LETTER

Conserving imperiled species: a comparison of the IUCN Red List and U.S. Endangered Species Act

J. Berton C. Harris[1], J. Leighton Reid[2], Brett R. Scheffers[3], Thomas C. Wanger[1,4], Navjot S. Sodhi[3,5], Damien A. Fordham[1], & Barry W. Brook[1]

[1]Environment Institute and School of Earth and Environmental Sciences, University of Adelaide, SA 5005, Australia
[2]Department of Environmental Studies, University of California, Santa Cruz, CA 95064, USA
[3]Department of Biological Sciences, National University of Singapore, Singapore 117543, Singapore
[4]Agroecology, Grisebachstr 6, University of Göttingen, 37077 Göttingen, Germany
[5]Deceased

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Correspondence
J. Berton C. Harris, Environment Institute and School of Earth and Environmental Sciences, University of Adelaide, SA 5005, Australia.
Tel: +61 8 8303 5254; fax: +61 8 8303 4347.
E-mail: bert.harris@adelaide.edu.au, aramidopsis@gmail.com

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Abstract

The United States conserves imperiled species with the Endangered Species Act (ESA). No studies have evaluated the ESA's coverage of species on the International Union for Conservation of Nature (IUCN) Red List, which is an accepted standard for imperiled species classification. We assessed the ESA's coverage of IUCN-listed birds, mammals, amphibians, gastropods, crustaceans, and insects, and studied the listing histories of three bird species and Pacific salmonids in more detail. We found that 40.3% of IUCN-listed U.S. birds are not listed by the ESA, and most other groups are underrecognized by >80%. Species with higher IUCN threat levels are more frequently recognized by the ESA. Our avian case studies highlight differences in the objectives, constraints, and listing protocols of the two institutions, and the salmonids example shows an alternative situation where agencies were effective in evaluating and listing multiple (related) species. Vague definitions of *endangered* and *threatened*, an inadequate ESA budget, and the existence of the *warranted but precluded* category likely contribute to the classification gap we observed.

Introduction

Imperiled species lists have a variety of important uses that include classifying species' conservation status, setting conservation priorities, and directing management (de Grammont & Cuarón 2006). While some imperiled species lists have been criticized because of their qualitative nature and application to multiple objectives (Possingham *et al.* 2002), the lists are firmly established as valuable tools for biological conservation (Lamoreux *et al.* 2003; Miller *et al.* 2007; Mace *et al.* 2008). The IUCN Red List is the most widely used global imperiled species list (e.g., Rodrigues *et al.* 2006; Schipper *et al.* 2008; BLI 2010), and its classifications are correlated with other leading systems such as NatureServe (O'Grady *et al.* 2004; Regan *et al.* 2005). The Red List classifies species as imperiled (*Critically Endangered*, *Endangered*, or *Vulnerable*), not imperiled (*Near Threatened* or *Least Concern*), extinct (*Extinct*, *Extinct in the Wild*), or *Data Deficient* (IUCN 2001, 2009). If species meet quantitative thresholds of any of the following criteria they will be added to the Red List: (1) decline in population size, (2) small geographic range, (3) small population size plus decline, (4) very small population size, or (5) quantitative analysis. For example, if a species had an estimated population size of <2,500 mature individuals, and had undergone a continuing decline of ≥20% over the last 5 years, it would be classified as *Endangered*. The IUCN Red List, like any categorical imperiled species classification, must make normative decisions that include risk tolerance in the designation of

category boundaries; see IUCN (2001) for more details, and Mace *et al.* (2008) for the development and justification of Red List methods.

In addition to global imperiled species lists, many countries produce national red lists (local or regional imperiled species lists). These lists serve five major functions: (1) classifying the status of species at the local level where they are usually managed, (2) evaluating locally imperiled species and imperiled subspecies, (3) informing local conservation prioritization, (4) providing data to the global Red List, especially for species not yet evaluated by the IUCN, and (5) in some cases, legally protecting species (Miller *et al.* 2007; Rodríguez 2008; Zamin *et al.* 2010). See http://www.nationalredlist.org/ for an up-to-date listing of countries with national red lists and the methods they employ.

One of the most prominent and legislatively important national red lists is the U.S. Endangered Species Act (ESA). The ESA, passed in 1973 and administered by the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS), classifies an at-risk species (including subspecies and distinct populations) as *endangered* if it is "in danger of extinction throughout all or a significant portion of its range" or *threatened* if it is "likely to become endangered in the foreseeable future throughout all or a significant portion of its range" (USFWS 2009a; Figure S1; see supporting information). The USFWS is responsible for listing terrestrial and some marine species, while the NMFS lists marine species. Once a species is listed, the agencies work toward legally prohibiting "take" (killing, capturing, etc.), protecting critical habitat, and developing and implementing recovery plans for listed species (Schwartz 2008). Take of *endangered* animals is unconditionally prohibited, but for plants, only if they are on federal land. The agencies may develop a 4(d) rule to apply take prohibitions to *threatened* species. Designation of critical habitat and implementation of recovery plans are complicated processes that are not automatically applied by the USFWS (Schwartz 2008). The ESA has the power to stop development that will impact imperiled species. Hence there are more consequences and political obstacles to listing species under the ESA compared to lists that are not legally binding.

In short, the ESA is arguably the world's most effective biodiversity protection law. The act has succeeded in improving the conservation status of most listed species over time, and may have prevented 227 extinctions (Taylor *et al.* 2005; Schwartz 2008). Nonetheless, the U.S. government's implementation of the ESA has been problematic, including poor coverage of imperiled species (Wilcove & Master 2005), inadequate funding (Miller *et al.* 2002; Stokstad 2005), and political intervention (Ando 1999; Greenwald *et al.* 2006; Stokstad 2007). Despite the existence of the ESA, an extinction crisis continues in the United States (Elphick *et al.* 2010; Figure S2). For instance, 29 species and 13 subspecies went extinct while being considered for listing from 1973–1995 (Suckling *et al.* 2004). Most of these species already had very small population sizes when listing was proposed (*sensu* McMillan & Wilcove 1994), but several species, such as Curtus's pearly mussel (*Pleurobema curtum*), likely could have been conserved had they been listed rapidly (Suckling *et al.* 2004).

Studies have analyzed the ESA's coverage of species on the NatureServe list, a leading classification of imperiled species in the United States (http://www.natureserve.org; Stokstad 2005; Wilcove & Master 2005; Greenwald *et al.* 2006), but, to our knowledge, no previous work has evaluated the ESA's coverage of IUCN-listed species. In the most comprehensive NatureServe comparison, Wilcove & Master (2005) investigated the ESA's coverage of plants, fungi, and animals considered imperiled on NatureServe's (2005) list. Wilcove & Master (2005) estimated that at least 90% of the country's imperiled species are not covered by the ESA. Given that the Red List is becoming the benchmark for global imperiled species classifications (e.g., Mace *et al.* 2008), an evaluation of the ESA's coverage of IUCN-listed species is needed. We refined previous work by focusing on birds, which are one of the best-known animal groups, and for which classification patterns might approximate a best case scenario. Then we looked in detail at three IUCN-listed birds that are not ESA-listed and, more generally, Pacific salmonids as case studies of classification under the ESA. We also compared classifications of insects, crustaceans, gastropods, amphibians, and mammals to evaluate if similar patterns existed to the previous NatureServe comparisons. Considering Wilcove & Master's (2005) results, we hypothesized that many U.S. IUCN-listed species would not be recognized by the ESA, and that poorly studied and lower-risk species (*Vulnerable* compared to *Critically Endangered*) would more likely be overlooked.

Methods

Our evaluation of the ESA's coverage of IUCN-listed species was not intended to evaluate extinction risk, but to provide a general indication of the breadth of coverage of the ESA compared to the Red List. The Red List—based on proxy measures of risk—is imperfect, but it is the most widely used, and among the most encompassing systems for global and national red lists (Lamoreux *et al.* 2003; de Grammont & Cuarón 2006; Rodrigues *et al.* 2006; Miller *et al.* 2007; Mace *et al.* 2008).

We compared classifications for all IUCN-listed birds known to be resident or fairly common visitors in the United States including Hawaii and Alaska (Pyle 2002; Dunn & Alderfer 2006). IUCN classification data came from BirdLife International's website (BLI 2010); ESA classifications came from the ESA website (USFWS 2009b). We followed the taxonomy of Chesser *et al.* (2010). If the ESA listed a single subspecies or a single population of an IUCN-listed species we considered the species to be covered by the ESA. We also collated data on *Extinct*, *Extinct in the Wild*, and *Possibly Extinct* birds (BLI 2010) and plotted these over time. Our extinction data were collected independently but are complimentary to Elphick *et al.*'s (2010) analysis that focused on estimating extinction dates.

For the case studies we examined IUCN-listed birds in Table 1 that were evaluated by the ESA, yet still not ESA-listed. We selected three species with adequate conservation status information and well-documented listing histories: Kittlitz's murrelet (*Brachyramphus brevirostris*), ashy storm-petrel (*Oceanodroma homochroa*), and cerulean warbler (*Dendroica cerulea*). We reviewed the peer-reviewed and gray literature for each species to examine the species' conservation status and IUCN and ESA listing history. While all three species have large or relatively large ranges, each has undergone population declines and been listed as imperiled by the IUCN since 2004. Given that these species were not selected randomly, we do not mean to imply that their cases can be generalized to all imperiled birds in the United States; rather, the case studies are examples of what can happen when declining, IUCN-listed species are considered for ESA listing. We also present the case of Pacific salmonids (Salmonidae: *Oncorhynchus*) as an example where U.S. agencies were successful at evaluating and listing multiple species proactively.

To evaluate if patterns found in previous NatureServe comparisons were evident in IUCN data (IUCN 2009), we compared classifications for all insects, crustaceans, gastropods, amphibians, and mammals evaluated by the IUCN in the United States. We studied classifications in animals because the IUCN has evaluated many more animals than plants or fungi, and we selected the six animal groups because they represent a broad sample of taxonomy, distribution, and habitats. The IUCN has not yet evaluated all U.S. resident insects, crustaceans, or gastropods, so our comparisons for these groups are not as representative as for birds, mammals, or amphibians. Nonetheless, the IUCN has evaluated more U.S. species of these groups than the ESA (IUCN 2009; USFWS 2009b), and our comparison gives baseline coverage of each group that should complement previous NatureServe comparisons.

Table 1 Endangered Species Act status (*endangered* (E), *threatened* (T), or not listed) of IUCN-listed extant and possibly extinct birds in the United States organized by IUCN category. Twenty-five of the 62 IUCN-listed imperiled birds in the United States are not listed by the Endangered Species Act (IUCN 2009; USFWS 2009b; BLI 2010)

Species and IUCN classification	ESA classification
Critically endangered	
Laysan duck (*Anas laysanensis*)	E
California condor (*Gymnogyps californianus*)	E
Eskimo curlew (*Numenius borealis*)[a,b]	E
Kittlitz's murrelet (*Brachyramphus brevirostris*)[a]	Not listed
ivory-billed woodpecker (*Campephilus principalis*)[a]	E
millerbird (*Acrocephalus familiaris*)	E
olomao (*Myadestes lanaiensis*)[b]	E
puaiohi (*Myadestes palmeri*)	E
nihoa finch (*Telespiza ultima*)	E
ou (*Psittirostra psittacea*)[b]	E
palila (*Loxioides bailleui*)	E
Maui parrotbill (*Pseudonestor xanthophrys*)	E
nukupuu (*Hemignathus lucidus*)[b]	E
akikiki (*Oreomystis bairdi*)	E
Oahu alauahio (*Paroreomyza maculata*)[b]	E
akekee (*Loxops caeruleirostris*)	E
akohekohe (*Palmeria dolei*)	E
poo-uli (*Melamprosops phaeosoma*)[b]	E
Bachman's warbler (*Vermivora bachmanii*)[a,b]	E
Endangered	
Gunnison sage-grouse (*Centrocercus minimus*)	Not listed
Hawaiian duck (*Anas wyvilliana*)	E
black-footed albatross (*Phoebastria nigripes*)[a]	Not listed
black-capped petrel (*Pterodroma hasitata*)[a]	Not listed
Newell's shearwater (*Puffinus newelli*)	T
ashy storm-petrel (*Oceanodroma homochroa*)[a]	Not listed
whooping crane (*Grus americana*)[a]	E
marbled murrelet (*Brachyramphus marmoratus*)[a]	T
akiapolaau (*Hemignathus munroi*)	E
Hawaii creeper (*Oreomystis mana*)	E
Maui alauahio (*Paroreomyza montana*)	Not listed
akepa (*Loxops coccineus*)	E
golden-cheeked warbler (*Dendroica chrysoparia*)[a]	E
tricolored blackbird (*Agelaius tricolor*)[a]	Not listed
Vulnerable	
Hawaiian goose (*Branta sandvicensis*)	E
Steller's eider (*Polysticta stelleri*)[a]	T
greater prairie-chicken (*Tympanuchus cupido*)	E[c]
lesser prairie-chicken (*Tympanuchus pallidicinctus*)	Not listed
short-tailed albatross (*Phoebastria albatrus*)[a]	E
Hawaiian petrel (*Pterodroma sandwichensis*)[a]	E
pink-footed shearwater (*Puffinus creatopus*)[a]	Not listed
buller's shearwater (*Puffinus bulleri*)[a]	Not listed
Hawaiian coot (*Fulica alai*)	E
bristle-thighed curlew (*Numenius tahitiensis*)[a]	Not listed
red-legged kittiwake (*Rissa brevirostris*)[a]	Not listed
Xantus's murrelet (*Synthliboramphus hypoleucus*)[a]	Not listed
red-cockaded woodpecker (*Picoides borealis*)	E
black-capped vireo (*Vireo atricapilla*)[a]	E
elepaio (*Chasiempis sandwichensis*)	E

Continued.

Table 1 Continued.

Species and IUCN classification	ESA classification
Florida scrub-jay (*Aphelocoma coerulescens*)	T
pinyon jay (*Gymnorhinus cyanocephalus*)	Not listed
bendire's thrasher (*Toxostoma bendirei*)[a]	Not listed
omao (*Myadestes obscurus*)	Not listed
bicknell's thrush (*Catharus bicknelli*)[a]	Not listed
sprague's pipit (*Anthus spragueii*)[a]	Not listed
Laysan finch (*Telespiza cantans*)	E
Kauai amakihi (*Hemignathus kauaiensis*)	Not listed
Oahu amakihi (*Hemignathus flavus*)	Not listed
anianiau (*Magumma parva*)	Not listed
iiwi (*Vestiaria coccinea*)	Not listed
cerulean warbler (*Dendroica cerulea*)[a]	Not listed
rusty blackbird (*Euphagus carolinus*)[a]	Not listed
saltmarsh sparrow (*Ammodramus caudacutus*)	Not listed

[a]Not endemic to the United States; [b]Possibly extinct (IUCN 2009); [c]Attwater's race (*Tympanuchus cupido attwateri*).

Results

Birds

Of the 62 IUCN-listed birds in the United States, 25 species (1 *Critically Endangered*, 6 *Endangered*, 18 *Vulnerable*; 40.3% of the total) are not listed by the ESA (Table 1). Ten of the 25 species not listed by the ESA are endemic to the United States (40%). Species in IUCN categories of lower risk are more likely to be unrecognized: 5.3% of *Critically Endangered*, 42.9% of *Endangered*, and 62.1% of *Vulnerable* birds are not recognized by the ESA. Conversely, 23 bird species (29 total taxa including subspecies and populations) are ESA-listed as imperiled but not considered by the IUCN to be globally imperiled (six *Near Threatened* and 17 *Least Concern*; Table S1).

Twenty-three U.S.-resident bird species have gone extinct since 1825 (including one species, *Corvus hawaiiensis*, which survives only in captivity) (Figure 1). In addition, seven species are *Possibly Extinct* with the last confirmed sightings ranging from 1937 to 2004. Plotting the last confirmed sightings of *Extinct*, *Extinct in the Wild*, and *Possibly Extinct* birds by decade shows extinction peaks in the 1890s and 1980s (Figure S2). Of the 23 extinct species, 21 were endemic to Hawaii (as well as five of the seven *Possibly Extinct* species). Two species have been declared *Extinct* (*Moho braccatus* and *Myadestes myadestinus*), one *Extinct in the Wild* (*C. hawaiiensis*), and six *Possibly Extinct* (*Numenius borealis*, *Myadestes lanaiensis*, *Psittirostra psittacea*, *Hemignathus lucidus*, *Paroreomyza maculata*, and *Melamprosops phaeosoma*) since the passage of the ESA. *Vermivora bachmanii* was probably extinct when the ESA was passed, and the other species already had very small population sizes (with the possible exceptions of *Myadestes myadestinus* and *Melamprosops phaeosoma*).

Other animal groups

Our evaluation of the ESA's coverage of IUCN-listed insects, crustaceans, gastropods, amphibians, and mammals indicates that underrecognition of IUCN-listed species is not restricted to birds. We found 50% underrecognition for mammals, 80% underrecognition for amphibians, and 88.9–95.2% underrecognition for the invertebrates, which contributed to a mean of 74.1% underrecognition overall (Table 2). *Vulnerable* species (IUCN classification) were more often unrecognized (mean of 83.2%) compared to *Critically Endangered* (67.3%) or *Endangered* (64.9%) (Table 2).

Discussion

Our data indicate that 40.3% of the U.S.'s IUCN-listed birds and more than 80% of lesser-known taxa have not been placed on the ESA list of *endangered* and *threatened* species. This underrecognition of species on one of the leading global lists suggests that the U.S. system is failing to keep pace with global listing assessments of imperiled species. It is unlikely that this classification gap can be attributed to species being stable in the United States but imperiled in their range outside the country. All unrecognized nonendemic birds (Table 1) have substantial proportions of their breeding and/or nonbreeding range in the United States. Possible exceptions are *Pterodroma hasitata*, *Puffinus creatopus*, and *P. bulleri*, but these three species are fairly common to common nonbreeding visitors to waters off the U.S. coast and therefore are eligible for listing even though they are not U.S. breeders. The ESA includes other nonbreeding species (e.g., *Numenius borealis*).

The ESA list includes 23 species of birds that are *Near Threatened* or *Least Concern* globally (Table S1). Nineteen of these species have only some populations or subspecies listed, which shows the ESA is protecting some regionally imperiled species. The remaining species, *Somateria fischeri*, *Buteo solitarius*, *Charadrius melodus*, and *Dendroica kirtlandii*, are ESA-listed in their entire range, but not by the IUCN, probably as a result of differences in listing criteria between the ESA and IUCN.

Bird species considered less-imperiled on the IUCN scale are more likely to not be listed under the ESA. Along these lines, Scott *et al.* (2006) found that nearly 80% of species listed by the ESA are *endangered* rather than *threatened*. There are several potential explanations for these patterns that are not mutually exclusive. The USFWS may: (1) list severely imperiled species first, due to an inability to consider all species at once, (2) primarily list species as a result of pressure from citizen petitions, which could focus on highly imperiled species, or

Figure 1 Hawaiian honeycreepers in peril. Extant species are in color; extinct and possibly extinct species are in grayscale. Five of the extant species shown (alauahio, Kauai amakihi, Oahu amakihi, anianiau, and iiwi) are IUCN-listed species that are unrecognized by the ESA. Numbers in parentheses specify how many species appear similar to the illustration. Note that akikiki is extant. Paintings and labels © H. Douglas Pratt, revised from Pratt (2005, Plate 7), used by permission.

(3) accept a higher risk of extinction compared to the IUCN. Risk prioritization seems to occur. Wilcove *et al.* (1993) found very small population sizes at the time of listing for 1,075 vertebrates and 999 invertebrates listed from 1985–1991, suggesting that species are not listed until they are highly imperiled. Outside pressure is also likely to be important. Petitions and/or lawsuits were involved with 71% of listings from 1974–2003 and have become even more important in recent years (Greenwald *et al.* 2006). In fact, the USFWS is so occupied with petitions and lawsuits from citizen groups that its ability to advance its own listing priorities is hampered (Stokstad 2005), and it requested a subcap to limit funding used to address petitions (USFWS 2011). Differences in risk tolerance may also contribute to classification differences between the IUCN and ESA. The ESA might be expected to list only highly imperiled species because listing results in legal protection, unlike the IUCN that has no legal enforcement ability in the United States.

This pattern of delaying listing until species are critically imperiled could be interpreted optimistically; at least the majority of species facing the greatest threat are protected. Unfortunately, chances of recovery are much reduced for highly imperiled species (Traill *et al.* 2010). The recent cases of two Hawaiian birds, akikiki *Oreomystis bairdi* and akekee *Loxops caeruleirostris*, are prime examples (Figure 1). Both were long known to be in serious trouble (listed by the IUCN as *Endangered* in 1994 and *Critically Endangered* in 2004 and 2008, respectively), but neither was listed by the ESA until 2010, while the akekee population continued to decline steeply (ABC 2008). Listing species before they reach critical

Table 2 Coverage of IUCN-listed animals (IUCN 2009) by the U.S. Endangered Species Act (USFWS 2009b). IUCN categories: CR = *Critically Endangered*, EN = *Endangered*, VU = *Vulnerable*. Percent of species that are unrecognized by the ESA are given in parentheses. For across-group totals, the mean percent of species unrecognized (± SE) is given

	Number of CR species	CR species not recognized	Number of EN species	EN species not recognized	Number of VU species	VU species not recognized	Number of species evaluated by IUCN	Total IUCN-listed species	Total unrecognized
Amphibians	2	2 (100)	17	13 (76.5)	36	29 (80.6)	272	55	44 (80)
Birds	19	1 (5.3)	14	6 (42.9)	29	18 (62.1)	888	62	25 (40.3)
Mammals	4	2 (50)	20	7 (35)	12	9 (75)	451	36	18 (50)
Gastropods	62	57 (91.9)	30	27 (90)	103	92 (89.3)	458	195	176 (90.3)
Insects	10	8 (80)	12	10 (83.3)	83	82 (98.8)	207	105	100 (95.2)
Crustaceans	17	13 (76.5)	37	23 (62.2)	135	132 (97.8)	203	189	168 (88.9)
Total	114	83 (67.3 ± 14.2)	130	86 (64.9 ± 9.1)	398	362 (83.2 ± 5.8)	2479	642	531 (74.1 ± 0.09)

imperilment would reduce extinctions and probably costs. It would be interesting for a future study to quantify the USFWS's savings from protecting species under the ESA when they are *Vulnerable* compared to *Critically Endangered*.

Our avian case studies (supporting information) exemplify USFWS decisions to not list declining, IUCN-listed species, and illustrate problems associated with vague categories, inadequate funding, and the *warranted but precluded* category. All three cases would have been more straightforward to resolve if clear, quantitative thresholds were included in the definitions of *threatened* and *endangered*. The effects of funding constraints were especially clear in the cerulean warbler's case where the USFWS took 6 years to reach a decision. The Kittlitz's murrelet case highlights the paradox of the *warranted but precluded* category; it seems unlikely that funds are so limited, or the *Critically Endangered* murrelet's priority is so low, that it should not be listed. While the USFWS is required to make a decision in 12 months, all three case study species experienced protracted listing times of 22 months to 6 years. These listing times are actually shorter than average; Greenwald *et al.* (2006) found the mean listing time for all species from 1974–2003 was >10 years.

In contrast to the avian case studies, the salmon case shows how the agencies can objectively and proactively list large groups of species by advancing their own listing priorities (supporting information). In the 1990s the NMFS coordinated teams of scientists to evaluate salmonids in Washington, Idaho, Oregon, and California. By 1999, the NMFS had listed 21 evolutionary significant units of salmonids as *threatened* and five as *endangered*. This case is an example of how science can be effectively translated to ESA policy. Public awareness of the value of salmonids for food and fishing likely contributed to the NMFS's comprehensive actions. Therefore, it seems reasonable that listing of other groups, such as unlisted birds in Table 1, could be accelerated if public interest in imperiled species increased (Schwartz 2008).

The multitaxa results suggest that underrecognition of IUCN-listed birds and mammals is less severe than in other, lesser-known groups (Table 2). This pattern could be explained if the USFWS accepts variable levels of extinction risk among taxa or if poorly known groups tend to be neglected (Wilcove & Master 2005). Wilcove & Master (2005) estimated that approximately 90% of the U.S.'s imperiled species (including animals, fungi, and plants) are not included on the ESA list. Given that Wilcove & Master's (2005) estimate was an extrapolation based on a few well-known groups, it is difficult to compare our results. Nonetheless, our finding of 74.1% underrecognition of IUCN-listed animals

suggests the ESA covers more IUCN-listed species than NatureServe-listed species.

Our data indicate that a nearly 10-fold increase in listing would be required for the ESA to protect the gamut of IUCN-listed species. Considering the history and objectives of the two institutions, it is not surprising that the ESA covers fewer species. The Red List is intended to identify all imperiled species and has no regulatory apparatus. The ESA, however, legally protects species, so adding a species bears significant cost and responsibility to the agencies (funding per species is greater for the NMFS compared to the USFWS). The ESA is additionally influenced by politics because listing can have profound economic consequences (Ando 1999). If protecting all IUCN-listed species under the ESA is an unattainable endpoint, then triage could play a role in dictating listing decisions once all species are evaluated with objective and thorough procedures. A critical question under triage would be how to prioritize species based on endangerment, recovery likelihood, taxonomic uniqueness, and cost (Bottrill *et al.* 2008). We hold that listing a full complement of imperiled species under the ESA is not an insurmountable task.

Vague definitions of the *threatened* and *endangered* categories may also contribute to a lack of congruence between the ESA and IUCN lists (see "Introduction" for definitions). The ESA has been in place since 1973, but there is still ample room for debate on the meaning of these two key terms (Greenwald 2009; D'Elia & McCarthy 2010). There is a division between science and policy in ESA implementation by design, where science informs, but does not dictate, listing policy (Laband & Nieswiadomy 2006). In the case of the ashy storm-petrel, a lack of consensus when science informed policy delayed the listing decision and led to an outcome that is still contested by citizen groups and will likely incur further litigation costs to the USFWS. Such consequences from vague categories might be avoided if precedent quantitative thresholds were in place to guide decision-making when science is translated to policy. The IUCN uses unambiguous criteria, objective categories that measure probability of extinction, and a dynamic system that quantifies uncertainty in assessments (de Grammont & Cuarón 2006). Incorporating similarly quantitative attributes in the ESA decision-making framework would improve credibility of listing decisions and could reduce replication of effort between the USFWS and nongovernmental institutions such as the IUCN and NatureServe (Arroyo *et al.* 2009). Further, if ESA classifications eventually became more similar to IUCN methods, ESA data would be more useful for informing the Red List (Rodríguez 2008), which is an important function of national red lists to which the ESA does not currently contribute (Miller *et al.* 2007). Countries such as Singapore that use IUCN methods are able to evaluate hundreds of species in a few years (Davison *et al.* 2008); such rapid assessments could help reduce the backlog of ESA candidate species.

An increase to the ESA listing budget could speed the closing of the classification gap. External and internal observers agree that budgetary constraints are a primary barrier to listing species in a timely manner (GAO 1979; Stokstad 2005; Greenwald *et al.* 2006; USFWS 2006; Schwartz 2008). The protracted decision making in our avian case studies supports this conclusion.

Finally, we find that the *warranted but precluded* category compounds the classification gap by excluding imperiled species from the ESA. *Warranted but precluded* was created in 1982 to designate species that should be listed, but for which listing is currently precluded because of funding constraints (supporting information). While w*arranted but precluded* findings can occasionally stimulate conservation efforts to prevent species from declining further (WGA 2011), this category has often been used by the USFWS as a loophole to slow listing (Greenwald *et al.* 2006). Given that citizen groups are unlikely to reduce pressure following *warranted but precluded* decisions, this category may be more likely to increase, rather than decrease long-term conservation costs.

In conclusion, our research agrees with previous findings that most of the United States' imperiled species are not yet listed under the ESA. Our data indicate that less-imperiled (but at-risk) species are most likely to be overlooked, which does not bode well for the ESA's ability to mitigate declines before species become critically imperiled. Our avian case studies exemplify how a lack of consensus on key definitions, funding constraints, and the *warranted but precluded* category likely contribute to the classification gap between IUCN and ESA lists. By contrast, the salmonids case study shows how the agencies can proactively evaluate and list large groups of (albeit closely related) species.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Detailed case studies and ESA listing procedures

Table S1: Bird species listed as imperiled by the Endangered Species Act but not included on the IUCN Red List.

Figure S1: Pathways to be listed under the Endangered Species Act.

Figure S2: Bird extinctions by decade in the United States.

Figure S3: Case study species.

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Supporting information

ESA listing procedures

Proposals for listing new species under the ESA are initiated in two ways: on the USFWS's own accord (discretionary path), or by way of a petition from a member of the public (USFWS 2009a; Figure S1). The status of species on the candidate list is evaluated annually until it is listed, or listing is determined to be unwarranted. If a species is petitioned, the USFWS undertakes a 90-day finding, and if there is substantial information that listing may be warranted, the USFWS conducts a scientific status review to determine if the species should be listed. In the "12 month finding" due 12 months after the USFWS receives the petition, the USFWS decides if listing is *not warranted*, *warranted*, or *warranted but precluded* (the latter if sufficient information is available to warrant listing but listing is precluded by higher listing actions, and the species is placed on the candidate list) (US Congress 1982; USFWS 2009a).

Case studies

Ashy storm-petrel (*Oceanodroma homochroa*)

The ashy storm-petrel is a smoky-gray seabird that feeds on small fish, squid, and crustaceans in the California current (Fig. S3A). The species nests on islands off California and Baja California (Mexico) and disperses along the California coast during the non-breeding season, but does not migrate long distances (BLI 2010). The current global population estimate is 5,200–10,000 breeding birds (BLI 2010). At the species' main breeding colony on southeast Farallon Island, the population declined by 42 % from 1972–1992 (Sydeman *et al.* 1998), and there is evidence of continuing recent declines across its range (BLI 2010; Ainley & Hyrenbach 2010). These declines led to the species being listed by the IUCN as *Endangered* in 2004 (criteria A2ce+3ce+4ce; IUCN 2009). The storm-petrel is threatened by pesticide pollution, climate change (changes in ocean currents and upwelling; Ainley & Hyrenbach 2010), squid fishing (lights may increase nest predation), and nest predation from expanding western gull (*Larus occidentalis*) and burrowing owl (*Athene cunicularia*) populations (BLI 2010).

The Center for Biological Diversity (CBD) filed a petition to list the storm-petrel under the ESA in October 2007 (CBD 2010). In response to the USFWS repeatedly missing deadlines to decide whether or not to list the species, the CBD filed two intents to sue (March 2008 and January 2009) and finally sued the USFWS for delaying its decision (April 2009) (CBD 2010). On 18 August 2009, nearly 10 months after the deadline required by the ESA, the USFWS decided to not list the species (USFWS 2009c). Initially the USFWS decided listing was *warranted but precluded*, but the USFWS's regional office revised the decision to *not warranted* (Vespa 2010). A USFWS biologist disputed the revision because it contained "inaccuracies" and made questionable interpretations on the species' population trend from an unpublished report produced by the Point Reyes Bird Observatory (Warzybok & Bradley 2007; Vespa 2010). After the CBD filed an intent to sue based on these scientific inaccuracies, the USFWS agreed to revise its 2009 finding (USFWS 2010). The revised finding is still pending.

Kittlitz's murrelet (*Brachyramphus brevirostris*)

The Kittlitz's murrelet has the highest IUCN threat level of any bird in the US that is not protected by the ESA (Table 1). The murrelet is a small, poorly-known seabird that is endemic to Alaska and Russia where it forages for fish and macrozooplankton in glacial meltwater near the coast (Fig. S3B). The species nests on glaciated mountaintops and upland habitats on islands (BLI 2010). The current global population estimate is 20,000–49,999, with 70 % of the population found in Alaska (BLI 2010). Several independent datasets suggest the murrelet has undergone a steep decline of 59–90 % in the last 15 years across most of its range (Kuletz *et al.* 2003; Kissling *et al.* 2007; BLI 2010), which led to it being listed as *Critically Endangered* by the IUCN in 2004 (criterion A4bcde; IUCN 2009). Kittlitz's murrelet is threatened by glacial recession, oil spills, disturbance from tour boat traffic, and entanglement in salmon fishing nets (Kuletz *et al.* 2003; BLI 2010). In 2008 the US government leased large portions of the Chukchi Sea shelf to oil and gas companies for offshore development, where oil spills could dramatically impact Kittlitz's murrelets (BLI 2008).

Kittlitz's murrelet was first petitioned for listing under the ESA by environmental groups in May 2001 (CBD 2009). In May 2004 the USFWS decided not to list the species and classified it as a candidate with a listing priority of 5 (facing non-imminent threats of high magnitude) (USFWS 2004). The USFWS (2004) stated:

> "…we believe that glacial retreat and oceanic regime shifts are the factors that are most likely causing population-level declines in this species. Existing regulatory mechanisms appear inadequate to stop or reverse population declines or to reduce the threats to this species."

Presumably, this statement refers to difficulty in addressing climate change as a threat. In November 2005 the CBD (2009) filed suit against the USFWS for delaying ESA protection of species on the candidate list, including the murrelet. In December 2007 the species moved up to priority 2 due to imminent threats of high magnitude (USFWS 2007). In March 2009 the CBD petitioned the Alaska Game & Fish Department to protect the species under the Alaska State ESA, but Alaska denied the petition in April, and the species remains at listing priority 2 (USFWS 2009d).

Cerulean warbler (*Dendroica cerulea*)

The cerulean warbler is a migratory insectivorous songbird that breeds in mature hardwood forests in the US and Canada, and winters in the foothills of the Andes from Venezuela to Bolivia (Hamel 2000; Fig. S3C). The global population estimate of 560,000 individuals (BLI 2010) is much larger than the other case study species, but Breeding Bird Survey data indicate that the species declined by 26 % per decade from 1980–2002 (Sauer *et al.* 2003 in BLI 2010) which contributed to an 82 % overall decline in the last 40 years (BLI 2006). The species was labeled the "fastest declining wood warbler in the US" (BLI 2006) and listed as *Vulnerable* in 2004 (criteria A2c+3c+4c; IUCN 2009). The warbler is threatened by habitat loss throughout its range (BLI 2010). Important contributors to habitat loss on the breeding grounds include mountaintop removal coal mining, logging, and urban development; cattle ranching and coffee farming are important factors on the wintering grounds (Wood *et al.* 2006; BLI 2010).

The warbler was petitioned for listing by 28 environmental groups in 2000. After two years (*c.f.* the 90 day deadline; Fig. S1), the USFWS decided that the petition had merit and started a 12-month finding (Bies 2007). After conservation organizations sued the USFWS for repeatedly missing deadlines (Bies 2007), the USFWS finally decided that listing was *not*

warranted for the species in 2006 (USFWS 2006). The USFWS used Breeding Bird Survey data to estimate an annual decline of 3 % and concluded that the species would still number in the tens of thousands by 2100 (USFWS 2006). The listing decision caused uproar in the environmental community because it downplayed the decline of the species and took just over six years to be announced (e.g. BLI 2006). The USFWS (2006) cited funding constraints for the long delays in reaching a decision.

Pacific salmonids

The National Marine Fisheries Service's actions to evaluate and list Pacific salmonids offer an example of how the ESA can be effectively applied to multiple species. Anadromous salmonids (*Oncorhynchus* sp.), which hatch in fresh water, migrate to the ocean, and then return to their natal waterways to breed, are threatened primarily by habitat loss from dams and overfishing (SOS 2011). In the 1990s, the NMFS initially responded to petitions to list individual populations of salmonids, but the NMFS eventually began a proactive effort to evaluate all populations of anadromous salmon and steelhead in Washington, Idaho, Oregon, and California (NMFS 2011). The NMFS first had to determine which populations should be considered distinct population segments, and subsequently defined 52 evolutionary significant units (ESUs) based on reproductive isolation and evolutionary distinctiveness. From 1994 to 1999 the NMFS, using teams of salmon experts to incorporate relevant scientific information, decided to list 21 ESUs as *threatened* and 5 as *endangered* (NMFS 2011). In a 2005 status review, the NMFS maintained all earlier listings and added an additional ESU to the list (NMFS 2005; Good *et al.* 2005). Only one species of *Oncorhynchus* found in the region reviewed by the NMFS, sockeye salmon (*O. nerka*; Fig. S2D), has been evaluated by the IUCN. The IUCN assessment identified 1 threatened subpopulation of the species in the region: Redfish Lake (Columbia River) sockeye (*Critically Endangered*) (Rand 2008). The NMFS listed the Snake River population (equivalent to Redfish Lake) as *endangered* and the Ozette Lake, Washington population as *threatened* (NMFS 2011). In this four state region the NMFS has undertaken a much more comprehensive review of the status of salmonid populations compared to the IUCN, although the IUCN Salmonid Specialist Group is working to evaluate the other species (SOS 2011). The NMFS's action on Pacific salmonids is an example of a US agency making ample use of science to proactively evaluate a large group of species.

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Supplementary table

Table S1. Twenty-three bird species are listed as imperiled by the ESA (USFWS 2009b) but not the IUCN (IUCN 2009). ESA categories are *endangered* (E) or *threatened* (T); IUCN categories are *Least Concern* (LC) and *Near Threatened* (NT). Taxonomy for the 'species' column follows Chesser *et al.* (2010).

species	IUCN status	taxon listed by ESA (if different)	ESA status	where listed
northern bobwhite (*Colinus virginianus*)	NT	masked bobwhite (*Colinus virginianus ridgwayi*)	E	entire range
spectacled eider (*Somateria fischeri*)	LC		T	entire range
wood stork (*Mycteria americana*)	LC		E	U.S.A. (AL, FL, GA, SC)
crested caracara (*Caracara cheriway*)	LC	Audubon's crested caracara (*Polyborus plancus audubonii*)	T	U.S.A. (FL)
aplomado falcon (*Falco femoralis*)	LC	northern aplomado falcon (*Falco femoralis septentrionalis*)	E	entire range, except where listed as an experimental population
snail kite (*Rostrhamus sociabilis*)	LC	Everglade snail kite (*Rostrhamus sociabilis plumbeus*)	E	U.S.A. (FL)
Hawaiian hawk (*Buteo solitarius*)	NT		E	entire range
clapper rail (*Rallus longirostris*)	LC	California clapper rail (*Rallus longirostris obsoletus*)	E	entire range
		light-footed clapper rail (*Rallus longirostris levipes*)	E	U.S.A. only
		Yuma clapper rail (*Rallus longirostris yumanensis*)	E	U.S.A. only
sandhill crane (*Grus canadensis*)	LC	Mississippi sandhill crane (*Grus canadensis pulla*)	E	entire range
black-necked stilt (*Himantopus mexicanus*)	LC	Hawaiian stilt (*Himantopus mexicanus knudseni*)	E	entire range
piping plover (*Charadrius melodus*)	NT		E	Great Lakes watershed in States of IL, IN, MI, MN, NY, OH, PA, and WI and Canada (Ont.)
			T	Entire, except those areas where listed as endangered above
snowy plover (*Charadrius alexandrinus*)	LC	western snowy plover (*Charadrius alexandrinus nivosus*)	T	U.S.A. (CA, OR, WA), Mexico (within 50 miles of Pacific coast)

roseate tern (*Sterna dougallii*)	LC	roseate tern (*Sterna dougallii dougallii*)	E	U.S.A. (Atlantic Coast south to NC), Canada (Newf., N.S, Que.), Bermuda
		roseate tern (*Sterna dougallii dougallii*)	T	Western Hemisphere and adjacent oceans, incl. U.S.A. (FL, PR, VI), where not listed as endangered
least tern (*Sternula antillarum*)	LC		T	U.S.A. (AR, CO, IA, IL, IN, KS, KY, LA_Miss. R. and tribs. N of Baton Rouge, MS_Miss. R., MO, MT, ND, NE, NM, OK, SD, TN, TX_except within 50 miles of coast)
		California least tern (*Sterna antillarum browni*)	E	entire range
spotted owl (*Strix occidentalis*)	NT	Mexican spotted owl (*Strix occidentalis lucida*)	T	entire range
		northern spotted owl (*Strix occidentalis caurina*)	T	entire range
willow flycatcher (*Empidonax traillii*)	LC	southwestern willow flycatcher (*Empidonax traillii extimus*)	E	entire range
loggerhead shrike (*Lanius ludovicianus*)	LC	San Clemente loggerhead shrike (*Lanius ludovicianus mearnsi*)	E	entire range
Bell's vireo (*Vireo bellii*)	NT	least Bell's vireo (*Vireo bellii pusillus*)	E	entire range
California gnatcatcher (*Polioptila californica*)	LC	coastal California gnatcatcher (*Polioptila californica californica*)	T	entire range
Kirtland's warbler (*Dendroica kirtlandii*)	NT		E	entire range
grasshopper sparrow (*Ammodramus savannarum*)	LC	Florida grasshopper sparrow (*Ammodramus savannarum floridanus*)	E	entire range
sage sparrow (*Amphispiza belli*)	LC	San Clemente sage sparrow (*Amphispiza belli clementeae*)	T	entire range
California towhee (*Melozone crissalis*)	LC	Inyo California towhee (*Pipilo crissalis eremophilus*)	T	entire range

218

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Supplementary figures

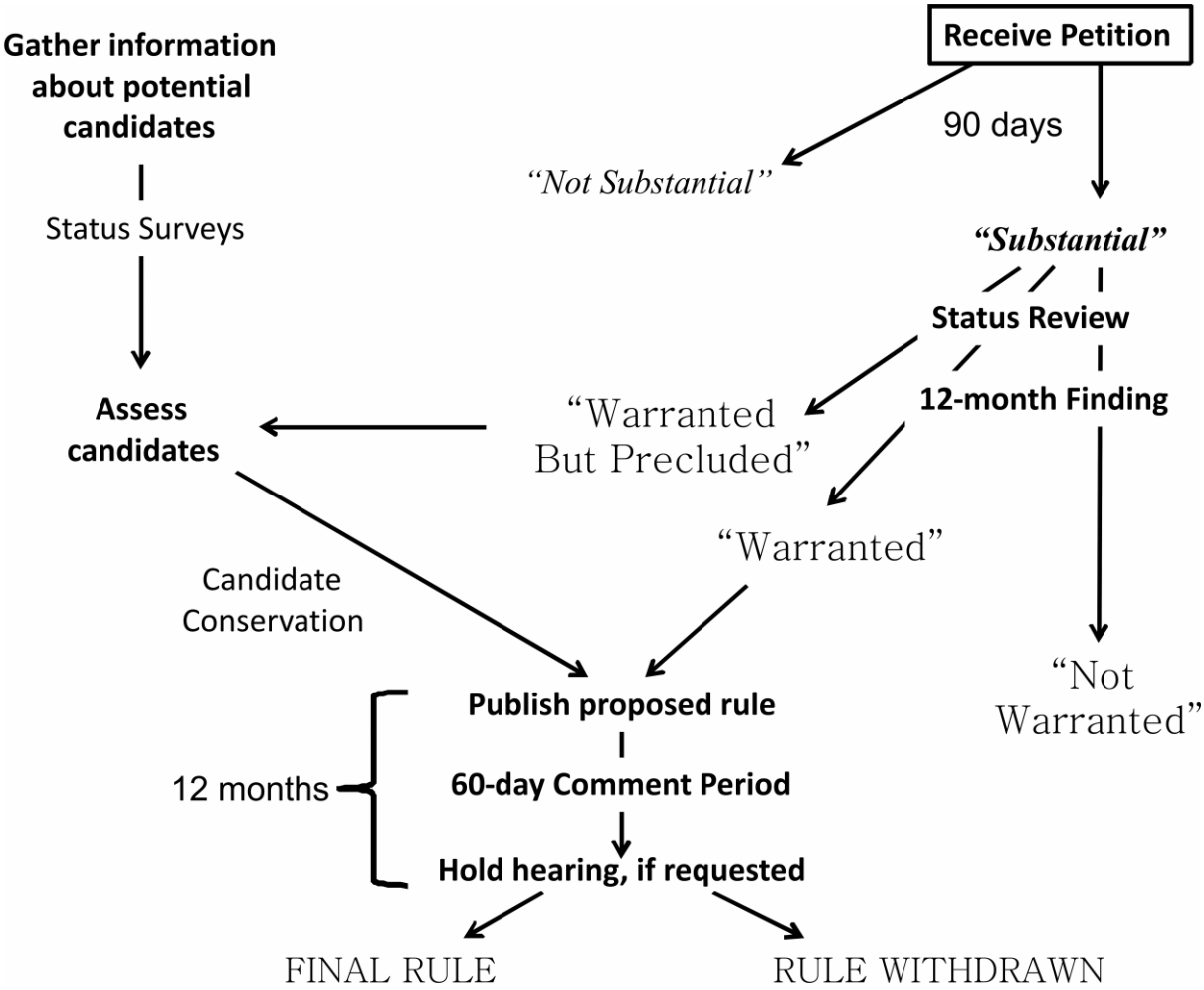

Figure S1. Species can be added to the ESA on the USFWS's own accord (discretionary pathway, left) or by way of petitions from parties outside the service (right). Figure adapted from USFWS (2009a).

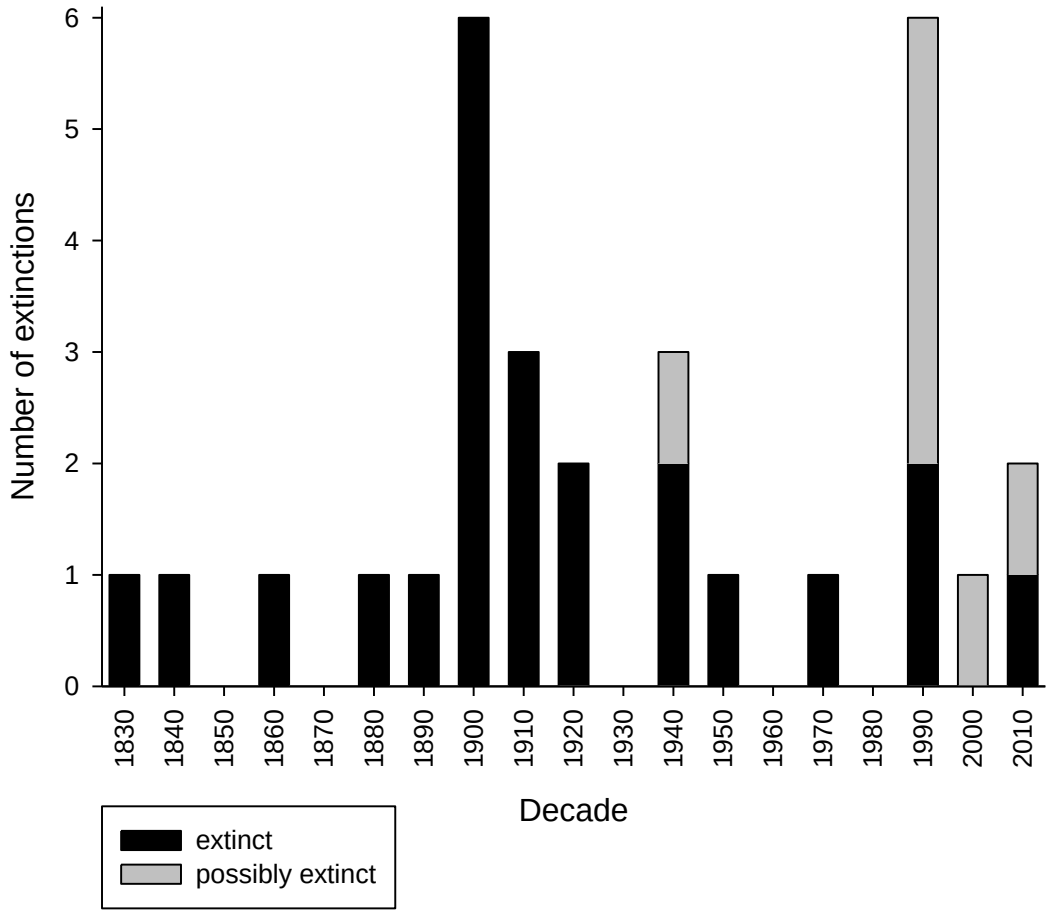

Figure S2. Bird extinctions by decade in the United States. Confirmed extinctions are shown in black; species classified as possibly extinct shown in gray. Extinction date is when species was last seen in the wild (data from IUCN 2009, BLI 2010). Twenty-five of the 30 *Extinct* and *Possibly Extinct* birds from the United States were endemic to Hawaii. Note the "extinction" in the 2000s was Hawaiian crow *Corvus hawaiiensis*, which was declared *Extinct in the Wild* in 2004.

Figure S3. Case study species. A. ashy storm-petrel (*Oceanodroma homochroa*), B. Kittlitz's murrelet (*Brachyramphus brevirostris*), C. cerulean warbler (*Dendroica cerulea*), D. sockeye salmon (*Onycorhynchus nerka*). Photographs by D. Pereksta, R. H. Day, L. Hays, and P. Colla, respectively; used with permission.