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Overcoming Challenges to the Recovery of Declining Amphibian Populations in the United States

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The US Endangered Species Act of 1973 (ESA) affords many potential benefits to species threatened with extinction. However, most at-risk amphibians—one of the most imperiled vertebrate groups—remain unlisted under the provisions of the ESA, and many impediments to recovery exist for those species that have been listed. Of the 35 US amphibian species and distinct population segments ("taxa") listed under the ESA, 40% currently lack a final (completed) recovery plan, 28.6% lack designated critical habitat, and 8.6% lack both. For taxa that have recovery plans, the time between their listing and the development of those plans was from 2 to 29 years, and the time between their listing and the designation of critical habitat ranged from 0 to 14 years. The underlying causes of such delays in protection are complex and constitute obstacles to recovery of imperiled species. We outline a series of strategic actions by which these challenges may be overcome.

Keywords: amphibian declines, critical habitat, Endangered Species Act, population demography, recovery planning

The Endangered Species Act of 1973 (ESA) is one of the most important environmental laws ever enacted in the United States. The purposes of the ESA are "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions set forth" (ESA 1973). Consequently, species that are listed under the ESA may potentially receive diverse benefits, such as the development of recovery plans, protection from unauthorized take, designation of critical habitat (CH), scientific research, captive breeding, public education, and habitat restoration and acquisition (Taylor et al. 2005). Since the ESA was enacted, less than 1% of listed species have become extinct, and the status of 52% of listed species has stabilized or improved (Male and Bean 2005). For many species, improvements in population viability are proportional to the length of time a species has been listed (Male and Bean 2005).

Critics argue, however, that during the first 21 years (1973–1994) of the ESA's existence, 108 species of plants and animals became extinct (Suckling et al. 2004). Eighty-five of these species (79%) were not protected by the ESA prior to extinction, and listing delays likely contributed to the extinction of the remaining 23 listed species (Suckling et al. 2004). Globally, at least 32.5% of all amphibian species are at risk of extinction, making them one of the most imperiled vertebrate taxa (Stuart et al. 2004). In the United States, only one modern-day amphibian species (*Plethodon ainsworthi*) has been declared extinct by the International Union for the Conservation of Nature (IUCN), although some contend that this species is not a valid taxon (Himes and Beckett 2013). NatureServe and the IUCN revealed that 80%–82% of at-risk amphibian species in the United States remained unlisted under the ESA (Gratwicke et al. 2012, Harris et al. 2012). Moreover, amphibians received only 25% of the ESA funding allocated to other vertebrate groups between 2004 and 2007 (Gratwicke et al. 2012). These delays and biases are not unique to amphibians. There are demonstrably fewer plant, invertebrate, fish, and amphibian species listed compared with reptiles, birds, and mammals (Evans et al. 2016). Plants and invertebrates have also had longer delays in the listing process than vertebrates (Puckett et al. 2016).

Our intent is to explore some of the issues that historically have been challenges for the successful recovery of declining amphibian populations and then to outline strategic actions that could help reduce such challenges, especially when a lack of demographic data may hinder recovery efforts. We focus on amphibians because of the severity of their declines and because of the ecosystem services they provide (Hocking and Babbitt 2014). The loss of these services could

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have cascading impacts on the structure, composition, and dynamics of food webs, as well as on the transfer of energy and nutrients between aquatic and terrestrial ecosystems.

Challenges to recovery: Delays and biases in listing, the development and implementation of recovery plans, and the designation of critical habitat

The principal legislative tools authorized by the ESA for promoting species recovery are funding, recovery-plan development, and CH designation (Gibbs and Curie 2012). Studies of these tools' effectiveness, however, have produced conflicting results: Gibbs and Currie (2012) questioned whether species-recovery data could adequately assess the effectiveness of recovery plans and other tools. Issues regarding funding for species recovery have been addressed by others (e.g., Gratwicke et al. 2012, Evans et al. 2016, Gerber 2016) and are not discussed herein. However, the other tools—recovery plans and CH—clearly must exist before they can effectively promote species recovery. We examined the extent of recovery-plan development and CH designation for threatened and endangered amphibians in the United States. According to the USFWS Environmental Conservation Online System (US Fish and Wildlife Service (USFWS) 2016a), 35 taxa of amphibians in the United States and its territories, including three distinct population segments (DPS) of the California tiger salamander (*Ambystoma californiense*) and two DPS of the southern mountain yellow-legged frog (*Rana muscosa*), are currently listed as threatened or endangered. For each of these 35 taxa, we summarized data on the year that a taxon was listed, whether a recovery plan exists, and whether CH has been designated (table 1). As of August 2016, 40% and 28.6% of these taxa lack either a final recovery plan or designated CH, respectively, and three species (8.6%) lack both (table 1; figure 1). However, the percentage of amphibian taxa with designated CH (71.4%) is greater than that of all listed US species combined: As of 2015, CH had been designated for only 45% of listed species (Martin et al. 2016).

For many listed amphibians that have recovery plans and CH, time lags occurred between when a species was listed, when a recovery plan was developed and implemented, and when CH was designated. For example, for the 18 taxa with completed recovery plans, the time lapse between listing and completion of those plans was from 2 to 29 years (mean = 8.9, standard deviation [SD] = 6.23 years; median = 7 years; mode = 5 years; table 1). The recovery plan for the Puerto Rican golden coquí (*Eleutherodactylus jasperi*) was completed in 1984—7 years after listing—although no individuals have been found since 1981 (Diaz 1984). Existence of a recovery plan does not guarantee that recovery actions are implemented; for the desert slender salamander (*Batrachoseps aridus*) few recovery actions have been implemented since its recovery plan was developed in 1982 (USFWS 2016a). Conversely, a lack of a recovery plan does not prevent recovery efforts from being executed, which could stabilize declining populations and reverse the need for listing (e.g., the relict leopard frog, *Lithobates onca*; see below).

Under the ESA, CH is defined as "the specific areas within the geographic area, occupied by the species at the time it was listed, that contain the physical or biological features that are essential to the conservation of endangered and threatened species, and that may need special management or protection" (USFWS 2016b). Critical habitat designation occurring at or near the time of listing can offer "a form of early conservation planning guidance …to bridge the gap until the Services [USFWS and National Marine Fisheries Service (NMFS)] can complete recovery planning" (USFWS 2016c). For 22 amphibian taxa that have designated CH, there were delays of up to 14 years (mean = 4.09, SD = 4.47 years; median = 2.0 years; mode = 0 years; table 1). Seven of these taxa had no delays because CH was designated simultaneously with listing (table 1).

In addition to delays in recovery planning and CH designation, there have been delays in the listing process as well. In a recent review, Puckett and colleagues (2016) concluded that 1338 species waited a median of 12.1 years for final listing as threatened or endangered under the ESA; the median for amphibians (n = 22) was 9.99 years from "initiation" to listing. These figures may overestimate the actual length of delays, however, because of differing interpretations of the USFWS's category 2 (C2) label (USFWS 1996). Beginning in 1982, the USFWS periodically released comprehensive reviews of the conservation status of animal taxa (USFWS 1982). In these notice of review (NOR) documents, species of interest were assigned to categories: category 1 (C1) species were those for which the USFWS had enough information to warrant listing, but a proposed rule was precluded; C2 species were those for which listing was "possibly appropriate" but lacked sufficient data (USFWS 1996). From October 1976 to September 1984, author CKD was the herpetologist for the USFWS endangered-species program and compiled the amphibian portions of the 1982 and 1985 NORs. He emphasized that those NORs did not confer any legal or official status to C2 species. With fewer communication methods than those in the present day, information on species' statuses was slow to reach the endangered-species office; therefore, CKD included species on the NORs about which he had heard concerns (even from informal conversations with colleagues) and hoped that the C2 designation would spur biologists to submit additional information. For example, CKD included the flatwoods salamander (*Ambystoma cingulatum*) on the 1982 and 1985 NORs but said that empirical information regarding its status was very limited.

In a 1996 NOR, the USFWS eliminated category designations to reduce confusion regarding C2 species; most former C1 species became "candidate species," whereas most former C2 species were removed altogether (USFWS 1996). Eighty-three amphibian taxa were designated C2 on at least one NOR between 1982 and 1994 (USFWS 1982, 1985, 1991, 1994a); 57 former C2 taxa were removed in 1996. In total, 19 of the 83 C2 taxa have been listed as threatened or endangered, including 7 of the 57 taxa that were removed in 1996 (USFWS 2016a).

Table 1. Amphibian species in the United States and its territories that are currently listed as threatened or endangered under the US Endangered Species Act (ESA).

Species	Common name	Status	USFWS lead region	Time from initial to proposed	Time from proposed to listing	Total time	Date listed	Completed recovery plan?	Designated critical habitat finalized?
Anurans									
Anaxyrus baxteri	Wyoming toad	E	6 (mountain–prairie)	28	355	383	1984	Yes (revised, 2015; original completed 1991)[1]	No
Anaxyrus californicus	Arroyo toad	E[2]	8 (CA/NV)	216	500	716	1994	Yes (1999)	Yes (initial final 2001, 2005; revised 2011)[3]
Anaxyrus canorus	Yosemite toad	T	8 (CA/NV)	*(4798)*	*(431)*	*(5229)*	2014	No	Yes (2016)
Anaxyrus houstonensis	Houston toad	E	2 (SW)	*	*	*	1970	Yes (1984)	Yes (1978)
Eleutherodactylus cooki	Guajón	T	4 (SE)	321	618	939	1997	Yes (2004)	Yes (2007)
Eleutherodactylus jasperi	Golden coquí	T (believed to be extinct)	4 (SE)	0	220	220	1977	Yes (1984)	Yes (1977)
Eleutherodactylus juanariveroi	Llanero coquí	E	4 (SE)	1604	358	1962	2012	No	Yes (2012)
Lithobates chiricahuensis	Chiricahua leopard frog	T	2 (SW)	2165	729	2894	2002	Yes (2007)	Yes (2012)
Lithobates sevosus	Dusky gopher frog	E	4 (SE)	3106	560	3666	2001	Yes (Final 2015)	Yes (2012)
Peltophryne lemur	Puerto Rican crested toad	T	4 (SE)	719	224	943	1987	Yes (1992)	No
Rana draytonii	California red-legged frog	T	8 (CA/NV)	804	841	1645	1996	Yes (2002)	Yes (2010)
Rana muscosa (Northern DPS)	Southern mountain yellow-legged frog	E	8 (CA/NV)	*(4816)*	*(431)*	*(5247)*	2014	No	Yes (2016)
Rana muscosa (southern California DPS)	Southern mountain yellow-legged frog	E	8 (CA/NV)	*(1623)*	*(953)*	*(2576)*	2002	No	Yes (2006)
Rana pretiosa	Oregon spotted frog	T	1 (Pacific)	*(8883)*	*(365)*	*(9248)*	2014	No	Yes (2016)
Rana sierrae	Sierra Nevada yellow-legged frog	E	8 (CA/NV)	*(0)*	*(431)*	*(431)*	2014	No	Yes (2016)
Salamanders									
Ambystoma bishopi	Reticulated flatwoods salamander	E	4 (SE)	0	181	181	2009	No	Yes (2009)
Ambystoma californiense (Central California DPS)	California tiger salamander	T	8 (CA/NV)	*	*	*	2004	No (Draft 2016)	Yes (2005)
Ambystoma californiense (Santa Barbara County DPS)	California tiger salamander	E	8 (CA/NV)	*	*	*	2000	No (Draft 2015)	Yes (2004)
Ambystoma californiense (Sonoma County DPS)	California tiger salamander	E	8 (CA/NV)	*	*	*	2002	No (Draft 2014)	Yes (Final 2005; Revised 2011)[3]
Ambystoma cingulatum	Frosted flatwoods salamander	T	4 (SE)	2038	471	2509	1999	No	Yes (2009)
Ambystoma macrodactylum croceum	Santa Cruz long-toed salamander	E	8 (CA/NV)	*	*	*	1967	Yes (1977; Draft Revised 1999)[1]	No; Proposed in 1978
Ambystoma tigrinum stebbinsi	Sonora tiger salamander	E	2 (SW)	1229	644	1873	1997	Yes (2002)	No

Table 1. Continued.

Species	Common name	Status	USFWS lead region	Time from initial to proposed	Time from proposed to listing	Total time	Date listed	Completed recovery plan?	Designated critical habitat finalized?
Batrachoseps major aridus	Desert slender salamander	E	8 (CA/NV)	*	*	*	1973	Yes (1982)	No
Cryptobranchus alleganiensis bishopi	Ozark hellbender	E	3 (Great Lakes-Big Rivers)	3235	393	3628	2011	No	No
Eurycea chisholmensis	Salado salamander	T	2 (SW)	3723	551	4274	2014	No	No
Eurycea nana	San Marcos salamander	T	2 (SW)	0	731	731	1980	Yes (Revised 1996)	Yes (1980)
Eurycea naufragia	Georgetown salamander	T	2 (SW)	3949	551	4500	2014	No	No
Eurycea (= Typhlomolge) rathbuni	Texas blind salamander	E	2 (SW)	*	*	*	1967	Yes (Revised 1996)	No
Eurycea sosorum	Barton Springs salamander	E	2 (SW)	757	1168	1925	1997	Yes (2005)	No
Eurycea tonkawae	Jollyville Plateau salamander	T	2 (SW)	2627	363	2990	2013	No	Yes (2013)
Eurycea waterlooensis	Austin blind salamander	E	2 (SW)	3723	363	4086	2013	No (Draft 2015)	Yes (2013)
Phaeognathus hubrichti	Red Hills salamander	T	4 (SE)	0	429	429	1977	Yes (1983)	No
Plethodon neomexicanus	Jemez Mountains salamander	E	2 (SW)	*(6929)*	*(1065)*	*(7994)*	2013	No	Yes (2013)
Plethodon nettingi	Cheat Mountain salamander	T	5 (NE)	0	324	324	1989	Yes (1991)	No
Plethodon shenandoah	Shenandoah salamander	E	5 (NE)	0	324	324	1989	Yes (1994)	No

Note: “Time from initial to proposed” is the interval (in days) from when a species became a candidate (either first designated as C1, listed as a candidate after 1996, or when a petition was filed) to the date when it was proposed for listing; “time from proposed to listing” is the interval from when a species was proposed for listing to when a species was finally listed; “total time” is the sum of these two. The italicized numbers in parentheses represent the number of days in the above categories for species that were not included in Puckett and colleagues (2016). Time data are not provided for the remaining species (indicated by *) because they were either listed prior to the enactment of the ESA or because their individual times until listing were unclear due to the involvement of multiple DPSs.
Abbreviations: E = endangered; T = threatened; DPS = Distinct Population Segment.
[1] Earlier date used in calculating time to development of a recovery plan from date of listing.
[2] The Arroyo toad was proposed to be downlisted to threatened in 2012, but the proposed rule was withdrawn in 2015.
[3] Designated critical habitat was revised for the Sonoma County DPS of the California tiger salamander and for the Arroyo toad. For these two species, we used the earlier date of designation of critical habitat in calculating the time to the designation of critical habitat from the date of listing.

In many instances, Puckett and colleagues (2016) considered the date a species was designated C2 to be the initial date that the USFWS considered it for listing. For example, flatwoods salamanders were listed as C2 in the 1982 NOR (USFWS 1982); however, the USFWS had no legal obligation to consider flatwoods salamanders for listing until a petition was filed in May 1992 (USFWS 1994b). We repeated the calculations for the 22 amphibian species included in Puckett and colleagues (2016), assuming that the initial date was when (a) a species was first designated as C1, (b) a species was listed as a candidate post-1996, or (c) when a petition was filed (table 1). Under these assumptions, the median time to listing was 4.82 years, versus 9.99 years in Puckett and colleagues (2016).

Some salient examples of amphibians that experienced listing delays include the dusky gopher frog (*Lithobates sevosus*), now listed as endangered, and the black warrior waterdog (*Necturus alabamensis*), recently proposed to be listed as endangered (USFWS 2016d). The dusky gopher frog, considered to be one of the “100 most critically endangered species in the world” by the IUCN (Baillie and Butcher 2012), was formally listed as endangered in 2001 (USFWS 2001), with CH designated in 2012 (USFWS 2012), although concern about its status was first raised in 1982 (USFWS 1982). These delays occurred despite the species existing in low abundance at a single breeding site (USFWS 2001). Lannoo (2012) pointed out that “roughly 8–10 Dusky Gopher Frog generations” elapsed during the 30 years between the time of first concern and critical habitat designation. This postponement likely contributed to the species’ extreme endangerment. Currently, this species may exist in three small populations—each composed of

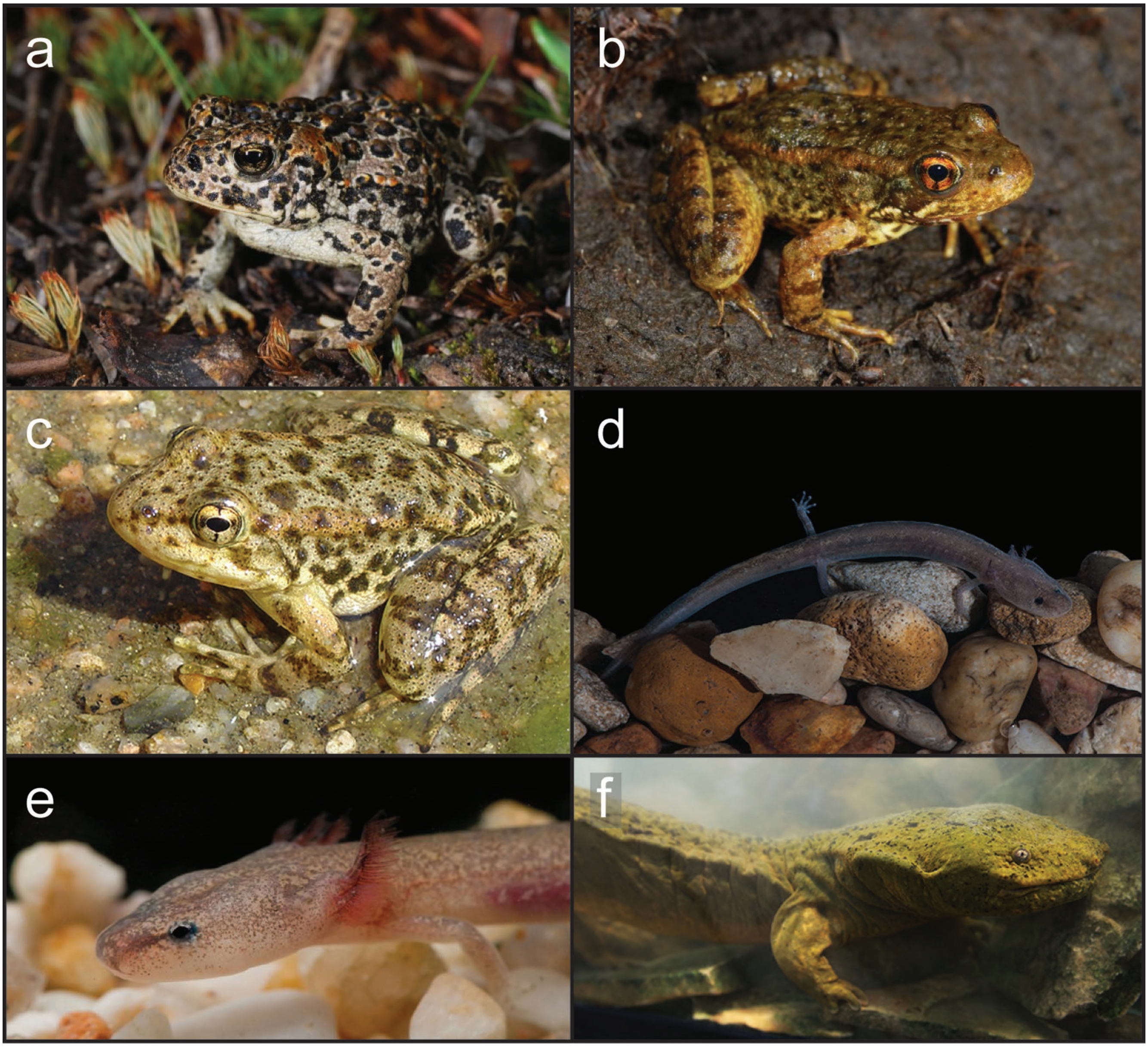

*Figure 1. The six species of amphibians recently listed under the Endangered Species Act that either received designated critical habitat in 2016 but still lack recovery plans (a, b, and c) or still lack both critical habitat and recovery plans (d, e, and f): (a) the Yosemite toad (*Anaxyrus canorus*), listed as threatened in 2014 (photograph: Sam Murray); (b) the Sierra Nevada yellow-legged frog (*Rana sierrae*), listed as endangered in 2014 (photograph: Sam Murray); (c) the southern mountain yellow-legged frog (*Rana muscosa*), of which the northern distinct population segment was listed as endangered in 2014 (photograph: Todd Hoggan); (d) the Salado salamander (*Eurycea chisholmensis*), listed as threatened in 2014; (e) the Georgetown salamander (*Eurycea naufragia*), also listed as threatened in 2014 (photographs: Nathan Bendik); and (f) the Ozark hellbender (*Cryptobranchus alleganiensis bishopi*), listed as endangered in 2011 (photograph: Kory G. Roberts).*

a single breeding pond—although recent surveys failed to detect egg masses in one of the ponds (Hinkson and Richter 2016).

The black warrior waterdog was recognized by the USFWS as a C2 species in 1991 and given candidate status in 1999. Its need for protection was re-emphasized in separate megapetitions submitted in 2004 (for 225 species) and 2010 (for 404 species; USFWS 2016a). A proposed rule to list this species as endangered was published in October 2016, along with a proposed rule for designation of CH (USFWS 2016d). Although these are extreme examples, they illustrate that some species have experienced lengthy delays in listing, which deny imperiled species protection provided by the ESA (Puckett et al. 2016).

Until recently, the relict leopard frog had been considered potentially in need of ESA protection for 39 years, since author CKD compiled the first amphibian NOR in 1977. Once thought to be the first North American amphibian to become extinct, this species was rediscovered in 1991 and added to the candidate species list in 2002. However, the relict leopard frog has gone from presumed extinction to a success story in the making. The Relict Leopard Frog Conservation Team, composed of federal, state, and local partners, implemented ongoing habitat restoration and management, established new breeding sites, reared tadpoles in captivity, and translocated individuals to new and naturally occurring populations. Consequently, the status of the relict leopard frog has improved such that it is stable or increasing across its range; it was removed from the candidate list in October 2016 (USFWS 2016e).

Why do delays and biases occur?

Critics argue that, historically, the scientific community as a whole bears significant responsibility for its delays in acknowledging the existence of a global amphibian crisis. For example, after the first reports of enigmatic amphibian declines in the 1970s, it took 19 years for concerns that these declines were a global phenomenon to gain momentum (Stuart 2012). It was then another 8 years before global consensus was reached and another 2 years for a major driver of many declines, the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*), to be identified (Stuart 2012). Stuart (2012) stated that this delay "has to be close to a record in terms of slowness of scientific response in the face of a global crisis."

In addition to this initially slow response from the majority of the scientific community, other factors have postponed timely conservation actions, such as "political indecision, scientific disagreement, lack of funding, or lack of basic knowledge" (Muths and Fisher 2015). Here, we discuss some of these factors as well as others not previously mentioned, such as the influence of increasing trends in citizen petitions, human behavioral biases, and the availability of demographic information for decisionmaking.

Increasing trend in petitions: A controversy. An important facet of the ESA is that it affords the public the opportunity to petition for species listing, and citizen-initiated petitions, litigation, and related lawsuits have increased substantially in recent years. Since 2007, the USFWS has been petitioned to list more than 1250 species, which is nearly as many species as those listed during the previous 30 years of administering the ESA (USFWS 2016f). In particular, the USFWS received three "megapetitions," which consisted of simultaneous requests for reviews of hundreds of species, including 53 reptile and amphibian species across the United States (Adkins Giese et al. 2012). In the view of the USFWS, "the deadlines for responding to this large increase in petitions, driven in large part by these megapetitions, have overwhelmed the capacity of the [USFWS] Listing Program and required diverting significant human and financial listing resources to the task of completing findings for the petitioned species" (USFWS 2016f). The USFWS has since revised its regulations such that future petitions will be limited to a single "taxonomic" species, as opposed to previous acceptance of multispecies petitions and megapetitions (USFWS 2016g). This change is expected to "improve the content and specificity of petitions … to enhance the efficiency and effectiveness of the petition process to support species conservation" (USFWS 2016g).

As a result of settlements between the Department of Interior and two environmental organizations in 2011, the USFWS listed a total of 248 species between 2012 and 2016, compared with 82 that were listed in the previous 5 years (2007–2011; USFWS 2016a). This overall increase in listing actions likely explains the increase in number of listed amphibians in the last two time intervals shown in figure 2. Of those amphibian species that have been listed under the ESA, nearly one-third (28%) were listed from 2012 to 2014 (table 1; figure 2). Following the 2011 settlements, the USFWS committed to publishing certain ESA listing actions, such as petition findings, listing determinations, and CH designations in fiscal years 2013–2018, and along with the NMFS is working to accomplish regulatory changes to implement the ESA (USFWS 2016f).

Human behavior. Resource managers make decisions every day, but those regarding threatened and endangered species management are especially difficult because they are characterized by public scrutiny, threat of litigation, a sense of urgency, and various types of uncertainty (Kujala et al. 2013). Failure to solve complex conservation problems, such as species recovery, rarely result from a single missed opportunity, but are more likely the cumulative effect of failing to take appropriate action on multiple occasions (Yaffee 1997, Brook et al. 2014). A lack of action does not imply a lack of activity: What may be perceived as largely symbolic actions, such as developing strategies and spending money, may be occurring despite a lack of overt progress in solving a particular problem (Whitten et al. 2001, Jaramillo-Legorreta et al. 2007, Martin et al. 2012).

We identify at least three human behavioral issues that may have been the ultimate drivers in delays in species recovery: (1) *Status quo bias*: "Doing nothing" or maintaining the current condition are valid management alternatives, and it is not uncommon for decisionmakers to adhere to familiar management activities even when they perform suboptimally with regard to the stated objectives (Samuelson and Zeckhauser 1988, Maguire and Albright 2005). (2) *Fear of failure*: Maguire and Albright (2005) reported that when forest managers relied on mental shortcuts for making complex decisions, they systematically biased their decisions toward risk aversion to the point of jeopardizing management goals. Despite what may seem like obvious opportunities

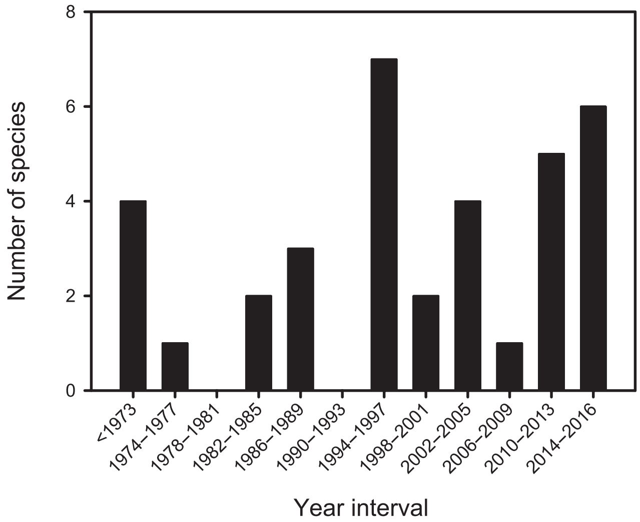

Figure 2. The number of species of US amphibians that have received federal protection up to when the Endangered Species Act was enacted in 1973 and in 4-year intervals since.

to act when observed from the outside, decisionmakers may feel less responsible for the negative consequences of failing to act than they do for the negative consequences of deliberate intervention (Camerer and Kunreuther 1989). Fear of failure is derived from two main sources: uncertainty about the future and apprehension about reactions of constituents, peers, funders, and other stakeholders (Meek et al. 2015). (3) *Conservation complacency*: There are multiple examples of species that, despite alarms from scientists, nevertheless keep declining to the point of near or ultimate extinction (e.g., the Vaquita; Jaramillo-Legorreta et al. 2007). Conservation complacency arises from several key sources. First, humans often adopt culturally transmitted perceptions about certain animal groups, as in the case of persistent negative attitudes toward snakes, arachnids, and many top predators (Musiani and Paquet 2004, Ripple et al. 2014, Pontes-da-Silva et al. 2016). Second, a lack of an understanding of historical ecosystem conditions can lead to "shifting baseline syndromes," or "generational amnesia," in which each generation of humans becomes accustomed to a more impoverished natural biodiversity (Jachowski et al. 2015). Third, inadequate or missing data on population status can cause researchers to overlook sudden, rapid declines of common species (Lindenmayer et al. 2011) and can foster "low political will" to make decisions for species recovery, as in the case of the now-extinct Javan rhinoceros, *Rhinoceros sondaicus annamiticus* (Brook et al. 2014). Last, reliance on an overly simple paradigm about indications of extinction vulnerability fails to consider the complexity of ecosystems and the importance of subtle population declines. For example, ecosystems can experience relatively subtle changes until they reach a tipping point and undergo a sudden shift to a contrasting regime in which a loss of biodiversity may occur (Scheffer 2009). Ultimately, an awareness of how human behavior influences decisionmaking is essential for improving conservation outcomes (Yaffee 1997).

Limited demographic information for decisionmaking. Demographic data are infrequently available for most species threatened with extinction (but see Jaramillo-Legorreta et al. 2007, Hinkson and Richter 2016). Such data are beneficial for informing listing and recovery for at least three reasons: (1) developing population projection models that can help determine whether a species warrants protection and, consequently, its recovery criteria (but see Wolf et al. 2015); (2) determining the spatial scale and connectivity of CH necessary to maintain metapopulation dynamics; and (3) providing a framework to guide decision analyses that help evaluate recovery approaches, develop timelines, establish habitat conservation targets, identify management triggers, and inform monitoring frequency or reintroduction strategies (Kissel et al. 2014).

Population projection models, including population viability analyses (PVAs), produce probabilistic predictions about extinction and future population growth and abundance on the basis of the uncertain outcomes of activities to conserve or "take" individuals. Furthermore, quantitative models provide a framework for evaluating proposed management activities against goals and objectives, such as maximizing recovery or increasing adult population size, which are not only transparent and defendable but are also structured to allow for learning and revision (McGowan and Ryan 2010). The ESA does not require the use of PVAs or other population projection models to determine whether a species is endangered or to develop recovery plans, although the National Research Council recommended their use when evaluating take decisions (ESA 1973, NRC 1995 in McGowan and Ryan 2010). Some have cautioned, however, that there can be significant limitations in relying solely on PVAs to develop recovery criteria (Wolf et al. 2015).

Historically, the importance of spatial scale and connectivity to population declines and potential recovery has been undervalued, even though local extirpations of fragmented populations are common (Fahrig and Merriam 1994). Considering the spatial relationships among landscape elements, the movement and dispersal characteristics of the species of interest (Pittman et al. 2014, Sinsch 2014), and the temporal changes in the landscape structure is essential when making decisions about CH (Fahrig and Merriam 1994). Although such information can be scant for many species, the necessary habitat features of both wetlands and surrounding upland terrestrial core habitat are well defined for a variety of pond-breeding amphibians (Semlitsch and Bodie 2003). The features that either promote or impede movement and connectivity between populations across the landscape are becoming better understood, in part because of contributions from experimental studies on habitat resistance (Cosentino et al. 2011), fine-scale molecular genetics studies that differentiate distance from habitat features (Peterman et al. 2015), and new approaches to assess functional connections among habitat patches (Peterman et al. 2016).

Modifications to procedures and standards used for designating CH have to be done in a legal framework, however, not just a biological one. The ability to do this must be framed within the enacted law, be contained in the official administrative record, and be consistent with the Services' revised regulations (i.e., Code of Federal Regulations) for implementing the ESA (USFWS 2016c).

A paucity of demographic data can significantly impede the ability to make informed conservation decisions. Demographic data can be used to estimate a population's probability of extinction and recovery, determine the effects of years of negative growth on long-term population trends, assess the sensitivity of a population's trend to stochastic mortality events (Butler et al. 2013), and inform population supplementation strategies (Kissel et al. 2014). In the absence of such information, there can be uncertainty regarding conservation objectives and the potential demographic outcomes of management actions. When a clear decision framework is lacking, stop-gap, reactive decisions have often been the approach to the conservation and management of natural resources (Butler et al. 2013). The use of population demography for conservation decisions, coupled with the use of critical decisionmaking skills in conservation practitioners (Johnson et al. 2015), could strengthen recovery planning for imperiled species (Doak et al. 2015).

In many cases, scientific information that is needed to inform recovery decisions may be scarce because it is either underreported or inaccessible, such as that contained in "grey" literature, and because "much information never makes it into a written form of any kind [but], rather, is contained in the minds of experts" (Meek et al. 2015). Research-implementation gaps can also limit the availability of information; that is, a "great divide" may occur between the existence of scientific information and its availability to and, ultimately, its implementation by conservation practitioners (Arlettaz et al. 2010). The ESA requires only that listing decisions be made using the "best available science," but evaluating whether data are sufficient to make a determination can be challenging (Weijerman et al. 2014, Lowell and Kelly 2016). "Access to comprehensive and accurate information positively contributes to biodiversity conservation," and for extremely small populations, the "open sharing of available information can make the difference between timely conservation actions that lead to persistence, and extinction" (Meek et al. 2015).

Conclusions

The USFWS and NMFS continuously seek to improve the process by which they implement the Endangered Species Act. Recent improvements include the development of a multiyear listing work plan, reforming regulations, encouraging more effective conservation partnerships, and adopting a Species Status Assessment (SSA) framework, which is "an analytical approach…to deliver foundational science for informing all ESA decisions" (USFWS 2016h). In addition, across all taxa, there has been a threefold increase in the number of listed species in recent years: Recent listings constitute nearly one-third of all the amphibian species that have ever been listed under the ESA. The listing process itself has become more transparent: Updates on progress on ESA petitions under review, the status of species proposed for listing or that are candidates for listing, and the status of species that are candidates for a status change or delisting are publicly available in the USFWS online system (2016a). These are excellent steps toward overcoming challenges to species recovery. In addition, consideration of the following six points by researchers, agency personnel, conservation practitioners, and resource managers could further enhance the recovery process: (1) Clarify the objectives for listing and recovery to include demographic criteria that will provide a sound framework for species recovery (Doak et al. 2015). (2) Increase the collection and dissemination of basic demographic, life-history, and natural-history data to minimize delays in the development of recovery plans and help inform listing and recovery decisions. (3) For researchers, minimize the various "cultural barriers" that inhibit the sharing of information that is relevant for the recovery of imperiled species (Meek et al. 2015), as well as any gaps between conservation research and its implementation by conservation practitioners (Arlettaz et al. 2010). Pragmatic solutions, such as increasing collaboration, may enhance information sharing, and research information gaps may be reduced if more conservation scientists become actively involved in the process of implementing conservation actions (Arlettaz et al. 2010, Meek et al. 2015). (4) For conservation practitioners, supplement university and agency training in science and policy with critical skills in decisionmaking (Johnson et al. 2015). Subsequently, evaluate the effectiveness of management actions and modify as needed to improve recovery results (Gibbs and Currie 2012). (5) Within the legal framework of designating CH, incorporate information on landscape structure, along with the movement and dispersal characteristics of the species of interest, to address the need to restore genetic connectivity for species in fragmented landscapes. (6) At all levels, promote strong leadership and address status-quo biases, fear of failure, and conservation complacency.

In bringing the issue of climate change to the public forum, Gore (2006) invoked these words of Winston Churchill: "the era of procrastination, of half-measures, of soothing and baffling expedients, of delays, is coming to its close. In its place we are entering a period of consequences." For amphibians and other imperiled biodiversity, the outcome of their "period of consequences" ultimately depends on whether challenges to species recovery, such as those discussed here, are overcome.

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