scores for state-listed species would be significantly higher than scores for unlisted species ($t = 2.12$, df $= 65$, $p = 0.038$), as desired. Therefore, following these criteria improves the consistency of listing decisions. Alternatively, one could decide that the full set of 8 risk metrics, not just those identified as most important based on the classification trees, provides the most comprehensive assessment of risk. Thus, an alternative reclassification scheme would be to confer listed status based on a species rank in the overall risk scores (Fig. 1). By providing an unbiased comparison of conservation risk across all species, such quantitative methods promote efficiency and effectiveness by ensuring that the correct species are given legal protection quickly and in an easily defensible manner.

Regardless of whether any species are reassessed in the wake of our study, this work emphasizes the value of using standardized methods in the decision-making process (deMaster et al. 2004; Regan et al. 2009; Cummings et al. 2018). Although we used the imperiled herpetofauna of California as an example, these suggestions apply to all taxonomic groups and all governing bodies in the United States. The quantitative analysis we adopted would not have been possible if CDFW had not pursued such a rigorous quantitative assessment of their SSC candidates. We encourage other state and federal agencies to adopt similar standardized risk assessments to update their own imperiled species lists. With limited resources for conservation, this is an imperative step to increase the transparency and consistency of the decision-making process to combat biodiversity loss in the Anthropocene.

Acknowledgments

We thank R.C. Thomson, A.N. Wright, and H.B. Shaffer for developing the quantitative criteria used in this study and for assistance and comments during our scoring process. Funding for this project was supported by the University of Miami. The findings and conclusions of this manuscript are those of the authors and do not necessarily reflect those of the California Fish and Wildlife Department or U.S. Fish and Wildlife Service.

Supporting Information

A summary table with risk scores and rationale for each assessed state-listed species (Appendix S1) and literature cited for species' assessments (Appendix S2) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Barnosky AD, et al. 2011. Has the earth's sixth mass extinction already arrived? Nature **471:**51–57.

Bean MJ, Rowland MJ. 1997. The evolution of the national wildlife law. 3rd edition. Praeger, Westport, Connecticut.

Bland LM, Collen B, Orme CDL, Bielby J. 2015. Predicting the conservation status of data-deficient species. Conservation Biology **29:**250–259.

Crutzen KR, Stoermer EF. 2000. The Anthropocene. IGBP Global Change News, **41**:17–18.

Cummings JW, Converse SJ, Smith DR, Morey S, Runge MC. 2018. Implicit decision framing as an unrecognized source of confusion in endangered species classification. Conservation Biology **32:**1246–1254.

de Grammont P, Cuarón AD. 2006. An evaluation of threatened species categorization systems used on the American continent. Conservation Biology **20:**14–27.

De'ath G, Fabricius KE. 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology **81:**3178–3192.

DeMaster DP, Angliss RP, Cochrane J, Mace PM, Merrick R, Miller M, Rumsey S, Taylor BL, Thompson GG, Waples RS. 2004. Recommendations to NOAA Fisheries: ESA listing criteria by the Quantitative Working Group. Technical memorandum NMFS-F.SPO-67. National Oceanic and Atmospheric Administration, Maryland.

Dirzo R, Young HS, Galetti M, Ceballos G, Isaac NJB, Collen B. 2014. Defaunation in the Anthropocene. Science **345:**401–406.

George S, Snape III WJ. 2010. State endangered species acts. Pages 345–359 in Baur DC, Irvin WR, editors. Endangered Species Act law, policy, and perspectives. American Bar Association.

Mace GM, Collar NJ, Gaston KJ, Hilton-Taylor C, Akçakaya HR, Leader-Williams N, Milner-Gulland EJ, Stuart SN. 2008. Quantification of extinction risk: IUCN's system for classifying threatened species. Conservation Biology **22:**1424–1442.

Meuser E, Harshaw HW, Mooers AØ. 2009. Public preference for endemism over other conservation-related species attributes. Conservation Biology **23:**1041–1046.

O'Grady JJ, Reed DH, Brook BW, Frankham R. 2004. What are the best correlates of predicted extinction risk? Biological Conservation **118:**513–520.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from https://www.R-project.org/.

Regan TJ, Taylor BL, Thompson GG, Cochrane JF, Merrick R, Nammack M, Rumsey S, Ralls K, Runge MC. 2009. Developing a structure for quantitative listing criteria for the U.S. Endangered Species Act using performance testing: phase I report. Technical Memorandum NMFS-SWFSC-437. National Oceanic and Atmospheric Administration, Maryland.

Rodrigues ASL, Pilgrim JD, Lamoreux JF, Hoffman M, Brooks TM. 2006. The value of the IUCN Red List for Conservation. Trends in Ecology & Evolution **21:**71–76.

Schwartz MW. 2008. The performance of the Endangered Species Act. Annual Review of Ecology, Evolution, and Systematics **39:**279–299.

Therneau, T, Atkinson, B. 2018. Rpart: recursive partitioning and regression trees. R package version 4.1-13. Available from https://CRAN.R-project.org/package=rpart (accessed December 2018).

Thomson RC, Wright AN, Shaffer HB. 2016. California amphibian and reptile species of special concern. First Edition. University of California Press, Oakland, California.

Waples RS, Adams PB, Bohnsack J, Taylor BL. 2007. A biological framework for evaluating whether a species is threatened or endangered in a significant portion of its range. Conservation Biology **21:**964–974.