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Review

The Universal Precautionary Principle: New Pillars and Pathways for Environmental, Sociocultural, and Economic Resilience

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Abstract: Global environmental degradation is linked to a worldwide erosion of ethnic identity and cultural diversity, as well as market disruption. Cultures rely heavily on the local environment around them, and local communities play a key role in conserving natural resources. People's identity, connection with land, and the adaptation of Indigenous and local knowledge are prerequisites for resilience. Though the Environmental Precautionary Principle (EPP) aims to tackle environmental degradation by privileging the environment in the face of uncertainty, it is not sufficient on its own; it does not take into account the intimate connection between nature and local culture, nor does it prioritize community or cultural wellbeing. We suggest expanding this concept into a multi-faceted Universal Precautionary Principle (UPP), which recognizes people's connection to the land, and elevates community, cultural, and economic wellbeing as equally important values alongside environmental concerns. Here, we coin the Universal Precautionary Principle, outline its four core pillars—systems, governance, diversity, and resilience—and introduce its three subsets: Environmental Precautionary Principle, Sociocultural Precautionary Principle, and Economic Precautionary Principle. We discuss potential outcomes of its application, and offer operational guidelines to implement the Universal Precautionary Principle in practice, before concluding that it is a crucial tool to build environmental, sociocultural, and economic resilience. In essence, reciprocity is the keystone for continuance—if the environment is healthy, people are more likely to be healthy. Equally, if people are healthy, the environment is more likely to be healthy; for both people and the environment to be healthy, their culture and economy must be healthy.

Keywords: cultural; diversity; environmental; governance; precautionary principle; resilience; sociocultural; socio-ecological systems; sustainability; systems; transformative resilience

1. Introduction

Biodiversity continues to decline around the world despite international programs, platforms, and conventions designed to slow or reverse the losses [1–3]. Closely linked to these declines is the global erosion of ethnic identity and cultural diversity [4]. Special precaution is needed for Indigenous peoples and local communities (IPLC), especially in projects and activities where

outsiders, agencies, or process professionals control large amounts of the decision-making power [5]. The Environmental Precautionary Principle (EPP), which asserts a need to caste uncertainty in favor of environmental protection, has made strides in political, judicial, and management arenas to mitigate such risks (see Box 1). It may have slowed the process of biocultural decline and lessened our planet's crisis. However, the EPP has not gone deep enough, and it alone cannot tackle the multi-faceted systemic issues that are urgently at stake.

We believe that the EPP is now outdated in its current form, and has missed the mark by excluding society, culture, and economy. To be relevant today, it needs to be redefined with a broader coupled socio-ecological scope.

Cultural diversity is at great risk and its health is of equal importance for the planet's wellbeing as is the health of biodiversity [6]. Cultures rely heavily on the natural resources around them, which are reflected in their languages, knowledge systems, beliefs, arts, morals, customs, laws, and economies [7]. These attributes are learned, shared between individuals as members of society, and transmitted from one generation to another, using social mechanisms often very specific to local communities [8]. However, as communities' availability and access to biological resources are lost, so too are these cultural mechanisms and attributes. This is especially prevalent now as globalized markets and capitalist economies shift power dynamics and put an increasing strain on cultural, social, and natural resources. Therefore, if local communities and their threatened

Definition & History of the EPP

The Environmental Precautionary Principle (EPP) stems from the German concept, Vorsorgeprinzip, which was first used in Germany's 1974 Clean Air Act [35]. The literal meaning of Vorsorge combines both worrying about and caring for the future. According to this principle, the responsibility towards future generations commands that the natural foundations of life are preserved and that irreversible types of damages must be avoided. In essence, the EPP requires that preventative action must be taken to avoid irreversible changes with unforeseeable consequences, prior to conclusive scientific evidence of danger [72].

The EPP was internationally introduced in 1984 at the First International Conference on the Protection of the North Sea and incorporated in international environmental law in the 1992 Maastricht Treaty of the European Union [38,76]. It became internationally recognized as Principle 15 in the Rio Declaration in 1992 [77], and its most widely used definition was later coined in 1998 as the Wingspread Statement: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established" [78]. Four pillars [73] accompanied its definition:

1. Taking preventative action in the face of uncertainty.
2. Shifting the burden of proof to the proponents of an activity.
3. Exploring a wide range of alternatives to the possibly harmful action.
4. Increasing public participation prior to decision-making.

Differing formulations of the EPP (also now known as the Precautionary Principle or PP) are found today in many international legal instruments; it has been used to inform management, policy, and community decisions worldwide, and has especially maintained a foothold in Europe [71]. While it has generated considerable traction, it also carries with it many controversies and an ensuing danger that its definition is becoming increasingly diluted [38,76].

Box 1. Definition and history of the Environmental Precautionary Principle.

cultures are to be safeguarded, restored, and revitalized, increasing recognition of the importance of coupling natural, sociocultural, and economic systems is paramount [9]. As part of this, IPLCs' access to scientific knowledge, including the availability of research from their particular perspective, as well as their adaptability to learn new knowledge systems, is crucial to people's agency regarding governance and resource management choices. People's connection with land, as well as the adaptation and application of their knowledge through meaningful roles in management and research, is a prerequisite for transformative resilience and adaptive co-management [10–12].

The EPP was created as a political and ethical construct to privilege the environment in the face of uncertainty. A focus on environment was particularly useful in the last two decades of the 20th century because environmental concerns were often neglected, and the full cost of environmental degradation for current and future generations was either ignored or discounted from most economic decision-making; it was seen as nothing more than an externality. However, the environmental justice movement has emphasized power asymmetries regarding how environmental decisions are made, which often relegate the voices of IPLCs [13]. An unintended consequence of the EPP may be to favor biophysical risks at the expense of culture, community wellbeing, social justice, and socio-ecological linkages that safeguard the overall system [14]. Due to competing values and finite resources, we predict that many risks could emerge for IPLCs without explicit protection from complementary and equally asserted principles to defend their culture, society, and economies. Greater recognition for worldviews and cultures that have unique ways of seeing, thinking, and valuing is critical for the realization of justice, sustainability, and resilience [15]. Studies have demonstrated that environmental attitudes and values, concern for environmental problems, and levels of environmental activism can vary considerably according to race and ethnic backgrounds [16–18]. In addition, international agreements and platforms, such as the 1992 Convention on Biological Diversity and the 2012 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, assert the need for partnership and increased participation by Indigenous peoples in environmental management at all levels [19]. However, shifting these assertions from theory to practice, where true recognition and equitability is realized at a community level, is often where systems break down and barriers manifest.

We therefore propose a re-invention of the Precautionary Principle through a systems lens—with an understanding of the nested interconnectivity, responses, surprises, and patterns of adaptation that environmental, sociocultural, and economic systems inevitably present. In this reinvigorated version, we propose one overarching Universal Precautionary Principle (UPP) that contains three domains: The Environmental Precautionary Principle, the Sociocultural Precautionary Principle, and the Economic Precautionary Principle (see Figure 1). We propose four 'pillars'—systems, governance, diversity, and resilience—to guide the application of the UPP across legal, policy, management, and community platforms.

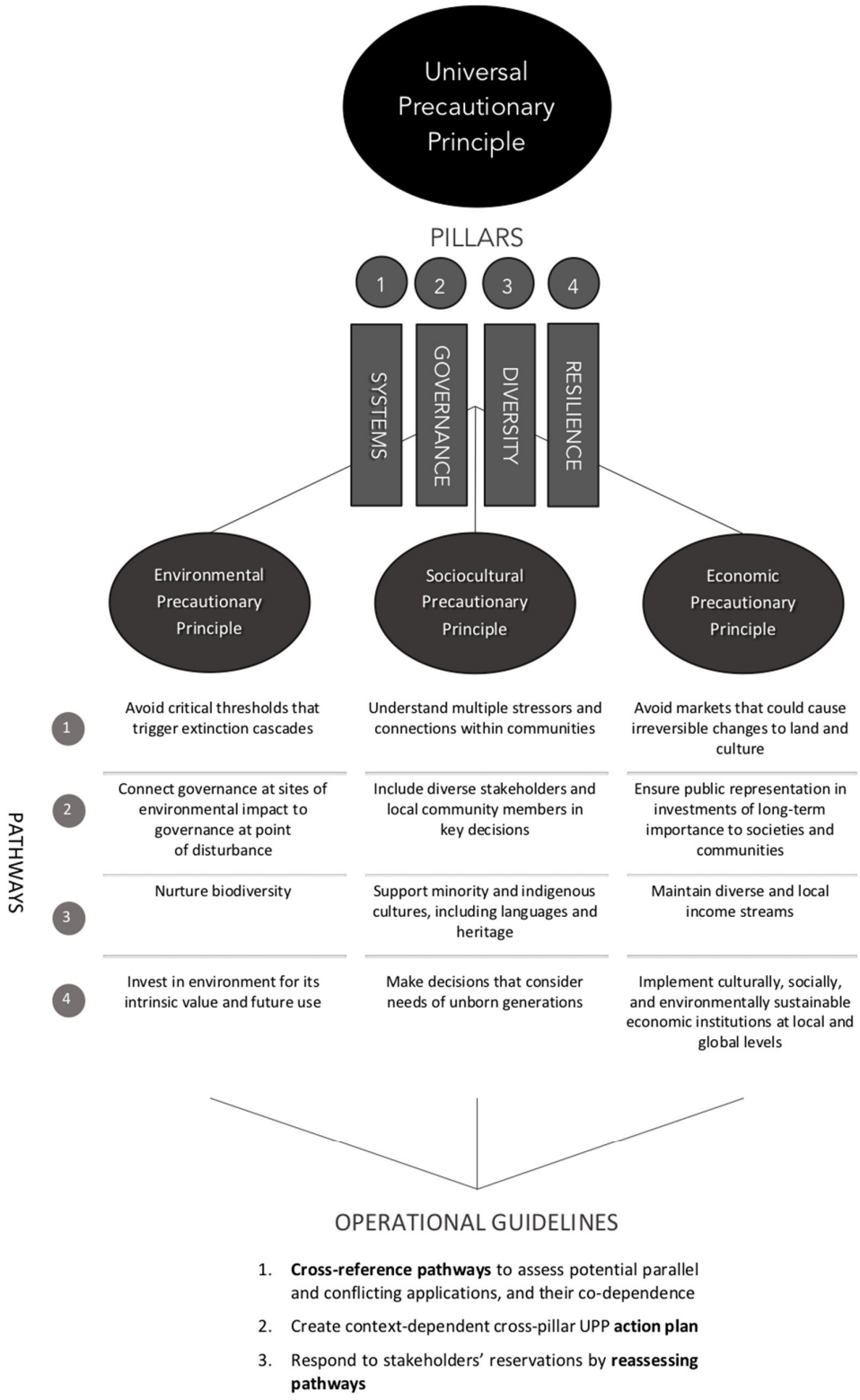

Figure 1. The Universal Precautionary Principle, with its four pillars of action (Systems, Governance, Diversity, Resilience), its three domains (Environmental Precautionary Principle, Sociocultural Precautionary Principle, Economic Precautionary Principle), their pathways for application, and operational guidelines.

2. Definitions & Pillars of the UPP

Our definition of the UPP expands upon the original EPP as defined in the Rio Declaration (see Box 1), and reads as follows (with bold text indicating the changes we have made to the original definition of the EPP): "When an activity raises threats of harm to **environmental, sociocultural, and economic wellbeing and resilience**, precautionary measures and preventative action should be taken **using a systems approach**, even if some cause and effect relationships are not fully established."

The UPP aims to provide all IPLCs and stakeholders with choices in development decisions that affect the individual or collective lives of current and/or future generations, including the land upon which they live. With the ability to make better choices and include more actors in decisions, we will be able to collectively enhance the environmental, sociocultural, and economic wellbeing for all peoples. The UPP is a practical application of transformative resilience; it aims to provide tools that allow our systems and communities to prepare for and become resilient to future challenges in ways that allow them to adapt and thrive.

The UPP is interdisciplinary in nature, and meant to be applicable in multiple fields including but not limited to environmental conservation, international development, economic development, education, technology, social justice, and security. Environmental, sociocultural, and economic capital and resilience may be affected by any activity involving human communities and their land, identity, individual and collective intellectual property, and local economies. In such circumstances, the UPP should be applied.

Like the EPP, but in a slightly different configuration, our UPP framework is built on four central pillars that provide high-level best-practice guidelines relating to the ethics, process, and understanding of change (see Box 2). The roles of the pillars are to highlight the values, roles, and responsibilities of change agents, as well as to humanize the conversation about the consequences of change. Our use of the term, "pillar" or "pillar of action" emulates the five Pillars of Action launched by the Food and Agriculture Organization of the United Nation (FAO) in 2014, as part of its Global Soil Partnership [20]—an innovative way to assess compliance in each of their program's building-blocks or central values. To us, this term represents foundations that are built from equal but different "materials" or frameworks: These four pillars are integral to the successful implementation of the UPP; they therefore launch us to critically monitor the UPP, against each pillar.

Pillars of Action

1. Systems Pillar: Use a systems approach to safeguard and grow environmental, sociocultural, and economic capital.
2. Governance Pillar: Share decision-making across multiple actors and scales for collective action.
3. Diversity Pillar: Use diverse approaches to knowledge, economies, and decision-making to identify risks and choices.
4. Resilience Pillar: Take preventative action in the face of uncertainty to enable adaptation and avoid intergenerational transfer of debt.

Box 2. The four central pillars of the Universal Precautionary Principle.

The pillars function together across the environmental, sociocultural, and economic domains to protect options for, and the identities of, future generations and to bind the three domains into one. The focus should be on the co-dependence of the domains so that actions in one domain do not jeopardize the wellbeing of the other domains. They represent a code for continuance—or social contract—with current and future generations to mitigate the impact of disturbance on the earth's natural and human capital.

We propose the recognition of a Sociocultural Precautionary Principle and an Economic Precautionary Principle to stand alongside the Environmental Precautionary Principle when making choices about the future wellbeing of our people and the planet.

Formulating these as three separate principles, one for each domain, ensures that precautionary measures are taken in each domain and that none will undermine another. Binding the three domain principles into a single UPP focuses on the ways in which these three equal domains are co-dependent and interact with each other, so that the identification of solutions is more enduring and likely to succeed. For example, myopic focus on just the environmental risks treats a symptom caused primarily by economic activities, potentially missing opportunities for sociocultural adjustments that are crucial to the mitigation of environmental threats.

1) **Systems Pillar:** *Use a systems approach to safeguard and grow environmental, sociocultural, and economic capital.*

Our first pillar of action emphasizes the application of a systems approach to maintain and nurture environmental, sociocultural, and economic capital. A systems approach avoids compartmentalization of environment, society, culture, and economy, promoting the view that there are strong reciprocal flows (or linkages) between humans-to-humans and humans-to-environment [21–24]. Fundamental to this approach is a systemic (humans as integrated parts of nature) conception, which recognizes the coupling between humans and nature [25,26]. Each domain—environmental, sociocultural, and economic—is important in evaluating threats or opportunities; safeguarding the linkages between them (by nurturing and renewing them, and sometimes by forming new links) is a crucial part of systems adaptation and resilience. Unless these linkages are safeguarded, well-meaning actors may inadvertently isolate parts of a system, doing violence to its people and land, and undermining what they are trying to achieve.

2) **Governance Pillar:** *Share decision-making across multiple actors and scales for collective action.*

The second pillar asserts the use of governance models that are appropriate to scale, and that empower people collectively as active agents for decision-making to enhance adaptive social contracts for sustainability. It promotes the 'right of choice' by actors affected by the planned action. The importance of shared and collective governance, especially as it relates to IPLCs, is widely recognized in international and national conventions, agreements, and commitments, although barriers to substantive tangible sharing of power and benefits remain [27]. Equitable power-sharing is not necessarily established when formal agreements are made between Indigenous peoples and governments. Rather, the dynamics of shared decision-making—including the role of informal institutions, social networks, trust, communication, learning, and adaptive processes—are important determinants of the extent to which power is actually shared. This pillar recognizes the need for decentralization of shared decision-making, and the fulfillment of international human rights (both legally bound and unbound) in practice. Crucial components of this pillar include concepts such as free, prior, and informed consent (FPIC); intellectual property rights; knowledge access; and benefit-sharing [4,28,29]. All actors should share the costs and benefits of the activity, although this might not necessarily occur in the same way, or evenly; it should instead be shared equitably based on power, vulnerabilities, privilege, skills, and resources of each group. Power-sharing structures designed to promote equity between actors should be seen not as ends in themselves, but as "enabling peoples to continue negotiating towards participation […] as equal partners" [30]. Additionally, included in this pillar is the concept of 'adaptability to scale'; too often scale is predetermined, and problems are assessed at scales that are too small or too large. Matching governance to appropriate scales will allow actors to see a wide range of choices and be able to choose better ones. While assessing problems at global scales, for example, may present more complex and sometimes unreachable solutions, it is important to understand these loops and connections, to then apply and adapt them locally, recognizing that decisions of caring and intervention occur at multiple scales.

3) **Diversity Pillar:** *Use diverse approaches to knowledge, economies, and decision-making to identify risks and choices.*

A diversity of worldviews, co-production of knowledge, and Multiple Evidence Base approaches offer different ways to think about, relate to, value, and make decisions about the environment, society, culture, and economy [31]. A pluralistic approach to knowledge engages different 'ways of knowing' and offers diverse approaches to identifying and responding to risk and uncertainty [32,33]. However, we recommend celebrating this pluralistic perspective of knowledge as an opportunity for exchange, enrichment, and deeper understanding. This pillar suggests a more informed and inclusive approach to problem identification and decision-making processes, interdisciplinary approaches to learning, and collective opportunities for sharing lessons across stakeholder groups. The uncertainty that is inevitable due to the dynamic and changing nature of biophysical environments, human communities, and local economies may be slightly more predictable if action is informed by a wide range of knowledge systems [8,34]. While the power asymmetry of knowledge systems and its holders remains a valid issue, this pillar encourages multi-directional respectful sharing of knowledge, with the mutual goal of knowledge transfer to future generations. Approaches that recognize the inherent value of all knowledge systems, while supporting participatory mechanisms that enable dynamism within communities and reinforce intergenerational knowledge transmission, should be adopted. This pillar promotes reciprocal capacity-building through two-way learning, where capacities of scientists are built by local knowledge holders, and in return, local knowledge holders are exposed to scientific concepts and methods, so as to reinforce opportunities for building synergies between Indigenous & local knowledge (ILK) and science.

4) **Resilience Pillar:** *Take preventative action in the face of uncertainty to enable adaptation and avoid intergenerational transfer of debt.*

The term 'resilience' refers to the ability of an environmental or human system to respond to disturbance and change, by either transcending through a chaos point to persist or adapting to transform into a novel version of itself [23,35,36]. Drawing from the EPP, this pillar asserts that where there are threats of serious or irreversible damage to environmental, sociocultural, and/or economic systems, a lack of certainty should not be used as a reason to postpone measures to prevent a system's capacity to adapt in response to disturbances [37]. Change agents need to consider costs for future generations when making choices, rather than prioritizing short-term benefits for current generations. In most cases, we expect the burden of proof and responsibility to lie primarily with the proponent of the action, but encourage a multi-lateral process that involves potentially affected communities at the beginning of the risk analysis as well as in the potential implementation, execution, and approval of the activity [38]. Within this pillar, environmental and sociocultural goals are judged as equally important to economic goals; therefore, the 'correct' outcome depends on context. Different actors may have varying opinions regarding the correct outcome, depending on their values, needs, investment, and circumstance. Long-term relationship-building, local dialogue among actors and stakeholders, and multi-lateral needs and risk assessments—using both quantitative and qualitative measures—should transpire to determine which outcomes and processes are appropriate for each unique context. Efficiency is not the first priority, but one of an array of equally important elements to ensure a successful and collaborative project that will foster resilience across the three core domains. The understanding that process and intangibility are equally important to outcome and output, and that therefore 'the ends cannot justify the means', is a recognition that underlies the resilience pillar.

3. Coupled Pathways towards Application

Below, we analyze each pillar of action in relation to specific principles. A key attribute of the Universal Precautionary Principle is that the pathways to apply each of its domains must be coupled;

therefore, while we separate the above pillars to acknowledge their independent values, the co-dependence and coupling of each pillar while assessing individual domains is essential to an effective precautionary principle in practice (See Box 3).

3.1. Environmental Precautionary Principle

The most pernicious and accumulating risk to environmental health is species extinction. Biodiversity may be valued by some actors for its intrinsic ('existence') value and spiritual portent, while others hold its value primarily in the way it underpins adaptability of life systems to future disturbance, allowing it to continue to deliver ecosystem services to current and future generations. Species with minor roles in ecosystem regulation and regeneration may now possess the key mix of characteristics needed to thrive and nurture life in new ecological conditions. Retaining biodiversity is a key insurance for the future because evolution operates slower than environmental disturbance wrought by humans and their economic activities.

Habitat alteration or removal poses an immediate risk to biodiversity, and to environmental services in general. This threat can be reversed for some habitats, but it will require a systems approach and considerable time and investment (Pillar 1). In this age of global transport and worldwide exchange of food and fiber, the introduction of invasive competitors and predators to new ecosystems is accelerated. Invasive species often cause irreversible and devastating change. Human population growth and technological advances in harvesting practices risk overexploitation where resource extraction exceeds the natural capacity of the ecosystem to regenerate. Increasingly, intensive and technologically based agriculture is underpinned by ecological subsidies (water and nutrients) that can overwhelm local ecosystem regulatory services and the ecosystems from which the subsidies are sourced.

Ecological forces operate at multiple scales, so the best efforts of local actors to restore and protect biodiversity or environmental health may be negated by ecological forces operating at much wider spatial or slower temporal scales. The planet itself has already breached an estimated four of nine quantified planetary boundaries for sustainability [39], and is closely approaching three of the remaining ones. Local impacts of human activities are varied and can be acute and serious, calling for environmental and ecological justice [40]. Governance scales of action must be matched to achieve effective collaboration for enduring solutions to environmental problems (Pillar 2).

Science produces exceptional data that can assist with the protection and revitalization of ecosystem services and endangered species, through its in-depth multi-sited experiments. Indigenous and local knowledge can also provide invaluable insight through its longitudinal studies that are situated in place. If approached with care, the comparative and reciprocal sharing of data produced by both types of knowledge could serve to protect ecosystems locally and globally, with long-term strategies for the benefit of future generations, while actively engaging local stewards (Pillar 3).

Diminishment of ecosystem services, as well as the destruction of the underlying ecological processes of renewal and ecosystem cycling, depletes the natural capital from which current and future livelihoods are drawn. Whether the decline in natural capital is gradual or precipitous, the maintenance of long-term environmental resilience (Pillar 4) demands a long view that spans many human generations.

We propose updating the definition of the EPP that was promulgated at the Rio Summit to be slightly more focused: "When an activity raises threats of harm to the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established."

This new definition removes the clause "and human health," which is now highlighted within

Our Trajectory

This paper began as a presentation of the Cultural Precautionary Principle (CPP) at the International Conservation Biology Conference in Auckland, New Zealand, in December 2011. At the time, we proposed the CPP as apposite to the existing Environmental Precautionary Principle, noting the gaps that exist for both collective cultural wellbeing and people's connection to their land. However, as we further developed the CPP, we began to notice that we too were conforming to the same silos that we were critiquing—we were missing key components of the world's system by only addressing one gap among many and further compartmentalizing the principle at hand. Instead, we realized that we needed to include our new proposed principle under a larger Universal Precautionary Principle (UPP). Under this holistic systemic approach, environment, culture, society, and economics are analyzed both together and separately.

As we further developed the UPP, we realized that we were lacking the "socio-" in the Sociocultural Precautionary Principle. We thus added this element, after discussing whether it would be more beneficial to present two separate principles (social and cultural) or one linked concept (sociocultural). We decided that coupling the term was more conducive to our needs, due to the interlinked nature of the two. However, we want to emphasize that we see culture and society as separate, and worry that culture may be undermined within this domain when applied.

After analyzing the Sociocultural Precautionary Principle as a much-needed complement to the EPP, we saw a final gap—the Economic Precautionary Principle. Though economy could arguably be seen within each of the other principles (a bio-economy, under environment; a monetary or trade economy, under society and culture), we felt that the economic relevance of society, culture, and environment, as well as the perturbations caused by historical and current economic climates, affect the other domains significantly enough to warrant its own attention.

Despite concluding that a holistic systemic approach to applying the precautionary principle is necessary for solving complex interdisciplinary challenges, we feel it is necessary to define three distinct domains (or sub-principles). We worry that certain domains may undermine others, if they are not clearly differentiated, and thus, that protection mechanisms for all three domains may not be sought.

Box 3. The trajectory that led us to form the Universal Precautionary Principle.

our Sociocultural Precautionary Principle. Health is one of many concepts that needs to be reconsidered through a holistic perspective, within overall social and cultural wellbeing, both individual and collective, as defined by the World Health Organization [41].

3.2. Sociocultural Precautionary Principle

Gaining accurate and reliable insights into environmental attitudes and values of IPLCs has been historically problematic due to language barriers, economic deficiencies, and distrust based on histories of systemic oppression. The knowledge of IPLCs is often ignored, and its principles are rarely reframed or operationalized into mainstream environmental management [13,42–45], let alone economics. Conversely, those who are acknowledged can be romanticized and generalized, leaving little room for local case-based knowledge, differences, and adaptations [46–48]. While generalized

assertions of cultural differences in environmental values abound [33,42,43,49–54], none are sufficiently detailed or quantified to strongly assert the size of ethnic difference, to identify common ground, or to begin the process of incorporating values into ecological economic approaches. Often, agencies seeking cross-cultural partnerships will come equipped with little awareness of local Indigenous cultural aspirations, or their ethics and values for environmental management [10]. Advanced consideration of codes contained within the Sociocultural Precautionary Principle will therefore raise awareness by decision-makers, policy brokers, and practitioners of potential impacts and uncertainty of their decisions and actions (Pillar 1). The operationalization of such codes through multi-lateral accessible platforms, which include diverse actors at multiple scales – including local community leaders – in collaborative decision-making, will help deconstruct these barriers and attitudes (Pillar 2). Such a principle may serve as a map or code of ethics to guide both the process and outcomes of activities that occur on or that impact the land, natural and cultural resources, or livelihoods of IPLCs.

Culture is highly vulnerable to economic development, especially when such change is directed by outsiders [12,46,48,55–57]. The word "culture" has been used to both defend human rights and to strip people of their agency. Despite these judgments, all people possess both individual self-expression and cultural worldviews. The UPP stresses that these plural identities be recognized and respected when embarking on activities, and that minority and Indigenous cultures be especially safeguarded [4,58–61]. Cultural heritage and language is in danger of becoming fragmented as relationships between generations (from elders to youth), and between people and their land are severed [12,61]. Additionally, economic barriers prevent the viability of cultural heritage to persist for current and future generations [12,46,61]. Learning about both the threats and significance of the cultural heritage of those whose land the activity is being proposed, and setting in place mechanisms to ensure that these cultural cornerstones will have the tools to thrive and adapt, rather than be displaced, is critical (Pillar 3).

Humans offer both threats and safety for life's systems. On the one hand, human activities are undoubtedly creating unprecedented disturbances of local, regional, and planetary environments. On the other hand, all motivation and endeavor to conserve and sustain life's systems is underwritten by human capacity for thought, research, and co-operation. Caring and acting is fundamentally an ethical and moral construct of humans, their society, and their culture. Those attributes are more likely to emerge from a secure and well-ordered society with a strong sense of collective identity and equitable distribution of wellbeing. At its heart, a sustainability ethic is a social contract in which an individual's opportunities are, at least in part, subsumed by an agreement to act for the social and cultural good. Social awareness and collaboration is needed to discourage individuals or businesses from maximizing short-term benefits by eroding natural, social, and economic capital, or transferring the burden and cost of environmental degradation onto others (Pillar 4), including unborn generations.

We therefore propose a Sociocultural Precautionary Principle as follows (with bold text indicating modifications from the original EPP definition): "When an activity raises threats of harm to **cultures, community wellbeing, and human health**, precautionary measures should be taken even if some cause and effect relationships are not fully established."

Culture, in our sense of the word, is the collective heritage and identity of people [61,62]. It is the "set of distinctive spiritual, material, intellectual and emotional features of society or a social group, … [that] encompasses, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs." [63] (Page 3). Society, accordingly, pertains to "an extended social group having a distinctive cultural and economic organization." [64] It is "the relationship [of humans] to one another when associated in any way" [65]. As such, "society" is the group or organization itself, while "culture" defines the characteristics of said group.

3.3. Economic Precautionary Principle

All people and communities need to maintain a resilient monetary or bio-economy in order to persist in place. The security of sustenance underpins longer-term planning and a commitment to

protect and enhance natural, social, and economic capital in that place (Pillar 1). The central role of economy in securing human existence is recognized by the 2004 Millennium Assessment's ecosystem services framework as the provisioning of services, and highlighted in the first two UN Sustainable Development Goals (no poverty, zero hunger).

Just as ecological disturbance has driven biodiversity loss and degradation of ecosystem services, the disturbance of local economies threatens local livelihoods. Global food and fiber exchange, as well as urbanization, have perturbed local markets and altered local land use. Distanciation (progressively more numerous links in the commodity chain between producer and consumer) threatens to sever direct communication, trust, and reciprocity between producers and consumers. Many consumers no longer know where their food and fiber come from, let alone care for the environmental costs of production or share responsibility that supply will continue. Material trading by barter has been displaced by monetary exchange. Distanciation in general decouples communication, monitoring, and the political agency required to intervene, if sustainability challenges arise (Pillar 2). The globalization of commerce has created a domino effect for people's local livelihoods and lifestyles that seemingly have no direct connection to it on the other side of the world. Additionally, the commodification of the commons (in the form of ranching, logging, and mining, for example) can lead to unsustainable exploitation and ecological injustice by undermining sustainable commons systems and community governance, and negatively influencing the life opportunities of those that hitherto used the commons [66].

Equitable sharing of wealth and access to services that foster wellbeing promote collective identity and social cohesion for sustainability. Continuous updating of local knowledge secures bio-economies by alerting producers and gatherers of change, new threats, and new opportunities. Diverse income streams better assure stability should some products or markets fail, while increasing adaptability to allow systems to continue to prosper as economic constraints and opportunities change (Pillar 3). Building capital provides a store of resources for experimentation to develop new products and markets, and to ride out market or production failures.

The prospect of building and transferring wealth to one's children is a powerful motivation for economic success and resilience (Pillar 4). However, the modern market economy has an inbuilt mechanism for shortsightedness in the forms of inflation and discounting of future values. By building and supporting local economies, and capacitating local producers to contribute to the economy in diverse ways, economic resilience can be attainable. The recognition of different economies is a first step. Disturbances caused by globalization, as well as the perturbation of globalization on economic systems, needs to be recognized in order to support communities as they actively and creatively engage in the economy.

We propose an Economic Precautionary Principle as follows (with bold text indicating the modifications from the original EPP definition): "When an activity raises threats of harm to **human communities' monetary or bio-economies**, precautionary measures should be taken even if some cause and effect relationships are not fully established."

3.4. Operationalizing Pathways as a System

We recommend reconvening each of the three domains into the Universal Precautionary Principle to operationalize it through a systems lens. In the application phase, pathways merge; no longer shall each domain be recognized or analyzed in silos, but instead as holistic "pathways of application" that are bound together by the four pillars of action [22,67,68].

Simultaneously building natural, social, and economic capital nurtures shock resilience because there is sufficient buffering in the socio-ecological system to withstand perturbations like droughts and floods, market collapse, or social disorder [37]. Building and sustaining capital creates space for experimentation and learning as a deliberative process. Learning from and attention to systems feedback between domains is particularly important for transformative resilience—the ability to re-engineer socio-ecological systems to new orientations in order to reduce and avoid risk in the first place, rather than just cope better with the perturbations when they come. The UPP makes it more

likely that humans can share awareness and knowledge to change before crisis forces it upon us, harm occurs, and reduced choices for healthy feedback loops are available.

In the UPP's operational stage, cross-scale bridging is crucial. Multiple stakeholders from IPLCs, regional and federal governments, international agencies, civil society organizations, and industry professionals need to collaborate to create a risk assessment strategy and action plan. Power imbalances and systemic oppression need to be considered when facilitating processes that involve cross-scale dialogue and decision-making, as the pretense of choice and options may not in fact present balanced options for all stakeholders. The process through which FPIC has been historically conducted, for example, often includes top-down and unidirectional practices, without multi-level co-creation of strategies and action plans. Additionally, genuinely free consent that includes multiple equitable options, after supplying adequately translated and accessible information, is rarely sought out in practice. Therefore, to truly operationalize the UPP, institutions need to move beyond tokenized "checkboxes" to appease funders and ethics reviewers. Indeed, its process—and the multi-lateral cross-scale knowledge-sharing that will inevitably take place through a due-diligent process—should be celebrated, not dreaded. We recommend that all stakeholders come to the process of operationalizing the UPP prior to being wedded to an idea regarding the precise shape of the activity, with the understanding that alongside collaboration inevitably comes compromise, change, and adaptation.

The UPP focuses not only on correct outcomes but also on appropriate processes, and requires active and reciprocal involvement from affected communities in the establishment and approval of all decision-making related to the planning, process, and goals of activities. To do so, agencies, policy-brokers, and funders need to actively support this process; otherwise, practitioners will not have the resources needed to prioritize process. The Western-economic structures of our most powerful institutions are not currently conducive to the values espoused in the UPP [69]. Many institutions' reporting frameworks, for example, only measure outcomes and outputs, thus relegating process to become nothing more than a "means to an end." By abiding by the UPP, "the end cannot justify the means;" the process itself must abide by respectful, reciprocal, and equitable practices. To measure such a process, over the course of an activity, social capital will have been built rather than depleted—evidenced by trust, long-term relationships, and knowledge-sharing, among other attributes. We recommend that such processes be included in reporting requirements, to elevate its importance and give practitioners the time and resources necessary to prioritize appropriate process over mere efficiency and checkboxes.

The operationalization of the UPP, while context-dependent, needs to consider all platforms—legal, policy, management, and community. This could include a launch of parallel processes that include public advocacy that engage media and community, alongside the implementation of legal precedence through case law, for example. From an international policy perspective, encouraging the UPP as a tool in thematic, regional, and global assessments such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) or as an operational tool for working groups of the Convention on Biological Diversity (CBD) would be a valuable first step. In terms of national implementation, new *sui generis* legislation and/or acts of parliament that emerge from land-claim settlements (such as the Treaty of Waitangi—Te Urewera Act 2014, or the "Whanganui River Act," in New Zealand), for example, could allow Indigenous communities to apply customary and environmental management, based on the UPP tool.

The UPP has the potential to serve as a fundamental tool for convention text, resolutions, decisions, guidelines, strategic plans and frameworks, and other mechanisms. This tool could be socialized as *the* standard of ethics for countries when actively engaging biological and cultural diversity.

The implementation of the UPP in practice is context-dependent. Its practitioners therefore must be willing to adapt to the particular circumstances of local, regional, and global sociocultural, economic, and natural environments. Historically, policy-brokers have tended to desire universal formulas and step-by-step guides to implement strategies [60,61,70]—it is indeed more efficient; however, we caution against this, as using unmodified universal models can "rubber-stamp"

templates onto case-specific circumstances, without recognizing the particular contexts, players, or agents involved. While the UPP forms the "why" and guides practitioners to value fragile and essential parts of our planet's lifeways, the "how" (implementation) must be considered within place, and in collaboration with the people who will be most affected by the activity's decisions.

4. Discussion

The EPP was, in our view, an excellent heuristic for highlighting a general problem of environmental risk that has guided decision- and policy-makers, as well as investments in environmental restoration. Our enunciation of the equivalent Sociocultural Precautionary Principle and Economic Precautionary Principle, and especially joining them under a Universal Precautionary Principle, seeks to highlight that the enduring solution to healing environmental neglect is to focus much of our endeavor on nurturing people, their culture, and their economy in ways that promote sustainability.

Penetration of the EPP into advocacy, education, policy, legislation, management, and research was enhanced by its fundamental nature, which made it generally applicable to a wide variety of local, national, and international risk assessments [35,38,71]. Crucially, the principle gained traction for use by process professionals, communities, and businesses that operate in quite different ways than academics. Simple and direct language and brevity helped in the identification of core guidelines, even though specific applications were locally nuanced and hotly contested [35,72,73].

If the UPP is to gain similar effectiveness, it will need to be tested, adopted, and continuously refined by a diverse range of users and scales. Involvement of international facilitating agencies like the United Nations Educational, Scientific and Cultural Organization (UNESCO), the FAO, the CBD, and the International Union for Conservation of Nature, among other biodiversity-related multi-lateral instruments, could speed this refinement process. Global economic forums like the World Bank, International Monetary Fund, and The Organization for Economic Co-operation and Development, could use the UPP to guide a more pluralistic and systems-oriented analysis of the consequences of their policies, investments, research, and reporting. Safety depends on these institutions broadening their primary focus of economic development to avoid disrupting the other pillars on which longer-term economic resilience co-depends. Changing global corporate business will become even more challenging in the future due to their lack of dependence and concentration on local place, remote shareholder governance models, and the potential for the sheer force of their economic activities to disrupt diverse and locally tuned economies. Both public and private global economic actors could use the UPP to build awareness of the importance, vulnerability, and diversity of local economies. Crucial local experiments will provide the true test of the tool's utility and efficacy for delivering systems resilience and wellbeing.

Collecting critical case studies of the application of the UPP—including counterfactual thought experiments regarding how an activity would have turned out had the UPP been applied—is an urgent priority. Research on metrics or qualitative inferences that are structured around the pillars (Box 2) could focus critical evaluation and hasten learning to improve processes that we expect will be crucial for success in conflict resolution and collaboration. Assessing changes in social capital is particularly challenging, but we believe it is too often given the lowest priority in assessing risk and measuring success of the outcomes. Truly including diversity requires a discussion about how to redesign global frameworks of governance [69,74,75]. If social capital has grown as a result of the respectful process between a range of actors and knowledge-holders by the end of any specific risk assessment, actors will be more prepared and confident to effectively engage in the application of the UPP in the future.

The insufficient attention that has thus far occurred regarding the necessary pathways to achieve environmental and cultural health—the nurturing of people, their communities and cultures, and their diverse economies—is surprising given the self-evidence of their co-dependence: People are unlikely to collaborate for sustainability unless they have fair access to resources; communities cannot maintain a presence, a place to make a stand, unless they have a healthy economy; they are unlikely to notice danger or care for a place unless they are secure in the knowledge that it will continue to

nurture them, their kin, and their culture for the foreseeable future; and basic human needs must be met before there is room and capacity for investment in long-term continuance. An overarching reciprocity is the keystone for continuance—if the environment is healthy, people are more likely to be healthy. Equally if people are healthy, the environment is more likely to be healthy; for both people and the environment to be healthy, their culture and economy need to be healthy. We are noticing a growing number of environmentally concerned actors who are turning their attention to nurturing society and culture as a means to engineering a healthy environment. An ultimate sign of safety and long-term commitment to systems sustainability will be when the UPP is applied simply to create wellbeing for society, culture, and livelihoods as outcomes in their own right, rather than merely as a tactic to ensure that environmental care ensues.

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