SPECIAL ARTICLE

Mexico's Biocultural Diversity in Peril

Omar Vidal[1*] & Richard C. Brusca[2]

1. Bosque de Granados 141, Col. Bosques de las Lomas, Ciudad de México 11700, México; vidalpomar@gmail.com
2. Department of Ecology & Evolutionary Biology, University of Arizona, United States of America;
    rbrusca@desertmuseum.org
    * Correspondence

ABSTRACT. Introduction: Places with high species diversity have high linguistic diversity, whereas areas with low species diversity tend to have low linguistic diversity. **Objective:** To characterize the intriguing relationship between biological and cultural diversity, a correlation that has been discussed at a global scale, but here tested for the first time in Mexico. **Methods:** We compiled exhaustive databases on both endangered species and endangered languages, and reviewed available literature on Mexico's biocultural diversity with a focus on endangered and critically endangered species and languages. **Results:** With 364 living languages, Mexico is the world's fifth most linguistically diverse country, but 64 of these languages are facing a very high risk of disappearance and 13 have already disappeared. Mexico is also the fourth most biologically diverse country, but 1 213 species of its flora and fauna are threatened with extinction and at least 127 species were recently extinct. **Conclusions:** Indigenous peoples are custodians of much of the world's biocultural diversity. As the world grows less linguistically and culturally diverse, it is also becoming less biologically diverse. Mexico's biological and linguistic diversity show strong geographic overlap, with the states of Oaxaca, Chiapas, Veracruz, Guerrero, and Michoacán harboring most species and most languages. Similarly, Mexico's biodiversity hotspots mirror language hotspots, and areas with the highest number of endangered species overlap with areas where the endangerment of languages is also the highest.

Key words: languages, linguistics, traditional knowledge, indigenous people, biodiversity, Mexico, endangered species, extinction.

The United Nations Convention on Biological Diversity defines "indigenous" as those people who have historical continuity with pre-invasion and pre-colonial societies, that have developed on their own territories, and who consider themselves distinct from other sectors of society now prevailing in those territories. To raise awareness of their importance for humanity, the United Nations designated 2019 as the "International Year of Indigenous Languages."

Biocultural diversity encompasses the link between biological diversity and humankind's cultural diversity, and identification of ecological conservation hotspots and linguistics are the two pillars of biocultural diversity analyses. Trends in biological diversity and cultural/linguistic diversity parallel one another (Maffi, 2001, 2005) and there is a documented correlation between the two (Mühlhäusler, 1995; Harmon, 1996; Nettle & Romaine, 2000; Oviedo, Maffi, & Larsen, 2000; Moore et al., 2002; Sutherland, 2003; Stepp et al., 2004; Fincher & Thornhill, 2008; Gorenflo, Romaine, Mittermeier, & Walker-Painemilla, 2012). Research across both continental and regional scales have identified patterns of co-occurrence

of linguistic and biological diversity around the world, and nations/areas with high biodiversity also tend to have high linguistic and cultural diversity (Toledo, 1994; Harmon, 1995, 1996; Nettle, 1996; Nettle & Romaine, 2000; Stepp et al., 2004; Loh & Harmon, 2005; Toledo & Barrera-Bassols, 2008; Gorenflo et al., 2012). The countries with the highest linguistic diversity (jointly having 54 % of all living languages) are Papua New Guinea, Nigeria, India, Mexico, Cameroon, Australia, the Democratic Republic of the Congo, and China (Harmon, 1995); and the most bioculturally diverse countries as measured by their centers of biological, linguistic, and agricultural diversity, as well by the presence of indigenous peoples, include those plus Indonesia, Brazil and Peru (Toledo & Barrera-Bassols, 2008).

The conceptual framework of biocultural diversity draws upon a common interest in understanding and preserving the relationships between biological, linguistic, and cultural variety and range. For indigenous people, biological, cultural, and linguistic diversities are intrinsically linked, as are environment and development. Biocultural diversity is often used as an index, or measure, to assess geographical regions in terms of the status or linkages between biological, cultural and linguistic diversity (Harmon, 1996; Sutherland, 2003; Harmon & Loh, 2010; Gorenflo et al., 2012). Languages, like genes, are "documents of history," and a vast amount of information about our past is inscribed in the content and structure of the approximately 7 100 languages that are spoken today (Gray, Quentin, & Greenhill, 2018). Present-day indigenous cultures and languages are an expression of the long historical legacy of interrelationships between humans and nature (Toledo & Barrera-Bassols, 2008). Conservation practitioners should also embrace biocultural approaches for social justice, legal, and practical reasons (Gavin et al., 2013, 2015). This view was convincingly articulated in the Indigenous Peoples International Declaration on Self-Determination and Sustainable Development at the 2012 United Nation's Rio+20 Summit, which reaffirmed that cultural belief systems and worldviews of indigenous people are fundamental to biodiversity protection and sustainable development.

Species are the basic units of biodiversity, while languages serve to measure the diversity of cultures, and the striking parallels in their evolution suggest that nature and culture evolved in similar fashion (Harmon, 1996). In practical terms, there is an emphasis on language over other aspects of culture and identity because it strongly circumscribes an indigenous group. *Homo sapiens* displays a remarkable linguistic diversity that correlates strongly to areas of plant and animal diversity—and both may be moderated by similar environmental factors, such as temperature and rainfall. Both domains also involve the transmission of discreet heritable units: genes in biology, and socially-transmitted units such as words and morphosyntax in linguistics. Both can be altered as they pass through generations and thus, they display a hierarchical relationship over time. Languages, like biological species, are therefore related through nested patterns of descent allowing their evolutionary history to be depicted in branching patterns, or trees (Dunn, 2014). Of course, some words do enter languages by way of diffusion, or "borrowing" from other cultural sources (Campbell, 1997), and these instances are comparable to horizontal gene transmission in the scheme of biodiversity assessment and phylogenetics. Nonetheless, just as the historical evolution of species can be inferred by phylogenetic analysis, so the history of linguistic diversity can be estimated by phylogenetics (e.g., Bouckaert et al., 2012; Birchall, Dunn, & Greenhill, 2016; Gray et al., 2018). In both cases, the phylogenies can be overlain by areas of endemicity to produce dated phylogeographic reconstructions. In the case of cultures and linguistics, this amounts to what has been called "virtual archeology."

Three types of language diversity have been recognized (Gavin et al., 2013). *Language richness* refers to the number of languages within a given area. *Phylogenetic language diversity* is the minimum total length of all branches needed to span a set of "language

taxa" on a phylogenetic tree. *Linguistic disparity* refers to the range of expression in a language trait within a clade. Languages differ on a multitude of structural levels, including phonology, morphology, and syntax. There is a strong latitudinal gradient in both language richness and biological richness (Gavin et al., 2013, 2015).

It has been proposed that human languages reached their maximum number (estimated at 12 000) at the end of the Pleistocene, directly predating the rise of agriculture (Harrison, 2007). In the non-sedentary hunter-gatherer societies of the time, the dominant force in language creation is likely to have been fissioning mechanisms (Hamilton, Milne, Walker, Burger, & Brown, 2007), although such historical "splits" might be blurred by inter-language diffusion, or borrowing, as noted above (e.g., Campbell, 1997). The number of languages has been in decline since the Neolithic as agricultural groups have spread, replacing hunter-gatherers, and population movements have tended to reduce global language diversity (Nettle, 1999a, 1999b). A substantial body of theoretical work suggests that the spread of politically complex agricultural societies was a dominant factor in the reduction of language diversity (Renfrew, 1994).

After examining nearly 7 000 languages spoken on Earth today against the planet's biological diversity and biodiversity hotspots, Gorenflo et al. (2012) found that more than 4 800 languages occur in regions containing high biodiversity, and 3 202 languages occur in 35 previously defined biodiversity hotspots. Of the languages found in biodiversity hotspots, 1 553 are spoken by 10 000 or fewer people, and 544 are spoken by 1 000 or fewer people.

Greater geographic heterogeneity, as measured by more-diverse habitats or higher topographic complexity, is commonly correlated with greater species diversity (e.g., Kerr & Packer, 1997). A link between geographic heterogeneity and diversity also appears to exist for languages. Environmental variables have been noted as important predictors of linguistic diversity patterns, and historical processes of co-evolution of small-scale human groups with their local ecosystems have been proposed (Harmon, 1996; Maffi, 1998).

Three narratives have been offered to explain the correlation between biological and cultural diversity (Maffi, 2001): *geographic determinism* (both species and languages diversify in heterogeneous landscapes with geographic barriers); *ecological determinism* (linguistic diversification occurs in response to high biodiversity as cultural groups encode their knowledge of rich biotas); and *historic determinism* (areas of high linguistic diversity today are "residual," persisting because of their geographic isolation from extensive agricultural development, implying that now-impoverished areas were once more diverse).

Today, linguistic diversity and biological diversity face similar threats and are both in crisis because of human population growth and increasing consumption (Loh & Harmon, 2014). One of the biggest challenges for biocultural conservation is ensuring that indigenous peoples obtain recognition of their rights to the resources found on their lands and territories on which they depend on for their economic, spiritual, cultural, and physical well-being (Inter-American Commission on Human Rights, 2009), and that these translate into tangible policies and action at the national and international level. Which is, by no means, an easy task since it has been estimated that about 12-20 % of areas under human management worldwide are indigenous lands (Toledo, 2001a).

Different cultures perceive and value biodiversity in different ways because of their distinct heritage and experience. Posey (1999) argued that cultural diversity parallels ecological diversity, and local traditional adaptations are often the most environmentally sound. Through time, as local communities interact closely with their environment and modify it as they adapt to specific ecological niches, they acquire detailed knowledge of the environment and how to manage it for their long-term benefit. Languages thus carry deep eco-cultural knowledge, and embedded in indigenous

Rev. Biol. Trop. (Int. J. Trop. Biol.) Vol. 68(2): 669-691, June 2020

671

languages is knowledge about habitats, plant life, animal behavior, conservation methods, and many other aspects of the natural world (Harrison, 2007).

The world's inhabitants today speak around 7 100 languages, patterned unevenly across the Earth. But, roughly half of the world speaks only 24 languages, and have from tens to hundreds of millions of speakers, while the other half of the population speaks the remaining 7 073 languages, of which around half have fewer than 10 000 speakers (Lewis, Simons, & Fennig, 2016; Simons & Fennig, 2018). Since 1950, 230 languages have disappeared and at least 3 000 have become endangered, of which 577 are critically endangered (78 have 10-50 speakers, and 146 have fewer than 10 speakers) (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2010). And, according to UNESCO, nearly 40 % of the world's population lack access to education in a language that they speak or understand. In the next 30 years, over half of the world's languages will likely go extinct or be spoken by only a few old people (Harrison, 2007).

While much effort has and is being spent to stem the loss of plant and animal species, the loss of languages is receiving far less attention and is actually being ignored in many parts of the world, particularly in developing countries, for a variety of reasons. As the world grows less linguistically and culturally diverse, it is also becoming less biologically diverse. Biologists estimate an annual loss of species at 1 000 times or greater than historic rates, and linguists predict that 50-90 % of the world's languages will disappear by the end of this century (Nettle & Romaine, 2000; Gorenflo et al., 2012).

More than 70 % of the world's biodiversity is found in only 17 countries, of which 15 are in the developing world and 6 are in Latin America (Mittermeier, Myers, Gil, & Mittermeier, 1999). The most species-rich, human-accessible environments are tropical rain forests and deciduous forests, coral reefs, and large tropical lakes (Millennium Ecosystem Assessment [MEA], 2005). Even though the world's tropical forests occupy only 7 %

of the land area, they have been estimated to contain over half the world's species (Oviedo et al., 2000; Corlett & Primack, 2010). Of the 93 579 species of plants and animals assessed by the Red List of the International Union for the Conservation of Nature (IUCN) until 2018, more than 26 000 (28 %) are threatened with extinction, including 41 % species of amphibians, 35 % of reptiles, 25 % of mammals, 13 % of birds, 7.5 % of bony fishes and 63 % of cycads. Those estimates, however, are very conservative given that the species evaluated only represent about 4 % of the nearly two million living species described to date (Brusca, Moore, & Shuster, 2016; Primack & Vidal, 2019), and far less than the estimated total number of species on Earth (estimates range from around 10 to 100 million species of prokaryotes, protists, plants, fungi, and animals) (Mora, Tittensor, Adl, Simpson, & Worm, 2011; Brusca et al., 2016). At least 479 species of vertebrates and 116 species of plants have gone extinct in modern times, due mainly to habitat destruction and fragmentation, overexploitation, and invasive species. Although the global extent of protected land has roughly doubled in size since the 1992 Earth Summit in Rio de Janeiro, with more than 202 000 protected areas now covering 14.7 % of the world's terrestrial area, 6×10^6 km^2 (32.8 %) of that protected land globally is under intense human pressure (Jones et al., 2018).

In this paper, we test the hypothesis that a pattern of co-occurrence of biological and cultural diversity exists in Mexico. We do this by examining the available data on species diversity and language diversity across all Mexican states, and by looking for areas of overlap between regions of high diversity and extinct/threatened/endangered diversity in species and languages.

MATERIALS AND METHODS

Much has been written on Mexico's biodiversity (for a review see Sarukhán et al., 2017). However, little has been published in the peer-reviewed literature on its rich linguistic

diversity. We extensively reviewed the available literature, including government reports, on Mexico's biocultural diversity with a particular focus on endangered and critically endangered species and languages to look for overlapping geographical distributions and threats. Most of the information we use regarding the languages of Mexico comes from an exhaustive appraisal of reports by Mexico's National Institute of Indigenous Languages (Instituto Nacional de Lenguas Indígenas [INALI], 2012) and official published government records (Diario Oficial de la Federación, 2008, 2010a). From these sources, we compile a robust set of data, though much of it is qualitative (not quantitative).

Our ranking criteria for biological species follow the IUCN, and we consider a species *critically endangered* when it faces an extremely high risk of becoming extinct, and *endangered* when it faces a very high risk of becoming extinct (IUCN, 2018). We follow two closely aligned criteria for defining endangered languages. The first, more detailed criterion, from INALI (2012), considers that a language has *very high risk* of disappearance when the total number of speakers is less than 100, the number of child speakers is less than 25 %, and the speakers are less than 30 % of the population in all localities; and a language is at *high risk* of disappearance when the total number of speakers is less than 1 000 but higher than 100, the number of child speakers is less than 25 %, and the number of speakers in just one locality is less than 30 %. The second criterion considers a language *critically endangered* when the number of speakers is less than 50, and *endangered* when the number of speakers is less than 250 (Loh & Harmon, 2014; Simons & Fennig, 2018). Both of these criteria are in line with the degrees of endangerment established by UNESCO (2010).

A linguistic variant has structural and lexical differences when compared with other variants in the same linguistic group. And those that speak a variant have a sociolinguistic identity that contrasts with the sociolinguistic identity of those that speak other variants within the same linguistic group (Diario Oficial de la Federación, 2008). Those differences could be sounds, words, meanings, and uses that result in speakers of one variation being unable to understand speakers of other variations. Variants are therefore often seen as equivalent to languages (INALI, 2012) and are considered as such in this paper.

RESULTS

Biological Species

Mexico harbors 10-12 % of the world's biological diversity and is ranked as the fourth megadiverse country after Indonesia, Brazil and Colombia (Mittermeier & Mittermeier, 1992; Mittermeier et al., 1999; Toledo, Boege, & Carrera-Bassols, 2010; Sarukhán et al., 2017). So far, 118 030 (66.44 %) of the estimated 177 641 species of animals and vascular plants of Mexico have been described (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad [CONABIO], 2008; Sarukhán et al., 2017): 23 314 species of vascular plants, 564 mammals, 1 150 birds, 908 reptiles, 399 amphibians, 2 763 fishes (2 224 marine), 11 472 non-arthropod invertebrates, 11 185 non-insect arthropods, and 66 275 insects. These estimates include terrestrial, freshwater, and coastal marine species.

As in other parts of the world, tropical regions in Mexico contain more species than temperate areas; although there are certain groups that are particularly diverse in arid zones, such as cacti, of which at least 677 species are found in the country, 518 of them being endemic (Dávila et al., 2002; Villaseñor, 2016). The states of Oaxaca, Chiapas, Veracruz and Guerrero (all in the South/Southeast and close to Guatemala and Belize) and Michoacán are home to the bulk of the country's biodiversity (see also Toledo et al., 2001). Mammal, reptile and amphibian species richness is much higher in Oaxaca, Chiapas, Veracruz and Tabasco (CONABIO, 2008) and although it varies among different groups, tropical humid regions appear to have fewer endemic species

than arid and semiarid regions (CONABIO, 2016). Oaxaca alone is home to almost half of Mexico's known species of vertebrates, 19 % of the known invertebrates, and 40 % of the known plants (Gonzalez-Perez, Briones-Salas, & Alfaro, 2004).

At least 127 species of Mexican flora and fauna (58 % of them endemic) are known to have gone extinct through 2008 (Table 1). However, since most recorded extinctions have occurred on islands and in continental lagoons and rivers, and include only flowering plants and vertebrates, the actual number of extinctions (including other habitats and taxa) is probably much higher. There are today 1 213 Mexican species (many endemic) threatened with extinction (Diario Oficial de la Federación, 2010b; IUCN, 2018; **Supplemental Material**): 94 (73 endemic) species of mammals, 66 (24) birds, 97 reptiles, 219 (182) amphibians, 181 fishes, 8 mollusks, 98 other invertebrates, and 450 plants (including 12 conifers, 41 cycads, 133 cacti and 22 magnolias). Unsurprisingly –given the extent of habitat destruction and fragmentation in Oaxaca, Chiapas, Veracruz, Guerrero, Michoacán, and states adjacent to the Gulf of California, including its many islands and islets– threatened hotspots are located mostly in those regions.

Languages

Today, 25.7 million (21.5 %) of Mexico's inhabitants are indigenous peoples, and 7.4 million (6.5 % of all Mexicans older than three years) speak an indigenous language (Instituto Nacional de Estadística y Geografía [INEGI], 2010, 2015); although in some states such as Chiapas, Oaxaca and Yucatán that percentage is nearly 30 % (CONABIO, 2016). Indigenous land represents approximately 14.3 % (or 28 million hectares) of the country's total territory (Boege, 2008, 2009) and nearly half of the most important watershed headwaters are occupied by indigenous peoples. About a third of Mexico's protected natural areas (at the federal level) have indigenous populations living within them, and approximately 70 % of Mexico's indigenous land is under some sort of priority for the conservation of its rich biological resources (Toledo et al., 2010). There are 64 172 named localities with indigenous people and a quarter of Mexico's social properties are located within 4 786 *ejidos* (communal land, which in Mexico is land expropriated from owners of large tracts and redistributed for shared use as farmland, especially to poor populations, in accordance with the Agrarian Reform Act of 1917) and 1 258 agrarian communities in territories own by indigenous people (INEGI, 2015). The states of Oaxaca, Chiapas, Veracruz, Guerrero, Hidalgo, Estado de México, and Yucatán are home to 77 % of the Mexico's indigenous people, while the states of Coahuila, Colima and Zacatecas have the lowest indigenous populations.

Today, with 364 living languages, Mexico is the world's fifth most linguistically diverse country after Papua New Guinea, Indonesia,

TABLE 1

Mexico's recorded extinct species of fauna and flora (CONABIO, 2008; Sarukhán et al., 2017)

Taxa	Extinct Species	Endemic Species	States/Islands
Plants	26	5	Hidalgo, Veracruz, Jalisco, Isla Guadalupe
Fish	38	20	Nuevo León, Coahuila, Jalisco, Durango, México, Veracruz
Amphibians	29	29	Oaxaca, Veracruz, Guerrero, Querétaro, Hidalgo, Durango
Birds	19	11	México, Sonora, Coahuila, Michoacán, Colima (Isla Benedicto), Baja California (Islas Todos los Santos), Isla Guadalupe, Isla Socorro
Mammals	15	9	Baja California (Islas Todos los Santos, Coronado, Turner, and San José), Nayarit (Archipiélago las Marías), Sonora (Isla San Pedro), Isla Ángel de la Guarda, Isla San Juanito
Totals	127	74	

Nigeria and India (Diario Oficial de la Federación, 2008; Toledo et al., 2010; INALI, 2012). Mexico's indigenous languages belong to 11 linguistic families and 68 linguistic groups (Diario Oficial de la Federación, 2008; INEGI, 2010; INALI, 2012). This cultural richness is, however, threatened.

Four linguistic groups comprise the largest numbers of speakers in Mexico –Náhuas (1 376 000 speakers), Maya (759 000), Mixteco and Zapoteco (> 400 000)– while 22 groups each have less than 1 000 speakers. Oaxaca, Puebla, Chiapas, Veracruz and Guerrero are the states with the highest linguistic diversity; densities of languages in Oaxaca, Veracruz and Guerrero are comparable to areas in Papua New Guinea, the Himalayas, Nigeria, and Cameroon (CONABIO, 2008). Ninety percent of the people who speak the Cochimí-Yuman family (Cucapá, Paipai, Kumiai, Ku'ahl and Kiliwa) live in Baja California and Baja California Sur, all of which are at high or very high risk of disappearance. Cochimí is not a "modern" Yuman language, but one that likely split off from a Proto-Yuman tongue long ago (Mixco, 1978).

The status of speakers among ethnic groups differs greatly throughout Mexico. There are groups in which only the elders speak the language (in Mexico), as is the case of the Ixcateco, Ayapaneco, Kiliwa, Paipái, Cucapá and Ku'ahl; and those for which adults speak the language, but children do not, such as Tlahuica, Mocho', Tuzanteco, Teko, Awakateko, Oluteco, Ayapaneco, Texistepequeño, Chocholteco, Kaqchikel, Ixil, and Ixil chajuleño (INALI, 2012). However, Kaqchikel and Ixil are languages probably represented today in Mexico by relatively recent immigration from Guatemala, where they remain strongly represented. At least 13 languages have gone extinct in Mexico: Pericú, Solteco, Naolan, Opata, Pochuteco, Cuitlatec, Pame (Southern), Tepecano, Tubar, Chiapaneco, Eudeve, Pochuteco and Cochimí. Of the 364 languages spoken today in Mexico, 64 are in very high risk of disappearance (less than 100 speakers survive) and 43 are in high risk of disappearance (less than 1 000 but more than 100 speakers survive (INALI, 2012) (Table 2, Fig. 1). Nine languages in Mexico are also considered by Simons and Fennig (2018) to be critically endangered (less than

Fig. 1. Mexico's languages at very high risk of disappearance shown in red (from INALI, 2012; coloring denotes areas in which the language is spoken), and its most biologically diverse states bordered in green.

TABLE 2

Extinct, critically endangered, and endangered languages in Mexico

EXTINCT

Language (family)	Number of Speakers	State	Locality (municipality: villages) (1)
Pericú (2)		Baja California	Los Cabos region
Solteco (Oto-mangue) (3)	None	Oaxaca	
Cuitlatec (4)	None	Guerrero	Balsas River
Naolan (unclassified) (5)	None	Tamaulipas	San Juan Naolan, near Tula
Pochuteco (6)	None	Oaxaca	Pochutla
Opata (Uto-azteca) (7)	None	Sonora	Arivechi, Bacanora, Nacori, Onavas, Sahuaripa, Suaqui. Tecoripa is the traditional area
Pame, sureño (Oto-mangue)	None	Estado de Mexico (possibly Hidalgo)	Jiliapan
Tepecano (Uto-azteca)(8)	None	Jalisco	Villa Guerrero: Azqueltán (earlier Atzqueltlán), San Martín de Bolaños on Río Bolaños
Tubar (Uto-azteca) (9)	None	Chihuahua near de border with Sonora and Sinaloa	
Chiapaneco (Oto-mangue)	None (10)	Chiapas	El Bosque, Las Margaritas, Ocosingo, Alenque and Sabanilla municipalities
Eudeve (11)	None	Sonora (12)	
Pochuteco (Uto-azteca) (13)	None	Oaxaca	Pochutla
Cochimí (Cochimí-yumana) (14)	None (15)	Baja California Baja California Sur	Noth of Loreto
CRITICALLY ENDANGERED (less than 50 speakers and no children –5 to 14 years of age– speak the language)			
Kiliwa (Cochimí-yumana)	2 (16)*	Baja California	Ensenada: Arroyo de León (Ejido Kiliwas), Ejido San Francisco R. Serrano (Valle San Matías), Ensenada, Francisco Zarco (Guadalupe), Juntas Nejí, La Zorra, Lázaro Cárdenas (Valle de la Trinidad), Licenciado Gustavo Díaz Ordaz, Parcela Número 19 (Familia Castro Ejido Nalta), Rancho las Pinzas
Awakateco (Maya)	3*	Campeche	Champotón: Maya Tecún I, Maya Tecún II, Santo Domingo Kesté
Tuzanteco (Maya)	5*	Chiapas	Tuzantán: Estación Tuzantán
Ayapaneco (Mixe-zoque)	8 (17)*	Tabasco	Jalapa de Méndez: Ayapa, El Carmen (La Ensenada), Vicente Guerrero Primera Sección
Ixil nebajeño (Maya)	12*	Quintana Roo	Othón P. Blanco: Maya Balam

Language (family)	Number of Speakers	State	Locality (municipality: villages) (1)
Zapoteco de Mixtepec (Oto-mangue)	14 (18)*	Oaxaca	San Cristóbal Amatlán: San Agustín Mixtepec
Ku'al (Cochimí-yumana)	20 (19)*	Baja California	Misión de Santa Catarina, Comunidad Indígena de Santa Catarina, El Aguajito (Mat Chip) [Rancho Matchip], Rancho Escondido, Rancho Wikualpuk (El Ranchito), Ensenada
Ixcateco (Oto-mangue) (20)	21 (21)*	Oaxaca	Oaxaca de Juárez, Santa María Ixcatlán
Kaqchikel (Maya)	35*	Campeche	Campeche: Quetzal-Edzná I, Quetzal-Edzná II, Los Laureles. Champotón: Maya Tecún II, Santo Domingo Kesté
		Quintana Roo	Quintana Roo. Othón P. Blanco: Kuchumatán, Maya Balam, San Isidro la Laguna
Zapoteco de San Felipe Tejalapám (Oto-mangue)	50 (22)*	Oaxaca	San Felipe Tejalapam: Arroyo Central, Cañada Cera, Conejo (Rancho El Conejo), El Chilar, El Copalito, El Cucharal, El Paredón, El Roble, La Aurora, La Unión, Llano Ceniza, Llano El Coyote, Los Paderones, San Felipe Tejalapám

<table>
ENDANGERED (less than 250 speakers no children –5 to 14 years of age– speak the language)
</table>

Language (family)	Number of Speakers	State	Locality (municipality: villages) (1)
Ixil chajuleño (Maya)	52	Campeche	Campeche: Los Laureles, Quetzal-Edzná
		Quintana Roo	Quintana Roo. Othón P. Blanco: Kuchumatán
Zapoteco de Asunción Tlacolulita (Oto-mangue)	53	Oaxaca	Asunción Tlacolulita: Asunción Tlacolulita, Primera Sección Norte
Oluteco (Mixe-zoque)	60*	Veracruz	Oluta: Correa de Abajo, El Chorro, El Mirador, El Ángel Gabriel, Los Laureles, Oluta, Tenejapa
Chocholteco del oeste (Oto-mangue)	62	Oaxaca	Ocotlán: Boquerón, San Antonio Nduayaco, Tierra Colorada, Unión Palo Solo. San Francisco Teopan: Concepción Buenavista, Santiago Ihuitlán Plumas, Tepelmeme Villa de Morelos, Tlacotepec Plumas. San Miguel Tequixtepec: Los Batos. San Miguel Tulancingo: Agua Dulce, Buena Vista, El Coatillo, El Español, Gasucho, Loma Larga, Rancho Marino Sánchez, San Miguel Tulancingo. San Pedro Nopala: San Mateo Tlapiltepec, Santa María Jicotlán. Santa Magdalena Jicotlán: San Mateo Tlapiltepec, Santiago Tepetlapa. Teotongo: El Progreso, El Tecomate, Guadalupe, La Luz
K'iche' (occidental) (Maya)	65	Campeche	Champotón: Santo Domingo Kesté
K'iche' (central) (Maya)	65	Campeche	Champotón: Santo Domingo Kesté
Teko (Maya)	71*	Chiapas	Amatenango de la Frontera: Amatenango de la Frontera, Barrio Nuevo, Chiquisbil, El Porvenir, Granadillal, Las Marías, Nuevo Amatenango, Sabinalito. Frontera Comalapa: Nuevo Mazapa. Mazapa de Madero: Bacantón Altamirano Uno, Chimalapa, Mazapa de Madero, Nuevo Paraíso, Reforma, Tierra Blanca, Valle Obregón, Veracruz, Villa Hidalgo.

Language (family)	Number of Speakers	State	Locality (municipality: villages) (1)
Zoque del sur (Mixe-zoque)	84	Chiapas	Ocozocuautla: El Edén, El Pedregal, Nuevo Chapultenango, Salina Cruz, San Antonio, San Luis las Maravillas, San Pedro, Velasco Suárez Uno. Tuxtla Gutiérrez: Copoya, Julio César Ruiz Ferro Segunda Sección, Lindavista, Los Crisantemos.
Pápago (Pima alto) (Yuto-nahua)	94	Sonora	Altar: Altar, El Cubabi, El Cumarito. Caborca: El Soñic, Heroica Caborca, Juárez, La Escondida, Las Norias (De Romero), Puerto Lobos, San Francisco Pápagos (San Francisquito), San Pedro, Santa Eduwiges (La Cachora), SPR Mayobampo (Rancho Corralero). General Plutarco Elias Calles: Ejido Luis Echeverría Álvarez, El Chamizal, El Desierto de Sonora, Quitovac, San Antonio, Santa Rosa (La Angostura), Sonoyta.
K´iche' (oriental) (Maya)	96	Campeche	Campeche: La Libertad. Champotón: Maya Tecún II, Santo Domingo Kesté.
		Chiapas	Chiapas. Las Margaritas: San Mateo Zapotal. Marqués de Comillas: Boca de Chapul, Pico de Oro.
		Quintana Roo	Quintana Roo. Othón P. Blanco: Kuchumatán, Maya Balam, San Isidro la Laguna.
Kickapoo (Álgica) (23)	105	Coahuila	Múzquiz: Ciudad Melchor Múzquiz, El Nacimiento de los Kikapúes (Nacimiento de la Tribu Kikapoo)
Mexicano de occidente (Yuto-nahua)	107	Jalisco	Cuautitlán de García Barragán: Ayotitlán, Cortapico, Cuautitlán de García Barragán, Cuzalapa, Chacala, Chanquehahuil, El Chico, La Guaca, La Rosa, La Rosita, Los Encinos, Los Sauces, Los Terreros, Mojoneras, Paso Real, Plan de Méndez, Plan de San Antonio, Rancho Viejo, San Miguel, Santa Rosa, Tierras Blancas, Tierras Negras
Kuapá (Cucapá) (Cochimí-yumana)	119 (24)	Baja California	Baja California. El Mayor Cucapá, Pozas de Arvizu. Mexicali: Campo Camerina (Colonia Terrenos Indios), Campo del Prado (Colonia el Mayor), Campo Flores, Campo Sonora (Colonia Terrenos Indios), Colonia la Puerta, Comunidad Indígena Cucapá el Mayor [Ejido el Mayor], Ejido Cucapá Mestizo, Ejido Doctor Alberto Mota (El Indiviso), Ejido Durango, Ejido México, Familia Regalado (Ejido Sonora 2 Campos Nuevos), La Casa de las Curvas (Colonia el Mayor), Mexicali, Sainz Domínguez (Colonia el Mayor), San Felipe.
		Sonora	Sonora. San Luis Río Colorado: Pozas de Arvizu (La Reserva).
Mexicano alto de occidente (Yuto-nahua)	127	Nayarit	Acaponeta: Acaponeta, Agua Tendida, Buenavista (Las Paredes), El Duraznito, El Naranjo, El Resbalón, Huanacaxtle, La Guásima, La Laguna (La Lagunita), La Paloma Nueva Reforma, Mesa las Arpas, Paredes, Rancho los López, Rancho de Ernesto Aguilar, San Diego de Alcalá, San Diego el Naranjo, San Dieguito de Abajo, San José de Gracia, Santa Cruz, Saycota, Sayulilla, Unidad Habitacional, Zacatecas. Del Nayar [El Nayar]: Dolores, Los Chapiles, Santa Teresa, Tierras Cuevas
Mochó (Maya)	141*	Chiapas	Motozintla: Motozintla de Mendoza

Language (family)	Number of Speakers	State	Locality (municipality: villages) (1)
Pima del norte (Yuto-nahua)	155	Chihuahua	Madera: Agua Amarilla, Ciudad Madera, Ejido el Lago, El Cable, El Campo Seis, El Cordón, El Cuatro, El Largo, El Pedregal, El Potrero, El Presón, El Represito, El Río Chiquito, El Táscate, El Yerbanís, Junta de los Arroyos [Junta de los Ríos], La Bolada, La Ciénega, La Nopalera, Las Espuelas, Las Lajas, Los Arbolitos, Madera, Mesa Blanca, Mesa el Tecolote, Mesa de La Simona, Mesa del Garabato, Rancho Huapoca, San Isidro, San Juan de Enmedio. Moris: Bermúdez, Los Cien Pinos
Pima del sur (Yuto-nahua)	159	Chihuahua	Ocampo: Basaseachi, Pinos Altos, Santo Domingo, Sapareachi, Tierritas. Temósachi: Agua Caliente, Casa Blanca, Ciénega Blanca, Cordón de Enmedio (Paraje Piedra Colorada], El Arbolito, El Llorón, El Nogal, El Saucito, El Terrero (Piedras Azules), Janos, La Ciénega, La Ciénega Blanca [Ciénega Blanca], La Guajolota, La Ornela, La Providencia, La Salitrera, La Viñata, Las Tierritas, Los Hornitos, Nabogame, Peñasco Blanco, Piedra Blanca, Piedras Azules, San Antonio, San Ignacio, Temósachi, Tierras de María, Yahuirachi, Yepáchic.
Paipai (Cochimí-yumana)	162 (25)	Baja California (26)	Ensenada: Arroyo de León (Ejido Kiliwas), Camalu, Cañón de la Parra, Comunidad Indígena de Santa Catarina, Ejido 18 de Marzo (El Álamo), El Aguajito (El Mat Chip), El Alamar, El Pinacate [Chknan], El Ranchito [Wikwalpuk], El Sauzal, Ensenada, Ex Hacienda Sinaloa, Héroes de la Independencia (Llano Colorado), Lázaro Cárdenas (Valle de Trinidad), La Huerta, La Vinata [Wipuk], Leyes de Reforma (El Rodeo), Misión Santo Domingo, Ojo de Agua Colorada, Poblado Héroes de Chapultepec, Poblado Puerta Trampa, Pórticos del Mar, Ranchito Xonuko, Rancho Agua de Vida, Rancho el Sauco, Rancho Escondido, Rancho las Canoas, Rancho Mariscal, Rancho San Belem, Rancho Santa Martha, Real del Castillo Nuevo (Ojos Negros), Rincón de Santa Catarina, San Isidoro, Sauce Largo [Yokakgul], Sauce Solo [Yokazis], Úrsulo Galván, Valle de la Trinidad, Yokakiul
Zapoteco de la Sierra sur, noroeste bajo (Oto-mangue)	164*	Oaxaca	Villa Sola de Vega: Agua del Sabino, Arroyo de la Rosa (El Aguacate), Barrio de Santa Anita (Sección Tercera), El Anís (San José El Anís), El Duraznillo, El Mangalito, El Nido, El Progreso, Guayabo, La Ciénega de la Palma, La Labor, La Nopalera, La Siempre Viva, La Singuera, Las Juntas (El Puente), Las Trancas, Llano Mazorca, Llano Monte, Llano de León, Loma de Ocote, Río Espejo, Río Húmedo, Río Manteca, Río de Boca, San Felipe Zapotitlán, San Juan Viejo, San Sebastián de las Grutas, Villa Sola de Vega
Chocholteco del este (Oto-mangue)	180	Oaxaca	San Juan Bautista Coixtlahuaca: El Capulín (Sección Primera), El Tepozón (Sección Segunda), El Zapotal (Sección Tercera), La Mulata, Santa Catarina Ocotlán. San Miguel Chicahua: Llano Seco.
Chocholteco del sur (Oto-mangue)	200	Oaxaca	San Miguel Huautla: Ocotlán. Santa María Nativitas: Barrio Nicolás, Barrio Santiago, El Mirador, El Porvenir, Loma del Tepejillo, Pie del Cordoncillo, Primera Sección (Santa Cruz), San José Monte Verde, San Pedro Buenavista, Santa María Nativitas.

Language (family)	Number of Speakers	State	Locality (municipality: villages) **(1)**
Zapoteco de Valles, oeste (Oto-mangue)	211	Oaxaca	Magdalena Mixtepec: Magdalena Mixtepec, Santa Catalina Mixtepec. San Bernardo Mixtepec: Asunción Mixtepec, Barrio del Carmen, Barrio del Rosario, La Loma Grande, Rancho Teja, San Bernardo Mixtepec, San Jerónimo Tititlán. San Pablo Cuatro Venados: El Esponjado, El Jabalí, El Moral, El Poleo, El Sacatón, La Nevería, Llano Manteca, Llano de Toro, Piedra Blanca, Río Jalapillas, Río Minas, San Cristóbal, San Pablo Cuatro Venados, Santiago Clavellina. San Pablo Huixtepec: San Pablo Huixtepec.
Mixteco del noroeste bajo (Oto-mangue)	220*	Oaxaca	San Bartolo Soyaltepec: Barrio del Calvario, Cerro Totocani, El Caballo Blanco, El Águila, Guadalupe Gavillera, Jataitno, La Unión Reforma, Río Verde, San Bartolo Soyaltepec, San Isidro Tejocotal, Santa Cruz Pipila. Santa María Chachoápam: San Agustín Monte Lobos, Santa María Chachoápam. Santo Domingo Tonaltepec: Cerro de Sol, Deque Inu (Cabeza de Cigarro), Dequeto, Río Verde, San Francisco Río Blanco, Santo Domingo Tonaltepec, Vista Hermosa, Yuquini. Santo Domingo. Yanhuitlán: Santo Domingo Yanhuitlán, Tooxi, Yudayo.
Kumiai (Cochimí-yumana)	221 **(27)**	Baja California **(28)**	Ensenada: El Porvenir (Guadalupe), Ensenada, Francisco Zarco (Guadalupe), La Huerta, La Misión, Rancho Dinuwa, Rancho Plazola, Real del Castillo Nuevo (Ojos Negros), San Antonio Necua (Cañada de los Encinos), San Salvador de Gálvez. Playas del Rosarito: Comunidad Indígena San José de la Zorra (San José de la Zorra) [San José la Zorra], La Zorra, Primo Tapia. Tecate: Colonia Luis Echeverría Álvarez (El Hongo), Ejido Guadalajara 2 (El Gato), Ejido Nueva Colonia Hindú, El Álamo, El Testerazo, El Venado, Encino Solo, Escuela Mescuich [Mescuich], Familia López Gaspar, Hacienda Santa Verónica, La Ciénega, Rancho Cañada Verde, Rancho Jacuín, Rancho las Auras, Rancho las Priscilas, Rancho Limón, Rancho Neji Sección C [Juntas de Neji], Rancho Puerto el Roble, Santa Elena, Tecate, Valle de las Palmas.
Chontal de Oaxaca bajo (Chontal de Oaxaca)	223	Oaxaca	Santa María Ecatepec: La Reforma, San Juan Acaltepec, Santo Domingo Chontecomatlán, Santo Tomás Teipan
Mixteco de San Miguel Piedras (Oto-mangue)	243*	Oaxaca	San Miguel Piedras: Chidoco (Chidoco de Juárez), Colorado, El Fresno, El Potrerito, Guadalupe Victoria, Río Minas (Río Minas Piedras), San Miguel Piedras
Zapoteco de San Bartolo Yautepec (Oto-mangue)	246	Oaxaca	San Bartolo Yautepec: Joaquín López Mariano (Rancho), Puerto San Bartolo, San Bartolo Yautepec

Localities are from Diario Oficial de Federación (2008), status and notes are mainly from INALI (2012), Hammarström et al. (2018) and Simons & Fennig (2018). Critically endangered (< 50 speakers survive) and endangered (< 250 speakers survive) languages as in Simons and Fennig (2018); those denoted by * are in very high risk of disappearance (< 100 speakers survive) and high risk of disappearance (< 1 000 but > 100 speakers survive) following INALI (2012).

1. Localities included are those with historic settlements.
2. Also known as edúes y coras.
3. Related to Chatino and Zapoteco languages.
4. Last speaker died in the 1960s.
5. Extinct ca. 1950.
6. Boas (1917).
7. Last speakers reportedly died around 1930, but the 1990 census lists 12 speakers.
8. Formerly spoken by a small group of people. The last speaker was born in 1895 (Holt 2001) and no remaining speakers are known after 1972.
9. As many as 100 in 1970; see also Lionnet (1978).
10. Ethnic population is 32.
11. Also known as heve and dohema; extinct since about 1940; see also Lionnet (1986).
12. In her essay "El noroeste: Sonora" (http://www.fundacionunam.org.mx/humanidades/eudeves-una-etnia-extinta/), historian Isabel Verdugo de Juárez locates the territory occupied by Eudeves as: "In the north they were found along the mid-portion of the San Miguel River (Horcasitas River) in Saracachi, Cucurpe o Opodepe. In the south they we found at the springs along the Matepe River, the banks of Moctezuma River and part of Nevoma or Yaqui Rivers. This area encompassed the historical sites of Batuco, Tepupa, Bacanora, Soyopa and Tónachi."
13. Extinct in 1954 (Boas 1917; Knab 1980).
14. From the first contact with Europeans 300 years ago, the Cochimíes have occupied the central part of the Baja California peninsula and the state of Baja California Sur. Although there was some minor dialect variation over the vast area where Cochimí was spoken, they were mutually intelligible (T. Bowen, pers. comm.). Originally, there were no large settlements and they were basically nomads. The guamas or sorcerers had an important position in the original culture; there were no writing or formal artistic expressions. They were gatherers and fishers, who did not practice agriculture nor have livestock.
15. Ethnic population is 150; this may include Kumiai in La Huerta who call themselves Cochimí; old Cochimí is extinct (Simons & Fennig 2018).
16. A total of 15 Kiliwa people survived in 2018 and the number of speakers is given as 29 (INALI 2012); however, in February 2018 one of the last three speakers died in Ejido Tribu Kiliwas, Valle de la Trinidad, near Ensenada.
17. Ethnic population of 16 in 2016.
18. It has been reported that in 2003 there were only two native speakers (the youngest then 72 years old) and three semi-speakers; the community apparently agreed to stop speaking Zapotec in 1965 (Beam de Azcona, 2004).
19. A total of 166 elder speakers was also reported (INALI 2010).
20. Reported as Xuani-Ixcateca by Molina Cruz (2010), who described efforts to save this language using video (see also https://www.youtube.com/watch?v=lN2M-Rb7LM0).
21. A total of population of nine and only a few elder speakers (in 2009) were reported (Simons & Fennig, 2018).
22. A total of 30 speakers, all over the age of 70, were reported in 1998 (Simons & Fennig, 2018).
23. The Kickapoo arrived in Mexico in the nineteenth century when, after the Anglo-Saxon invasion of their territory, they asked the Mexican government for a place to live; in exchange the government asked them to defend Mexican residents against the frequent attacks from the Comanche. Since then, the Kickapoo of Mexico have been known in the United States as the "Texas gang."
24. Caccavari Garza (2014) reported less than 30.
25. Caccavari Garza (2014) reported less than 50.
26. According to Caccavari Garza (2014) most people are in Comunidad Indígena de Santa Catarina, but they are also present in San Isidoro, Valle de la Trinidad and Ejido Héroes de la Independencia.
27. Caccavari Garza (2014) reported less than 50.
28. According to Caccavari Garza (2014) mainly located in two municipalities and the communities of Juntas de Nejí en Tecate, San José de la Zorra, San Antonio Necua y La Huerta, Ensenada.

50 speakers survive), and 29 endangered (less than 250 speakers survive). The ones with the highest risk of going extinct in the immediate future are: Kiliwa (2 speakers survive), Awakateco (3 speakers), Tuzanteco (5 speakers), Ayapaneco (8 speakers), Ixil nebajeño (12 speakers), Zapoteco de Mixtepec (14 speakers), Ku'al (20 speakers), Ixcateco (21 speakers), Kaqchikel (35 speakers), Zapoteco de San Felipe Tejalapám (50 speakers), Ixil chajuleño (52 speakers), and Zapoteco de Asunción Tlacolulita (53 speakers). Mexico's 56 extinct and endangered languages occur in 16 states, most (77 %) in Oaxaca (16), Baja California

Rev. Biol. Trop. (Int. J. Trop. Biol.) Vol. 68(2): 669-691, June 2020

681

(7), Chiapas (6), Campeche (6), Sonora (4) and Quintana Roo (4) (Table 2, Table 3).

As a stark reminder, one language and one species, both located in Baja California, will probably go extinct within the next very few years. With only two speakers alive in late 2018, the Kiliwa is Mexico's most endangered language and is condemned to extinction (INALI, 2012; Caccavari Garza, 2014). And, with a population of fewer than two dozen individuals in 2018 (Comité International para la Recuperación de la Vaquita [CIRVA], 2019), probably even fewer today, the vaquita porpoise (*Phocoena sinus*), Mexico's only endemic and the world's most endangered marine mammal, is being driven to extinction by illegal fishing for the endangered and endemic totoaba (*Totoaba macdonaldi*) (Vidal, 1995; Brusca, Álvarez-Borrego, Hastings, & Findley, 2017; Thomas et al., 2017; Rojas-Bracho et al., 2018).

TABLE 3
States in Mexico with extinct or endangered languages

State	Number of extinct and endangered languages
Oaxaca	16
Baja California	7
Chiapas	6
Campeche	6
Sonora	4
Quintana Roo	4
Chihuahua	3
Jalisco	2
Tabasco	1
Veracruz	1
Guerrero	1
Tamaulipas	1
Baja California Sur	1
Mexico State	1
Coahuila	1
Nayarit	1

DISCUSSION

Places with high species diversity, especially tropical forests, tend to have high linguistic diversity, and areas with low species diversity, such as tundra and deserts, have low linguistic diversity (Sutherland, 2003; Loh & Harmon, 2005). For instance, Papua New Guinea covers less than 1 % of the world's land area but is home to the world's third largest tropical rainforest (after the Amazon and the Congo) (Bryan, Shearman, Ash, & Kirkpatrick, 2010), and is also home to 6-8 % of the Earth's animal and plant species (two thirds of them endemic) and 12 % of the world's living languages (Papua New Guinea's Fifth National Report to the Convention on Biological Diversity, 2014; Simons & Fennig, 2018).

Indigenous people are custodians and landowners of much of the biodiversity worldwide. The world's 370 million indigenous people make up less than 5 % of the total human population, yet they manage or hold tenure over 25 % of the world's land surface that supports about 80 % of the global biodiversity (Raygorodetsky, 2018).

There are increasing numbers of examples of non-industrial people living in harmony with their natural environment, such as rural communities in Hawaii (McGregor, 1999); the Kayapo Indians of Middle Xingu Valley in Brazil (Posey, 1999); the Dai, an indigenous ethnic group in Southwest China (Shenghi, 1999); and the Sápara of Ecuador (Raygorodetsky, 2018). Numerous studies have proven how traditional ecological knowledge and practices have effectively served to protect and maintain natural environments (e.g., Posey, 1999; Berkes, 2001; Cunningham, 2001; Wiersum, 2004; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], 2018). In addition, biocultural conservation can help secure the rights of indigenous and local people and help maintain a focus on social justice.

The current rate of extinction of languages worldwide, and loss of knowledge they contain, has no parallel in human history (Harrison, 2007). Language loss in some areas, such as the Americas, has reached 60 % over the last 35 years (Harmon & Loh, 2010). Indeed, the most rapid losses in linguistic diversity have occurred in this region, where 60 % of languages are threatened or have gone extinct since

1970. And this is not limited to developing countries. Policies in the United States, particularly between the 1870s and 1930s, greatly suppressed Native American languages and culture. It was only after years of activism by indigenous leaders that the U.S. Native American Languages Act was passed in 1990, which allowed for the preservation and protection of indigenous languages.

Languages can go extinct either because the entire population of speakers dies out, or because the speakers shift to a different language and forget their mother tongue due to the loss of intergenerational transmission. Much of the decline in linguistic diversity is a result of language shift away from small indigenous languages toward national or regional languages (Loh & Harmon, 2014). Along with the disappearance of languages, most of the rich traditional knowledge of these indigenous cultures is largely lost forever, including knowledge of the natural history of the world in which the language resided.

Languages are a critical measure of the cultural diversity of nations, while species richness is a measure of their biological diversity. Mexico offers an important case on the challenges to conserve both. With at least 118 species of economically important plants totally or partially domesticated by indigenous pre-Hispanic farmers, Mexico has been a global center of plant domestication. More than 15 % of edible vegetable species consumed in the world originated in Mexico (CONABIO, 2008; Perales & Aguirre, 2008; Bellón et al., 2009; Sarukhán et al., 2017). In addition, between 3 000-4 000 medicinal plant species are regularly used by Mexicans, and indigenous people in Mexico use 5 000-7 000 plant species in various cultural activities (Boege, 2008). It has been suggested that almost every species of plant and animal, type of soil, landscape, and mountain in Mexico has its match in a linguistic expression, knowledge category, practical use, mythical or religious meaning, or a known individual or collective experience (Toledo et al., 2001a, 2001b).

Mexico's early cultures relied heavily on natural resources, including the harvesting of coastal and estuarine resources in the Holocene. In the Baja California-Gulf of California region this included fishing and intensive hunting of dolphins and sea turtles beginning at least 10 000 years ago (Bowen, 1976, 2000, 2006, 2009; Felger & Moser, 1987; Felger, Nichols, & Seminoff, 2005; Fujita, 2006; Marlett, 2014). By around the year AD 1000, four important centers of indigenous socio-economic and cultural concentration surged in this region, which reflected changing patterns of harvesting of marine resources. First, during the early 16th and 17th centuries, the Pericú, who lived along the deserts of Los Cabos region in the South of the peninsula, were hunters and shell gatherers (*concheros*), and disappeared (together with their language, its phylogenetic classification remaining unknown) in the second half of 18th century (Fujita, 2006). The exploitation of marine mammals, the associated stone tools, and the construction of enormous shell mounds by the Pericú display striking similarities to the Chumash people of the Channel Islands in Southern California in the United States (Beer, Gonzalez, Huddart, Rosales-Lopez, & Lamb, 2008). Second, the Guaicuras and the Cochimís, the latter inhabiting the center and North of the Baja California peninsula, were also shell gatherers and fishers. Third, the Seris on the ("mainland") coastal Sonoran Desert were (and still are) fishers and gatherers. And fourth, the Yumas, Pimas Altos and Papagos in North-Central Sonora and the tip of the peninsula were desert gatherers-farmers (Nolasco, 1982). The central desert area of the Baja California peninsula had the least linguistic diversity (and probably the lowest biological diversity; T. Bowen, personal communication).

Loss of biocultural diversity in Mexico (and the Americas in general) began as soon as Europeans arrived. Although estimates of the Native American population size of Mexico upon first arrival of Europeans in 1519 vary greatly (from less than 3 million to over 52 million), most researchers put it at around 20 million (Koch, Brierley, Maslin, & Lewis,

Rev. Biol. Trop. (Int. J. Trop. Biol.) Vol. 68(2): 669-691, June 2020

683

2019). At the time, large areas of land were under cultivation with maize, cacao, and fruit orchards (Whitmore & Turner, 1992). This indigenous population quickly began to collapse from warfare, slavery, and the introduction of pathogens unknown in the Americas (e.g., influenza, smallpox, bubonic plague). The most devastating epidemic in Mexico occurred in 1520, when a single smallpox outbreak killed an estimated 30 to 50 % of the indigenous population (Cook & Borah, 1960; Dobyns, 1993; McCaa, 1995). Following the first comprehensive census in 1568, the population of central Mexico had already declined to 2.7 million (Sanders, Pasons, & Santley, 1979), which corresponds to an approximate decline of 87 % within the first 50 years of European arrival (based on a contact population of 20 million) (Whitmore & Turner, 1992). A rapid population collapse of up to 90 % is plausible for the most populous parts of the country (Koch et al., 2019). One can only speculate how many indigenous languages were lost or put on a path toward extinction during this period. In Northern Mexico many groups of hunters and gatherers who spoke unknown languages perished because of the extermination campaigns launched by Spanish conquerors (Borah & Cook, 1963).

Today, there is strong geographical overlap between the states that harbor the bulk of Mexico's biological and linguistic diversity, with Oaxaca, Puebla, Chiapas, Veracruz, Guerrero and Michoacán standing out. Furthermore, Mexico's biodiversity hotspots closely mirror its language hotspots: areas with the highest number of endangered plant and animal species overlap with those where the endangerment of languages is greatest. Most of Mexico's dry forests, tropical rain forests, and temperate rain forests, which are home to high levels of biological and linguistic diversity, belong to indigenous communities, and almost a third of the country's federally protected areas are within indigenous territories (Sarukhán et al., 2017). It has been estimated that nearly 90 % of Mexico's indigenous population live in forested areas, while the rest live in arid and semi-arid regions with shrub or grasslands (Toledo et al., 2001a, 2001b).

Oaxaca is a good example of how the geography of languages and biodiversity overlap and have evolved together. Its complex geological history produced an elaborate topography and highly diverse range of ecosystems, from tropical coastal areas to temperate pine-oak forests, thorn scrub and cloud forests, which in turn favored adaptive radiation, speciation, and a high diversity of flora and fauna (Ordoñez, 2004). At least 8 431 species of plants (nearly 40 % of Mexico's known flora) and 4 542 animal species (half of the country's vertebrates and 19 % of its known invertebrates) are present in Oaxaca (García-Mendoza, Ordoñez, & Briones-Salas, 2004; CONABIO, 2008). For more than 10 000 years, its indigenous peoples have dispersed and evolved within the state's diverse ecosystems, and today 157 languages (43 % of Mexico's 364 languages) are spoken in more than 4 000 indigenous communities (de Ávila Blomberg, 2004).

The most insidious threats to Mexico's biodiversity are habitat destruction and fragmentation (mostly by deforestation for agriculture and livestock), overexploitation, invasive species, and climate change. The country has already lost about 70 % of its forest cover, mainly the tropical forests of the Southeast (Sarukhán et al., 2017). Prieto-Amparán et al. (2019) analyzed non-tropical land use in Mexico and found the area of primary forest reduced from 55.8 % in 1990 to 37.7 % in 2017 in their study region (which included temperate primary and secondary forest, human settlements, unvegetated areas, and water bodies). In just one year (2016), 253 000 hectares of Mexico's forests disappeared (Global Forest Watch, 2018). The effects of climate change will exacerbate all those threats (Peterson, Tian, Martínez-Meyer, Soberón, & Sánchez-Cordero, 2005).

The largest areas of forest and wildlands in Mexico are usually communal lands (Stoleson et al., 2005), and at least 70 % of its forested areas are held by ejidos (Segura, 2000; Molnar & White, 2001). However, this is rapidly

changing as ejidos sell their land to private landowners (Stoleson et al., 2005), typically to non-campesinos, and the cultural erosion and loss of traditional knowledge that ensues encourages loss of biodiversity (Laird, 2002).

Languages disappear for a variety of reasons: all speakers may die; speakers may succumb to pressures to speak a different language and forget their mother tongue; speakers may choose to stop speaking their native tongue because of interests in participating in national education, finding jobs that pay salaries and could come with various benefits, or marry into a family with speakers from another language. The threat to Mexico's languages includes a combination of factors such as the reduced number of speakers, their geographical dispersion, predominance of adult speakers, and trends for abandoning transmission of languages to new generations (INALI, 2012). All of this is compounded by a lack of interest or even neglect by authorities, which has led to exclusion of indigenous languages from public and institutional spaces, mass media communications such as radio and television, and their diminishing use among communities and families. Some indigenous people seem to have accepted that their languages will disappear, and they will soon be able to communicate only in Spanish (INALI, 2012), while others desire to reverse the extinction trend. And many more simply do not know what to do to save their (Mexico's) cultural heritage.

Traditional peoples have accumulated vast amounts of ecological knowledge, and that knowledge is embodied in their languages. Thus, as languages go extinct, associated traditional ecological knowledge is also lost (Oviedo et al., 2000). This happens because, in most traditional cultures, knowledge is not recorded in writing but is passed on orally to other groups or new generations. In such cases, the loss of local languages means the loss of the traditional means of knowledge transmission.

The science of biocultural diversity is in its infancy. Although we do not yet fully understand it, there is evidence of ancient and profound connections between biological and linguistic diversity. When species go extinct entire biological communities and ecosystems can be disrupted or permanently altered. Regardless of their economic, scientific and aesthetic value to humans, plant and animal species have a value of their own because of their unique evolutionary history, genomic diversity, and, ultimately, because of their very existence. When we allow languages to disappear, we squander the culture of humanity, the millennial knowledge of the natural world, and a part of our own past. The IPBES released its definitive new global synthesis of "Assessing nature's contributions to people" (Díaz et al., 2018). It is the first such report since the landmark MEA (2005) was published, and the first ever that is fully intergovernmental. It is also the first assessment to systematically include indigenous and local knowledge at a global scale.

For decades, scientists and conservationists have advocated for the establishment of protected areas to conserve ecosystems and biological diversity (Vidal, López-García, & Rendón-Salinas, 2014). But, as has been advocated for more than two decades, the world's biodiversity will only be effectively preserved by also protecting the diversity of human cultures, and vice versa (Oviedo et al., 2000; Maffi, 2001; Toledo, 2001b). Protecting areas that are implemented under participatory and co-management schemes is the most effective strategy for conserving biodiversity while improving the economic and social conditions of local communities. Conservation area networks comprising priority areas should serve as the baseline for identifying the most suitable strategies depending on the areas' socio-economic contexts and specific characteristics.

We have shown that Mexico's biocultural diversity is at crossroads. Federal, state and municipal governments, businesses, conservation organizations, philanthropists, and multilateral agencies that care about biodiversity need to realize that their resources and efforts will only be effective in the long-term if they simultaneously support protection of indigenous cultures and traditional knowledge. Given

that the regions harboring Mexico's highest biocultural diversity are considered strategic for the country's water, environmental and food security, as well as to ensuring the rights of indigenous peoples, it has recently been proposed that they should be an important component of the 2019-2024 national development plan (Luque & Ortiz Espejel, 2019). We hope this policy initiative results in concrete action to protect Mexico's unique cultural and natural heritage. Biological and cultural diversity are two sides of the same coin. Since endangered languages and endangered species strongly overlap geographically in Mexico, it makes sense to combine efforts to protect both. But time is of the essence. All constituents need to urgently reinforce efforts and significantly augment investments if we are to rescue and preserve the country's unique biocultural diversity and traditional knowledge for the benefit of present and future generations.

ACKNOWLEDGMENTS

RESUMEN

La diversidad biocultural de México en peligro. Introducción: Lugares con diversidad de especies alta contienen diversidad lingüística alta, mientras que áreas con diversidad de especies baja tienden a contener diversidad lingüística baja. **Objetivo:** Caracterizar las relaciones entre la diversidad biológica y la diversidad cultural, una correlación que ha sido examinada a escala global pero que en este trabajo es comprobada por primera vez para México. **Métodos:** Recopilamos bases de datos extensas sobre las especies y las lenguas en peligro de extinción, y revisamos la literatura disponible sobre la diversidad biocultural de México, con énfasis en las especies y lenguas en peligro y en peligro crítico de extinción. **Resultados:** Con 364 lenguas vivas, México es el quinto país más diverso lingüísticamente hablando, pero 64 de estas lenguas están en muy alto riesgo de desaparecer y 13 ya desaparecieron. México también es el cuarto país más biodiverso, pero 1 213 especies de su flora y fauna están amenazadas de extinción y al menos 127 desaparecieron recientemente. **Conclusiones:** Los pueblos indígenas son custodios de mucha de la diversidad biocultural del mundo. A medida que el mundo se vuelve menos diverso lingüística y culturalmente, también se vuelve menos diverso biológicamente. La diversidad biológica y lingüística de México muestran una marcada superposición geográfica, y los estados de Oaxaca, Chiapas, Veracruz, Guerrero y Michoacán son los que más especies y lenguajes albergan. De manera similar, los sitios en donde la biodiversidad está en mayor peligro también corresponden con los sitios en donde las lenguas lo están, y las áreas con el mayor número de especies en peligro traslapan con las áreas en donde las lenguas están en mayor peligro.

Palabras clave: idiomas, lingüística, conocimiento tradicional, pueblos indígenas, biodiversidad, México, especies en peligro de extinción, extinción.

REFERENCES

Berkes, F. (2001). Religious traditions and biodiversity. *Encyclopedia of Biodiversity, 5*, 109-120.

Beer, N., Gonzalez, S., Huddart, D., Rosales-Lopez, A., & Lamb, A. (2008, May). The palaeodiet of the Pericue Indians of the Cape region of Baja California Sur, Mexico. *Eos Transactions American Geophysical Union, 89*(23), Jt. Assem. Suppl., Abstract U54B-03.

Birchall, J., Dunn, M., & Greenhill, S.J. (2016). A combined comparative and phylogenetic analysis of the Chapacuran Language family. *International Journal of American Linguistics, 82*(3), 255-284.

Boas, F. (1917). El dialecto mexicano de Pochutla, Oaxaca. *International Journal of American Linguistics, 1*(1), 9-44. Retrieved from https://bibliotecatilcoatle.files.wordpress.com/2015/04/el-dialecto-mexicano-de-pochutla-oax-boas-2-37.pdf

Boege, E. (2008). *El patrimonio biocultural de los pueblos indígenas de México: hacia la conservación in situ de la biodiversidad y agrodiversidad en los territorios indígenas*. México: Instituto Nacional de Antropología e Historia, Comisión Nacional para el Desarrollo de Pueblos Indígenas.

Boege, E. (2009). El reto de la conservación de la biodiversidad en los territorios de los pueblos indígenas. In CONABIO, *Capital natural de México* (Vol. II): *Estado de conservación y tendencias de cambio* (pp. 603-649). México: CONABIO.

Borah, W., & Cook, S.F. (1963). *The aboriginal population of central Mexico on the eve of the Spanish conquest*. Ibero-Americana Series, No. 45. Berkeley, CA: University of California Press.

Bouckaert, R., Lemey, P., Dunn, M., Greenhill, S.J., Alekseyenko, A.V., Druimmond, A.J., . . . Atkinson, Q.D. (2012). Mapping the origins and expansion of the Indo-European language family. *Science, 337*, 957-960.

Bowen, T. (1976). *Seri Prehistory: The Archaeology of the Central Coast of Sonora, Mexico.* Anthropological Papers, No. 27. Tucson, AZ: University of Arizona Press.

Bowen, T. (2000). *Unknown Island. Seri Indians, Europeans, and San Esteban Island in the Gulf of California.* Albuquerque, NM: University of New Mexico Press.

Bowen, T. (2006). Recursos culturales de la región de las Grandes Islas en el Golfo de California. *Gaceta Ecológica (Instituto Nacional de Ecología), 81*, 19-29.

Bowen, T. (2009). *The record of Native People on Gulf of California Islands*. Arizona State Museum Archaeological Series, No. 201. Tucson, AZ: University of Arizona Press.

Brusca, R.C., Álvarez-Borrego, S., Hastings, P.A., & Findley, L.T. (2017). Colorado River flow and biological productivity in the Northern Gulf of California, Mexico. *Earth-Science Reviews, 164*, 1-30.

Brusca, R.C., Moore, W., & Shuster, S.E. (2016). *Invertebrates* (3rd ed.). Sunderland, MA: Sinauer Associates.

Bryan, J., Shearman, P., Ash, J., & Kirkpatrick, J.B. (2010). Estimating rainforest biomass stocks and carbon loss from deforestation and degradation in Papua New Guinea 1972-2002: Best estimates, uncertainties and research needs. *Journal of Environmental Management, 91*, 995-1001.

Caccavari Garza, E. (2014). Lenguas Yumanas: crisis de la diversidad lingüística en Baja California. *Revista Digital Universitaria (UNAM), 15* (2), 1-12. Retrieved from http://www.revista.unam.mx/vol.15/num2/art13/art13.pdf

Campbell, L. (1997). *American Indian languages: The historical linguistics of Native America.* New York, NY: Oxford University Press.

Comité International para la Recuperación de la Vaquita (CIRVA). (2019). Report of the Eleventh Meeting of the CIRVA, February 19-21, Southwest Fisheries Science Center. La Jolla, CA: CIRVA.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). (2008). *Capital natural de México* (Vol. I): *Conocimiento actual de la biodiversidad*. México: CONABIO.

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). (2016). *Estrategia nacional sobre la biodiversidad de México y plan de acción 2016-2030*. México: CONABIO.

Cook, S.F., & Borah, W. (1960). *The Indian population of central Mexico, 1531-1610*. Berkeley, CA: University of California Press.

Corlett, R.T., & Primack, R.B. (2010). *Tropical rain forests: An ecological and biogeographical comparison.* Malden, MA: Blackwell Publishing.

Cunningham, A.B. (2001). *Applied ethnobotany: People, wild plant uses and conservation.* London, U.K.: Earthscan.

Dávila, P., Arizmendi, M.C., Valiente-Banuet, A., Villaseñor, J.L., Casas, A., & Lira, R. (2002). Biological diversity in the Tehuacán-Cuicatlán valley, Mexico. *Biodiversity and Conservation, 11*, 421-442.

De Ávila Blomberg, A. (2004). La clasificación de la vida en las lenguas de Oaxaca. In A.J. García-Mendoza, M.J. Ordoñez, & M. Briones-Salas (Eds.), *Biodiversidad de Oaxaca* (pp. 481-539). México: Instituto de Biología UNAM, Fondo Oaxaqueño para la Conservación de la Naturaleza, World Wildlife Fund.

Diario Oficial de la Federación. (2008). Catálogo de las lenguas indígenas nacionales: variantes lingüísticas de México con sus autodenominaciones y referencias geoestadísticas. Ciudad de México, México: Instituto Nacional de Lenguas Indígenas (INALI).

Diario Oficial de la Federación. (2010a). *Programa de revitalización, fortalecimiento y desarrollo de las lenguas indígenas nacionales 2008-2012, PINALI.* Ciudad de México, México: Instituto Nacional de Lenguas Indígenas (INALI).

Diario Oficial de la Federación. (2010b). *NORMA Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo*. Ciudad de México, México: Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., . . . Shirayama, Y. (2018). Assessing nature's contributions to people. *Science, 359*(6373), 270-272.

Rev. Biol. Trop. (Int. J. Trop. Biol.) Vol. 68(2): 669-691, June 2020

687

Dobyns, H.F. (1993). Disease transfer at contact. *Annual Reviews of Anthropology, 22*, 273-291.

Dunn, M. (2014). Language phylogenies. In C. Bowern, & B. Evans (Eds.), *Routledge Handbook of Historical Linguistics* (pp. 190-211). New York, NY: Routledge.

Felger, R.S., & Moser, M.B. (1987). Sea turtles in Seri Indian culture. *Environment Southwest, Autumn*, 18-21.

Felger, R.S., Nichols, W.J., & Seminoff, J.A. (2005). Sea turtles in northwestern Mexico: Conservation, ethno-biology, and desperation. In J.E. Cartron, G. Ceballos, & R.S. Felger (Eds.), *Biodiversity, Ecosystems, and Conservation in Northern Mexico* (pp. 405-424). New York, NY: Oxford University Press.

Fincher, C.L., & Thornhill, R. (2008). A parasite-driven wedge: Infectious diseases may explain language and other biodiversity. *Oikos, 117*, 1289-1297.

Fujita, H. (2006). The Cape region. In D. Laylander & J.D. Moore (Eds.), *The Prehistory of Baja California: Advances in the Archaeology of the Forgotten Peninsula* (pp. 82-98). Gainesville, FL: University Press of Florida.

García-Mendoza, A.J., Ordoñez, M.J., & Briones-Salas, M. (Eds.). (2004). *Biodiversidad de Oaxaca.* Ciudad de México, México: Universidad Nacional Autónoma de México.

Gavin, M.C., Botero, C.A., Bowern, C., Colwell, R.K., Dunn, M., Dunn, R.R., … Yanega, G. (2013). Toward a mechanistic understanding of linguistic diversity. *BioScience, 63*, 524-535.

Gavin, M.C., McCarter, J., Mead, A., Berkes, F., Stepp, J.R., Peterson, D., & Tang, R. (2015). Defining biocultural approaches to conservation. *Trends in Ecology & Evolution, 30*(3), 140-145.

Global Forest Watch [Website]. (2018). Retrieved from https://www.globalforestwatch.org/

Gonzalez-Pérez, G., Briones-Salas, M., & Alfaro, A.M. (2004). Integración del conocimiento faunístico del estado. In A.J. García-Mendoza, M.J. Ordoñez, & M. Briones-Salas (Eds.), *Biodiversidad de Oaxaca* (pp. 449-466). México: Instituto de Biología UNAM, Fondo Oaxaqueño para la Conservación de la Naturaleza, World Wildlife Fund.

Gorenflo, L.J., Romaine, S., Mittermeier, R.A., & Walker-Painemilla, K. (2012). Co-occurrence of linguistic and biological diversity in biodiversity hotspots and high biodiversity wilderness areas. *Proceedings of the National Academy of Sciences, 109*(21), 8032-8037.

Gray, R.D., Quentin, D., & Greenhill, S.J. (2018). Language evolution and human history: What a difference a date makes. *Philosophical Transactions of The Royal Society B: Biological Sciences, 366*(1567), 1090-1100.

Hamilton, M.J, Milne, B.T., Walker, R.S., Burger, O., & Brown, J.H. (2007). The complex structure of hunter-gatherer social networks. *Proceedings of the Royal Society B: Biological Sciences, 274*(1622), 2195-2203.

Hammarström, H., Forkel, R., & Haspelmath, M. (Eds.). (2018). Glottolog 3.3 [Software]. Available from http://glottolog.org

Harmon, D. (1995). The status of the world's languages as reported in 'Ethnologue.' *Southwest Journal of Linguistics, 14*, 1-28.

Harmon, D. (1996). Losing species, losing languages: Connections between linguistic and biological diversity. *Southwest Journal of Linguistics, 15*, 89-108.

Harmon, D., & Loh, J. (2010). The index of linguistic diversity: A new quantitative measure of trends in the status of the world's languages. *Language, Documentation and Conservation, 4*, 97-151.

Harrison, K.D. (2007). *When languages die: The extinction of the world's languages and the erosion of human knowledge.* London, U.K.: Oxford University Press.

Holt, D. (2001). Valedictory: Lino de la Rosa. *Ogmios Newsletter of Foundation for Endangered Languages 2.4, 16*, 30. Retrieved from https://www.ogmios.org/ogmios/

Instituto Nacional de Lenguas Indígenas (INALI). (2010). *Proyecto de documentación inicial de la lengua ku'ahl* (Informe Ejecutivo, Contrato INALI.C.B.17/020/2010). México: INALI. Retrieved from http://site.inali.gob.mx/pdf/estudios_opiniones/Documentacion_kuahl.pdf

Instituto Nacional de Lenguas Indígenas (INALI). (2012). *Lenguas indígenas nacionales en riesgo de desaparición: Variantes lingüísticas por grado de riesgo*. A. Embriz Osorio & O. Zamora Alarcón (Coords.). México: INALI.

Instituto Nacional de Estadística y Geografía (INEGI). (2010). *Censo de población y vivienda 2010*. México: INEGI. Retrieved from https://www.beta.inegi.org.mx/proyectos/ccpv/2010/

Instituto Nacional de Estadística y Geografía (INEGI). (2015). *Resultados de la encuesta intercensal 2015. Tabulados básicos.* México: INEGI. Retrieved from https://www.inegi.org.mx/est/contenidos/Proyectos/encuestas/hogares/especiales/ ei2015/

Inter-American Commission on Human Rights. (2009). *Indigenous and tribal peoples' rights over their ancestral lands and natural resources* (OEA/Ser.L/V/II, Doc. 56/09, 30 December 2009). Washington, DC: OAS. Retrieved from http://cidh.org/countryrep/Indigenous-Lands09/TOC.htm

International Union for the Conservation of Nature (IUCN). (2018). The IUCN Red List of Threatened Species. Version 2018-2 [Website]. Retrieved October 09, 2018 from https://www.iucnredlist.org/

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2018). *The IPBES regional assessment report on biodiversity and ecosystem services for the Americas*. J. Rice, C.S. Seixas, M.E. Zaccagnini, M. Bedoya-Gaitán, & N. Valderrama (Eds.). Bonn, Germany: Secretariat of the IPBES.

Jones, K.R., Venter, O.P., Fuller, R.A., Allan, J.R., Maxwell, S.L., Negret, P.J., & Watson, J.E.M. (2018). One-third of global protected land is under intense human pressure. *Science, 360*(6390), 788-791.

Kerr, J.T., & Packer, L. (1997). Habitat heterogeneity as a determinant of mammal species richness. *Nature, 385*(6613), 252-254.

Knab, T. (1980). When is a language really dead: The case of Pochutec. *International Journal of American Linguistics, 46*(3), 230-233. https://doi.org/10.1086/465658

Koch, A., Brierley, C., Maslin, M.M., & Lewis, S.L. (2019). Earth system impacts of the European arrival and great dying in the Americas after 1492. *Quaternary Science Reviews, 207*, 13-36.

Laird, S.A. (Ed.). (2002). *Biodiversity and traditional knowledge: Equitable partnerships in practice*. London, U.K.: Earthscan Publications.

Lewis, M., Simons, P.G.F., & Fennig, C.D. (2016). *Ethnologue: Languages of the world* (19th ed.)*. Dallas, TX: SIL International.

Lionnet, A. (1978). *El idioma Tubar y los Tubares*. Ciudad de México, México: Universidad Iberoamericana.

Lionnet, A. (1986). *El Eudeve: Un idioma extinto de Sonora*. Ciudad de México, México: Universidad Nacional Autónoma de México.

Loh, J., & Harmon, D. (2005). A global index of biocultural diversity. *Ecological Indicators, 5*, 231-241.

Loh, J., & Harmon, D. (2014). *Biocultural diversity: Threatened species, endangered languages*. Zeist, The Netherlands: WWF Netherlands.

Luque, D., & Ortiz Espejel, B. (2019). *Hacia una política de bienestar comunitario de pueblos indígenas y comunidades equiparables en regiones de alta densidad biocultural de México* (Propuesta elaborada por la Red Temática CONACYT Patrimonio Biocultural de México). México: CONACYT.

Maffi, L. (1998). Language: A resource for nature. *Nature and Resources: The UNESCO Journal on the Environment and Natural Resources Research, 34*, 12-21.

Maffi, L. (Ed.). (2001). *On biocultural diversity: Linking language, knowledge and the environment*. Washington, DC: Smithsonian Institution Press.

Maffi, L. (2005). Linguistic, cultural, and biological diversity. *Annual Reviews of Anthropology, 29*, 599-617.

Marlett, C.M. (2014). *Shells on a desert shore: Mollusks in the Seri world*. Tucson, AZ: University of Arizona Press.

McCaa, R. (1995). Spanish and Nahuatl views on smallpox and demographic catastrophe in Mexico. *Journal of Interdisciplinary History, 25*, 397-431.

Millennium Ecosystem Assessment (MEA). (2005). *Ecosystems and human well-being: Synthesis*. Washington, DC: Island Press.

Mittermeier, R.A., & Mittermeier, C.G. (1992). La importancia de la diversidad biológica de México. In J. Sarukhán & R. Dirzo (Eds.), *México ante los retos de la biodiversidad* (pp. 6373). Ciudad de México, México: CONABIO.

Mittermeier, R.A., Myers, N., Gil, P.R., & Mittermeier, C.G. 1999. *Hotspots: Earth's biologically richest and most endangered terrestrial ecoregions*. Monterrey, México: Cemex, Conservation International, Agrupación Sierra Madre.

Mixco, M.J. (1978). *Cochimí and Proto-Yuman: Lexical and syntactic evidence for a new language family in Lower California. University of Utah Anthropological Papers 101*. Salt Lake City, UT: University of Utah Press.

Molina Cruz, M. (2010). *La recuperación de la lengua Xuani-Ixcateca de Oaxaca, a través del video* (Tesis de Licenciatura). Universidad Pedagógica Nacional Unidad Ajusco, México.

Molnar, A., & White, T.A. (2001). Forestry and land management. In M.M. Giugale, O. Lafourcade, & V.H. Nguyen (Eds.), *Mexico: A comprehensive development agenda for the new era* (pp. 669-690). Washington, DC: World Bank.

Moore, J.L., Manne, L., Brooks, T., Burgess, N.D., Davies, R., Rahbek, C., . . . Balmford, A. (2002). The distribution of cultural and biological diversity in Africa. *Proceedings of the Royal Society B: Biological Sciences, 269*(1501), 1645-1653.

Mora, C., Tittensor, D.P., Adl, S., Simpson, A.G.B., & Worm, B. (2011). How many species are there on Earth and in the ocean? *PLoS Biology, 9*(8), e1001127. https://doi.org/10.1371/journal.pbio.1001127

Mühlháusler, P. (1995). *The Politics of Multiculturalism in the Asia/Pacific*. Darwin, Australia: Northern Territory University Press.

Rev. Biol. Trop. (Int. J. Trop. Biol.) Vol. 68(2): 669-691, June 2020

689

Raygorodetsky, G. (2018). Indigenous peoples defend Earth's biodiversity—but they're in danger. Retrieved November 17, 2018, from https://www.nationalgeographic.com/environment/2018/11/can-indigenous-land-stewardship-protect-biodiversity-/

Nettle, D. (1996). Language diversity in West Africa: An ecological approach. *Journal of Anthropologic Archaeology, 15*, 403-438.

Nettle, D. (1999a). Is the rate of linguistic change constant? *Lingua, 108*, 119-136.

Nettle, D. (1999b). *Linguistic diversity.* New York, NY: Oxford University Press.

Nettle, D., & Romaine, S. (2000). *Vanishing Voices.* New York, NY: Oxford University Press.

Nolasco Armas, M. (1982). De nómadas cazadores y recolectores a aldeas agrícolas indiferenciadas (el caso del noroeste de México). *Anales de Antropología, 19*, 59-72.

Ordoñez, M.J. (2004). El territorio. In A.J. García-Mendoza, M.J. Ordoñe, & M. Briones-Salas (Eds.), *Biodiversidad de Oaxaca* (pp. 469-479). México: Instituto de Biología UNAM, Fondo Oaxaqueño para la Conservación de la Naturaleza, World Wildlife Fund.

Oviedo, G., Maffi, L., & Larsen, P.B. (2000). *Indigenous and traditional peoples of the world ecoregion conservation. An integrated approach to conserving the world's biological and cultural diversity.* Gland, Switzerland: World Wide Fund for Nature International.

Papua New Guinea's Fifth National Report to the Convention on Biological Diversity. (2014). Port Moresby, Papua New Guinea: Government of Papua New Guinea.

Perales, H.R., & Aguirre, J.R. (2008). Biodiversidad humanizada. In CONABIO, *Capital Natural de México* (Vol. I): *Conocimiento actual de la biodiversidad* (pp. 565-603). México: CONABIO.

Peterson A.T., Tian, H., Martínez-Meyer, E., Soberón, J., & Sánchez-Cordero, V. (2005). Modeling ecosystems shifts and individual species distribution shifts. In T. Lovejoy & L. Hannah (Eds.), *Climate change and biodiversity* (pp. 45-78). Washington, DC: Smithsonian Institution Press.

Pōmaika'i McGregor. D. (1999). Research in action: Ethnohistory of Puna. *Social Process in Hawaii. 39*, 181-207.

Posey, D.A. (1999). Cultural and spiritual values of biodiversity. A complementary contribution to the global biodiversity assessment. In D.A. Posey (Ed.), *Cultural and Spiritual Values of Biodiversity* (pp. 1-19). London, U.K: UNEP and Intermediate Technology Publications.

Prieto-Amparán, J.A., Villarreal-Guerrero, F., Martínez-Salvador, M., Manjarrez-Domínguez, C., Vázquez-Quintero, G., & Pinedo-Álvarez, A. (2019). Spatial near future modeling of land use and land cover changes in the temperate forests of Mexico. *PeerJ Preprints, 7*, e27542v1 https://doi.org/10.7287/peerj.preprints.27542v1.

Primack, R.C., & Vidal, O. (2019). *Introducción a la biología de la conservación.* Ciudad de México, México: Fondo de Cultura Económica, Ediciones Científicas Universitarias.

Renfrew, C. (1994). World linguistic diversity. *Scientific American, 270*, 116-123.

Rojas-Bracho, L., Brusca, R.C., Álvarez-Borrego, S., Brownell Jr., R.L., Camacho-Ibar, V., Ceballos, G., . . . Taylor, B.L. (2018). Unsubstantiated scientific claims can lead to tragic conservation outcomes. *BioScience*, 69(1), 12-14.

Sanders, W.T., Pasons, J.R., & Santley, R.S. (1979). *The basin of Mexico: The ecological processes in the evolution of a civilization.* New York, NY: Academic Press.

Sarukhán, J., Koleff, P., Carabias, J., Soberón, J., Dirzo, R., Llorente-Bousquets, J., . . . García Méndez, G. (2017). *Capital natural de México. Síntesis: evaluación del conocimiento y tendencias de cambio, perspectivas de sustentabilidad, capacidades humanas e institucionales.* México: CONABIO.

Segura, G. (2000, May). Mexico's forest sector and policies: A general perspective. *Constituting the Commons: Crafting Sustainable Commons in the New Millennium.* Paper presented at the International Association for the Study of Common Property (IASCP) Biennial Conference, Bloomington, IN.

Shengji, P. (1999). The holy hills of the Dai. In D.A. Posey (Ed.), *Cultural and Spiritual Values of Biodiversity* (pp. 381-382). London, U.K.: UNEP and Intermediate Technology Publications.

Simons, G.F., & Fennig, C.D. (Eds.). (2018). *Ethnologue: languages of the world* (21st ed.).* Dallas, TX: SIL International. Retrieved from https://www.ethnologue.com/ethnoblog/gary-simons/welcome-21st-edition

Stepp, J.R., Cervone, S., Castaneda, H., Lasseter, A., Stocks, G., & Gichon, Y. (2004). Development of a GIS for global biocultural diversity. *Policy Matters, 13*, 267-270.

Stoleson, S.H., Felger, R.S., Ceballos, G., Raish, C., Wilson, M.F., & Búrquez, A. (2005). Recent history of natural resource and population growth in northern Mexico. In J.E. Cartron, G. Ceballos, & R.S. Felger (Eds.), *Biodiversity, Ecosystems, and Conservation in*

Northern Mexico (pp. 52-86). New York, NY: Oxford University Press.

Sutherland, W.J. (2003). Parallel extinction risk and global distribution of languages and species. *Nature, 423*, 276-279.

Thomas, L., Jaramillo-Legorreta, A., Cárdenas-Hinojosa, G., Nieto-García, E., Rojas-Bracho, L., Ver Hoef, J.M., . . . Tregenza, N. (2017). Last call: Passive acoustic monitoring shows continued rapid decline of critically endangered vaquita. *Journal of the Acoustic Society of America, 142*(5), EL512-EL517.

Toledo, V.M. (1994). Biodiversity and cultural diversity in Mexico. *Different Drummer, 1*(3), 16-19.

Toledo, V.M. (2001a). Biocultural diversity and local power in Mexico. In L. Maffi (Ed.), *On biocultural diversity: Linking language, knowledge and the environment* (pp. 472-488). Washington, DC: Smithsonian Institution Press.

Toledo, V.M. (2001b). Indigenous peoples and biodiversity. In S.A. Levin (Ed.), *Enciclopedia of Biodiversity* (pp. 451-463). San Diego, CA: Academic Press.

Toledo, V.M., Alarcón-Chaires, P., Moguel, P., Olivo, M., Cabrera, A., Leyequien, E., & Rodríguez-Aldabe, A. (2001). El atlas etnoecológico de México y Centroamérica: fundamentos, métodos y resultados. *Etnoecológica, 6*(8), 7-41.

Toledo, V.M., & Barrera-Bassols, N. (2008). *La memoria biocultural: La importancia ecológica de las sabidurías tradicionales*. Barcelona, Spain: Icaria Editorial, S.A.

Toledo, V.M., Boege, E., & Carrera-Bassols, N. (2010). The Biocultural heritage of Mexico: An overview. *Langscape, 2*(6), 7-13.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2010). *Atlas of the world's languages in danger*. Paris, France: UNESCO.

Vidal, O. (1995). Population biology and incidental mortality of the vaquita, *Phocoena sinus*. *Reports of the International Whaling Commission, Special Issue, 16*, 247-272.

Vidal, O., López-García, J., & Rendón-Salinas, E. (2014). Trends in deforestation and forest degradation after a decade of monitoring in the monarch butterfly biosphere reserve in Mexico. *Conservation Biology, 28*, 177-186.

Villaseñor, J.L. (2016). Checklist of the native vascular plants of Mexico. *Revista Mexicana de Biodiversidad, 84*, 559-902.

Whitmore, T.M., & Turner, B.L. (1992). Landscapes of cultivation in Mesoamerica on the eve of the conquest. *Annals of the Association of American Geographers, 82*, 402-425.

Wiersum, K.F. (2004). Use and conservation of biodiversity in East African forested landscapes. In P.A. Zuidema (Ed.), *Tropical forests in multi-functional landscapes. Proceedings of Seminar Series Issues in International Nature Conservation* (pp. 33-39). Utrecht, The Netherlands: Utrecht University Prince Bernard Centre for International Nature Conservation.

Rev. Biol. Trop. (Int. J. Trop. Biol.) Vol. 68(2): 669-691, June 2020

691