Language extinction triggers the loss of unique medicinal knowledge

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Abstract

There are nearly 7,400 languages in the world and over 30% of these will no longer be spoken by the end of the century[1]. So far, however, our understanding of whether language extinction may result in the loss of linguistically-unique knowledge remains limited. Here, we ask to what degree indigenous knowledge of medicinal plants is associated to individual languages and quantify how much indigenous knowledge may vanish as languages and plants go extinct. Focussing on three independent regions that have a high biocultural diversity —North America, northwest Amazonia, and New Guinea— we show that >75% of all 12,495 medicinal plant services are linguistically-unique, i.e., only known to one language. Whereas most plant species associated with linguistically-unique knowledge are not threatened, most languages that report linguistically-unique knowledge are. Our finding of high uniqueness in indigenous knowledge and strong coupling with threatened languages suggests that language loss will be even more critical to the extinction of medicinal knowledge than biodiversity loss.

Indigenous people have accumulated a sophisticated knowledge about plants and their services —including knowledge that confers significant health benefits[2]—that is encoded in their languages[3]. Indigenous knowledge, however, is increasingly threatened by language loss and species extinctions[4,5]. On one hand, language disuse is strongly associated to decreases in indigenous knowledge about plants[6]. On the other hand, global change will constrain the geographic ranges of many human-utilized endemic plants and crops[7,8]. Together, language extinction and reductions in useful plant species within the coming century may limit the full potential of nature's contributions to people and the discovery of unanticipated uses[9]. So far, however, our understanding of the degree to which the loss of indigenous languages may result in the loss of linguistically-unique knowledge and how this risk compares to that posed by ecological extinction has been limited (Fig. 1).

Unravelling the structure of indigenous knowledge about medicinal services has important implications for its resilience[10]. Most indigenous cultures transmit knowledge orally[11]. Therefore, if knowledge about medicines is shared widely amongst indigenous groups that speak different languages, knowledge resilience would be high. That is, even if some indigenous languages go extinct, their medicinal plant knowledge would still be safeguarded in other surviving languages with whom such knowledge is shared. To assess the extent of this, we analyzed three large ethnobotanical datasets for North America[12], northwest Amazonia[13], and New Guinea[14]. Together, these data span 3,597 medicinal plant species, and 12,495 plant services associated to 236 indigenous languages (see Methods). We defined a 'medicinal plant service' as the combination of a plant species and a medicinal subcategory (e.g., *Ficus insipida* + Digestive System).

Our results show that in all regions, indigenous knowledge about medicinals plants exhibits a strong pattern of linguistic uniqueness, with 73%, 91%, and 84% of the medicinal services in North America, northwest Amazonia, and New Guinea being cited by only one language, respectively (Fig. 2). This finding raises the question of whether unique knowledge is mostly found in languages that are threatened.

Our analysis indicates that threatened languages support 82% and 66% of all unique knowledge in North America and northwest Amazonia, respectively (Supplementary Fig. 1). By contrast, threatened languages account for only 18% of all unique knowledge in New Guinea. This result highlights that the Americas are an indigenous knowledge hotspot (i.e., most medicinal knowledge is linked to threatened languages), and thus a key priority area for future documentation efforts.

Once we have quantified the overall amount of unique knowledge, we next proceed by mapping how it is distributed across the linguistic phylogeny. This will serve to identify whether unique knowledge is uniformly distributed across all linguistic groups, or whether a few linguistic groups deserve more protection than others. First, we built language phylogenies for all the indigenous languages in our sample. Next, we calculated the degree of phylogenetic clustering of unique knowledge using Pagel's lambda (λ)[15]; values of λ close to 1 indicate strong phylogenetic clustering, whereas values close to 0 indicate data without phylogenetic dependence. We did not find clustering of unique knowledge along the language phylogenies in any of the three regions (Fig. 3, Extended Data Table 1). This indicates that when planning for medicinal knowledge conservation, the entire linguist spectrum —rather than a few "hot" nodes— needs to be considered.

So far, we have focused on how unique knowledge is distributed along the cultural dimension. Let us turn now to examine the other component of the indigenous knowledge network, namely the plants. To understand the degree of threat faced by medicinal plants, we queried the IUCN Red List of Threatened species[16]. We found conservation assessments for 22%, 31% and 32% of the medicinal species recorded in North America, northwest Amazonia, and New Guinea, respectively. Of the total medicinal flora with IUCN assessments, 4%, 1%, and 4% were classified as threatened in North America, northwest Amazonia, and New Guinea, respectively (see Methods). To ascertain whether the observed patterns may change as more species are formally assessed, we also obtained conservation predictions from a machine-learning study[17] (see Methods) which contains assessments for 57%, 25%, and 49% of the medicinal species recorded in North America, northwest Amazonia, and New Guinea, respectively. According to that study, the probability of a medicinal species belonging to a threatened category ranged from 0.0002 to 0.8341 in North America (mean $\pm$ SD, 0.156 $\pm$ 0.158), 0.149 to 0.822 in northwest Amazonia (mean 0.483 $\pm$ 0.119), and 0.063 to 0.679 in New Guinea (mean 0.357 $\pm$ 0.141), respectively. In summary, both the IUCN conservation assessments and machine-learning predictions suggest that most medicinal plant species in our sample are not threatened. Finally, we found that less than 1% of all unique knowledge in each region was associated to both threatened languages and threatened plants (Extended Data Table 3). However, there is considerable uncertainty about the potential loss of unique knowledge from the extinction of plants because 61% and 46% of the unique knowledge in North America and northwest Amazonia that is associated to threatened languages belongs to plants that lack plant conservation assessments. IUCN conservation assessments are urgently needed for these plant species.

To assess whether unique knowledge is strongly clustered biologically, we built phylogenies of the medicinal floras of each region, and calculated Pagel's lambda (Fig. 4). We only found significant clustering of unique knowledge in North America, although values were low (Extended Data Table 1). This relatively weak phylogenetic signal across the three regions suggests that when planning for biocultural conservation, the entire medicinal flora —rather than a few clades— must be considered.

Here, we have shown that in North America, northwest Amazonia, and New Guinea, indigenous knowledge of medicinal plant services exhibits a low redundancy across languages that is typical of systems with high information content[18,19]. This low redundancy in medicinal knowledge among languages does not support the notion of high cross-cultural consensus, i.e., that cultures resemble each other in their knowledge, but instead highlights the unique biocultural heritage each culture holds. The invention and diversification of languages involves two opposing forces. On the one hand, sharing facilitates the exchange of information and the spread of valuable ideas that may enhance the fitness within populations. On the other hand, the diversification of languages is the result of innovations, and eventually linguistic barriers may limit information spread. In areas of high linguistic or biological diversity, and/or geographic barriers, the balance between sharing and innovating may tip towards the latter. This may result in the amplification of differences among cultures, as we have shown here for the case of medicinal knowledge.

The United Nations declared 2019 as the year of the world's Indigenous languages to raise awareness of their endangerment across the world. Our study suggest that each indigenous language brings unique insights that may be complementary to other societies who seek potentially-useful medicinal remedies. Therefore, the predicted extinction of up to 30% of indigenous languages by the end of the 21st century[1] would substantially compromise humanity's capacity for medicinal discovery.

Methods

Plant Services. We obtained a list of medicinal plant species and services associated to individual indigenous groups from three regions: 1) North America: from the Native American Ethnobotany database[12]— the largest repository of indigenous knowledge for the region; 2) northwest Amazonia: from Richard E. Schultes's book on the medicinal plants of northwestern Amazonia, which integrates nearly half a century of his field research[13]; and 3) New Guinea: from an ethnobotanical review of 488 references and 854 herbarium specimens[14].

We classified uses from the three data sources into medicinal subcategories following the classification in the *Economic Botany Data Collection Standard*[20], with modifications explained by Cámara-Leret *et al.*[21]. Medicinal subcategories included Blood and cardiovascular system; Cultural diseases and disorders; Dental health; Digestive system; Endocrine system; General ailments with unspecified symptoms; Infections and infestations; Metabolic system and nutrition; Muscular-skeletal system; Nervous system and mental health; Poisoning; Pregnancy, birth and puerperium; Reproductive system and reproductive health; Respiratory system; Sensory system; Skin and subcutaneous tissue; Urinary system; Veterinary; Not specified; Other medicinal uses. We defined 'unique knowledge' as a medicinal service cited exclusively by one indigenous language. By omitting 'plant parts' (e.g., bark, leaf, fruit, seed) from our definition of medicinal plant services (i.e.,the combination of plant species and a medicinal subcategory), our categorization is more conservative and underestimates the detection of medicinal knowledge that is restricted to one language.

Language Phylogenies and Threat. Medicinal services in the literature were associated to 119 indigenous languages in North America, 37 languages in northwest Amazonia, and 80 languages in New Guinea. For each region, we built language trees through phylogenetic inference using machine learning techniques on the word lists of the Automated Similarity Judgement Program (ASJP v.18) and used the Glottolog classification as a constraint tree[22]. To assess the degree of threat faced by languages in our sample, we queried the Ethnologue[23] which uses the Expanded Graded Intergenerational Disruption Scale (EGIDS) to quantify language threat[24]. For a list of the languages analyzed, see Extended Data Table 2.

Vascular Plant Phylogenies and Threat. We verified plant species taxonomy using recently published checklists to the vascular plants of the Americas[25] and New Guinea[26]. Using the list of medicinal plant species in each region, we queried the mega-tree GBOTB.-extended of Smith & Brown[27] with the *phylo.maker* function of the R package V.PhyloMaker[28]. The phylogenies used in all subsequent analyses comprised 2,475 species in North America, 645 species in northwest Amazonia, and 477 species in New Guinea. To assess the threat faced by medicinal plant species, we queried the conservation assessments published by the IUCN Red List of Threatened species[16], which classifies species as Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, and Critically Endangered, Extinct in the Wild, and Extinct. Following IUCN, species assessed to be Near Threatened, Vulnerable, and Endangered were considered threatened. Because most plant species lack IUCN conservation assessments, we also obtained endangerment probabilities from a recent study that used machine-learning to predict the conservation status of 30,497 plant species[17].

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Supplementary Information is available for this paper as Extended Data Tables 1–3.

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References

1. Simons, G. F. & Lewis, M. P. in *Responses to Language Endangerment* 3–19 (John Benjamins Amsterdam, The Netherlands, 2013).
2. McDade, T. W. *et al.* Ethnobotanical knowledge is associated with indices of child health in the Bolivian Amazon. *Proc. Natl Acad. Sci. USA* **104,** 6134–6139 (2007).
3. Berlin, B. *Ethnobiological classification: Principles of Categorization of Plants and Animals in Traditional Societies* (Princeton University Press, 2014).
4. Sutherland, W. J. Parallel extinction risk and global distribution of languages and species. *Nature* **423,** 276–279 (2003).
5. Aswani, S., Lemahieu, A. & Sauer, W. H. Global trends of local ecological knowledge and future implications. *PLoS One* **13,** e0195440 (2018).
6. Saynes-Vásquez, A., Caballero, J., Meave, J. A. & Chiang, F. Cultural change and loss of ethnoecological knowledge among the Isthmus Zapotecs of Mexico. *J. Ethnobiol. Ethnomed.* **9,** 40 (2013).
7. Cámara-Leret, R. *et al.* Climate change threatens New Guinea's biocultural heritage. *Sci. Adv.* **5,** eaaz1455 (2019).
8. Pironon, S. *et al.* Potential adaptive strategies for 29 sub-Saharan crops under future climate change. *Nat. Clim. Change* **9,** 758–763 (2019).
9. Díaz, S. *et al.* Assessing nature's contributions to people. *Science* **359,** 270–272 (2018).
10. Cámara-Leret, R., Fortuna, M. A. & Bascompte, J. Indigenous knowledge networks in the face of global change. *Proc. Natl Acad. Sci. USA* **116,** 9913–9918 (2019).
11. Nettle, D., Romaine, S., *et al.* *Vanishing Voices: The Extinction of the World's Languages* (Oxford University Press on Demand, 2000).
12. Moerman, D. *Native American Ethnobotany: A Database of Foods, Drugs, Dyes and Fibers of Native American Peoples, Derived from Plants.* 2020. `http://naeb.brit.org/`.
13. Schultes, R. E. & Raffauf, R. F. *The Healing Forest: Medicinal and Toxic Plants of the Northwest Amazonia.* (Dioscorides Press, 1990).
14. Cámara-Leret, R. & Dennehy, Z. Information gaps in indigenous and local knowledge for science-policy assessments. *Nat. Sustain.* **2,** 736–741 (2019).
15. Pagel, M. Inferring the historical patterns of biological evolution. *Nature* **401,** 877–884 (1999).
16. IUCN. *The IUCN Red List of Threatened Species. Version 2020-2.* 2020. `https://www.iucnredlist.org/accessed2020-05-08`.
17. Pelletier, T. A., Carstens, B. C., Tank, D. C., Sullivan, J. & Espíndola, A. Predicting plant conservation priorities on a global scale. *Proc. Natl Acad. Sci. USA* **115,** 13027–13032 (2018).
18. Shannon, C. E. A mathematical theory of communications. *Bell Syst. Tech. J* **27,** 379–423 (1948).
19. Margalef, R. Information theory in biology. *Gen. Syst.* **3,** 36–71 (1958).
20. Cook, F. E. *et al.* *Economic Botany Data Collection Standard.* (Royal Botanic Gardens (Kew), 1995).
21. Cámara-Leret, R., Paniagua-Zambrana, N., Balslev, H. & Macía, M. J. Ethnobotanical knowledge is vastly under-documented in northwestern South America. *PLoS One* **9,** e85794 (2014).

22. Jäger, G. Global-scale phylogenetic linguistic inference from lexical resources. *Sci. Data* **5,** 1–16 (2018).

23. Simons, G. F. & Fennig, C. D. Ethnologue: Languages of the World, 21st Edn Dallas. *TX: SIL International* (2018).

24. Lewis, M. P. & Simons, G. F. Assessing endangerment: expanding Fishman's GIDS. *Rev. Roum. de Linguistique* **55,** 103–120 (2010).

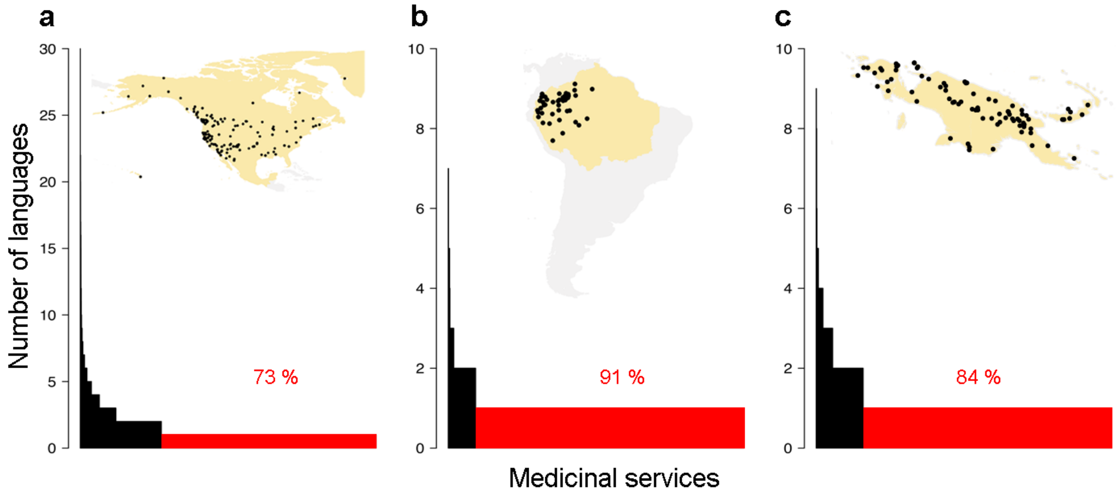
25. Ulloa, C. U. *et al.* An integrated assessment of the vascular plant species of the Americas. *Science* **358,** 1614–1617 (2017).

26. Cámara-Leret, R. *et al.* New Guinea has the world's richest island flora. *Nature* **584,** 579–583 (2020).

27. Smith, S. A. & Brown, J. W. Constructing a broadly inclusive seed plant phylogeny. *Am. J. Bot.* **105,** 302–314 (2018).

28. Jin, Y. & Qian, H. V. PhyloMaker: an R package that can generate very large phylogenies for vascular plants. *Ecography* **42,** 1353–1359 (2019).

Fig. 1 | Medicinal plant knowledge and its association to indigenous languages. The figure illustrates a regional pharmacy with remedies (jars with plants) cited by languages (jar labels). In this paper, we assess to what degree the knowledge contained in this pharmacy would be eroded by the extinction of either indigenous languages or plants.



210 **Fig. 2 | Most medicinal knowledge is unique to a single language.** Histograms depict the number of indigenous languages that cite a medicinal service. **a**, North America; **b**, northwest Amazonia; **c**, New Guinea. Red bars show medicinal plant services only known to one language. Dots within the maps indicate the distribution of languages.

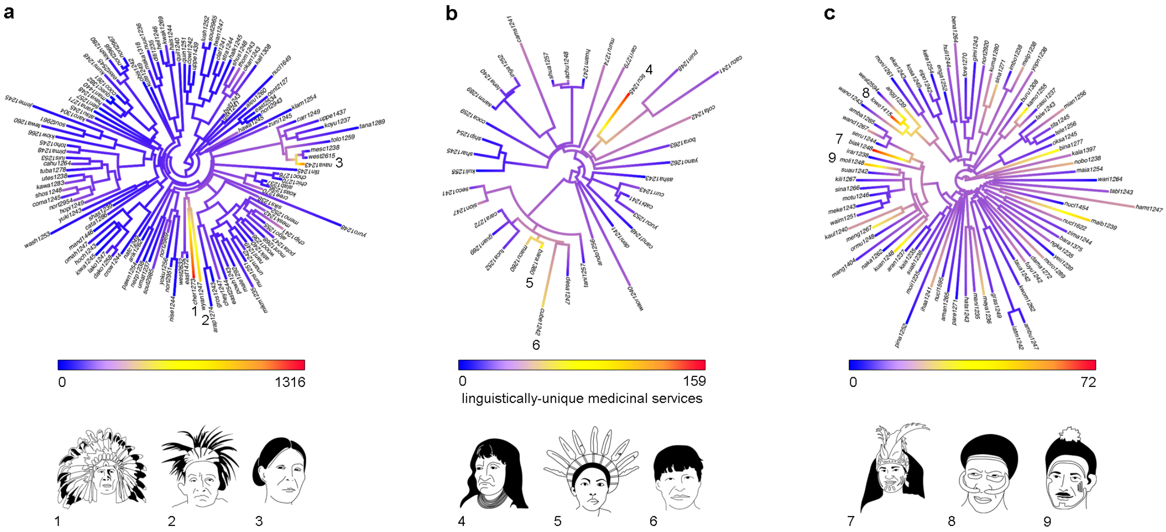


Fig. 3 | Distribution of unique knowledge across languages. Trees represent language phylogenies of **a**, North America (n = 119 languages); **b**, northwest Amazonia (n = 37 languages); and **c**, New Guinea (n = 80 languages). Illustrations represent indigenous groups whose languages have the highest number of unique medicinal services per region. These languages are indicated by their corresponding numbers in the linguistic trees: 1, Cherokee; 2, Iroquois; 3, Navajo; 4, Tikuna; 5, Barasana; 6, Cubeo; 7, Biak; 8, Lower Grand Valley Dani; 9, Massim. Language names at phylogeny tips are abbreviated following Glottolog codes. For the list of language names and Glottolog codes, see Extended Data Table 2.

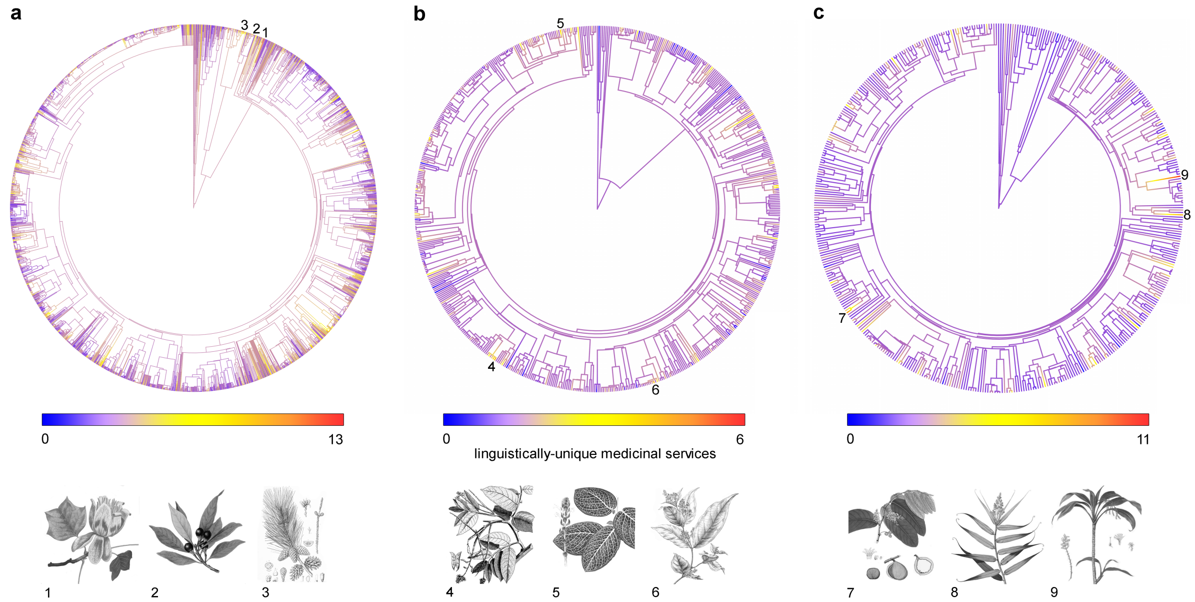


Fig. 4 | Distribution of unique knowledge across medicinal floras. Trees represent medicinal plant phylogenies of **a**, North America (n = 2,475 species); **b**, northwest Amazonia (n = 645 species); and **c**, New Guinea (n = 477 species). Illustrations and their corresponding numbers show the plant species with more unique medicinal services per region. 1, *Liriodendron tulipifera*; 2, *Persea borbonia*; 3, *Pinus glabra*; 4, *Tachigali paniculata*; 5, *Fittonia albivenis*; 6, *Tetrapterys styloptera*; 7, *Inocarpus fagifer*; 8, *Flagellaria indica*; 9, *Cordyline fruticosa*. All illustrations from http://www.plantillustrations.org belong to the public domain.

Extended Data Table 1 | Phylogenetic clustering (measured using Pagel's λ) of unique knowledge along the language and plant phylogenies of North America, Northwest Amazonia, and New Guinea. Statistically significant results: ***, P-value < 0.001.

	Languages	Plants
North America	0.31	0.21***
Northwest Amazonia	6.61e-05	6.61e-05
New Guinea	6.61e-05	0.02

Extended Data Table 2 | Names and Glottolog codes of the studied languages of North America, northwest Amazonia, and New Guinea.

Language name	Glottolog code
NORTH AMERICA	
Alabama	alab1237
Aleut	aleu1260
Algonquin	algo1255
Arapaho	arap1274
Arikara	arik1262
Atikamekw	atik1240
Atsugewi	atsu1245
Bella Coola	bell1243
Cahuilla	cahu1264
Central Carrier	carr1249
Catawba	cata1286
Central Alaskan Yupik	cent2127
Cherokee	cher1273
Cheyenne	chey1247
Chickasaw	chic1270
Chippewa	chip1241
Choctaw	choc1276
Clallam	clal1241
Cocopa	coco1261
Comanche	coma1245
Cowlitz	cowl1242
Creek	cree1270
Crow	crow1244
Dakota	dako1258
Ditidaht	diti1235
Eastern Keres	east1472
Eastern Canadian Inuktitut	east2534
Eastern Abenaki	east2544
Eastern Pomo	east2545
Gitxsan	gitx1241
Gros Ventre	gros1243
Haisla	hais1244
Halkomelem	halk1245
Havasupai-Walapai-Yavapai	hava1248
Hawaiian	hawa1245
Heiltsuk-Oowekyala	heil1246
Ho-Chunk	hoch1243
Hopi	hopi1249
Iowa-Oto	iowa1245
Towa	jeme1245
Kalispel-Pend d'Oreille	kali1308
Karok	karo1304
Kashaya	kash1280

Extended Data Table 2. (continued)

Language name	Glottolog code
NORTH AMERICA	
Kawaiisu	kawa1283
Kiowa	kiow1266
Klamath-Modoc	klam1254
Koasati	koas1236
Koyukon	koyu1237
Tipai	kumi1248
Kutenai	kute1249
Kwak'wala	kwak1269
Lakota	lako1247
Luiseno-Juaneño	luis1253
Northern Lushootseed	lush1252
Makah	maka1318
Malecite-Passamaquoddy	male1292
Mandan	mand1446
Maricopa	mari1440
Menominee	meno1252
Mescalero-Chiricahua Apache	mesc1238
Meskwaki	mesk1242
Mi'kmaq	mikm1235
Montagnais	mont1268
Munsee	muns1251
Nanticoke	nant1249
Natchez	natc1249
Navajo	nava1243
Nez Perce	nezp1238
Nisenan	nise1244
North Alaskan Inupiatun	nort2943
Northwest Maidu	nort2951
Northern Paiute	nort2954
Northern Pomo	nort2966
Northeastern Russian River Pomo	nort2967
Northern Ohlone	nort2969
Southern-Coastal Tsimshian	nucl1649
Nuu-chah-nulth	nuuc1236
Obispeño	obis1242
Okanagan	okan1243
Omaha-Ponca	omah1247
Pawnee	pawn1254
Pima Bajo	pima1248
Potawatomi	pota1247
Powhatan	powh1243
Quechan	quec1382
Quileute	quil1240
Quinault	quin1251
Seri	seri1257

Extended Data Table 2. (continued)

Language name	Glottolog code
NORTH AMERICA	
Shasta	shas1239
Shoshoni	shos1248
Shuswap	shus1248
Siksika	siks1238
Southern Tiwa	sout2961
Southern Puget Sound Salish	sout2965
Southern Sierra Miwok	sout2985
Northern Straits Salish	stra1244
Tanaina	tana1289
Rio Grande Tewa	tewa1260
Thompson	thom1243
Tlingit	tlin1245
Tohono O'odham	toho1245
Tolowa-Chetco	tolo1259
Tubatulabal	tuba1278
Twana	twan1247
Umatilla	umat1237
Unami	unam1242
Upper Tanana	uppe1437
Upper Chehalis	uppe1439
Ute-Southern Paiute	utes1238
Washo	wash1253
Western Apache	west2615
Western Keres	west2632
Woods Cree	wood1236
Huron-Wyandot	wyan1247
Yana	yana1271
Northern Yokuts	yoku1256
Yuki	yuki1243
Yurok	yuro1248
Zuni	zuni1245

Extended Data Table 2. (continued)

Language name	Glottolog code
NORTHWEST AMAZONIA	
Achuar-Shiwiar	achu1248
Andoque	ando1256
Asháninka	asha1243
Barasana-Eduria	bara1380
Bora	bora1263
Cabiyari	cabi1241
Kakua	cacu1241
Camsá	cams1241
Candoshi-Shapra	cand1248
Carapana	cara1272
Carijona	cari1279
Cocama-Cocamilla	coca1259
Cofán	cofa1242
Cubeo	cube1242
Curripaco	curr1243
Deni	deni1241
Desano	desa1247
Kotiria	guan1269
Huambisa	huam1247
Inga	inga1252
Kulina Pano	kuli1255
Macuna	macu1260
Murui Huitoto	muru1274
Puinave	puin1248
San Martín Quechua	sanm1289
Secoya	seco1241
Sharanahua	shar1245
Shipibo-Conibo	ship1254
Shuar	shua1257
Siona-Tetete	sion1247
Tanimuca-Retuarã	tani1257
Tena Lowland Quichua	tena1240
Ticuna	ticu1245
Tucano	tuca1252
Waorani	waor1240
Yanomámi	yano1262
Yucuna	yucu1253

245 **Extended Data Table 2.** (continued)

Language name	Glottolog code
NEW GUINEA	
Amanab	aman1265
Ambai	amba1265
Ambulas	ambu1247
Angguruk Yali	angg1239
Dombano	aran1237
Barapasi	bara1375
Benabena	bena1264
Biak	biak1248
Binandere	bina1277
Buruwai	buru1308
Casuarina Coast Asmat	casu1237
Damal	dama1272
Eipomek	eipo1242
Ekari	ekar1243
Enga	enga1252
Faiwol	faiw1243
Fore	fore1270
Fuyug	fuyu1242
Gimi (Eastern Highlands)	gimi1243
Grass Koiari	gras1249
Hamtai	hamt1247
Hatam	hata1243
Huli	huli1244
Iatmul	iatm1242
Iha	ihaa1241
Imbongu	imbo1238
Irarutu	irar1238
Kais	kais1235
Kalam	kala1397
Kamoro	kamo1255
Kaulong	kaul1240
Ketengban	kete1254
Kilivila	kili1267
Kosarek Yale	kosa1249
Kuanua	kuan1248
Kuman	kuma1280
Kwoma	kwom1262

Extended Data Table 2. (continued)

Language name	Glottolog code
NEW GUINEA	
Lower Grand Valley Dani	lowe1415
Maia	maia1254
Maybrat-Karon	maib1239
Mangga Buang	mang1404
Sougb	mani1235
Mekeo	meke1243
Melpa	melp1238
Mengen	meng1267
Meyah	meya1236
Mian	mian1256
Moi (Indonesia)	moii1235
Molima	moli1248
Moni	moni1261
Marori	moro1289
Motu	motu1246
Nakanai	naka1262
Ngkontar Ngkolmpu	ngka1235
Nobonob	nobo1238
North Tairora	nort2920
Yawa	nucl1454
Kwerba	nucl1595
Marind	nucl1622
Oksapmin	oksa1245
Ormu	ormu1248
Pare	pare1271
Pinai-Hagahai	pina1252
Serui-Laut	seru1244
Sinaugoro	sina1266
Sinasina	sina1271
Suabo	suab1238
Suau	suau1242
Tabla	tabl1243
Tauade	taua1242
Telefol	tele1256
Tifal	tifa1245
Waima	waim1251
Wandamen	wand1267
Wano	wano1243
Waritai	wari1264
Western Dani	west2594
Yei	yeii1239
Yopno	yopn1238
Zimakani	zima1244

Extended Data Table 3 | The percentage of unique knowledge associated to threatened and non-threatened languages and plants. **a**, North America (n = 7,565 medicinal services); **b**, northwest Amazonia (n = 773 medicinal services); **c**, New Guinea (n = 873 medicinal services). Language threat follws the classification in the Ethnologue[23]. Plant threat follows the IUCN Red List of Threatened species[16].

A

Plant Risk \ Language Risk	Not threatened	Threatened
Threatened	<1	<1
Not threatened	2	20
Unknown	15	61

B

Plant Risk \ Language Risk	Not threatened	Threatened
Threatened	<1	<1
Not threatened	10	20
Unknown	23	46

C

Plant Risk \ Language Risk	Not threatened	Threatened
Threatened	1	<1
Not threatened	26	8
Unknown	55	9