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Biocultural vulnerability exposes threats of culturally important species

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There are growing calls for conservation frameworks that, rather than breaking the relations between people and other parts of nature, capture place-based relationships that have supported social–ecological systems over the long term. Biocultural approaches propose actions based on biological conservation priorities and cultural values aligned with local priorities, but mechanisms that allow their global uptake are missing. We propose a framework to globally assess the biocultural status of specific components of nature that matter to people and apply it to culturally important species (CIS). Drawing on a literature review and a survey, we identified 385 wild species, mostly plants, which are culturally important. CIS predominate among Indigenous peoples (57%) and ethnic groups (21%). CIS have a larger proportion of Data-Deficient species (41%) than the full set of International Union for Conservation of Nature (IUCN) species (12%), underscoring the disregard of cultural considerations in biological research. Combining information on CIS biological conservation status (IUCN threatened status) and cultural status (language vitality), we found that more CIS are culturally Vulnerable or Endangered than they are biologically and that there is a higher share of bioculturally Endangered or Vulnerable CIS than of either biologically or culturally Endangered CIS measured separately. Bioculturally Endangered or Vulnerable CIS are particularly predominant among Indigenous peoples, arguably because of the high levels of cultural loss among them. The deliberate connection between biological and cultural values, as developed in our "biocultural status" metric, provides an actionable way to guide decisions and operationalize global actions oriented to enhance place-based practices with demonstrated long-term sustainability.

biocultural diversity | conservation planning | cultural keystone species | Indigenous languages

Significance

Recognizing the connections between people and other parts of nature and incorporating them into decision-making will enable to operationalize actions simultaneously based on biological conservation priorities and cultural values. Our biocultural framework and metric show that high levels of cultural loss, particularly among Indigenous peoples, swamp the influence of biological status on assessing biocultural status. To sustain culturally important species, we need a more complete list of species that are culturally important for different groups and of their status, as well as larger support to the cultures that value them.

Biocultural Approaches to Conservation

At a time of global decline in nature, there are growing efforts to conserve the world's biodiversity both for nature's sake and for its contributions to humankind (1). In these efforts, conservation policies based mostly on biological criteria miss the social, cultural, and livelihood needs and aspirations held by local communities (2). They thus risk perpetuating existing inequalities in the distribution of social and ecological burdens and benefits of conservation (3, 4). For example, conservation proposals to safeguard 30% (5, 6) or 50% (7) of the planet face opposition on the grounds that they might increase the negative social impacts of conservation actions and pose immediate risks for people whose livelihoods directly depend on nature, in particular Indigenous peoples and local communities (8, 9). To help address these potential conflicts, researchers and practitioners increasingly emphasize the need for different conservation frameworks that, rather than focusing on breaking the relations between people and other parts of nature, include a broader range of worldviews, knowledge, and values and that capture place-based relationships that have supported social–ecological systems over the long term (10–13).

Biocultural approaches can widen existing conservation frameworks by recognizing and honoring the relationships between people and other parts of nature, proposing actions based on conservation priorities and cultural values aligned with local priorities (3, 14, 15). Examples of biocultural approaches to conservation include initiatives that recognize the spiritual significance of landscapes as manifested in sacred sites (16, 17), the importance of social norms, such as taboos or customary rules in wildlife management (18, 19), or the cultural significance of some species, including them in management strategies (20, 21) or in conservation planning in the face of climate change (22). Despite recent applications of biocultural approaches in specific case studies, we lack mechanisms that allow a global uptake of a biocultural framework (but a proposal is provided in ref. 23). This gap most likely exists because many of the interactions that mediate the relationships between people

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and nonhuman nature are context specific and difficult to articulate to outsiders (11, 24) resulting in challenges for the transferability, integration, and scalability of local knowledge (25).

Here, we propose a framework and implement a metric to assess the biocultural status of specific components of nature that matter to local communities. The proposed metric, "biocultural status," allows the combination of information on biological and cultural conservation status of different components of nature and is based on the logic that the disappearance of a culture entails the disappearance of relations between human and nonhuman components of nature (2, 26, 27). Drawing on research on cultural keystone species (e.g., refs. 21 and 28), we apply our framework to assess the biocultural status of "culturally important species" (CIS), here defined as species that have a recognized role in supporting cultural identity, as they are generally the basis for religious, spiritual, and social cohesion and provide a common sense of place, purpose, belonging, or rootedness associated with the living world (*Methods*).

CIS Characterization

Combining information from previous compilations of CIS and an online survey (see *Methods*), we identified 385 wild species that are culturally important for at least one sociocultural group. We differentiated between CIS that are important for "Indigenous peoples," "ethnic groups," "local communities," and "other sociocultural groups" (see *Methods* for definitions). We acknowledge that ours is not a comprehensive list of the total (currently unknown) number of CIS on Earth. We also acknowledge that the inclusion of species in the list is probably biased by researchers' interpretation of which species are culturally important for a specific sociocultural group as the compilation was not fully informed through diverse knowledge systems. However, the list represents the largest global compilation of wild species identified as culturally important to date. Our list is largely dominated by plants (n = 241; 63%), with a surprisingly low number of mammal (n = 50; 13%), fish (n = 27; 7%), and bird species (n = 16; 4%) (Fig. 1*A*). CIS were reported in every continent, with more reports in North America (23%) than elsewhere (Fig. 1*B*). Only four species (all sea turtles, i.e., *Caretta caretta*, *Chelonia mydas*, *Dermochelys coriacea*, and *Eretmochelys imbricata*) were reported as culturally important by groups in more than one continent. Other reports were continent specific.

Species in our list are culturally important for a variety of sociocultural groups but mainly for Indigenous peoples (57%) and ethnic groups (21%). Particularly, CIS are documented among Indigenous peoples in the Americas, Oceania, and Asia and among ethnic groups in Africa (Fig. 1*B*). Some CIS are also documented among local communities (mainly in South America) and other sociocultural groups in Europe (largely referring to CIS for citizens of a given region, such as Extremadura in Spain, Provence in France, or Epirus in Greece).

Biological and Cultural Status

We assessed the biological conservation status of CIS (hereafter biological status) using the International Union for Conservation of Nature Red List of Threatened Species (IUCN) (29) and the "cultural status" of the group(s) for which the species is culturally important using language vitality using the Ethnologue (30).

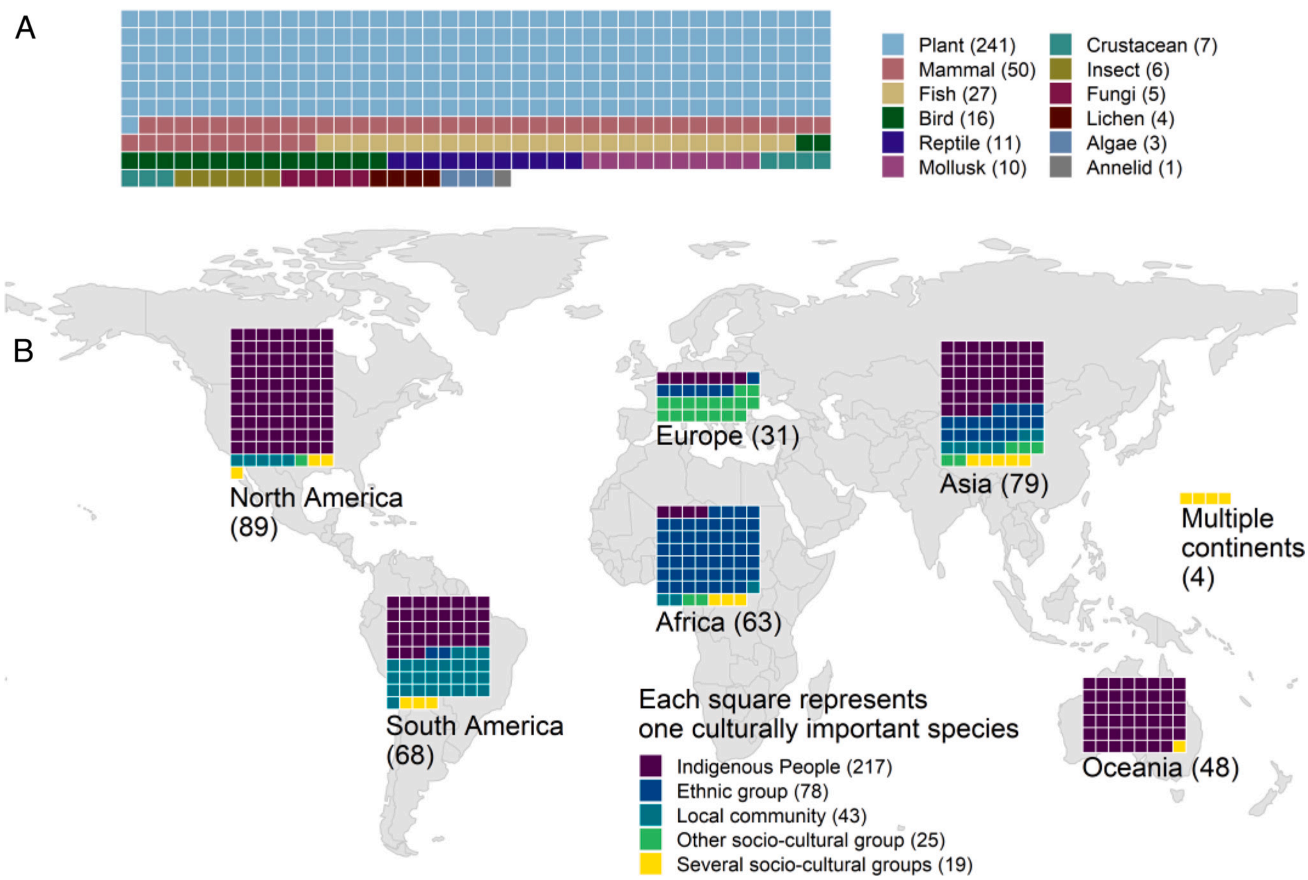

Fig. 1. Taxonomic and geographical distribution of culturally important species (n = 385). (*A*) Taxonomic distribution of CIS. (*B*) Number of CIS classified by continent and sociocultural group type (i.e., Indigenous people, ethnic group, local community, and other sociocultural group). Each square represents a CIS. In (*A*) square, color depicts taxonomic distribution and in (*B*) it depicts the sociocultural group who reported the CIS.

We used language vitality as a proxy for a group's cultural status because language is the primary means of cultural transmission (31) and the ability of cultures to name, use, and share knowledge about nature might disappear when languages go extinct (27, 32). We assigned a cultural status value to each CIS, combining information from the cultural status of all the groups for which the species is documented as culturally important (*Methods*).

The distribution of IUCN categories within our list of CIS generally aligns well with the general distribution of the IUCN Red List species [χ^2(df = 4, N = 32,713) = 3.23, P = 0.520] except for Data-Deficient species. Our list of CIS has a much higher proportion of Data-Deficient species (41%) than the full set of IUCN species (12%). The high share of Data-Deficient species in our list might result in an underestimation of the biological threat of some CIS as species categorized as Data-Deficient by the IUCN seem to be more threatened than data-sufficient species (33). The disproportionally high amount of missing data on the biological status of CIS also aligns with reports of mismatches in metrics externally defined and those locally considered important (e.g., ref. 34). Importantly, the data gap underscores that cultural considerations remain disregarded in much current biological research (3, 4).

CIS in our list are homogeneously distributed across the selected cultural status categories, with roughly one third of the species falling in the Not Threatened (36%), Vulnerable (28%), and Endangered (34%) categories. Only six CIS have a Data-Deficient cultural status.

Biocultural Status

We combined information on the CIS biological and cultural status to create categories for a new metric of biocultural status (Fig. 2). We acknowledge that there are biases in the datasets used to infer CIS biological (35) and cultural status (36), which preclude the precise assessment of biocultural status. However, using a Pearson's chi-square test of independence, we found that biological and cultural status of CIS in our sample are independent of one another (χ^2(df = 15, N = 382) = 14.95, P = 0.455). Overall, 163 (42%) of the CIS in our list are not of biological concern and a similar number (n = 139, 36%) are not of cultural concern. A much lower share of CIS are not of biocultural concern (n = 62; 16%), with 110 (29%) and 152 (39%) CIS having a Vulnerable and Endangered cultural status, respectively. Overall, then, more CIS in our list are culturally Vulnerable or Endangered than they are biologically Vulnerable or Endangered. Bootstrapped 95% confidence intervals show that the proportion of bioculturally Endangered and Vulnerable CIS is significantly greater than the proportion of Not Threatened and Data-Deficient CIS.

Many CIS with a biological status other than Data-Deficient are Least Concern or Near Threatened (n = 163, 42%) but span the range of cultural status (Fig. 2). Over one third of the species in the Least Concern and Near-Threatened categories (n = 62; 16% of all CIS) are culturally Not Threatened. Examples of species in this category are *Ciconia ciconia* (white stork), considered a "national bird" by the Polish (37), *Macleania rupestris* (uva camarona), whose fruit is widely consumed by high mountain peasants in Colombia (38), and *Ptaeroxylon obliquum* (sneezewood tree), whose durable wood is used by the Xhosa in West Africa to construct ceremonial houses and represents allegiance to the ancestors (39).

A similar number of species (n = 58; 15% of all CIS) are biologically Least Concern or Near Threatened but are important to culturally Endangered groups. Examples of species in this category include the venomous *Naja haje* (Egyptian cobra) of North Africa that is sacred to the Ikoma in Tanzania (40) and *Echyridella menziesii* (New Zealand freshwater mussel), a New Zealand endemic that is culturally keystone to the Maori (41).

Very few CIS are both biologically and culturally Endangered or Critically Endangered (n = 13; 3% of all CIS; Fig. 2). Species in this category include the Endangered *Fraxinus nigra* (black ash), which plays a central role in the spiritual and material culture (i.e., basketry) of different Native Americans and First Nations people in the Wabanaki Confederacy (42), the Critically Endangered crayfish *Cherax tenuimanus* in southwestern Australia, culturally

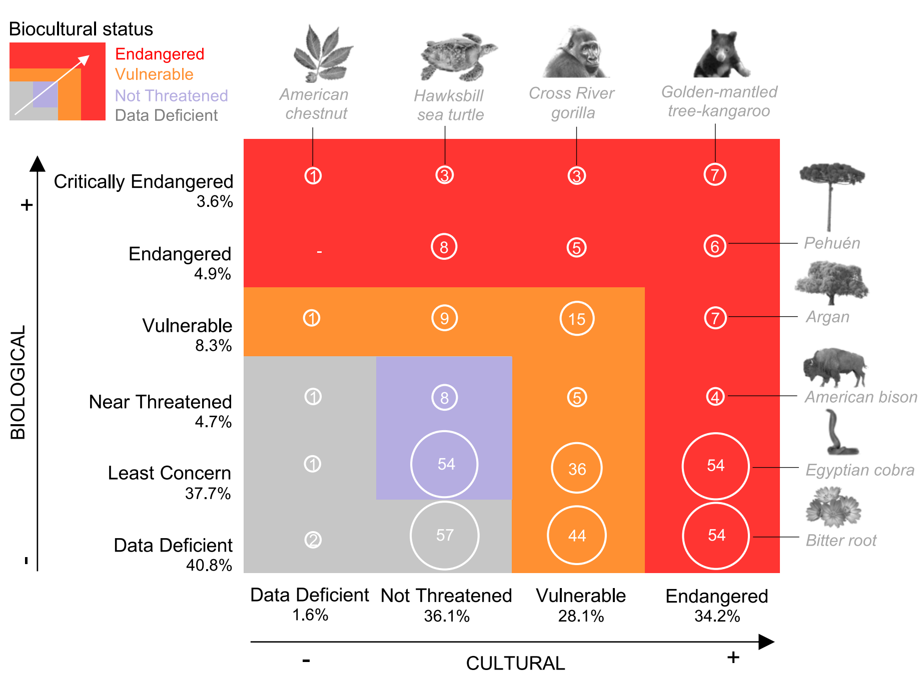

Fig. 2. Biological and cultural status of 385 culturally important species with representative examples. Biological status was assessed from the IUCN Red List of Threatened Species (28), and cultural status was derived from language vitality status from the Ethnologue (29). Colors depict biocultural status, and circle size indicates the number of CIS in each cell. A full list is provided in the *SI Appendix*.

important to the Endangered Indigenous Nations in the Murray-Darling River Basin (43), and the Endangered tree *Araucaria araucana* (pehuén), which plays a key role in the identity and concept of territoriality of the also Endangered Mapuche-Pehuenche people (44).

CIS in our list are not homogenously distributed across continents and sociocultural groups (*SI Appendix*, Table S1), probably following patterns of the global distribution of these groups, but potentially obscuring patterns for underrepresented cultural groups in a continent (e.g., Indigenous peoples in Europe). An analysis of the geographical distribution of biological, cultural, and biocultural status of CIS (Fig. 3*A*) shows that North America and Oceania have very high proportions of bioculturally Endangered CIS (71% and 67% of CIS listed in these continents), which is driven almost entirely by Endangered cultural status. Conversely, most species listed in Europe (68%) are not bioculturally threatened. Most of the Data-Deficient biocultural status is driven by lack of data on biological status, particularly prominent in Asia and South America (i.e., Data-Deficient Red List assessments).

Across sociocultural group types, the share of bioculturally Endangered (57%) and Vulnerable (33%) CIS is highest among Indigenous people (Fig 3*B*). Conversely, the share of bioculturally Not Threatened CIS is highest among other sociocultural groups (60%). Because Indigenous peoples' lands show lower declines in nature than other lands (45), the high share of bioculturally Endangered and Vulnerable CIS among Indigenous peoples probably derives from high levels of cultural endangerment of Indigenous peoples (as measured by language endangerment). In fact, a recent global analysis of language endangerment shows that areas with the highest proportion of endangered languages include Australia, North China, Siberia, North Africa and Arabia, North America, and parts of South America (46), which also display high cultural diversity and presence of Indigenous populations (45). That is, the high extinction risk of Indigenous languages may swamp the influence of biological status on biocultural status.

Our approach allows exploration of the biocultural status of species across continents and sociocultural groups, but it does not allow establishment of causal links between biological and cultural threats. One of the predominant conservation approaches is based on the idea of the need to protect a pristine "wilderness" free from the damaging role of humans. According to this approach, separating humans from other parts of nature (which can happen by multiple factors including the loss of cultural identity and traditional livelihoods, migration, or displacement) would lead to the recovery of wild species (47). Even if that is the case (48), breaking the relation between people and other components of nature might eventually lead to the decline of collective attention and memory to a species, or to the "societal extinction of species," with potential implications for global conservation efforts (26). By contrast, the biocultural approach argues that the removal of the relations between humans and other parts of nature could lead to declines both on the status of nature and on people's quality of life and ultimately to local extinction of species or habitat loss (2, 49). In part, this might occur because cultural decline entails a loss of culturally unique knowledge and behavior, including forms of nature care and management, which might negatively affect nonhuman parts of nature (27). While further research is needed to understand the causal effects of changing the relations between humans and other parts of nature, particularly in areas where such relations have supported social–ecological systems over the long term, the deliberate connection between cultural and biological values, as developed in our biocultural status metric for

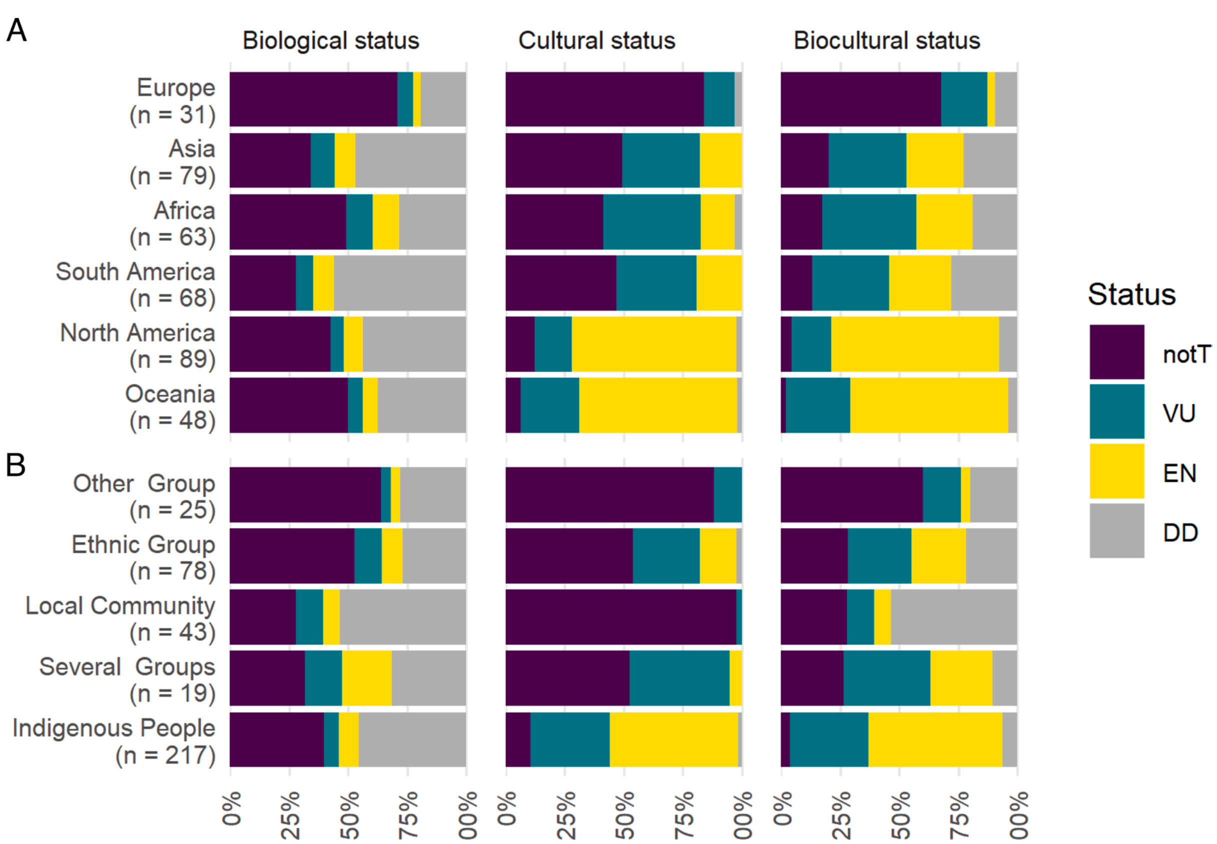

Fig. 3. Biological, cultural, and biocultural status of 385 culturally important species. (*A*) Distribution across continents; (*B*) Distribution across sociocultural group type. Colors depict status.

CIS, offers a tangible means to advance conservation that meets the needs of both people and nature. Importantly, while the focus of this work has been on CIS, the framework is transferable to species that are valued for their material contributions (e.g., food and regulation of freshwater) or even to other components of nature (e.g., domesticated species and culturally important sites or ecosystems).

As part of the conservation community increasingly seeks to include diverse worldviews, knowledge, and values in nature management and restoration, the framework and metric proposed here offer a concrete mechanism that combines local perspectives on which species are culturally important with scientific assessments of the biological and cultural status of these species. Thus, the framework and metric provide an actionable way to guide decisions and operationalize global actions oriented to enhance place-based practices that have supported the conservation of social–ecological systems over the long term (e.g., Indigenous people practices). In that sense, our results for a subset of the global CIS identify how and where global and local conservation priorities intersect and highlight the predominant biocultural vulnerability of CIS species from loss of culture. We derive two specific recommendations from these main results. First, there is a need for a larger focus to 1) assess a representative list of species with cultural significant relations informed by the concerned communities themselves using culturally appropriated methods and 2) accelerate evaluations on the biological status of CIS as there is a disproportionately high number of CIS with Data-Deficient biological status. Such focus would allow for the planning of actions simultaneously based on conservation priorities and cultural values aligned with local priorities. Second, as cultural endangerment drives the high levels of biocultural endangerment of CIS, there is a need to increase the support to maintaining thriving cultural diversity. In that sense, there are growing calls for the conservation community to actively engage with and support Indigenous rights to land, resources, diverse livelihoods, and lifeways, and particularly claims of Indigenous peoples and local communities for autonomous territorial management (13, 50, 51). By recognizing the connections between people and other parts of nature and directly incorporating them into decision-making, we hope our approach enables more effective action to reach the 2050 Convention of Biological Diversity goal of "living in harmony with nature."

Methods

Defining and Identifying CIS. To connect cultural perspectives with environmental conservation and restoration discourses, ethnobiologists have used the concept of "cultural keystone species" (e.g., refs. 28 and 42), proposing a set of criteria for identifying them (28). For the work presented here, we assembled information gathered by two previous compilations of cultural keystone species and an online survey. However, since we could not verify whether all the species in the list actually fit the criteria of cultural keystone species (as defined in ref. 28), here we use the more lax term CIS. The two compilations used include the list available in ref. 21 and an unpublished list provided by Michael Coe elaborated as part of his PhD dissertation and subsequent publications (52, 53). The analysis of the species appearing in the two compilations showed a geographical bias for North America and a likely taxonomic bias for plant species. To enlarge the list and potentially minimize the observed biases, we conducted an online survey (available in a dedicated web page between January and June 2021) and distributed it through social media and distribution lists of targeted networks (e.g., ICCA Consortium, and the list of the Anthropology and Environment Society of the American Anthropological Association). The survey, available in English, Spanish, French, Portuguese, Bahasa Indonesia, German, and Russian, asked for information (i.e., local name(s), scientific name, and uses) about species considered culturally important for any sociocultural group and requested details on the cultural identity of the group (i.e., group name, language, and territory). The survey included 503 entries of CIS. Most respondents only entered information on one CIS/group, although some informants entered as much as 10 CIS/group (average = 1.2). We eliminated incomplete records and records where the species could not be identified by the scientific name. We merged information from the literature and the survey to create our list of CIS (*SI Appendix*). Because our focus is on wild biodiversity, we excluded 23 domesticated species (i.e., crops or pets) from the analysis.

Plant taxonomic names were standardized using the Plants of the World Online (http://www.plantsoftheworldonline.org, accessed 1 January 2022), and animal names were standardized following the IUCN Red List of Threatened Species (2020). Names of cultural groups were recorded at the most specific level possible (e.g., Cree vs. First Nations), although in reports retrieved from the literature some authors provided only general names (e.g., Aboriginals and Indigenous communities). Cultural groups with internal divisions (i.e., the Cree people are formed by numerous subgroups, such as the Plains Cree, Woods Cree, and James Bay Cree) were aggregated in the denominator that best captures the identification used by the group based on language (e.g., Plains Cree or Oji-Cree).

Assessing Species' Biological, Cultural, and Biocultural Status. We assessed the biological and the cultural status of all the wild species in our list. We equated biological status with species' conservation assessments from the IUCN Red List of species (2020), which includes categories of Least Concern, Near Threatened, Vulnerable, Endangered, and Critically Endangered. We generally defined a cultural group as a community of practice who share a core set of beliefs, patterns of behavior, and values. We identified four types of sociocultural groups: 1) Indigenous peoples, those who belonging to specific nations or ethnic groups, self-identify as "Indigenous" or "Aboriginal" and live in nation-states acknowledging Indigenous peoples' rights; 2) ethnic groups, ethnically distinctive groups, who do not self-identify as Indigenous or who live in nation-states that do not acknowledge their specific rights as Indigenous peoplesIndigenous people's rights; 3) local communities, such as *caboclo* or mestizo riverine dwellers, and forest extractive communities who have long-term relations with the territory); and 4) other sociocultural groups, including citizens of regions in nation-states who are identified by their language and ways of thinking and behaving, including religion (e.g., Catalans in Spain or Epirus in Greece). To assess the cultural status of the group reporting the species, we used language vitality as a proxy as language is the primary means of cultural transmission (31, 32). Specifically, for each cultural group in our database, we collected information on language vitality from the Ethnologue, the most comprehensive and updated inventory of the status of languages in the world (https://www.ethnologue.com/about). While language is not a direct indicator of cultural vitality, it remains an approximate indicator, and a good one especially for aspects related to cultural transmission of knowledge about nature (27, 32). The Ethnologue uses four categories to classify languages: Institutional, Stable, Endangered, and Extinct. In this work, we used the first three categories, and when the categorization of the cultural group was too general to identify the language spoken by the group (e.g., "ethnic community"), we coded language vitality as "Data Deficient" except in cases for which we could assume the status. For example, of the more than 250 known Australian Indigenous languages, only about 145 are still spoken and of those 110 are critically endangered (46), so we assumed that the linguistic vitality of any Australian Indigenous language was Endangered.

As some species were reported as culturally important for more than one cultural group, we followed several steps to create a measure that captures a CIS cultural status. First, if the species was reported as culturally important for one group, or for groups with the same language vitality, we equated the species cultural status to language vitality using the following equivalence: Institutional language = Not Threatened, Stable language = Vulnerable, and Endangered language = Endangered. Second, if a species was reported as culturally important for groups with different levels of language vitality, we considered the species cultural status to be i) Not Threatened if the species was reported only by groups with Institutional only or a combination of Institutional and Stable languages, ii) Vulnerable if the species was reported only by groups with Stable languages or by any combination of groups with Institutional/Stable languages and Endangered/Extinct languages, and iii) Endangered if the species was reported only by groups with Extinct and/or Endangered languages. If the species was reported by several groups and one of the groups lacked information on language vitality, we classified its cultural status as Data Deficient.

To assess CIS biocultural status, we combined information on the species' biological and cultural status to create categories of biocultural status (Fig. 2). Specifically, we created the categories of Data Deficient, Not Threatened (which includes CIS biologically Least Concern or Near Threatened and culturally Not Threatened), Vulnerable (which includes CIS biologically Vulnerable and all categories of cultural status except Endangered), and Endangered (which includes CIS biologically Critically Endangered or Endangered and CIS culturally Endangered).

We provide descriptive statistics of the biological, cultural, and biocultural status of the 385 species in our list. We compare the share of CIS (n = 385) that falls into four main categories (i.e., Data Deficient, Not Threatened, Vulnerable, and Endangered) according to their i) biological, ii) cultural, and iii) biocultural status, aggregated by continent (excluding four global species) (Fig. 3*A*) and sociocultural group category (excluding 13 species with insufficient data on cultural group) (Fig. 3*B*). To calculate 95% confidence intervals around species' counts within each category, we resampled the dataset 1,000 times with replacement, counted the number of species in each category, and identified the 2.5% and 97.5% quantiles as the CI bounds. To test for independence of values given in the biological and cultural status datasets, we constructed a contingency table of species counts in each combination of biological status and cultural status and then performed a chi-squared test using the chisq.test () function in R. All analyses were performed in R version 4.2.1.

Data, Materials, and Software Availability. All study data are included in the article and/or *SI Appendix*.

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