

## BIODIVERSITY IN FOCUS: UNITED STATES EDITION APPENDIX (ONLINE METHODS SECTION)

### Conservation Status of Plants in the United States

This analysis includes data from plants in taxonomic groups that have been comprehensively assessed by NatureServe. These include:

- Flowering plants
- Conifers and relatives
- Ferns and relatives

We also report results for several more narrowly defined informal taxonomic groups of conservation interest (e.g., cacti, trees). Species included in the trees taxonomic group are those included on [a standardized checklist of US native tree species](#), which covers the contiguous United States, as well as additional tree species occurring in Alaska and Hawai'i.

The analysis includes all full species within the listed taxonomic groups that are native to the United States, including Alaska and Hawai'i, excepting species with a global conservation status rank of GX (Presumed Extinct) or GNA (Not Applicable, a rank used to describe species with little conservation value such as hybrid or domesticated species). Full species are defined using NatureServe's standard taxonomy. Conservation status ranks are based on rounded ranks retrieved from NatureServe's Biotics database on August 12, 2022. More information on NatureServe Conservation Status Assessments [is available online](#). The reported values for the percent of species at risk are calculated by dividing the number of species ranked as GH (Possibly Extinct), G1 (Critically Imperiled), G2 (Imperiled), or G3 (Vulnerable) by the total number of species assessed, excluding species with global conservation status ranks of GU (Unrankable) or GNR (Unranked). The latter are excluded in this calculation so that the reported value provides an estimate of the true percent of species that are at risk, assuming that the same proportion of GNR and GU species are at risk as those that have been assigned ranks.

### Conservation Status of Animals in the United States

This analysis includes data from animals in taxonomic groups that NatureServe has comprehensively assessed. These include:

- Mammals
- Birds
- Amphibians
- Reptiles (including true reptiles, crocodilians, and turtles)
- Fishes (including freshwater and anadromous fish as well as lampreys)
- Freshwater mussels
- Crayfish
- Freshwater shrimps (including fairy, clam, and tadpole shrimps)
- Freshwater snails
- Terrestrial snails

- Caddisflies, mayflies, and stone flies
- Dragonflies and damselflies
- Bees (bumble bees, carpenter bees, selected genera of chimney bees, selected genera of digger bees, selected genera of digger-cuckoo bees, leafcutter bees, mason bees, squash bees, striped sweat bees, select genera of sweat bees, or wool-carder bees)
- Beetles (hairy flower scarabs, tiger beetles, and trichodes checkered beetles)
- Moths (giant silkworm and royal moths, notodontid moths, papaipema moths, spinx months, tiger moths, and underwing moths)
- Butterflies and skippers

We report results using informal taxonomic groups as listed above. The analysis includes all full species within these taxonomic groups that are native to the United States, including Alaska and Hawai'i, excepting species with a global conservation status rank of GX (Presumed Extinct) or GNA (Not Applicable, a rank used to describe species with little conservation value such as hybrid or domesticated species). Full species are defined using NatureServe's standard taxonomy.

Note that the genus *Hylaeus*, commonly known as yellow-faced bees, and the only native bees in Hawai'i, have not been comprehensively assessed and are not included in this analysis.

Conservation status ranks are based on rounded ranks retrieved from NatureServe's Biotics database on August 12, 2022. More information on NatureServe Conservation Status Assessments [is available online](#). The reported values for percent species at-risk are calculated by dividing the number of species ranked as GH (Possibly Extinct), G1 (Critically Imperiled), G2 (Imperiled), or G3 (Vulnerable) by the total number of species assessed, excluding species with global conservation status ranks of GU (Unrankable) or GNR (Unranked). The latter are excluded in this calculation so that the reported value provides an estimate of the true percent of species that are at risk, assuming that the same proportion of GNR and GU species are at risk as those that have been assigned ranks.

### **Conservation Status of Ecosystems in the United States**

This analysis is based on the provisional conservation status of U.S. National Vegetation Classification (NVC) groups. NVC groups are a mid-level ecosystem classification unit that reflect distinctive combinations of species in the context of regional to continental scale climate, geology, and water cycles, and disturbance patterns of fire, wind, and flood (see <http://usnvc.org> for more information). Three-hundred eighty-three natural terrestrial NVC groups are included, including provisional NVC groups.

To simplify interpretation and recognize the current provisional status of the ecosystem ranks, we summarize ranks to three categories: Imperiled: G1–G2, Vulnerable: G3, and Apparently Secure: G4–G5. Results for all groups are summarized by National Vegetation Classification subclass, a higher level of the classification. These data were informed by both long-standing information on the at-risk status of the component fine scale ecosystems (NVC associations)

within each NVC group and consideration of the published Red List status of Terrestrial Ecological Systems, which have been [cross-referenced for direct use with NVC groups](#). The reported values for percent of NVC ecosystems at-risk are calculated by dividing the number of NVC groups ranked as G1 (Critically Imperiled)/G2 (Imperiled) or G3 (Vulnerable) by the total number of NVC groups assessed, including NVC groups that are currently unranked. The results are thus best interpreted as percent *known* to be at risk of [collapse](#) and may be an underestimate of the true percent at risk.

The analysis was completed based on provisional status as of March 2022; some changes in rank assignments are likely to occur as provisional ranks are finalized, but general patterns in ecosystem imperilment are expected to hold.

### **Protection Status of Imperiled Plants and Animals**

This analysis reports the protection category for imperiled species in the contiguous United States based on an overlay of habitat models with protected areas managed for biodiversity conservation.

Currently, habitat maps, a necessary input for this analysis, are only available for a subset of our nation's at-risk species and thus this analysis is limited to that subset. NatureServe has developed a library of predictive habitat models for imperiled vertebrates, vascular plants, select freshwater invertebrates (freshwater mussels and crayfishes), and select pollinators (bumble bees, butterflies, and skippers) in the contiguous United States; the analysis is based on these data. Species included are all those with global conservation status ranks of Critically Imperiled (G1) or Imperiled (G2) or that were listed as Threatened or Endangered under the ESA at the full species level in those four groups. From the initial list of 2280 species meeting these criteria as of 5 September 2018, we eliminated 64 species for which taxonomic or other uncertainties prevented accurate habitat modeling.

Percent protection was calculated by intersecting these habitat maps with protected areas managed for biodiversity conservation, as mapped using the [USGS Protected Areas Database](#) (USGS PAD-US version 2.0). We selected all areas with a Gap Status of 1 or 2 (that is, areas specifically managed for biodiversity conservation) in the fee, designation, and easement PAD-US dataset and used this to calculate the percent protection for each species. This includes, for example, National Parks, Wilderness Areas within National Forests, and easements managed for the long-term protection of biodiversity. Public lands protected from land cover conversion but subject to extractive uses such as logging and mining are classified as Gap Status 3 and not included in our calculations. For ease in interpretation, the results were binned into 5 categories, ranging from "Negligibly Protected" (< 1% of habitat protected) to highly protected (≥ 90% of habitat protected). More information on this analysis is provided in Hamilton et al., [2022](#).

### **Protection Status of At-Risk Terrestrial Ecosystems**

This analysis reports the protection category for at-risk ecosystems in the contiguous United States based on an overlay of U.S. National Vegetation Classification (NVC) groups with protected areas managed for biodiversity conservation. Groups are a mid-level ecosystem classification unit that reflect distinctive combinations of species in the context of regional to continental scale climate, geology, and water cycles, and [disturbance patterns](#) of fire, wind, and flood. We define at-risk groups as those with a provisional global conservation status of Imperiled (G1 and/or G2) or Vulnerable (G3).

The analysis includes only NVC groups that have been mapped as of March 2022. The source map used in this analysis is derived from the LANDFIRE Remap 2016 National Vegetation Classification layer for the contiguous United States, which maps current locations of existing vegetation defined by NVC groups. As the NVC group classification has evolved since publication of the LANDFIRE data, NatureServe updated the LANDFIRE map to the 2021 NVC group classification and integrated our most recent provisional conservation status ranks to identify at-risk ecosystems (i.e., those with a global conservation status of G1 (Critically Imperiled)/G2(Imperiled) or G3(Vulnerable)). Not all NVC groups are yet mapped and some 2016 mapped NVC groups were not a 1:1 match to the latest version of the classification; these groups are not included in this analysis.

Percent protection was calculated by intersecting the group map with protected areas managed for biodiversity conservation, as mapped using the [USGS Protected Areas Database](#) (USGS PAD-US version 2.0). We selected all areas with a Gap Status of 1 or 2 (that is, areas specifically managed for biodiversity conservation) in the fee, designations, and easement PAD-US dataset and used this to calculate the percent protection for each group. For ease in interpretation, the results were binned into 5 categories, ranging from “Negligibly Protected” (<5% of habitat protected) to highly protected (≥50% of habitat protected). Note that this calculation is based on the *current* mapped extent and does not consider the percent of the historical extent that has been protected. However, especially for ecosystem types where high percentages have been converted, considering the percent of the historical distribution that has been protected can provide additional valuable insights for investments in ecosystem restoration.

### **Threats to Imperiled Species**

This analysis reports the top three threats for imperiled plants, terrestrial animals, and freshwater animals based on threat data documented in NatureServe’s Biotics database for species occurring in the 50 United States as of September 2022. Imperiled species are defined as those with a NatureServe Global Conservation Status of G1 (Critically Imperiled) or G2 (Imperiled). Only species with documented threats are included, including those that have been assessed as having “no known threat”; consequently, this analysis is best interpreted as the percent of *assessed* species impacted by a given threat. For animals, we’ve restricted reporting to taxonomic groups for which at least 70% of G1 and G2 species have been assessed for threats. Terrestrial animals include mammals, birds, reptiles (excluding crocodiles and turtles, which are included in the assessment of freshwater animals), butterflies and skippers, giant silkworm and royal moths, papaipepa moths, sphinx moths, underwing moths, bumble bees,

leafcutter bees, mason bees, and tiger beetles. Freshwater animals include freshwater and anadromous fishes, amphibians, crocodiles, turtles, crayfishes, and dragonflies and damselflies. For plants, all imperiled species that have been assessed for threats are included, or 53% of native, full species occurring in the 50 states.

It should be noted that this analysis may be biased by patterns in which species have been assessed by threats; for example, funding for updating conservation status assessments, which includes documentation of threats, is most readily available for species occurring on federal lands (since agencies like the US Forest Service and Bureau of Land Management have invested in keeping that information up to date). Species that primarily occur on private land may be less likely to have threats data documented, thus biasing the results. The analysis is limited to imperiled species because the threats data are most complete for this group.

Threats are classified per the IUCN threats [classification](#) scheme using a standard hierarchical list of threat categories. Threats are reported for the top-level IUCN category, except in cases where the secondary category accounts for a clear majority of species impacted by the first-level threat is more easily interpretable. For example, we report the percent of freshwater animals impacted by “dams and water management” (a second-level category) rather than the percent impacted by “natural systems modifications” (a first-level category that also includes factors such as altered fire frequency). For brevity, those category names have been shortened or otherwise altered in the figures in this report. The table below provides both first-order and second-order threats from the IUCN classification and how they have been labeled in this report.

<b>IUCN THREAT CLASS</b>	<b>REPORTED AS</b>
2 – AGRICULTURE & AQUACULTURE	Agriculture
6 – HUMAN INTRUSIONS & DISTURBANCE	
6.2 – RECREATION	Recreation
7 – NATURAL SYSTEMS MODIFICATIONS	
7.1 – DAMS AND WATER MANAGEMENT	Dams and water management
8 – INVASIVE & OTHER PROBLEMATIC SPECIES, GENES & DISEASES	Invasives and disease
9 – POLLUTION	Pollution
11 – CLIMATE CHANGE & SEVERE WEATHER	Climate change

We also evaluated categories from the IUCN classification that are not listed above, but those did not rise to the level of top three threats for the taxonomic groups assessed.

### **Impact of Land Conversion on U.S. Ecosystems**

These maps illustrate the percent loss in ecosystem extent for major vegetation types in the contiguous United States, grouping data for U.S. National Vegetation Classification subclasses to show percent loss for forests and woodlands (i.e., temperate-boreal forest and woodland and tropical forest NVC subclasses), grasslands (i.e., temperate-boreal grassland and shrubland,

tropical savanna, grassland and shrubland, and tropical high montane grassland and shrubland NVC subclasses), deserts (i.e., cool semi-desert and warm desert NVC subclasses), and wetlands (i.e., forest wetland and shrub and herb wetland NVC subclasses). Note that forested wetlands, including extensive swamp forests in the Upper Midwest and Southeastern and Gulf Coastal Plain, are included in the wetland, not forest, map.

Historical extent of vegetation is based on LANDFIRE data for Biophysical Setting. For the contiguous United States and Hawai'i, the Biophysical Setting data reflects expected natural vegetation patterns had there been no land conversion and natural disturbance regimes were in place. The LANDFIRE products were updated by NatureServe to integrate data from USGS GAP, regional maps from the Nature Conservancy, and states' maps to create a merged product representing the best available spatial data as described in [Comer et al., 2020](#). Since the Biophysical Setting data for Alaska are currently being remapped, and nearly all of the current extent is in natural condition, the historical extent of vegetation in Alaska is represented by LANDFIRE's 2016 National Vegetation Classification layer with areas of recently disturbed vegetation (e.g., from large wildfire) included. Current extent of vegetation is based on LANDFIRE's 2016 National Vegetation Classification layer available for the contiguous United States, Alaska, and Hawai'i. Data for current extent are 30-meter resolution. Maps of historic extent are 30-meter resolution for Alaska and Hawai'i, and 90-meter resolution for the contiguous United States.

To calculate percent loss, we divided the difference between historical and current extent by the historical extent for each vegetation type (Historic Extent – Current Extent) / Historic Extent).

### **Geography of Species Diversity and Imperilment**

This analysis includes data for all plants and all animals in taxonomic groups that NatureServe has comprehensively assessed. The latter include: mammals, birds, amphibians, reptiles (including true reptiles, crocodylians, and turtles, fishes (including freshwater and anadromous fish as well as lampreys), freshwater mussels, crayfish, freshwater shrimps (including fairy, clam, and tadpole shrimps), freshwater snails, terrestrial snails, caddisflies, mayflies, and stone flies, dragonflies and damselflies, bees (bumble bees, carpenter bees, selected genera of chimney bees, selected genera of digger bees, selected genera of digger-cuckoo bees, leafcutter bees, mason bees, squash bees, striped sweat bees, select genera of sweat bees, or wool-carder bees), beetles (hairy flower scarabs, tiger beetles, and trichodes checkered beetles), moths (giant silkworm and royal moths, notodontid moths, papaipema moths, sphinx months, tiger moths, and underwing moths), butterflies and skippers, and caddisflies, mayflies, and stoneflies. The analysis includes all full species within these taxonomic groups that that are native to the United States, including Alaska and Hawai'i, except species with a global conservation status rank of GX (Presumed Extinct). Note that yellow-faced bees, the only native bees in Hawai'i, have not been comprehensively assessed and are not included in this analysis. Full species are defined using NatureServe's standard taxonomy.

To illustrate the taxonomic diversity in patterns, in addition to maps for all animals and all plants, we also provided for orchids (all species in the family Orchidaceae) and bees (as described above).

The total count of species per state is based on the subnational distribution as stored in NatureServe's Biotics database as of July 2022. To calculate the percentage of species at risk, we divided the count of at-risk species – that is all species documented for the state with a conservation status rank of GH (Possibly Extinct), G1 (Critically Imperiled), G2 (Imperiled), or G3 (Vulnerable)– by the total species counted for each state, excluding species with global conservation status ranks of GU (Unrankable) or GNR (Unranked). More information on NatureServe Conservation Status Assessments [is available here](#).

### **The Geography of Ecosystem Diversity and Imperilment**

The number of ecosystems per state reports the count of ecosystems in each state based on the subnational attribution of US National Vegetation Classification (NVC) groups as captured in NatureServe's Biotics database. Data were retrieved in January 2022. Groups are a mid-level ecosystem classification unit that reflect distinctive combinations of species in the context of regional to continental scale climate, geology, and water cycles, and disturbance patterns of fire, wind, and flood (see <http://usnvc.org> for more information).

The percent of state area with at-risk ecosystems was calculated based on the mapped distribution of at-risk groups. We divided the total land cover mapped as an at-risk group within the state by the total state area. We define at-risk groups as those with a provisional global conservation status of Imperiled (G1 and/or G2) or Vulnerable (G3). The mapped distribution of groups is based on the published LANDFIRE 2016 National Vegetation Classification maps for the contiguous United States, Alaska, and Hawai'i which represent the modeled distribution of current extent of these types as derived from satellite imagery from 2016. NatureServe updated the LANDFIRE map to 2021 NVC groups and integrated our most recent provisional conservation status ranks to identify at-risk ecosystems (i.e., those with a global conservation status of G1 (Critically Imperiled)/G2 (Imperiled) or G3 (Vulnerable)). Not all NVC groups are yet mapped and some 2016 mapped groups were not a 1:1 match to the latest version of the classification; these groups are not included in this analysis. In Alaska, distribution data and conservation status for NVC groups has yet to be developed, and thus, a comparable calculation for percent at-risk ecosystems was not possible. For this reason, results for Alaska are not included in this analysis, though extensive information on [Alaska ecosystems of conservation concern](#) is available from the Alaska Center for Conservation Science.

The analysis was completed based on provisional status as of March 2022; some changes in rank assignments are likely to occur as provisional ranks are finalized, but general patterns in ecosystem imperilment are expected to hold.

### **Land Conversion in the United States**

The map of land conversion in the United States is based on the LANDFIRE 2016 National Vegetation Classification data in that dataset.

### **Priority Areas for Conserving Unprotected, Imperiled Species**

This map displays areas of unprotected biodiversity importance (AUBIs) for species in the lower 48 United States that are protected by the [Endangered Species Act](#) and/or considered to be in danger of extinction. It is part of the [Map of Biodiversity Importance \(MoBI\)](#) data collection, a series of maps that identify areas of high importance for protecting species from extinction in the contiguous United States.

NatureServe has developed a library of predictive habitat models for imperiled vertebrates (209 species), vascular plants (1,636 species), select freshwater invertebrates (freshwater mussels and crayfishes; 228 species), and select pollinators (bumble bees, butterflies, and skippers; 43 species) in the contiguous United States; the analysis is based on these data. Species included are all those with global conservation status ranks of Critically Imperiled (G1) or Imperiled (G2) or that were listed as Threatened or Endangered under the ESA at the full species level in those four groups. From the initial list of 2280 species meeting these criteria as of 5 September 2018, we eliminated 64 species for which taxonomic or other uncertainties prevented accurate habitat modeling.

Using these habitat models, we derived information on range size and degree of protection to calculate a protection-weighted range-size rarity (PWRSR) index, which we summed for all species to map areas where under-protected and range-restricted species are most likely to occur, including areas where the presence of multiple imperiled species contributes to higher scores. The map of AUBIs depicts the highest scoring areas for PWRSR. These areas are of interest to conservationists due to both the restricted range sizes and need for protection from threats such as habitat loss.

Range-size rarity for each species is the inverse of the total area mapped as suitable habitat (using the 990-m raster). Protection-weighted range-size rarity (PWRSR) maps combine information on both range-size rarity and the degree to which habitat for the species is protected. Protected habitat was defined as that occurring within protected areas managed for biodiversity (i.e., Gap Status 1 and 2 lands in the [USGS Protected Areas Database](#); PAD-US 2.0). Each species was assigned a PWRSR score equal to the product of range-size rarity and the percent of habitat that is unprotected. The PWRSR raster sums these scores for all species with habitat that overlaps a cell. We delineated AUBIs by then selecting all pixels where summed  $PWRSR \geq 0.0005$ , an inclusive value designed to highlight areas of conservation value. A PWRSR score of 0.0005 corresponds to a single species with a range of 1,000 km<sup>2</sup> that is 50% unprotected, a single species with a range of 20 km<sup>2</sup> that is 1% unprotected, or multiple co-occurring species with lower PWRSR scores. Note that fully protected species do not contribute to PWRSR scores.

More information on this analysis is provided in [Hamilton et al., 2022](#).