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Linguistic, Cultural, and Biological Diversity: Patterns, Processes, and Prospects

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Abstract

Linguistic, cultural and biological diversity often co-occur and frequently decline under similar pressures. This review synthesizes recent evidence on the patterns, processes and prospects of this intertwined diversity. The paper outlines historical roots of the field and summarize contemporary research that maps spatial overlap between biodiversity hotspots and language richness, examines scale effects and links language vitality with traditional ecological knowledge. The review clarifies philosophical and ethical foundations, emphasizing justice, rights, epistemic pluralism and stewardship. It then surveys methods for measuring trends including linguistic vitality indices, practice-based indicators and biocultural dashboards co-designed with communities. Policy connections are highlighted through evolving international frameworks that call for inclusive governance, secure tenure, mother-tongue education and locally led monitoring. Practical pathways include recognition of indigenous and community land and sea rights, partnership models for protected and conserved areas, community-based monitoring using multiple knowledge systems and support for culturally grounded livelihoods. The findings demonstrate the need for plural and functional metrics, direct and sustained finance to local institutions, safeguards for data sovereignty and implementation that links global targets to place-based action that can sustain diversity in nature, languages and cultures.

Keywords: Biocultural Diversity, Linguistic Diversity, Biological Diversity, Language Endangerment, Traditional Ecological Knowledge (TEK), Biodiversity Hotspots, Cultural Keystone Species

Introduction

Nature and culture are deeply connected. Many places that hold large numbers of species also hold many languages and rich knowledge systems. These forms of diversity often grow together and decline together. The term *biocultural diversity* helps us see this linked pattern and think about how to protect it. Early syntheses argued that the loss of languages and local knowledge is tied to the loss of species and habitats and that both kinds

of diversity support human well-being and the ability of societies to adapt (Maffi, 2005).

Since around 2010, the field has changed in three important ways. First, new global datasets and mapping tools allow researchers to compare where species and languages occur and where they are at risk. A widely cited analysis showed that almost half of the world's languages fall within biodiversity hotspots and that many of these languages are spoken by relatively small populations, which increases endangerment (Gorenflo et al., 2012). This type of evidence encourages planners to consider language and culture when designing conservation actions. Second, conservation science has articulated "biocultural approaches." These approaches join ecological aims with respect for rights, local institutions and values. They call for partnership, equity, multiple knowledge systems and learning by doing (Gavin et al., 2015; Sterling et al., 2017). Third, international policy has begun to recognize the roles of indigenous peoples and local communities (IPLCs) in sustaining biodiversity and nature's contributions to people. The IPBES Global Assessment emphasized that lands managed by IPLCs often show better biodiversity outcomes and that their governance and knowledge are central to solutions (IPBES, 2019). In 2022, the Kunming–Montreal Global Biodiversity Framework (GBF) set goals and targets for 2030 that include participation, rights and knowledge in conservation and restoration (CBD, 2022).

Why does the link between languages, cultures and species matter? Languages carry names, classifications and stories about local plants, animals and places. Communities use this knowledge to guide hunting and fishing rules, seasonal harvests, seed selection, fire management and many other practices. When languages decline, schools discourage local knowledge or land access is reduced, such practices are harder to maintain. This can weaken both social and ecological resilience. By contrast, when language use is strong and communities have secure land and institutions, knowledge can be transmitted and adapted and ecosystems can remain healthy (Sterling et al., 2017).

At the same time, the field still has practical and conceptual problems. The overlap between places rich in species and places rich in languages is clear at the global level but it often becomes weaker when we zoom in to smaller areas because of local histories of settlement, migration and policy. Global maps can guide high-level priorities, but effective action must be grounded in local histories, institutions and governance (Gorenflo et al., 2012). Data on language vitality and traditional ecological knowledge (TEK) are improving, yet remain uneven across regions. Therefore, indicators should be co-designed with communities to measure what matters most in each place. Policy documents now talk more about rights and knowledge but making these ideas real needs funding, legal reforms and fair power-sharing (CBD, 2022; IPBES, 2019).

This review has three aims. First, it gathers evidence on patterns: where and how linguistic, cultural and biological diversity co-occur. Second, it explains processes: the social-ecological dynamics that link gains or losses in these forms of diversity. Third, it

outlines prospects: practical steps and policy pathways to protect and maintain biocultural diversity with justice. The focus is given on recent peer-reviewed studies, international assessments and toolkits for measurement and monitoring while acknowledging classical syntheses that shaped the field (Maffi, 2005; Gorenflo et al., 2012; Gavin et al., 2015; IPBES, 2019; Sterling et al., 2017; CBD, 2022). The review supports readers from multiple disciplines and regions.

Historical Background and Context

Ideas that link languages, cultures and species have deep roots in the history of science and the humanities. In biology, Darwin (1859) emphasized variation as the raw material of evolution and argued that selection operates on diverse forms shaped by local conditions. His legacy helped make "diversity" central to explanations of life's patterns and to later conservation thinking (Darwin, 1871). In linguistics and anthropology, classic works by Sapir and Whorf highlighted how language relates to perception and knowledge—often called linguistic relativity (Sapir, 1912; Whorf, 1940). Although debated and refined, this tradition kept attention on how languages encode categories, relationships and place-based understandings of the environment, themes that would later reappear in biocultural research.

The immediate intellectual precursors of biocultural diversity arose in the late twentieth century. In the early 1990s, linguists warned that many of the world's languages—especially those spoken by small Indigenous and minority communities—were being rapidly replaced by national and global languages; estimates projected that 50–90% of 6,000+ languages could be lost by 2100 (Hale et al., 1992; Krauss, 1992). This "language endangerment" call explicitly drew parallels with biodiversity loss and urged similarly urgent, coordinated responses. Conservationists and social scientists working in parallel were also pointing to common threats to cultural and biological diversity and invoking the 1988 Declaration of Belém's statement about an "inextricable link" between culture and nature.

By the mid-1990s, these strands converged under the term biocultural diversity, defined as the diversity of life in all its manifestations—biological, cultural and linguistic—interrelated within a complex socio-ecological adaptive system. A catalytic moment was the 1996 international working conference "Endangered Languages, Endangered Knowledge, Endangered Environments," and the founding of Terralingua the same year to promote research, education, policy and field practice on biocultural diversity. From this convergence, a multifaceted field with both theoretical and applied dimensions began to develop much like conservation biology had emerged earlier in response to the biodiversity crisis. Early syntheses revisited the analogy between species and languages and produced global comparisons of their distributions. Harmon's work became especially influential: he

reviewed the state of linguistic diversity, mapped overlaps with biodiversity and framed the "converging extinction crises," treating loss of "language richness" as a proxy for loss of "cultural richness" and asking why humanity should care (Harmon, 2002).

Methodological advances followed quickly. Using global datasets on languages, ethnic groups, religions, and major taxa (plants, birds, and mammals), Harmon and Loh (2010) created the Index of Biocultural Diversity (IBCD). The IBCD reports each country's raw richness, along with versions normalized by land area and by population size. The authors stressed that the index is designed to reveal broad patterns, not to direct fine-scale, site-level decisions. Subsequent geospatial research moved from illustration to hypothesis testing: Stepp and colleagues standardized biodiversity data into global "diversity zones" and found strong correlations between linguistic diversity and vascular plant diversity—especially in the tropics—while also noting links with low human population density and calling for regionally and historically informed studies. At the same time, critiques and refinements appeared. Manne (2003) showed that congruence weakens at finer spatial resolutions in parts of the Americas and argued for standardized, comparable methods across scales. Together, these studies established a durable lesson: global overlaps are useful for initial screening, but explanation and planning require sub-global analyses attentive to history, governance, and social processes. Parallel conceptual work emphasized mechanisms. Nichols (1992) related lineage diversity to low latitude, coastlines, high rainfall and mountains, while showing how large-scale economies and historical expansions reduce diversity—especially in the old World. Others highlighted "sympatric" linguistic boundary formation—distinct languages developing among interacting groups in shared ecologies—pointing to sociocultural processes alongside biogeography (Mühlhäusler, 1996; Hill et al., 1998).

By the early 2000s, the field had a recognizable agenda: document and explain spatial correlations; build ethical arguments for why diversity matters; and design tools and institutions to protect it. UNESCO processes on language vitality and the growing presence of biocultural language in conservation policy arenas, reinforced this trajectory (UNESCO, 2003). In short, classical ideas about variation and knowledge (Darwin, 1859; Sapir, 1912; Whorf, 1940) and late-twentieth-century alarms about endangerment converged into an integrated, transdisciplinary field that treats linguistic, cultural and biological diversity as interdependent and worthy of joint stewardship (Maffi, 2005).

Evolution of Research Programs

Research on biocultural diversity has grown fast in the past 15 years. The field has shifted from broad ideas to robust evidence, practical methods and policy relevance. One major line of research maps where languages and species overlap. A prominent global study overlaid language maps with biodiversity hotspots and remaining wild areas. It

showed that nearly half of the world's languages fall within these regions and many have few speakers, indicating risk (Gorenflo et al., 2012). This supports the view that history and ecology shape both nature and languages. However, the fit is weaker at fine scales because language homelands and species ranges respond differently to migration, government policy and markets. As a result, the field now uses a "scale-aware" strategy: use global maps to select broad priority regions, then examine local history, institutions and governance before acting (Gorenflo et al., 2012).

A second line of work clarifies what "biocultural approaches" mean in day-to-day conservation. Drawing on community conservation, co-management and social–ecological systems, Gavin and colleagues (2015) articulated principles about rights and responsibilities, strong local institutions, fairness and co-produced knowledge. Their contribution did two things: it translated biocultural ideas into a practical design and it defined success as achieving positive outcomes for both biodiversity and cultural well-being. Building on this, Sterling and co-authors (2017) called for indicators that capture two-way links between ecosystems and culture and for participatory processes that tie measurement to decisions. Together, these studies turn biocultural theory into workable governance with clear accountability and iterative learning (Gavin et al., 2015; Sterling et al., 2017).

A third line of research connects language vitality, traditional ecological knowledge (TEK) and community resilience. Reviews in ecology and conservation argue for closer engagement with Indigenous and local knowledge to understand long-term ecosystem change, disturbance management and feedbacks between people and nature (Molnár, & Babai, 2021). The evidence reveals a consistent pattern: when children stop using their local language, or when schools devalue it, the transmission of TEK from elders to youth weakens. In contrast, mother-tongue education, community media in the local language and secure rights to land and sea strengthen languages, sustain intergenerational knowledge transfer and support good environmental stewardship. Within this work, narrative is both a method and a focus: Indigenous storytelling conveys ethics, place-based baselines and practices and can guide conservation when led and owned by communities (Fernández-Llamazares & Cabeza, 2018). The Multiple Evidence Base approach further structures respectful collaboration among scientific, Indigenous and local knowledge systems by treating them as complementary and equally valid for decision-making (Tengö et al., 2014).

A fourth line develops indicators and assessments to track change and guide resource allocation, linking local priorities to regional and national reporting while informing everyday management. Early composite indices highlighted country-level patterns and raised policy awareness; current efforts favor finer-grained, co-designed indicators that reflect language use in governance, youth participation in knowledge transmission, access to land and resources and trends in culturally important species (Sterling et al., 2017). Methodologically, the field is becoming more rigorous and participatory. Spatial studies now

use standardized biodiversity layers, harmonized language datasets and transparent assumptions. Mixed-methods designs integrate GIS, ethnography and community monitoring to link patterns to processes. This attention to method addresses key critiques: avoiding simplistic proxies (e.g., treating language counts as "culture"), ensuring free, prior and informed consent and sharing benefits fairly in research partnerships (Gavin et al., 2015; Sterling et al., 2017).

Policy linkages are another hallmark of current research. Although many papers remain empirical or conceptual, they increasingly connect to global frameworks that shape finance and national strategies. Analyses of the Kunming–Montreal Global Biodiversity Framework (GBF) clarify its goals and targets and highlight explicit references to the roles, rights and knowledge of indigenous peoples and local communities—opening space for biocultural indicators and locally led governance in national biodiversity strategies (Stephens, 2023). This bridge between research and policy matters because it provides "hooks" for governments to adopt participatory monitoring, recognize Indigenous and community conserved areas and align conservation finance with cultural continuity.

Across these streams, several debates guide ongoing work. One debate concerns measurement: the field must avoid romantic or reductionist proxies and instead capture function—how language is used in daily life and decision-making, how knowledge is taught and how governance supports or suppresses stewardship. Another concerns power: biocultural projects succeed when they are locally led, respect data sovereignty and ensure that partnerships meet community-defined goals. A third concerns generalization: global patterns are compelling but solutions must be tailored to the specific histories and institutions of each place (Gavin et al., 2015; Sterling et al., 2017; Molnár, & Babai, 2021).

Emerging directions are visible. First, multi-scalar planning links coarse global screens to fine-grained regional analyses co-led with rightsholders, turning maps into context-sensitive strategies (Gorenflo et al., 2012). Second, plural metrics and data governance connect community-owned indicators to national reporting, building legitimacy and use for decisions (Sterling et al., 2017). Third, culture-based pathways—language revitalization in schools and media, storytelling in conservation and support for culturally grounded livelihoods—align ecological goals with dignity and self-determination (Fernández-Llamazares & Cabeza, 2018; Gavin et al., 2015). Overall, the field now treats biocultural diversity not only as a pattern to be mapped but as a relationship to be maintained. Evidence suggests that when rights, institutions and knowledge systems are respected and resourced, ecological and social outcomes improve together (Gavin et al., 2015; Sterling et al., 2017; Molnár, & Babai, 2021; Stephens, 2023).

Conceptual and Normative Foundations

The field of biocultural diversity rests on a simple idea with deep roots: diversity

is a basic condition of life and it spans nature, culture and language. Classic biology framed why diversity matters for evolution and adaptation (Darwin, 1859, 1871). Classic linguistics linked language, thought and knowledge of the environment, showing that speech communities organize perception and practice in place (Sapir, 1912; Whorf, 1940). Building on these traditions, biocultural scholars argue that the many forms of life—species, cultures and languages—are interrelated within a socio-ecological system and should be understood and cared for together (Maffi, 2005).

Within this field, Harmon's work provides the most systematic treatment of philosophical and ethical foundations. He reviewed evidence for global overlaps between linguistic and biological diversity and proposed that the loss of "language richness" can serve, with care, as a proxy for the loss of "cultural richness." On that basis, he asked the core normative question: if diversity in nature and culture is declining, why should we care? (Harmon, 2002). Harmon's answer draws on philosophy, biology, psychology and linguistics: intertwined diversity in nature and culture is the "preeminent fact of existence," and reducing it would interrupt the historical and evolutionary flow that sustains life (Harmon, 2002). Other authors echo this view by treating linguistic and cultural diversity as keeping options alive for the future and by warning that convergence toward a single cultural model narrows the pool of ideas needed to solve social and environmental problems (Maffi, 2005).

This ethical stance leads to three linked commitments. The First is justice and rights. International debates have increasingly connected human rights—especially the collective rights of indigenous peoples and minorities to land, resources, culture and language—to the protection of biodiversity. This rights framing ties individual and collective rights to shared responsibilities for stewardship of nature and culture (Maffi, 2005). The second is epistemic pluralism. Knowledge is multiple: scientific, indigenous and local. Each hold valid insights and rules for care. Early biocultural work highlighted how languages encode environmental classifications and practices, from plant and animal names to land-use rules which are vital for sustaining ecosystems (Sapir, 1912; Whorf, 1940).

The third is responsibility and participation. Research and practice should be grounded in partnerships with the communities whose languages and lands are at risk; many effective efforts to maintain linguistic, cultural and biological diversity arise from local, grassroots action rather than top-down programs (Maffi, 2005). Biocultural ethics also include cautions. Measures such as language counts are useful for awareness and coarse comparison but they cannot replace careful qualitative understanding of meanings, governance and power. Composite indices should be used to communicate general conditions and trends, not to make fine-scale decisions; they work best when combined with locally grounded knowledge and participation. Moreover, advocacy must avoid instrumentalizing culture; instead, it should support community-defined goals and control

over knowledge.

In sum, the philosophical and ethical underpinnings of biocultural diversity unite classical insights about variation and meaning with a contemporary rights-based and partnership-based ethic. The resulting view treats diversity as intrinsically valuable, as a source of adaptive capacity and as a shared responsibility. Protecting languages, cultures and species is therefore not only a scientific or policy task; it is a moral project aimed at sustaining the conditions that make human and nonhuman life flourish (Maffi, 2005).

Worldwide and Local Patterns in Language–Biodiversity

The co-occurrence of linguistic and biological diversity is now one of the most robust patterns in sustainability science. A generation of work has moved from evocative global maps to finer-scale analyses that examine mechanisms, risks and governance. Recent studies refine three core insights. First, areas rich in species frequently align with areas rich in languages but the strength of congruence depends on spatial scale and history. Second, language endangerment is often concentrated in environmentally distinctive regions where biodiversity is also at risk, creating "double jeopardy." Third, indigenous peoples' and local communities' lands remain central to maintaining both forms of diversity, though outcomes depend on rights, institutions and pressures. Together, these insights shape today's biocultural research and practice.

Global analyses still provide the clearest entry point. By overlaying biodiversity hotspots and high-biodiversity wilderness areas with language distributions, a landmark study found that nearly half of the world's languages fall inside these regions and that many have small speaker populations, a proxy for vulnerability (Gorenflo et al., 2012). The basic pattern still holds as datasets improve. Studies that use newer species layers and language data continue to show that languages and species often occur in the same places, while warning that overlap alone does not prove cause and effect without careful attention to social history, mobility and governance (Fa et al., 2020). Models that focus on languages help us see where the danger is highest. One global study looked at three danger signs—very small geographic range, few speakers and fast recent declines—and mapped where languages are most at risk. It linked these hotspots to pressures like road building and strong links to markets (Amano et al., 2014). The message is simple: many special ecological regions are also home to small, pressured language communities, so changes there can have big impacts.

Because of this, scale and context matter. The match between places rich in languages and places rich in species is strongest when we look at the whole world. It gets weaker when we zoom in, because language areas and species ranges reflect different histories of migration, state expansion and policy (Gorenflo et al., 2012; Fa et al., 2020). This is not a flaw—it tells us how to work. Use global overlap maps to choose broad

priorities, then do regional studies to understand settlement history, land rights and livelihood change before acting.

Research on Indigenous lands makes the picture clearer. A global map shows that indigenous peoples' lands cover more than a quarter of earth's land, include many areas with low human pressure and overlap strongly with biodiversity priorities (Garnett et al., 2018). Later studies contend that rights-based approaches are essential for durable outcomes because good governance and genuine power-sharing determine whether conservation supports—or undermines—cultural continuity (Fa et al., 2020; Tauli-Corpuz et al., 2020; Brittain et al., 2025). New evidence reinforces this view: within biodiversity hotspots, environmental conditions are often better on Indigenous lands than elsewhere—even after conflict—indicating that local stewardship can buffer shocks (Beattie et al., 2023). Results vary by place, depending on secure tenure, external pressures, and funding, but a consistent pattern emerges: Indigenous territories are central to healthy ecosystems and to the languages and knowledge connected to them.

Regional cases make this global pattern concrete. In the Americas, long histories of Indigenous stewardship have created rich biocultural mosaics. In Amazonia and Mesoamerica, communities manage forests, practice agroforestry, and follow ritual rules for hunting and fishing. Studies of intact forest landscapes and tropical protected areas show that many of the best-preserved forests lie within or near Indigenous territories, and that legal recognition of these territories can protect carbon and biodiversity while supporting cultural renewal (Fa et al., 2020; Garnett et al., 2018). Threats are uneven: new roads, mining and agribusiness push frontiers that lead to dispossession and language shift. So, research on "what helps" points to secure property rights, safety from violence and long-term, reliable finance for Indigenous and community governance—conditions that predict whether both ecosystem health and language transmission can continue (Brittain et al., 2025). In the Asia–Pacific, the Indo-Burma, Wallacea and Melanesian regions show very high language density together with high biological endemism. Many languages have small populations and are tightly linked to knowledge of fisheries, agroforestry and cultural burning. Regional policy and scholarship emphasize locally managed marine areas and community fisheries that align biodiversity goals with customary rules and language-based knowledge (Fa et al., 2020). A striking line of research quantifies the cost of language loss for knowledge: across New Guinea and North America, most medicinal plant uses are recorded in only one language, implying that language extinction can erase irreplaceable ethnobotanical knowledge even before plant species decline (Cámara-Leret & Bascompte, 2021). This supports investments in language transmission—through schooling, community media and archives—as a conservation strategy for key knowledge.

Across Africa, more studies now show how Indigenous and local knowledge strengthens food security and guides care for biodiversity. Recent editorials ask for fair partnerships that put TEK at the centre of conservation planning and case studies describe

how pastoralist and agro-pastoral livelihoods keep patchy habitats healthy and help languages survive (Tengö et al., 2014). Small languages persist when several conditions align: secure land rights, opportunities to maintain mobile livelihoods and supportive schooling. Accordingly, policy research urges a move beyond "fortress conservation" toward governance that safeguards mobility and resource access and that combines scientific monitoring with community-selected indicators (Tauli-Corpuz et al., 2020).

In small-island states and coastal regions, studies of locally managed marine areas and cultural taboos show how language-based rules determine who may harvest, when closures occur and how tenure operates. These rules often coincide with areas of high marine biodiversity and can recover quickly after shocks if social institutions remain strong—again linking ecosystem health to language and intergenerational knowledge transfer (Fa et al., 2020).

Urban areas add another layer. Cities and towns host many migrants and languages, yet they also create pressure to use dominant languages. Community gardens, seed exchanges, and cultural centers can help maintain plant diversity and everyday language use. This urban lens matters because many speakers of small languages spend part of their lives in towns, and urban demand strongly shapes rural land use. Still, compared with rural settings, cross-regional, systematic evidence on cities remains limited.

Across regions, similar forces drive either loss or persistence. Market integration and new infrastructure bring income and schooling, but they often weaken local resource rules and increase the value of national or global languages, accelerating language shift in small communities (Amano et al., 2014). Land dispossession disrupts intergenerational language transmission and undermines environmental stewardship.

Climate change disrupts seasonal calendars and migration routes, stressing species and the practices that sustain them. In contrast, secure tenure, intergenerational teaching and mother-tongue or bilingual education support continuity in both knowledge and ecosystems. These forces interact: where strong institutions recognize Indigenous rights, biodiversity and linguistic diversity are more likely to persist; where extractive frontiers advance and rights are insecure, losses tend to be rapid (Garnett et al., 2018; Fa et al., 2020; Brittain et al., 2025).

A growing literature examines how to measure these links. While early global comparisons relied on counts of languages and species, recent studies insist on functional metrics: the contexts in which languages are used, participation of youth in knowledge transmission, land access and trends in culturally important species. Reviews of traditional ecological knowledge (TEK) argue for respectful engagement and co-production that treats Indigenous, local and scientific knowledge as complementary and equally valid, rather than hierarchical (Tengö et al., 2014; Molnár & Babai, 2021). The "Multiple Evidence Base" approach has become influential in structuring such collaborations, helping bridge community monitoring with national biodiversity reporting. In parallel, critical work warns

against tokenistic use of TEK and urges "productive complicity," where partners are explicit about power, benefit-sharing and data sovereignty (Singleton et al., 2021).

Policy frameworks increasingly echo these findings. The International Decade of Indigenous Languages (2022–2032) focuses political attention on language revitalization and asks states to integrate language goals into education, media and public services (UNESCO, 2024). The Kunming–Montreal Global Biodiversity Framework (GBF) calls for inclusive conservation that recognizes rights and knowledge systems. It provides an umbrella for countries to link biocultural indicators with national biodiversity strategies, finance, and area-based measures (Tauli-Corpuz et al., 2020). Effective implementation, however, depends on enabling conditions. Comparative studies highlight the need for legal recognition of territories, co-management arrangements, long-term funding directed to Indigenous organizations, and monitoring that tracks not only hectares protected but also governance quality and cultural outcomes (Brittain et al., 2025; Fa et al., 2020).

The link between knowledge and language is a rapidly growing focus. A key 2021 study shows that most recorded medicinal plant uses are documented in only one language; if that language is lost, the knowledge is likely lost as well (Cámara-Leret & Bascompte, 2021). This means language policy is also environmental policy. Investing in language transmission—through mother-tongue education, community media, and archives—helps protect living knowledge that supports flexible, effective stewardship of nature. The same logic applies to place names, oral histories, and classification systems that encode ecological baselines. Safeguarding these cultural features preserves memories of landscape change and rules for stewardship.

Current debates show a maturing field. One concern is how large global numbers are used in advocacy. While it is broadly true that Indigenous territories contain much of the remaining biodiversity and many high-integrity habitats, scholars caution against repeating statistics without sources. They recommend using peer-reviewed estimates that clearly state scale and uncertainty (Garnett et al., 2018; Fa et al., 2020; Brittain et al., 2025). A second concern is measuring "culture" only by counting languages. Practice now adds indicators of language use, rights, and well-being, complemented by participatory narratives. A third shift is methodological: the field is moving from single case studies to comparative designs and open data, enabling broad patterns to be tested without losing local detail.

Across regions, similar patterns recur. Biocultural "refugia" often occur where customary tenure remains intact and people can stay mobile and follow seasonal rounds. These places support both species and small-population languages. By contrast, transition zones—road frontiers, peri-urban belts, and extractive concessions—often show the fastest losses of biodiversity and languages. Mixed results within the same country are common and usually reflect differences in governance as well as ecology. These lessons push conservation to look beyond protected-area maps and ask who governs, with what rights,

and toward which social goals. New evidence even suggests that under intense stress, Indigenous lands can maintain better environmental conditions than nearby areas, demonstrating the strength of community norms and institutions (Beattie et al., 2023).

The policy message is clear. Global biodiversity and climate goals will not be met unless conservation is aligned with language vitality and knowledge systems. This requires cross-sector action: education ministries should support mother-tongue instruction; justice and land agencies should secure territory and access; environment agencies should fund community monitoring and co-management; and media policies should make space for local languages. It also requires real accountability. Monitoring must include biocultural indicators designed with rightsholders, and funding must flow directly to local institutions over many years. These are not add-ons; they are the conditions that keep social–ecological feedbacks healthy so that species, languages, and livelihoods remain resilient (Tengö et al., 2014; Molnár & Babai, 2021; Brittain et al., 2025).

In sum, recent global and regional studies offer cautious optimism. Linguistic and biological diversity are tightly linked and face growing pressures in many of the same places. Yet where land and sea rights are recognized, where languages are used in schools and governance, and where knowledge is treated as living and valuable, nature and culture improve together. The next step is to act on this evidence: use global maps for screening, work locally with the people who speak the languages and steward the lands and measure what communities value—not only what is easy to count.

Indicators and Assessment Methods

Measuring biocultural diversity means describing how languages, cultures and ecosystems change together, using indicators that are scientifically reliable, ethically produced and useful for real decisions. Because culture and knowledge cannot be captured by a single number, assessment now uses a basket of indicators. This basket mixes numbers and narratives, works at local and larger scales and is designed with the communities who live with the outcomes (Gavin et al., 2015; Sterling et al., 2017; Tengö et al., 2014).

A first guiding idea is relevance through co-design. Indicators should come from local priorities and daily practices, for example language used in meetings about land and water or the involvement of young people in learning and passing on knowledge. At the same time, these indicators must be easy to add up for district and national reporting so they can inform public policy and budgets (Sterling et al., 2017). A second guiding idea is respect for many kinds of knowledge. Scientific, Indigenous and local knowledge are treated as complementary and equally valid. Assessments bring them together without forcing one system to translate into the terms of another. This way of working allows each system to keep its own tests of validity while still contributing to shared understanding and action (Tengö et al., 2014). A third idea is feasibility and repeatability. Methods must fit

long-term monitoring. Community-based data collection can be joined with official statistics, so the same measures are collected over time and compared fairly (Danielsen et al., 2010). A fourth idea is ethics and data governance. All work with cultural information should follow Free, Prior and Informed Consent and should respect indigenous data sovereignty. Communities should control how their information is stored, shared and used following the CARE principles of Collective Benefit, Authority to Control, Responsibility and Ethics (Carroll et al., 2020).

Within this framework, a central task is to know whether languages are being transmitted to the next generation. Status frameworks classify endangerment using factors such as intergenerational transmission, domains of use and institutional support (Moseley, 2010). However, single-time snapshots are not enough. Time series are also needed. The Index of Linguistic Diversity aggregates changes in speaker numbers across sets of languages to estimate regional and global trends (Harmon & Loh, 2010). Results show declines in several regions since 1970, which highlights the importance of policies that protect mother-tongue use at home, in schools and in public life (Harmon & Loh, 2010). Spatial risk models also include drivers such as very small geographic ranges, small numbers of speakers and fast infrastructure growth to predict where language loss is most likely (Amano et al., 2014). These models shift assessment away from one-time language counts and toward moving, place-specific pictures of vitality that can guide action.

Counting languages is less useful than knowing how languages are actually used. For this reason, many programs now track the share of community meetings or resource rules held in the local language, the proportion of children receiving mother-tongue or bilingual education, how often the language appears in ceremonies, seasonal rounds and media and whether young people join mentorships or apprenticeships in land- and sea-based practices. These measures link language directly to stewardship. They are also practical to collect through community surveys and school or administrative records which supports long-term monitoring and local decision-making.

Biocultural assessment also needs indicators for traditional ecological knowledge. The most useful indicators are specific to knowledge domains and linked to real practices. Surveys can record knowledge of culturally important species, weather and seasonality and place-names, while qualitative work shows how knowledge is learned, taught and applied in daily life. Mixed-methods research has revealed strong links between language and knowledge. A recent cross-regional study found that, in New Guinea and North America, most medicinal plant uses are recorded in only one language. This result means that language extinction can erase unique knowledge even before any plant species themselves are lost (Cámara-Leret & Bascompte, 2021). Findings like this support the use of indicators that track language use together with the continuity of key practices such as rotational agriculture, cultural burning and locally managed marine closures.

On the ecological side, assessments use standard biodiversity metrics—species

richness and abundance, habitat extent and integrity, and threat status—but interpret them through a biocultural lens. Species inventories can highlight cultural keystone species that carry names, stories, and ritual roles. Habitat indicators can track the condition of biocultural landscapes, such as agroforests and areas under customary marine tenure. Restoration metrics can measure the return of species linked to language and ceremony. Remote sensing now provides low-cost information on forest cover, fire, and fragmentation, while communities can ground-truth these data and interpret them with local categories. Together, satellite evidence and lived knowledge generate indicators that are both credible and meaningful.

Composite tools help communicate the big picture to policy audiences. The Index of Biocultural Diversity combines cultural indicators—languages, ethnicities, religions—with biological indicators—plants and birds/mammals—to portray richness and relative diversity by country (Terralingua, n.d.). Such indices are valuable for awareness, screening and international comparison. They should not replace local assessment, because they hide within-country differences and do not show function. For this reason, practice is moving toward dashboards. A dashboard is a small, co-designed set of indicators that blends linguistic vitality, knowledge and practice continuity, biodiversity and habitat condition and enabling conditions such as land and sea tenure, participation in governance and stable funding (Sterling et al., 2017). Dashboards are easier to maintain and easier to link to actions and budgets.

Community-based monitoring connects local observation to management and can be as accurate as professional monitoring for many variables, while adding legitimacy and faster response (Danielsen et al., 2010). Under the Multiple Evidence Base approach, knowledge holders and scientists each bring evidence using their own validation rules. Convergences and divergences are discussed before any synthesis. This process reduces bias and increases usefulness (Tengö et al., 2014). A practical example is a fisheries dashboard that combines catch per unit effort from local records, satellite-derived chlorophyll from remote sensing and locally chosen indicators such as taboo compliance or first-catch timing in the local calendar.

Measurement gains real power when it connects to policy frameworks. The Kunming–Montreal Global Biodiversity Framework encourages countries to report with indicators that capture governance quality and knowledge systems. National biodiversity strategies can therefore adopt biocultural indicators alongside ecological ones and direct finance to community monitoring aligned with those indicators. The IPBES assessment framework shows how multiple knowledge systems can inform national reporting. The International Decade of Indigenous Languages (2022–2032) encourages ministries of education, culture and communications to embed language indicators—such as mother-tongue instruction and media access—into their sector plans. Aligning these agendas reduces duplicate reporting and helps biocultural indicators count in budgets and laws.

Quality, equity and data governance remain constant concerns. Proxy traps should be avoided, because a high number of languages does not automatically mean high cultural vitality; function and rights must be measured, not only counts. Disaggregation by gender and generation is needed to show who benefits and who bears costs. Data sovereignty must be respected, because sensitive cultural information—such as sacred sites or ritual knowledge—requires community ownership, negotiated access and fair benefit-sharing (Carroll et al., 2020).

A practical workflow brings these ideas together. Work begins with a co-design workshop to set goals and select a short list of indicators across the four baskets of language, knowledge and practice, biodiversity and enabling conditions. Teams then build a baseline using available statistics, community surveys and remote sensing. Set repeat cycles in advance—for example, annual checks on language use in schools, seasonal checks on fisheries closures and biennial checks on forest integrity. Clarify data governance and roles: define who can access the data and how results will be returned to communities. The dashboard should then link directly to action. Teams should agree on simple thresholds that trigger responses, assign responsibility for each action and secure reliable funding to keep the system running. When these elements are in place, monitoring does more than record losses—it supports daily stewardship of land and water, helps protect rights and improves ecological outcomes (Sterling et al., 2017; Gavin et al., 2015).

Conservation and Stewardship of Biocultural Diversity

Protecting biocultural diversity means caring for the interconnected life of languages, cultures and ecosystems. The strongest evidence shows that lasting protection depends on secure collective rights, strong local institutions and genuine partnerships that share power and benefits fairly. Where these conditions are met, nature and culture improve together; where they are absent, both decline (Garnett et al., 2018; Brittain et al., 2025).

The first priority is to recognize land and sea tenure. Many of the world's most biodiverse places are the territories of indigenous peoples and local communities. Legal recognition of these territories—together with protection from violence and dispossession—supports the stewardship that has kept forests, grasslands and waters healthy for generations (Garnett et al., 2018). New studies inside biodiversity hotspots show that, even after conflict, environmental conditions on Indigenous lands are often better than on other lands. This shows how strong community governance can be when rights are secure (Beattie et al., 2023). These findings match international policy. The Kunming–Montreal Global Biodiversity Framework (GBF) calls for inclusive, rights-based conservation and asks countries to ensure full and fair participation of indigenous peoples and local communities in planning, management and monitoring (CBD, 2022). To make these promises real, governments need concrete steps: pass tenure laws, follow Free, Prior and Informed Consent

(FPIC) and provide direct, long-term finance to community institutions (Brittain et al., 2025).

Education and language policy are just as important. Languages carry traditional ecological knowledge (TEK), such as species names, harvesting calendars and rules for care. When children learn in their mother tongue and when local languages appear in media and public services, intergenerational transmission becomes more likely. The International Decade of Indigenous Languages (2022–2032) encourages states to invest in mother-tongue education, community media, archives and language technologies. These investments are, in effect, conservation of living knowledge (UNESCO, 2024). Evidence shows that losing small-population languages can erase unique medicinal and ecological knowledge even before species are lost. For that reason, language revitalization is also a direct environmental strategy (Cámara-Leret & Bascompte, 2021).

Governance arrangements should be built as partnerships, not as one-off consultations. Biocultural approaches emphasize that conservation works best when locally defined values, institutions and rights shape goals and methods (Gavin et al., 2015). Co-management of protected and conserved areas can formalize this partnership, but only when responsibilities and benefits are clear and when customary institutions remain central. In marine and fisheries contexts, locally managed areas and seasonal closures linked to cultural norms have shown strong potential to sustain both biodiversity and livelihoods. Across contexts, power sharing is key: communities should hold authority to make rules, monitor compliance and adjudicate disputes, with state and NGO partners in supporting roles (Sterling et al., 2017; Brittain et al., 2025).

Monitoring systems should reflect multiple ways of knowing and produce information that communities can use. Community-based monitoring can be accurate and cost-effective while building local capacity and legitimacy; it also makes it easier to connect ecological indicators with language use and practice (Danielsen et al., 2010). Under the Multiple Evidence Base approach, scientific, Indigenous and local knowledge each contribute observations and validation and the synthesis happens after respectful dialogue about convergence and divergence (Tengö et al., 2014). Practically, this means a biocultural dashboard might track forest integrity alongside language use in governance, youth participation in knowledge transmission and the status of culturally important species (Sterling et al., 2017). Data governance should follow the CARE principles—Collective benefit, Authority to control, Responsibility and Ethics—so that sensitive cultural information remains under community control and benefits flow back to rights holders (Carroll et al., 2020).

Sustaining biocultural diversity also requires support for culturally grounded livelihoods. Agroforestry, customary fisheries, cultural burning and biocultural tourism can align income with stewardship when they are co-designed and controlled locally. These practices maintain habitats while keeping language and knowledge active in daily life.

Conservation finance should therefore move beyond short projects toward multi-year funds that go directly to community organizations, cover institution-building costs and reward measured improvements in both ecological and cultural indicators (Brittain et al., 2025). Climate finance can help when safeguards prevent carbon-only strategies that harm biodiversity or culture; biocultural strategies often deliver mitigation, adaptation and equity together (IPBES, 2019).

Communication matters for maintaining commitment. Storytelling, ceremonies and place names encode ethics and baselines and can help mobilize stewardship when owned by communities (Fernández-Llamazares & Cabeza, 2018). Public narratives should avoid romanticizing "tradition" and instead highlight living adaptability, gender and generational diversity and the right to choose futures. Research partnerships should follow FPIC, pay for time and knowledge, share authorship where appropriate and ensure that results return in useful forms.

Finally, national implementation should link ministries and budgets. So, actions reinforce each other. Environment agencies can recognize indigenous and community conserved areas and include biocultural indicators in reports prepared under the GBF (CBD, 2022). Education ministries can expand mother-tongue programs and train teachers from local communities. Health and agriculture ministries can integrate TEK into prevention, nutrition and agroecology. Justice ministries can secure tenure and protect environmental and cultural defenders. When governments align these sectors, biocultural diversity becomes a cross-cutting strategy for resilience rather than a niche concern.

In short, protecting and maintaining biocultural diversity depends on rights, institutions and relationships. Evidence shows that when communities have secure tenure, a voice in decisions, resources for language and knowledge and respectful partnerships for monitoring and management, ecosystems and cultures flourish together (Garnett et al., 2018; Sterling et al., 2017; Brittain et al., 2025). The task ahead is to make these enabling conditions the rule rather than the exception.

Outlook and Emerging Directions

The next ten years give us a real chance to link biodiversity goals with the revival of languages and knowledge. Current policies already name the key parts. The Kunming–Montreal Global Biodiversity Framework asks for inclusive, rights-based conservation and for full participation of indigenous peoples and local communities in governing and monitoring nature (CBD, 2022). The IPBES Global Assessment underscores the urgency of action by documenting major biodiversity declines and showing that Indigenous lands perform well when rights and institutions are secure (IPBES, 2019). The task now is to shift from commitments to implementation: secure land and sea tenure; fund co-management;

and co-design indicators that track ecosystem health alongside language use, knowledge transfer and fairness (Sterling et al., 2017; Brittain et al., 2025).

Two methodological shifts will accelerate progress. First, replace one-size-fits-all indices with locally tailored, plural metrics. Use streamlined dashboards that combine habitat integrity, cultural keystone species, mother-tongue education and youth participation, while upholding data sovereignty (Sterling et al., 2017; Carroll et al., 2020). Second, build partnerships guided by the Multiple Evidence Base, in which scientific, Indigenous and local knowledge are each validated in their own terms and then integrated for action (Tengö et al., 2014).

Three near-term opportunities stand out. Community-led restoration and climate adaptation—such as agroforestry, cultural burning and locally managed marine areas—can advance climate, biodiversity and cultural goals when funding flows directly to community institutions over the long term (IPBES, 2019; Brittain et al., 2025). Education and media policies that expand mother-tongue teaching and language technology will help keep traditional ecological knowledge alive; otherwise, unique knowledge may vanish even before species do (Cámara-Leret & Bascompte, 2021). Finally, clear monitoring linked to GBF targets can make biocultural outcomes visible to governments and donors, creating feedback loops that reward effective stewardship (CBD, 2022).

In sum, the outlook is favorable if we center rights, back local leadership and use multiple knowledge systems—conditions that allow nature and culture to thrive together (Brittain et al., 2025; Sterling et al., 2017).

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