

# Agency plans are inadequate to conserve US endangered species under climate change

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**Despite widespread evidence of climate change as a threat to biodiversity, it is unclear whether government policies and agencies are adequately addressing this threat to species. Here we evaluate species sensitivity, a component of climate change vulnerability, and whether climate change is discussed as a threat in planning for climate-related management action in official documents from 1973 to 2018 for all 459 US animals listed as endangered under the Endangered Species Act. We find that 99.8% of species are sensitive to one or more of eight sensitivity factors, but agencies consider climate change as a threat to only 64% of species and plan management actions for only 18% of species. Agencies are more likely to plan actions for species sensitive to more factors, but such planning has declined since 2016. Results highlight the gap between climate change sensitivity and the attention from agencies charged with conserving endangered species.**

Climate change is a threat to ecosystems and biodiversity globally<sup>1,2</sup> and has emerged as a driver of observed and potential species decline and extinction<sup>3–5</sup>. Government laws and policies should play a vital role in supporting climate change adaptation for imperilled species, yet imperilled species protections have been critiqued as insufficient in Australia<sup>6,7</sup>, Canada<sup>8</sup> and Europe<sup>9</sup>. Funding shortfalls for environmental programmes mean that governments may not be adequately addressing baseline threats to species<sup>10,11</sup>, let alone more complex emerging threats from climate change<sup>12–15</sup>. Furthermore, the politicization of climate change in many countries, including the United States, has led to different levels of concern and action on the topic among political parties<sup>16,17</sup>. Understanding whether and to what extent government authorities are supporting climate change adaptation, especially for imperilled species, is critical for improving tools and processes to reduce climate change impacts on biodiversity<sup>18,19</sup>.

The primary law directing the conservation of imperilled species in the United States is the Endangered Species Act<sup>20</sup> (ESA). Central to the listing and recovery processes under the ESA is the enumeration and abatement of threats to species. The law directs the secretaries of the Interior and Commerce to use the “best available scientific and commercial data” to make listing determinations on the basis of five threat factors: (1) habitat destruction and degradation, (2) overutilization, (3) disease or predation, (4) inadequacy of existing protections or (5) other factors. While each factor may result from or be exacerbated by climate change, this threat is not explicitly described among the five factors. This is likely because the ESA was most recently amended legislatively in 1988<sup>21</sup>, the same year as the formation of the IPCC and 4 yr before the first detailed discussion of the consequences of climate change for biological diversity in the United States<sup>22</sup>.

Nonetheless, the two agencies responsible for implementing the ESA, the US Fish and Wildlife Service (FWS) and the National

Marine Fisheries Service (NMFS), have explicitly recognized the threat that climate change poses to species and the need to manage for its impacts. The FWS first described climate change as a threat in its January 2007 proposal to list the polar bear (*Ursus maritimus*) as threatened. Later that year, discussion of climate change appeared in recovery plans for the Indiana bat (*Myotis sodalis*) and Hawaiian monk seal (*Monachus schauinslandi*) and in 5 yr reviews for the red wolf (*Canis rufus*) and five sea turtle species (for references to species ESA documents, see the link in data availability). The only assessment of climate change in ESA documents to date (to our knowledge) found that by the end of 2008, 87% of species recovery plans still did not address whether climate change was a threat<sup>18</sup>. The scientific community has identified climate change as the ‘primary threat’ to nearly 40% of ESA-listed animals and over 50% of ESA-listed plants in the United States<sup>10</sup>, and agency options for climate-related management action under the ESA have been available for over a decade<sup>23</sup>. Thus, it is vital to understand whether the lead agencies responsible for endangered species conservation have improved the use of their authority to help species adapt to the threat of climate change.

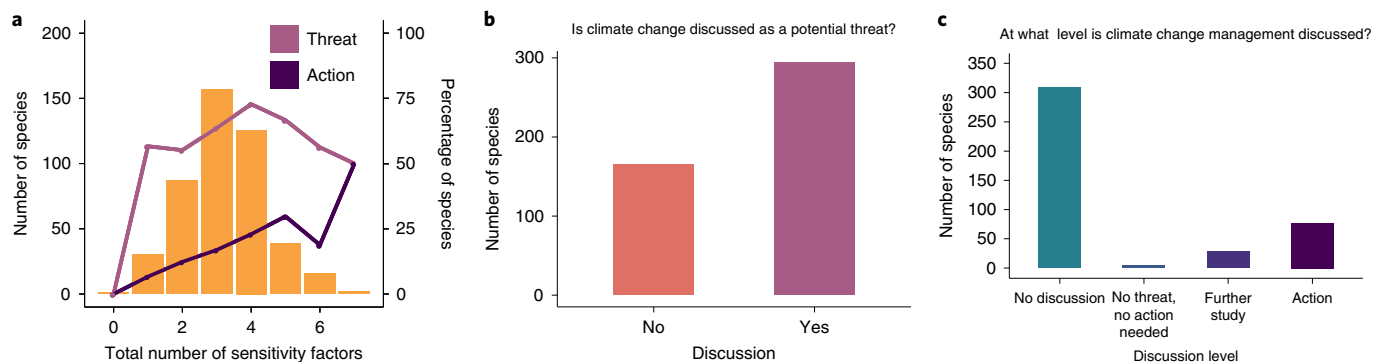
To determine whether threats from climate change are being addressed by US agencies, we compared the climate change sensitivity of species with agencies’ discussion of climate change and plans for managing climate change threats for the 459 ESA-listed endangered animals found within US lands and waters. Because climate change sensitivity had not been systematically assessed for many of these species, we developed a trait-based climate change sensitivity assessment<sup>24</sup>. This assessment is a simplified version of existing tools (Methods) and provides a preliminary evaluation of whether and which species’ life history and biological characteristics contribute to sensitivity to climate change (see Table 1). We focused on sensitivity (and related traits sometimes characterized as measures of adaptive capacity) because these, rather than

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**Table 1 | Questions in the rapid sensitivity assessment related to eight climate change sensitivity factors**

Factor	Question and description
Temperature	Does the species have specialized thermal tolerance or depend on habitat with an important temperature threshold? Species were considered temperature sensitive if available information indicated the species has or depends on habitats with obligate or preferential temperature thresholds (for example, sea ice).
Hydrology	Is the species dependent on habitat with a specialized hydrology? Species were considered sensitive if available information indicated they require narrow ranges of water depths, flow rates, timing or seasonality (for example, vernal pools or intermittent streams).
Disturbance	Is the species or its habitat sensitive to or dependent on a specific disturbance regime? This includes species in fire-adapted systems, species that rely on certain flood regimes and species impaired by disturbance, such as old-growth forest obligates and species sensitive to excessive flooding.
Isolation	Is the species or its habitat geographically restricted or does it face intrinsic or extrinsic barriers to shifting its range to maintain its climate space? While many endangered species are found in small, isolated populations, we scored species in this category if available information indicated they are confined to mountains, islands or headwaters; are narrowly endemic to spatially discrete habitats, such as caves, springs or rare soil types; or if species movement to other suitable habitat is limited by habitat loss, development, dams or other anthropogenic pressures.
Injurious species	Is the species or its habitat threatened by an invasive species, pest and/or disease organism that might benefit from climate change? We did not consider the species in question sensitive where the injurious species is ubiquitous or human oriented (for example, cats, rats, livestock).
Chemistry	Is the species sensitive to changes in chemical concentration, such as atmospheric CO <sub>2</sub> , water pH or dissolved oxygen?
Phenology	Does the species rely on specific triggers for life-cycle events, such as breeding, migration or colour change, that are likely to become out of sync with seasonal changes in resource availability or environmental conditions (that is, phenologic mismatch)?
Obligate relationships	Is the species dependent on one or a few species, such as a host or dominant food source, with limited alternatives if the required species declines due to climate change? We did not consider the species sensitive if it requires a host but can succeed in association with four or more species.



**Fig. 1 | Sensitivity to climate factors, threat assessment and planned management action. a–c.** Despite sensitivity to one or more climate factors (**a**), US endangered animals are not often assessed for whether climate change is a potential threat (**b**) and most do not receive planning for management actions to address climate change impacts (**c**). **a**, Species that are sensitive to more climate factors are more likely to receive management action planning (dark purple line;  $P < 0.05$ ) than are species sensitive to fewer factors, and are marginally more likely to receive evaluation of climate change as a threat (dark pink line;  $P = 0.07$ ). All endangered animals except one (Hawaiian goose (*Branta sandvicensis*)) are sensitive to one or more of eight climate factors (see Table 1 for description of factors). The two most sensitive species (seven factors) were a fish, the Clear Creek gambusia (*Gambusia heterochir*), and a mollusc, the shinyrayed pocketbook (*Lampsilis subangulata*). Bars represent the number of species; lines represent the proportion of species within each number of sensitivity factors. Analyses in **a** and **b** contain all endangered animals on the ESA ( $n = 459$ ); analysis in **c** excludes species for which only listing decisions exist (excluded  $n = 39$ ; included  $n = 420$ ; see text for details). Colours correspond to Figs. 2–4.

exposure, are the elements of vulnerability that management plans can address<sup>6</sup>. Furthermore, because of the small populations and range sizes of many of the species we evaluated, available exposure tools may not accurately capture granular scale and stochastic effects in a meaningful way<sup>25</sup>. Focusing on sensitivity greatly reduced the time required to assess each species, allowing the assessment to be applicable to large groups of species, such as the >2,300 US and foreign species listed under the ESA. Our assessment relies on affirmative statements about relevant aspects of biology and life history; certain traits had to be identified in the literature for a species to be determined sensitive, and a species was considered not sensitive

by default. Therefore, the assessment represents a conservative estimate of sensitivity and probably underestimated the actual sensitivity for some poorly studied species or those for which that information was not described in publicly available sources.

After assessing species sensitivity, we determined whether climate change was described as a threat for species by reviewing official ESA documents published by FWS and NMFS. All endangered species have listing determinations, and most have critical habitat designations, 5 yr reviews, recovery plans or recovery outlines. We focused on the most recently published one or two of these types of documents to determine whether climate change was described as

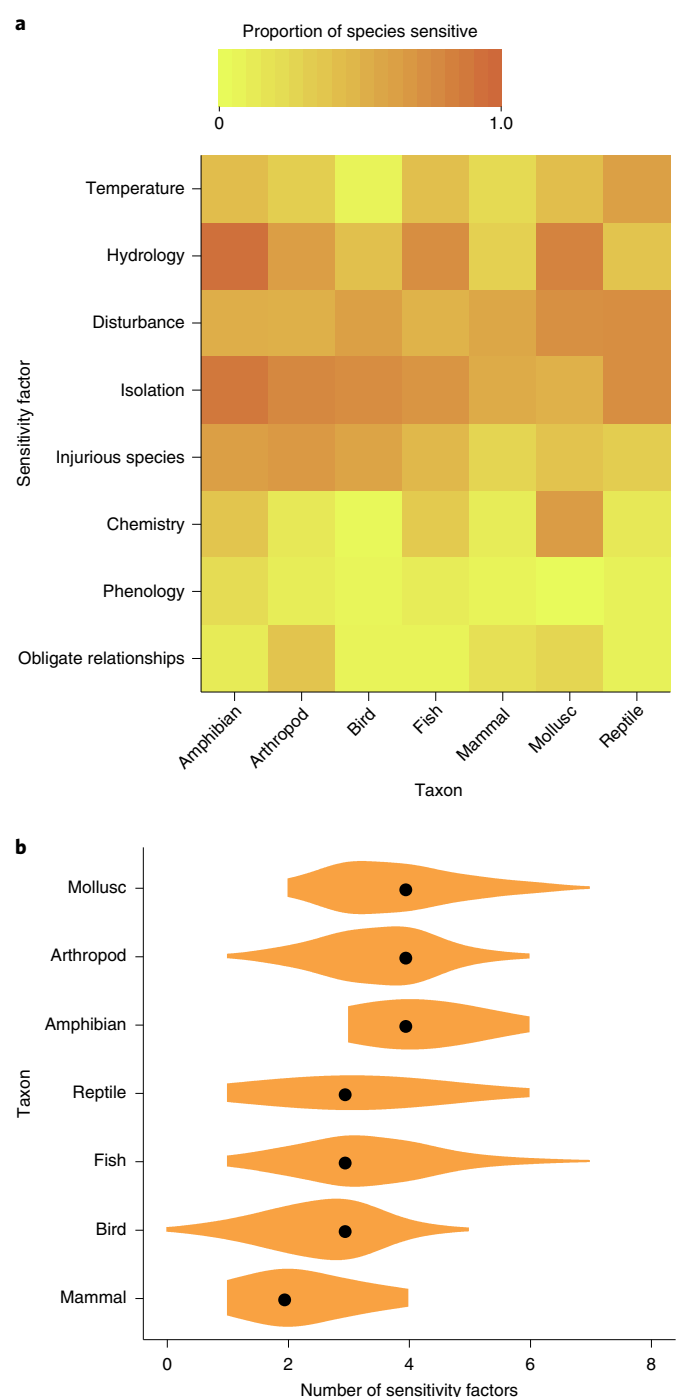
a threat. We then determined whether these agencies planned management action to address climate change threats as part of species recovery by evaluating the same ESA documents (excluding species whose only ESA document was a listing decision, as these are not management oriented). We tested whether species sensitivity was a significant predictor of whether species ESA documents contained discussion of climate change as a threat and to what extent federal agencies planned to respond to climate change impacts. Data and results of the study are available in a free, interactive web application at [https://defenders-cci.org/app/ESA\\_climate/](https://defenders-cci.org/app/ESA_climate/).

## Results

We found that nearly all endangered animals are sensitive to climate change impacts. All but one (Hawaiian goose (*Branta sandvicensis*)) of the 459 species (99.8%) are sensitive to at least one of the eight sensitivity factors (Table 1), and three-fourths (74%) are sensitive to three or more factors (Fig. 1a). However, agencies describe climate change threats in documents for only slightly more than half of species we assessed (64%; Fig. 1b) and plan management actions to address those threats for only a small fraction of species (18%; Fig. 1c). Logistic regression indicated that the number of sensitivity factors is a strong predictor of whether ESA documents discussed management action ( $F(1,419) = -2.97$ ,  $\beta = -0.31$ , where  $\beta$  is the estimate for 'sensitivity factor' as a covariate and  $P < 0.01$ ; Fig. 1a). Agencies are more likely to plan climate adaptation management actions for species that are sensitive to more climate factors than for species that are sensitive to fewer factors; for example, documents for species sensitive to one versus seven factors are 10% versus 41% likely to contain management actions. Likewise, species sensitivity is marginally related to whether climate change is considered as a threat ( $F(1,458) = 1.81$ ,  $\beta = 0.15$ ,  $P = 0.07$ ; Fig. 1a). These results indicate some prioritization of species on the basis of potential climate threat and sensitivity, though this may be unintentional. However, overall, there is a significant gap between the sensitivity of endangered animals to climate change and the attention that climate change receives from the agencies charged with recovery of these species.

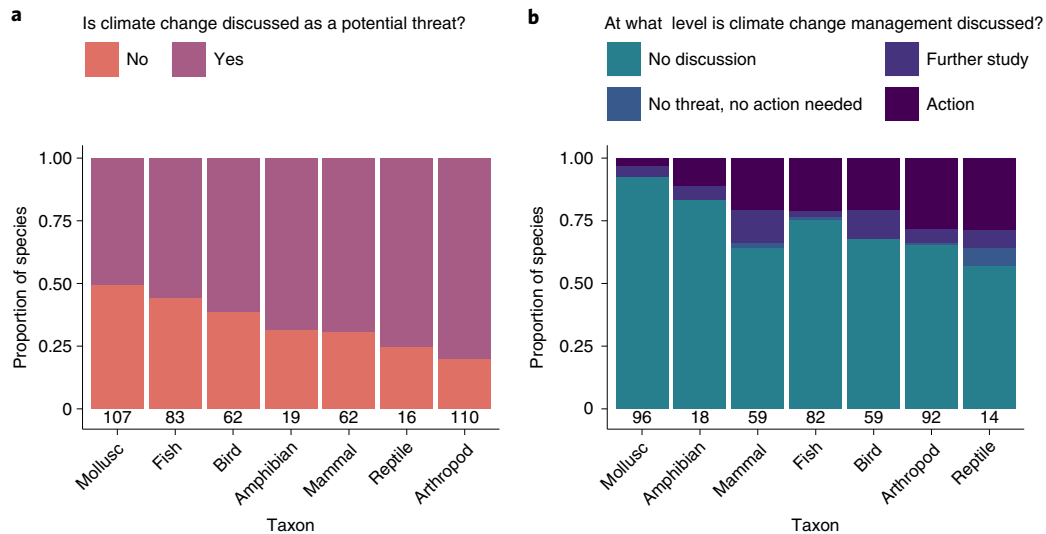
The prevalence of sensitivity factors varied considerably. The highest proportion of species across taxa was sensitive to isolation (mean across taxa = 0.71, all taxa  $\geq 0.50$ ), whereas the lowest proportion was sensitive to phenology (mean = 0.09, all taxa  $\leq 0.21$ ; Fig. 2a). Chemistry and obligate relationships showed the highest variation in sensitivity across taxa (mean = 0.25, s.d. = 0.22, coefficient of variation (c.v.) = 0.90; mean = 0.15, s.d. = 0.12, c.v. = 0.81, respectively); disturbance showed the least (mean = 0.61, s.d. = 0.11, c.v. = 0.17; Fig. 2a). Of the taxa assessed, mammals were sensitive to the fewest factors (Fig. 2b). Amphibians, molluscs and arthropods were sensitive to the greatest number of factors; many of these species exhibit an aquatic life-cycle phase and are thus subject to hydrological and chemical sensitivities. Furthermore, molluscs and arthropods also commonly depend on obligate species relationships, although reproductive host species are not known for some molluscs. Agencies appear to be prioritizing at least some of these high-sensitivity taxa for climate change-related management. Arthropods and reptiles had the greatest proportion of species for which climate change was evaluated as a threat (80% and 75%, respectively) and management action was described (28% and 29%, respectively), whereas molluscs had the least (50% evaluated as threat and 3% with management action; Fig. 3a,b).

Agencies have increasingly considered climate change as a potential threat to species in ESA documents over time, mirroring rising concern about climate change over the past few decades<sup>26</sup>. However, they have not yet widely translated this concern into management actions to help species adapt to climate change. After the agencies first described climate change as an influence on habitat loss (listing factor 1) in 2007, the proportion of species with climate



**Fig. 2 | Taxonomic differences in sensitivity to climate factors. a,b** Differences occur between taxa in the type (a) and total number (b) of climate factors. Analysis includes all 459 endangered species listed on the Endangered Species Act. See Table 1 for descriptions of factors, Supplementary Table 1 for the number of species in each taxa, and Supplementary Fig. 1 for taxa sensitivity by factor across management agency and region.

change mentioned in their ESA documents rose and thereafter stabilized at around 87% of species in 2015–2016 (Fig. 4a). In 2017–2018, however, this trend reversed, with declines in both the proportion of species for which climate change was listed as a threat and in the absolute number of newly published ESA-related documents for endangered animals. With regard to management planning, climate change was first identified as a topic for future



**Fig. 3 | Taxonomic differences occur in whether and how climate change is discussed in official management documents for endangered animals.**

**a**, Analysis of whether climate change is a threat contains all 459 US endangered animals listed under the ESA. **b**, Analysis of how climate change is a threat excludes species for which only listing decisions exist (excluded  $n=39$ ; included  $n=420$ ; see text for details). The number of species in each group is shown above the x axis.

study for the Indiana bat (*Myotis sodalis*) and Choctawhatchee beach mouse (*Peromyscus polionotus allopheys*) in 2007, and the first discussion of management action occurred in a 2008 recovery plan for the stellar sea lion (*Eumetopias jubatus*; Fig. 4b). The proportion of species with planned climate change-related action each year generally increased until peaking in 2014. Since then, discussion of action has steadily declined; of documents published in 2017, one species' 5 yr review (Kaua'i cave amphipod (*Spelaeorchestia koloana*)) described a management response to climate change, and no 2018 documents mentioned actions to address climate impacts. In summary, although the number of ESA documents mentioning climate change has increased over time, most species' documents either describe climate change as a potential problem without including any actions to specifically address the issue, or the documents do not discuss climate change at all. Across time (2007–2018), the proportion of species with planned climate change-related action each year has been low on average (mean = 0.23, range = 0.03–0.39; Fig. 4b), indicating a shortfall in planning of on-the-ground management for climate change that to date shows no sign of improving.

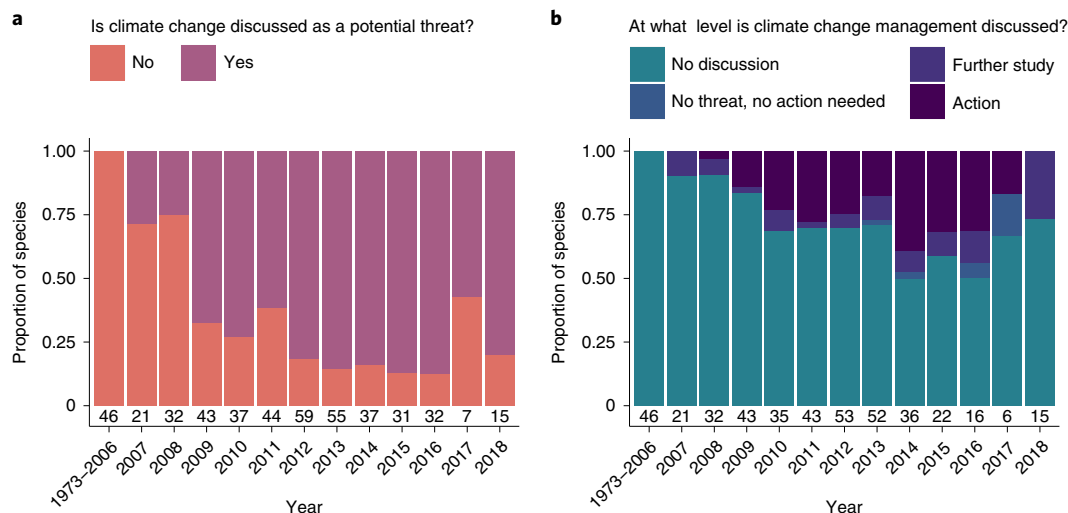
In short, across time and taxa, management agencies are inadequately assessing climate change threats, or planning action to manage those threats, to imperilled species. In terms of baseline assessment, this inadequacy affects species regardless of their climate sensitivity, as we found a weak relationship between the number of sensitivity factors and the consideration of climate change as a potential threat. Agencies may be inadvertently prioritizing species for management planning on the basis of their degree of sensitivity to climate factors. However, we further caution that the mere presence of management action in documents does not assure the adequacy of plans or, more important, the implementation of those plans<sup>6</sup>. Even for species with planned actions, we observed substantial variation in the content. Several 5 yr reviews merely recommended updating recovery plans to include climate change. More-robust discussions for action entailed protecting refugia (for example, Chinook salmon (*Oncorhynchus tshawytscha*) and white abalone (*Haliotis sorenseni*) recovery plans) and diverse microsites (for example, Karner blue butterfly (*Lycia melissa samuelis*) 5 yr review), improving connectivity (for example, jaguar (*Panthera onca*) recovery plan), establishing additional populations

for redundancy in case of stochastic climate events (for example, Sonoran pronghorn (*Antilocapra americana sonoriensis*) recovery plan), reducing non-climate-related threats (for example, water allocations in spikedace (*Meda fulgida*) 5 yr review) and designating critical habitat in areas likely to persist as or become important areas in the future (for example, tidewater goby (*Eucyclogobius newberryi*) and Bartram's scrub-hairstreak butterfly (*Strymon acis bartrami*) critical habitat designations). Our results offer insights for how agencies, including different management jurisdictions (Supplementary Information), might prioritize the types of climate change adaptation options to target susceptible taxa and sensitivity factors.

## Discussion

Three main issues may explain why the relevant US agencies have yet to address climate change threats as part of their imperilled species conservation programmes. First, the politicization of climate change has caused its prioritization to shift every 4 or 8 yr with changes in presidential administration. In 2017, the Trump administration revoked many policies and commitments on climate change established by the Obama administration, such as Executive Order 13653 on adaptation<sup>27</sup> and the Paris Agreement on climate change<sup>27,28</sup>. This has disrupted progress on both mitigation and adaptation nationally and internationally<sup>14</sup>. Imperilled species conservation in the face of climate change urgently requires the return of a bipartisan and durable commitment to both mitigation of and adaptation to climate change. For example, legislative bodies, such as the US Congress and central governments in other countries, could integrate climate change adaptation and mitigation into law rather than leaving these important processes to more labile policies.

Second, the infrequent and inconsistent inclusion of climate change in ESA species conservation may be a consequence of chronic underfunding and imbalanced funding of species recovery. In fiscal year 2012, 62% of species recovery funding was spent on the conservation of 10% of US listed species, resulting in as little as \$60 for some species (for example, Cumberland bean mussel (*Villosa trabalis*), whose ESA documents did not mention climate change)<sup>10,29,30</sup>. Another analysis of yearly appropriations from 1980



**Fig. 4 | Discussion of climate change as a threat and planning of management action in official documents over time. a, b.** Baseline assessment of climate change as a threat (**a**) to endangered animals has increased at a substantially faster rate than planning of management action (**b**). Analysis in **a** contains all 459 endangered animals listed on the Endangered Species Act; analysis in **b** excludes species for which only listing decisions exist (excluded  $n = 39$ ; included  $n = 420$ ; see text for details). The number of species in each group is shown above the x axis.

to 2014 found that <25% of required recovery funding has been allocated annually<sup>31</sup>. Increased funding to the agencies responsible for species recovery, paired with a more informed allocation of resources, could help redress this problem<sup>11,31</sup>.

Finally, climate change itself is a formidable conservation challenge that agencies generally lack the logistical tools and capacity to address. The broad spatial and temporal scales and uncertainty of specific threats mean that agencies should pair conceptual models with mechanistic approaches to identify stressors that materialize as species threats<sup>13,32</sup>. Agencies would benefit from embracing frameworks designed to enable systematic planning, implementing and monitoring of complex conservation challenges and integrating climate change with other threats<sup>33,34</sup>. In addition, agencies should proactively seek and embrace innovative tools that enable efficient management of the 2,300+ imperilled species listed on the ESA. The assessment used in this study is one such example, offering a time-efficient method for preliminary evaluations of species sensitivity to climate change.

Our study reveals that US government agencies have yet to adequately evaluate climate change threats to endangered animals listed under the ESA and plan commensurate action. The consistency between our US results and recent findings from Australia<sup>6,7</sup> suggest it is possible that many countries are similarly failing to protect imperilled species from climate change impacts. Climate change poses an ongoing and accelerating threat to many, if not most, imperilled species, and recovery will be unattainable unless a feasible process is in place to account for and ameliorate its impacts.

### Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at <https://doi.org/10.1038/s41558-019-0620-8>.

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### References

- Lipton, D. et al. in *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment Vol. II* (eds Reidmiller, D. R. et al.) 268–321 (US Global Change Research Program, 2018).
- IPCC *Climate Change 2014: Synthesis Report* (eds Core Writing Team, Pachauri, R. K. & Meyer, L. A.) (IPCC, 2014).
- Pounds, J. et al. Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature* **439**, 161–167 (2006).
- Urban, M. Accelerating extinction risk from climate change. *Science* **348**, 571–573 (2015).
- Diaz, S. et al. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES Secretariat, 2019).
- Butt, N. & Gallagher, R. Using species traits to guide conservation actions under climate change. *Climatic Change* **151**, 317–332 (2018).
- Hoepfner, J. M. & Hughes, L. Climate readiness of recovery plans for threatened Australian species. *Conserv. Biol.* **33**, 534–542 (2019).
- Scott, D. & Lemieux, C. Climate change and protected area policy and planning in Canada. *Forestry* **81**, 696–703 (2005).
- Araújo, M., Alagador, D., Cabeza, M., Nogués-Bravo, D. & Thuiller, W. Climate change threatens European conservation areas. *Ecol. Lett.* **14**, 484–492 (2011).
- Evans, D. M. et al. Species recovery in the United States: increasing the effectiveness of the Endangered Species Act. *Issues Ecol.* **20**, 1–28 (2015).
- Gerber, L. R. et al. Endangered species recovery: a resource allocation problem. *Science* **362**, 284–286 (2018).
- McClanahan, T. R. et al. Conservation action in a changing climate. *Conserv. Lett.* **1**, 53–59 (2014).
- Mawdsley, J. R., O'Malley, R. & Ojima, D. S. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. *Conserv. Biol.* **23**, 1080–1089 (2009).
- Bierbaum, R. et al. A comprehensive review of climate adaptation in the United States: more than before, but less than needed. *Mitig. Adapt. Strateg. Glob. Change* **18**, 361–406 (2013).
- Wilcove, D. S., Rothstein, D., Dubow, J., Phillips, A. & Losos, E. Quantifying threats to imperilled species in the United States. *Bioscience* **48**, 607–615 (1998).
- McCright, A. & Dunlap, R. E. The politicization of climate change and polarization in the American public's views of global warming, 2001–2010. *Sociol. Q* **52**, 155–194 (2011).
- McCright, A. M., Dunlap, R. E. & Marquart-Pyatt, S. T. Political ideology and views about climate change in the European Union. *Environ. Polit.* **25**, 338–358 (2015).
- Povilitis, A. & Suckling, K. Addressing climate change threats to endangered species in US recovery plans. *Conserv. Biol.* **24**, 372–376 (2010).
- Bernazzani, P., Bradley, B. A. & Opperman, J. J. Integrating climate change into habitat conservation plans under the US Endangered Species Act. *Environ. Manag.* **49**, 1103–1114 (2012).



20. *The Endangered Species Act of 1973* (US Congress, 1973).
21. *Endangered Species Act Amendments of 1988* (US Congress, 1988).
22. Peters, R. & Lovejoy, T. *Global Warming and Biological Diversity* (Yale Univ. Press, 1992).
23. Ruhl, J. Climate change and the endangered species act: building bridges to the no-analog future. *Environ. Law Policy Annu. Rev.* **39**, 10735–10745 (2009).
24. Pacifici, M. et al. Assessing species vulnerability to climate change. *Nat. Clim. Change* **5**, 215–225 (2015).
25. Case, M. J., Lawler, J. J. & Tomasevic, J. A. Relative sensitivity to climate change of species in northwestern North America. *Biol. Conserv.* **187**, 127–133 (2015).
26. Gustafson, A., Leiserowitz, A. & Maibach, E. Americans are increasingly 'alarmed' about global warming. *Climate Note* <https://go.nature.com/32Kq9YQ> (2019).
27. Trump, D. J. *Presidential Executive Order on Promoting Energy Independence and Economic Growth* Executive Order 13783 (The White House, 2017).
28. Shear, M. Trump will withdraw US from Paris Climate Agreement. *The New York Times* (1 June 2017).
29. *Federal and State Endangered and Threatened Species Expenditures* (US Fish and Wildlife Service, 2012).
30. Platt, J. How much did the US spend on the Endangered Species Act in 2012? *Scientific American* (1 November 2013).
31. Gerber, L. R. Conservation triage or injurious neglect in endangered species recovery. *Proc. Natl. Acad. Sci. USA* **113**, 3563–3566 (2016).
32. Heller, N. & Zavaleta, E. Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biol. Conserv.* **142**, 14–32 (2009).
33. Geyer, J. et al. Classification of climate-change-induced stresses on biological diversity. *Conserv. Biol.* **25**, 708–715 (2011).
34. Schwartz, M. W. et al. Decision support frameworks and tools for conservation. *Conserv. Lett.* **11**, e12385 (2018).

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## Methods

We compared the climate change sensitivity of species with agency evaluation and management planning of climate change threats for ESA-listed endangered animals in the United States. First, since systematic data did not exist for the climate change impacts on endangered species, we developed and conducted a trait-based, rapid assessment for evaluating climate change sensitivity. We focused the assessment on one element of species vulnerability: a species' potential 'sensitivity' to the effects of climate change. Sensitivity "refers to innate characteristics of a species or system and considers tolerance to changes in such things as temperature, precipitation, fire regimes, or other key processes"<sup>35</sup>. We created and answered eight yes-or-no questions based on whether the species' habitat, ecology, physiology or life cycle might be affected by changes in climate (Table 1). In doing so, we employed a biological approach to assessing sensitivity that considered the ecological impact to the species from the primary manifestations of climate change, including indirect impacts from effects on interacting species<sup>34</sup>. We derived the questions, or sensitivity factors, from factors listed in existing vulnerability assessment protocols, particularly the NatureServe Climate Change Vulnerability Index<sup>36</sup> and the US Forest Service's System for Assessing Vulnerability of Species<sup>37</sup>. Although not exhaustive, our questions covered the main categories of species sensitivity (or sometimes categorized under adaptive capacity) in these and other assessment frameworks<sup>38</sup>. We were thus able to assess many of the elements of vulnerability that can be addressed via management planning, while also completing most species in 30–60 min. This assessment could be useful to agencies for evaluating large numbers of species while still capturing the most critical elements of potential species sensitivity.

We assessed the climate change sensitivity of all animal species listed as endangered under the ESA (as of 31 December 2018) that are found in US states, territories and surrounding waters ( $n = 459$ ; see <http://www.fws.gov/endangered/>), with the exception of those deemed by agencies likely to be extinct or which have not been observed for 20+ yr and are probably extinct in the wild. We answered the assessment questions using freely accessible species information from species listing decisions and other publicly available information published by agencies and conservation organizations about the species and its threats. We predominantly referenced the FWS Environmental Conservation Online System (<https://ecos.fws.gov/ecp/>), the NMFS Endangered Species Conservation Directory (<https://www.fisheries.noaa.gov/species-directory/threatened-endangered>) and the NatureServe Explorer (<http://explorer.natureserve.org>). Using publicly available information enables the assessment to be used by the public or government, the latter of which requires decision data to be publicly visible<sup>39,40</sup>.

Consistency in measuring species sensitivity both within and between assessment tools is a recognized and ongoing challenge<sup>41,42</sup>. We took steps to ensure that sensitivity results were consistent within and between species in our assessment. Each species was assessed by at least two and as many as seven reviewers; species were initially reviewed by at least one of six reviewers (A.C., K.E., R.K., S.M., K.T. and L.V.) and were finally crosschecked by an expert reviewer (A.D.). All reviewers went through extensive training to ensure consistency in the application of the methodology (Table 1), including assessing and comparing the same species to validate and align the approach.

We also evaluated the extent to which FWS and NMFS ESA documents discussed climate change as a threat to species and included planned recovery actions to address climate change impacts. First, for all endangered animals, we recorded whether climate change was considered as a potential threat in each species' publicly available ESA documents (listing decisions, recovery plans and outlines, critical habitat designations and 5 yr reviews, published as of 31 December 2018). We focused on the most recently published agency documents, which should reflect cumulative knowledge about the species. Then, for all endangered animals except those with only listing decisions, which are not management oriented and thus not appropriate for evaluating management planning ( $n = 420$ ; excluded species  $n = 39$ ), we recorded what level of management action was discussed to address climate change in species recovery. We recorded the level of discussion as 'action', indicating that the documents articulated specific actions in response to climate change impacts; 'further study', indicating that the agency acknowledged they require additional information before an action plan could be developed; 'no threat, no action needed', indicating that the documents discussed climate change and decided that climate change is unlikely to impede species recovery; and 'no discussion', indicating that climate change was not mentioned.

We examined patterns in sensitivity and climate change discussion by time, taxa, agency and regional jurisdiction (see Supplementary Information for the latter two). We tested the relationships between the number of sensitivity factors and whether documents discussed climate change as a potential threat (yes/no) or discussed management action (by reclassifying discussion categories to create a binary variable of no action/action) using logistic regression run with the 'stats' package in R v.3.5.0. Data are available online<sup>43</sup>, and a free, interactive web application is available at [https://defenders-cci.org/app/ESA\\_climate/](https://defenders-cci.org/app/ESA_climate/).

**Reporting Summary.** Further information on research design is available in the Nature Research Reporting Summary linked to this article.

## Data availability

Data are archived on Open Science Framework and available at <https://osf.io/r9uca>. A free, interactive web application containing data and results from this study is available at [https://defenders-cci.org/app/ESA\\_climate/](https://defenders-cci.org/app/ESA_climate/).

## References

- Glick, P., Stein, B. A. & Edelson, N. A. *Scanning the Conservation Horizon* (National Wildlife Federation, 2011).
- Young, B. E., Dubois, N. S. & Rowland, E. L. Using the climate change vulnerability index to inform adaptation planning: lessons, innovations, and next steps. *Wildl. Soc. Bull.* **39**, 174–181 (2015).
- Bagne, K. E., Friggens, M. M. & Finch, D. M. *A System for Assessing Vulnerability of Species (SAVS) to Climate Change* (Forest Service, US Department of Agriculture, 2011).
- Foden, W. B. et al. Climate change vulnerability assessment of species. *WIREs Clim. Change* **10**, 1–36 (2018).
- US Fish and Wildlife Service *Information Quality Guidelines and Peer Review* (US Fish and Wildlife Service, 2012).
- NAO 202-735D: *Scientific Integrity* (NOAA, 2011).
- Lankford, A. J., Svancara, L. K., Lawler, J. J. & Vierling, K. Comparison of climate change vulnerability assessments for wildlife. *Wildl. Soc. Bull.* **38**, 386–394 (2014).
- Wheatley, C. J. et al. Climate change vulnerability for species—assessing the assessments. *Glob. Change Biol.* **23**, 3704–3715 (2017).
- Delach, A. et al. Agency plans are inadequate to conserve US endangered species under climate change (data sets). *Open Science Framework* <https://doi.org/10.17605/OSF.IO/R9UCA> (2019).

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## Author contributions

A.D. and A.C. designed the study. A.D., A.C., K.M.E., R.K., S.M., K.A.T. and L.J.V. collected data. A.D. and J.R.B.M. analysed data and wrote the manuscript. A.D., J.W.M., M.N.S. and J.R.B.M. interpreted results and J.W.M. built the web app. All authors provided critical feedback on the manuscript.

## Competing interests

The authors declare no competing interests.

## Additional information

**Supplementary information** is available for this paper at <https://doi.org/10.1038/s41558-019-0620-8>.






**Correspondence and requests for materials** should be addressed to A.D.

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# Agency plans are inadequate to conserve US endangered species under climate change

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## Supplemental Information

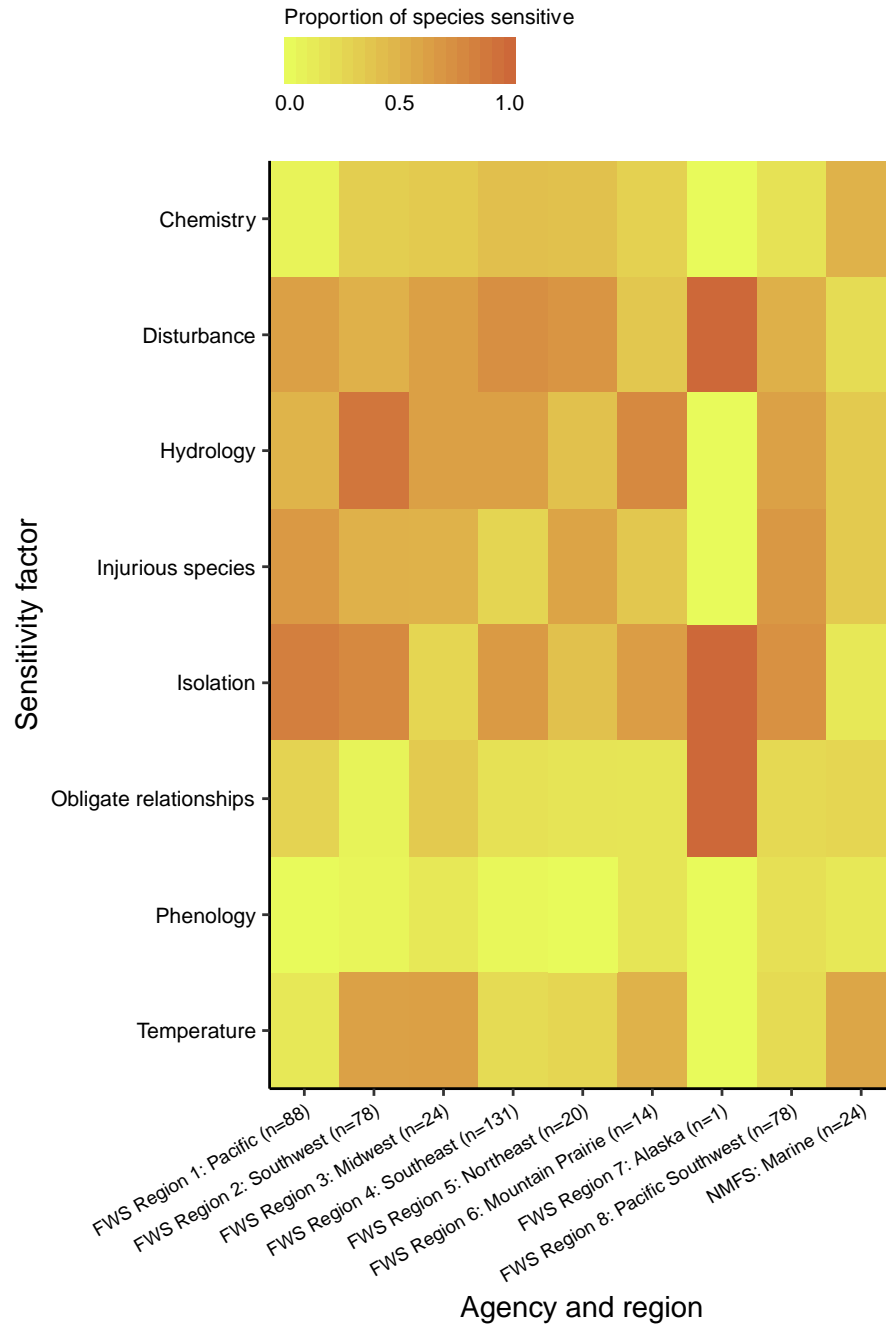
### Agency plans are inadequate to conserve US endangered species under climate change

Aimee Delach, Astrid Caldas, Kiel M. Edson, Robb Krehbiel, Sarah Murray, Kathleen A. Theoharides, Lauren J. Vorhees, Jacob W. Malcom, Mark N. Salvo and Jennifer R. B. Miller

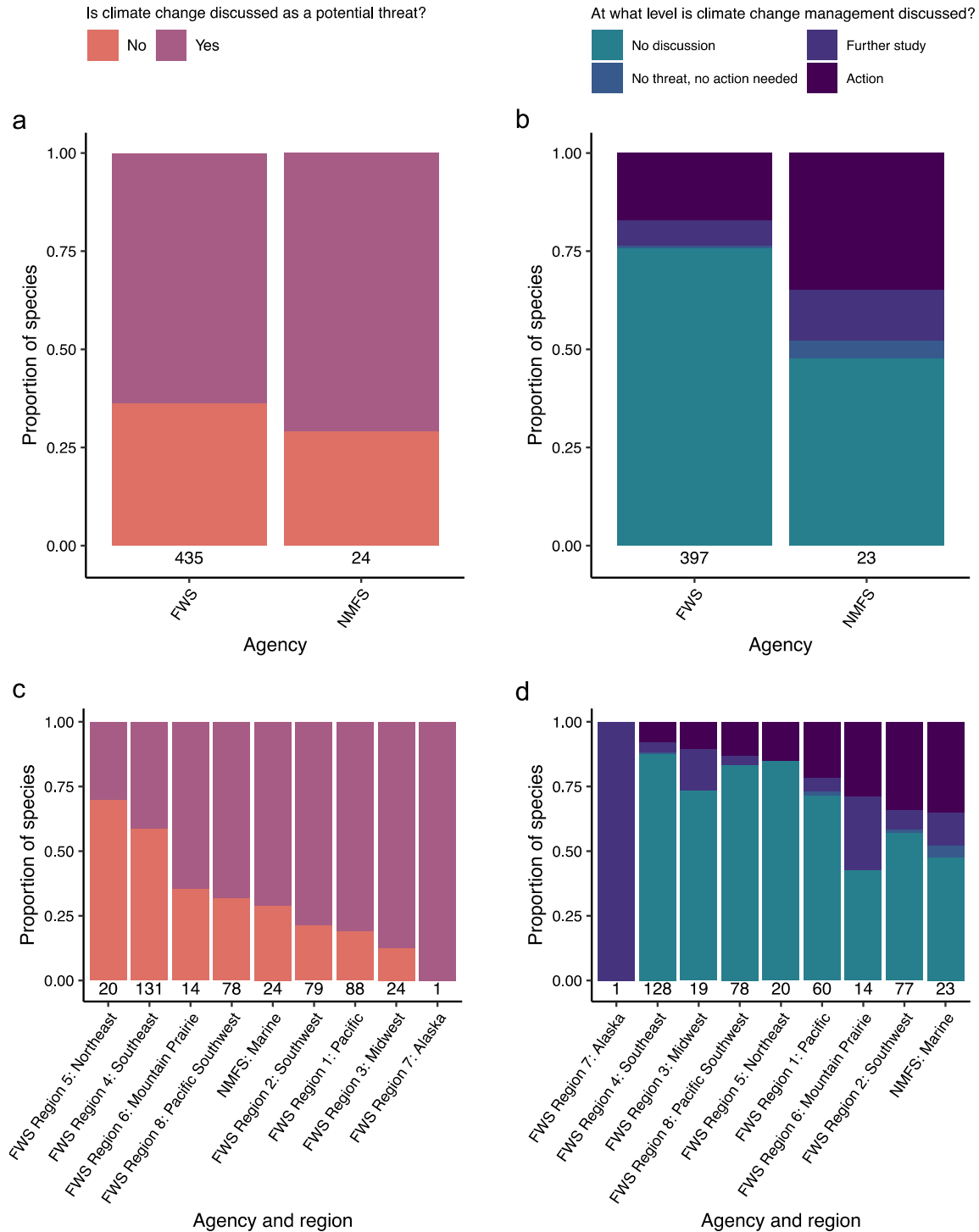
#### Results for agencies and regional management jurisdictions

Sensitivity of species to particular sensitivity factors generally mirrored nation-wide patterns (see main text; Fig. S1).

Analysis of discussion of climate change in management documents revealed that agencies are addressing climate change differently, and in some management jurisdictions more than others. Across agencies, documents from FWS and NMFS discussed climate change as a threat at similar proportions, for 64% (n=277) and 71% (n=17) of species under their purview, respectively (Fig. S2a; Supplemental Table 2; however, note the large difference in sample size). Within FWS, documents from Region 3 (Midwest) discussed climate change as a threat for 88% (n=24) of the terrestrial and aquatic species, in contrast to those from Region 5 (Northeast) which discussed climate change as a threat for only 30% (n=20) of species (Fig. S3c). With respect to planning climate change adaptation actions, differences between agencies and jurisdictions are more prominent: FWS planned actions for 17% of species (n=68) under their purview whereas NMFS planned action for 35% of species (n=8; Fig. S2b). The FWS' Region 2 (Southwest) planned actions for 34% (n=79) of species, whereas Region 4 (Southeast), the jurisdiction with the largest number of endangered animals (n=128) included actions in documents for only 8% of species (Fig. S2d). These results offer insights into how different agencies and jurisdictions might prioritize the types of climate change adaptation options to target susceptible taxa and sensitivity factors.



**Figure S1. The sensitivity of US endangered animals (n=459) differs by climate factor across management agency and regions.** FWS indicates US Fish and Wildlife Service and NMFS indicates US National Marine Fisheries Service. See Supplementary Table 2 for the number of species in each region and Table 1 for descriptions of climate sensitivity factors.



**Figure S2. Agency and regional differences occur in whether (a,c) and how (b,d) climate change is discussed in official management documents for endangered animals.** Analysis in **a** and **c** contains all 459 endangered animals listed on the Endangered Species Act; analysis in **b** and **d** excludes species for which only listing decisions exist (excluded n=39; included n=420; see text for details). The number of species in each group is shown above the x-axis. FWS indicates US Fish and Wildlife Service and NMFS indicates US National Marine Fisheries Service.

**Table 1.** Taxonomic breakdown of animals listed as endangered on the Endangered Species Act (n=459).

<b>Taxon</b>	<b>Number of species</b>	<b>Percentage of species</b>
Amphibian	19	4
Arthropod	110	24
Bird	62	14
Fish	83	18
Mammal	62	14
Mollusk	107	23
Reptile	16	3

**Table 2.** Breakdown by agency and region of species listed as endangered on the Endangered Species Act (n=459). FWS indicates US Fish and Wildlife Service and NMFS indicates US National Marine Fisheries Service.

<b>Agency and region</b>	<b>Number of species</b>	<b>Percentage of species</b>
FWS Region 1: Pacific	88	19
FWS Region 2: Southwest	79	17
FWS Region 3: Midwest	24	5
FWS Region 4: Southeast	131	29
FWS Region 5: Northeast	20	4
FWS Region 6: Mountain Prairie	14	3
FWS Region 7: Alaska	1	1
FWS Region 8: Pacific Southwest	78	17
FWS (combined)	235	91
NMFS: Marine	24	5

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*Give  $P$  values as exact values whenever suitable.*
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- ☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- ☒ ☐ Estimates of effect sizes (e.g. Cohen's  $d$ , Pearson's  $r$ ), indicating how they were calculated

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### Software and code

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Data collection

All data was collected from publically available documents and entered into Excel spreadsheets; no code was used.

Data analysis

Analysis was conducted using standard, open-access packages in R; no custom packages or algorithms were created or applied.

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# Ecological, evolutionary & environmental sciences study design

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Study description	Study consisted of three parts for data collection and analysis, all of which involved reading information in documents, entering relevant data into Excel, and then analyzing through regressions in R. First, we collected data about the sensitivity of species to climate change related to 8 sensitivity factors (Table 1). We collected data to assess these factors from federal species listing decisions, critical habitat designations, five-year reviews, recovery plans and outlines and other freely-available online species data from federal agencies and conservation organizations. We predominantly referenced the FWS' Environmental Conservation Online System (ECOS; <a href="https://ecos.fws.gov/ecp">https://ecos.fws.gov/ecp</a> ), NMFS' Endangered Species Conservation Directory ( <a href="https://www.fisheries.noaa.gov/species-directory/threatened-endangered">https://www.fisheries.noaa.gov/species-directory/threatened-endangered</a> ), and the NatureServe Explorer ( <a href="http://explorer.natureserve.org">http://explorer.natureserve.org</a> ). Second, we assessed the level with which climate change was discussed in these identified official Endangered Species Act documents published by agencies. Third, for all endangered animals except those with only listing decisions (n=420; excluded n=39), we recorded the level of management action was discussed to address climate change in species recovery. Data was collected in Excel spreadsheets. We tested the relationships between the number of sensitivity factors and whether documents discussed climate change as a potential threat (yes/no) or discussed management action (reclassified discussion categories to binary variable of no action/action) using logistic regression (two-tailed significance tests) run in R.
Research sample	The research sample consisted of all 459 animal species listed as endangered under the US Endangered Species Act.
Sampling strategy	No sub-sampling was used. Data was collected for the complete sample of all endangered animal species listed in the Endangered Species Act. Data was collected from the most recent relevant documents online.
Data collection	Authors A.D., A.C., K.E., R.K., S.M., K.T., and L.V. collected the data by reading documents and entering relevant info into Excel spreadsheets.
Timing and spatial scale	We assessed all animal species listed as endangered under the Endangered Species Act from January 1, 1973 through December 31, 2018 that are found in US states, territories and surrounding waters (n=459; see <a href="http://www.fws.gov/endangered">http://www.fws.gov/endangered</a> for complete list).
Data exclusions	Endangered animal species were excluded if they were deemed to be extinct by agencies or have not been observed for 20+ years and are likely extinct in the wild.
Reproducibility	We collected data using freely-accessible species information from online documents published by US federal and state agencies and conservation organizations. We specifically used publicly available information to ensure our assessment could be repeated or applied to other species by others, including the public and government. We tested the reproducibility of sampled data for some species in our study and determine that our methods enabled reproducibility at a satisfactory level, but did not explicitly quantify the reproducibility.
Randomization	Samples were not randomly assigned. Samples (species) were characterized into groups based on their characteristics (e.g., whether they were sensitive or not to climate change factors or whether climate change was considered as a potential threat) and then groups were compared.
Blinding	No blinding was used during data collection because data collection required extracting information about species themselves. The author (J.R.B.M.) who analyzed data was not involved in data collection and was not informed as to the expectations of data results.
Did the study involve field work?	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No

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