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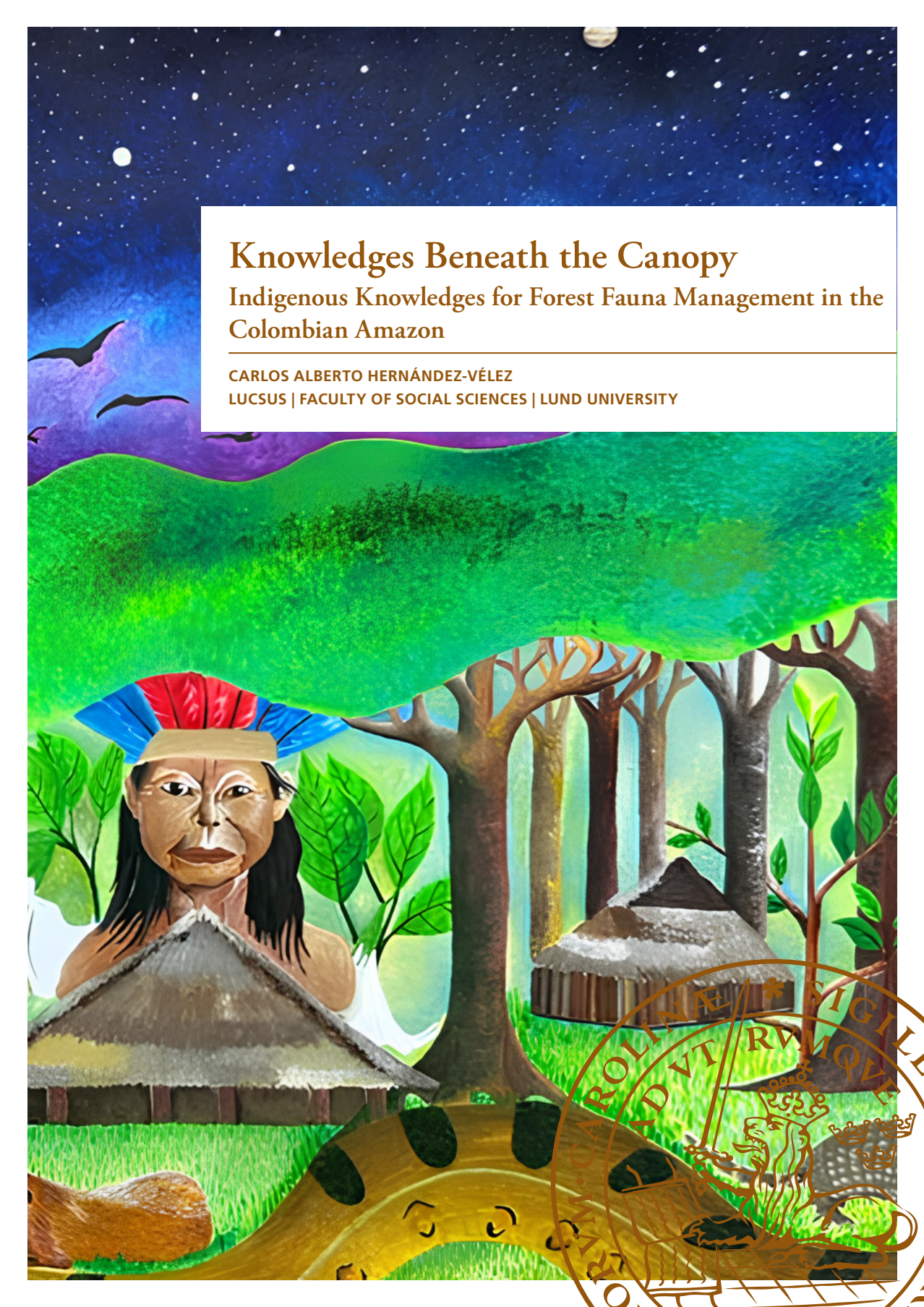
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Knowledges Beneath the Canopy

Indigenous Knowledges for Forest Fauna Management in the Colombian Amazon

CARLOS ALBERTO HERNÁNDEZ-VÉLEZ

LUCSUS | FACULTY OF SOCIAL SCIENCES | LUND UNIVERSITY

What if the future of Amazon sustainability depends not on producing more knowledge, but on weaving existing knowledge differently?

Through four years of co-production with Indigenous researchers, this work reveals how Traditional Ecological Knowledge continues to sustain forest fauna, biocultural resilience, and environmental stewardship in the Colombian Amazon. At the intersection of sustainability science, decolonial research, and Indigenous wisdom, it calls for a fundamental shift: from studying Indigenous knowledge to learning with it. This is an invitation to become Knowledge Weavers and to reimagine sustainability through relationships, reciprocity, and justice.



Carlos Alberto Hernández-Vélez is a transdisciplinary researcher educated in Biology, Anthropology, Conservation, and Sustainability Science. Collaborating with Indigenous peoples in the Colombian Amazon, he integrates ecological science, participatory research, and decolonial perspectives to foster transformative sustainability. His current work pioneers knowledge-respectful partnerships that bring Indigenous and scientific knowledges into dialogue, creating spaces for mutual learning and pushing the boundaries of sustainability thinking and practice, with a particular emphasis on forest fauna management in the Colombian Amazon.



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Abstract: Indigenous and Local Knowledge (ILK) is increasingly recognised for its importance in environmental governance. However, despite this recognition, most research on tropical forest fauna lacks the inclusion of Indigenous epistemologies. My thesis addresses what I refer to as the Inclusion-Participation-Dialogue-Coproduction Gap through four years of Participatory Action Research (PAR) with two Indigenous communities in the Colombian Amazon: Tipisca and Ceima Cachivera. Guided by transformative science, decolonial theory, and the Multi-Evidence Base Approach, I draw on 42 community workshops to study the role of Traditional Ecological Knowledge (TEK) in wildlife management, its current state, and its potential to contribute to sustainability transformations. Furthermore, I investigate how PAR can weave TEK and non-Indigenous knowledges for decolonial forest fauna management. My thesis consists of four articles and a synthesis chapter, using the Exchanging Research Seats (ERS) methodology, which integrates Indigenous protocols such as ceremonies and territorial walks. My findings show that forest fauna within Indigenous Knowledge Systems is understood relationally, embedded in cosmology, ceremony, and governance, and functions as a sophisticated management system grounded in principles of shamanic knowledge. Moreover, the Exchanging Research Seats methodology redistributed epistemic authority and enabled Indigenous researchers to present TEK to regional authorities, thereby strengthening Indigenous self-determination and intercultural networks. My work offers empirical data on Amazonian TEK, a conceptual framing of ILK and the ERS methodology as a decolonial practice. Thus, I demonstrate that biocultural resilience depends on positioning Indigenous knowledge as a guiding force rather than merely data, thereby urging sustainability practitioners to become knowledge weavers.

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Indigenous Knowledges for Forest Fauna Management in the Colombian Amazon

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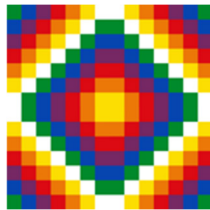
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For the reemergence of Indigenous wisdom around the globe

*This synergic remembrance will reunite all people with the interdependent
relational oneness we already are.*



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Abstract

Indigenous and Local Knowledge (ILK) is increasingly recognised for its importance in environmental governance. However, despite this recognition, most research on tropical forest fauna lacks the inclusion of Indigenous epistemologies. My thesis addresses what I refer to as the Inclusion-Participation-Dialogue-Coproduction Gap through four years of Participatory Action Research (PAR) with two Indigenous communities in the Colombian Amazon: Tipisca and Ceima Cachivera. Guided by transformative science, decolonial theory, and the Multi-Evidence Base Approach, I draw on 42 community workshops to study the role of Traditional Ecological Knowledge (TEK) in wildlife management, its current state, and its potential to contribute to sustainability transformations. Furthermore, I investigate how PAR can weave TEK and non-Indigenous knowledges for decolonial forest fauna management. My thesis consists of four articles and a synthesis chapter, using the Exchanging Research Seats (ERS) methodology, which integrates Indigenous protocols such as ceremonies and territorial walks. My findings show that forest fauna within Indigenous Knowledge Systems is understood relationally, embedded in cosmology, ceremony, and governance, and functions as a sophisticated management system grounded in principles of shamanic knowledge. Moreover, the Exchanging Research Seats methodology redistributed epistemic authority and enabled Indigenous researchers to present TEK to regional authorities, thereby strengthening Indigenous self-determination and intercultural networks. My work offers empirical data on Amazonian TEK, a conceptual framing of ILK and the ERS methodology as a decolonial practice. Thus, I demonstrate that biocultural resilience depends on positioning Indigenous knowledge as a guiding force rather than merely data, thereby urging sustainability practitioners to become knowledge weavers.

Keywords: Indigenous Ways of Knowing, Wildlife management, Epistemic Justice, Transformative Sustainability, Weaving Knowledge Methods, Amazonas, Colombia.

Sammanfattning

Urfolks- och lokal kunskap (ULK) erkänns alltmer för sin betydelse inom miljöförvaltning. Trots detta saknar mycket forskning om tropiska skogsdjur ofta inkludering av urfolks epistemologier. Mitt examensarbete tar itu med det jag kallar för 'Inkluderings-Deltagande-Dialog-Produktionsgapet' genom fyra år av delaktighetsbaserad handlingsforskning (DHF) med två urfolksgemenskaper i den colombianska Amazon: Tipisca och Ceima Cachivera. Med vägledning av transformativ vetenskap, dekolonial teori och den multi-bevisbaserade metoden, baserar jag mig på 42 samhällsworkshops för att studera rollen av traditionell ekologisk kunskap (TEK) i viltvård, dess nuvarande tillstånd och dess potential att bidra till hållbarhetsförändringar. Dessutom undersöker jag hur DHF kan väva samman TEK och icke-urfolkskunskaper för dekolonial förvaltning av skogsdjur. Mitt arbete består av fyra artiklar och ett synteskapitel, med hjälp av metoden 'Utbyte av Forskningsplatser' (UFP), som integrerar urfolksprotokoll som ceremonier och territoriella vandringar. Mina resultat visar att skogsdjur inom urfolkskunskapssystem förstås relationellt, inbäddat i kosmologi, ceremonier och styrning, och fungerar som ett sofistikerat förvaltningssystem grundat på shamanistisk kunskap. Dessutom omfördelade UFP-metoden epistemisk makt och möjliggjorde för urfolksforskare att presentera TEK för regionala myndigheter, vilket stärkte urfolks självbestämmande och interkulturella nätverk. Mitt arbete ger empiriska data om amazonisk TEK, en konceptuell ram för ULK och UFP-metoden som en dekolonial praktik. Därmed visar jag att biokulturell resiliens är beroende av att positionera urfolkskunskap som en vägledande kraft snarare än enbart data, och uppmanar därmed hållbarhetsarbetare att bli kunskapsvävare.

Nyckelord: Urfolkens sätt att veta, viltvård, epistemisk rättvisa, transformativ hållbarhet, vävning av kunskapsmetoder, Amazonas, Colombia.

Resumen

El Conocimiento Indígena y Local (ILK) es cada vez más reconocido por su importancia en la gobernanza ambiental. Sin embargo, a pesar de este reconocimiento, la mayoría de las investigaciones sobre la fauna de los bosques tropicales carecen de la incorporación de epistemologías Indígenas. Mi tesis aborda lo que denomino la Brecha de Inclusión-Participación-Diálogo-Coproducción a través de cuatro años de Investigación-Acción Participativa (IAP) con dos comunidades indígenas en la Amazonía colombiana: Tipisca y Ceima Cachivera. Guiada por la ciencia transformativa, la teoría decolonial y el enfoque basado en Evidencias Múltiples, sustento mi trabajo en 42 talleres comunitarios para estudiar el papel del Conocimiento Ecológico Tradicional (CET) en la gestión de la fauna silvestre, su estado actual y su potencial para contribuir a transformaciones hacia la sostenibilidad. Además, investigo cómo la IAP puede tejer conocimientos tradicionales y no indígenas para una gestión de la fauna silvestre de carácter decolonial. Mi tesis consta de cuatro artículos y un capítulo de síntesis, utilizando la metodología de Intercambio de Asientos de Investigación (IAI), que integra protocolos Indígenas, como ceremonias y caminatas territoriales. Mis hallazgos muestran que la fauna silvestre dentro de los Sistemas de Conocimiento Indígena se comprende de manera relacional, integrada en la cosmología, las ceremonias y la gobernanza, y funciona como un sistema de gestión sofisticado basado en principios del conocimiento chamánico. Además, la metodología de IAI redistribuyó la autoridad epistémica y permitió a investigadores Indígenas presentar el CET ante las autoridades regionales, fortaleciendo así la gobernanza local y las redes interculturales. Mi trabajo ofrece datos empíricos sobre el CET amazónico, un marco conceptual del ILK y de la metodología IAI como práctica decolonial. Por tanto, demuestro que la resiliencia biocultural depende de posicionar el conocimiento Indígena como una fuerza guía, en lugar de meramente como datos, instando así a los practicantes de la sostenibilidad a convertirse en tejedores de conocimiento.

Palabras clave: Conocimiento indígena, manejo de la vida silvestre, justicia epistémica, sostenibilidad transformativa, tejido de conocimientos, Amazonas, Colombia.

List of Articles

Article 1

van Maurik Matuk, F. A., Verschuuren, B., Morseletto, P., Krause, T., Ludwig, D., Cooke, S. J., Haverroth, M., Maesters, M., Mattijssen, T. J. M., Keßler, S., Lanza, T. R., Milberg, E., Ming, L. C., **Hernández-Vélez, C. A.**, da Silva, K. M. T., Souza, M. P. V., Souza, V. O., Fernandes, J. W., & dos Reis Carvalho, B. L. (2023). Advancing co-production for transformative change by synthesising guidance from case studies on the sustainable management and governance of natural resources. *Environmental Science & Policy*, 149, 103574. <https://doi.org/10.1016/j.envsci.2023.103574>.

Article 2

Hernández Vélez, C.A., Krause, Torsten, Jackson, Guy. (2026) Indigenous and Local Knowledges inclusion in Forest Fauna research - A Systematic Review in the Tropics. *AMBIO*. doi: 10.1007/s13280-026-02378-y.

Article 3

Hernández-Vélez, C.A. (forthcoming 2026). Exchanging Research Seats in the Amazon: Weaving Indigenous and academic methods in Participatory Action Research for sustainable forest fauna management. *Global Sustainability*.

Article 4

Hernández-Vélez, C.A. Torsten Krause, Airumakuchi Hunters Association: Edilberto Laureano del Águila, Milton Pinto Linares, Tipisca Community: Sirley Valentín, Teresa Suárez, Claudia Sadidt Grande, Remberto Macedo Ahue, Ceima Cachivera Community, Jacinta Uribe, Francy Ruth Trujiilo, Jaime Gutiérrez, Gilberto Gutiérrez, Emson Estiven Hernández, Emilio Hernández (in review 2026). Indigenous Knowledges for Sustainable Forest Fauna Management - Insights from Participatory Action Research in the Colombian Amazon. *People and Nature*.

Contributions to the Articles

In Article 1, I contributed to a multi-case comparative study led by F. Matuk. I was responsible for data collection, analysis, and interpretation of the results for my case study, and I contributed to revising the manuscript.

In Article 2, I conceived the main idea and designed the research. I coordinated the distribution of the literature review tasks among the coauthors and led the compilation of the dataset. I also led the analysis and interpretation of the results and was responsible for writing and editing the manuscript, with support from my coauthors.

In Article 3, as the sole author, I conceived and designed the study, collected the field data, and wrote and edited all text and figures. The manuscript benefited from revisions and feedback provided by my advisors.

In Article 4, I led the conception and design of the main ideas, which were subsequently adapted and expanded through a collective, participatory research process during fieldwork. The printed materials produced in this process were revised, edited and later collaboratively refined by all Indigenous coauthors. My advisors also contributed through writing and editorial support.

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Abbreviations

SES	Social-Ecological Systems
CAS	Complex Adaptive Systems
ILK	Indigenous and Local Knowledges
IWK	Indigenous Ways of Knowing
IKS	Indigenous Knowledge Systems
TEK	Traditional Ecological Knowledge
SK	Shamanic Knowledge
TSS	Transformative Sustainability Science
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IP&LC	Indigenous Peoples and Local Communities
PAR	Participatory Action Research
WK	Weaving Knowledges
MEB	Multi-Evidence Based approach
ERS	Exchanging Research Seats methodology
TICOYA	Tikuna Cocama Yagua Association
AATIAM	Association of Traditional Indigenous Authorities near Mitú
LRG	Local Research Group

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Pastora Guerrero (Magüta), Ignacia Díaz (Tuyuca), Emilo Hernández (Barassano), Cándido Muñoz (Tatuyo)

Prologue

"A long time ago, you came to live among us and spoke like a spirit. Little by little, you learned to imitate our language and to laugh with us. We were young, and at first, you didn't know me. Our ways of thinking and our lives were different because you are the child of those other people whom we call *napë pë*. Your teachers did not teach you to dream as we do. Then you came and became my friend. You placed yourself by my side and then wished to learn the words of the Xapiri, whom you call spirits in your language. So, I entrusted my words to you and asked if you would take them far away to be heard by the white people, who know nothing about us. We sat and talked in my home for a long time, despite the bite of the horsefly and the black fly. Few are the white people who have listened to our words in this way. I gave you my history so that you could respond to those who question themselves about what the inhabitants of the jungle think. In the past, our elders did not say anything about these things because the whites did not understand our language. It is for this reason that my words will be new to those who freely wish to hear them."

([Kopenawa & Albert, 2013](#))

"Game animals are people...They have their own mind (*inaya keti oca*) and their own thoughts (*inaya tuorise*), just like men. Their mind is even stronger than that of men. They can see and hear even though we cannot see and hear them. They have *malocas* and communities, they have their own dances and their own ritual paraphernalia and instruments. They have captains, shamans, singers, dancers and their own workers (*josa*). Each community of game animals has its own territory: the animals of the Taraira River are different from those of the Comeña, the animals of the Pirá are different from those of the Apaporis. Each group of animals has its own "culture"; those who live in the center of the jungle have different customs from those who live on the banks of the river, and those who live in savannas are different from those who dwell in Monte Bravo. And each kind of animal has its favourite food: what monkeys eat, birds do not eat, some birds prefer a certain kind of fruit while others prefer other fruits..."

Narration by Ignacio Makuna, knowledge keeper in Vaupés-Colombia, recorded by
Kaj Århem in 1989 (Århem et al., 2004).

Why Beneath the Canopy?



Aerial view of the Amazon canopy in Colombia
(Vaupés photo by C.A. Hernández-Vélez, 2015)

The canopy of a tropical rain forest operates as both a physical and a conceptual boundary. From an aerial perspective, it appears as a visible frontier; from the ground, it functions as a cover from the sky. From another vantage point, it separates communities that have lived beneath it for thousands of years from the Technosphere, which relies on satellite imagery and land-cover maps to construct a particular image of the forest. Yet, these two-dimensional images do not show the many different realities that the Amazon truly is. On the surface, these images portray a green tapestry cover that, by itself, is inherently connected to a vast knowledge of Indigenous communities and their realities, forces, and the ways they are actually shaping the tapestry into a much more complex system where the social and the ecological are intertwined in many ways. Recognising the importance of moving beyond a surface understanding that is not rooted in the deep knowledge beneath this canopy—knowledge passed down long before modern country boundaries—inspired me to live in the Amazon through recurrent cultural immersions. This is a constant reminder of how much there is to learn and experience beyond what meets the eye.

Yet, there is another form of canopy presented as the invisible aspects of our own thinking, constructed by our normalised beliefs.

My first immersion in the Colombian Amazon with Indigenous communities occurred when I was hired by a local school project as an intercultural teacher in a semi-isolated community in Vaupés (Yapú community along the Papurí River) between 2012 and 2015. This experience opened my curiosity and desire to deepen my self-investigation into my Indigenous and Mestizo¹ heritage.

One of my first reflections upon my return from the Amazon was the understanding of a systemic exclusion in my education of two major things: the incommensurable relevance of Indigenous Knowledge Systems (IKS) in the history and identity of Colombia, and the brutal and violent oppression of the original inhabitants of these territories. This was now evident to me, expressed in the country's denial of its Indigenous heritage. Here, the knowledge "beneath the canopy" emerged.

Colombia is defined as one of the world's most bio-culturally diverse countries ([Maffi & Woodley, 2012a](#))— with currently 117 Indigenous groups speaking 60 languages—and named after its Portuguese / Spanish conqueror, "Land of Columbus", denying its name to be connected to the beginning of its multicultural realities and roots.

The colonised identity is not exclusive to Colombia and reflects a *modus operandi* of hiding and suppressing information while creating new symbols to eliminate undesired ones. This is done in any systematic war on a culture where traditions are relabelled around the globe ([Türkmen, 2003](#)). Dominant symbols, names and structures have been set in place to hide crucial information about our lineages. For this reason, I began revisiting my family names, the country's toponymy, and historical symbolic figures, which led me to a new awareness that "Indigenous" is ubiquitously hidden in plain sight. In this sense, not only can we find the unknown knowledges beneath the Amazon canopy, but beneath nations' symbols, churches, behaviours, and normative history.

And there it was, the alternative story, very much alive and accessible to critical, curious, truth-longing eyes.

This is why, in this work, I am interested in the Knowledge "above and beneath" the Canopy (non-indigenous and IKS, respectively), creating bridges between the two that connect Indigenous and non-indigenous Knowledges, sustainable management of Forest Fauna, and inclusive dialogue methodologies.

¹ I relate to Gloria Anzaldúa definition of mestizo positionality as: a *state of consciousness* formed by living within contradictions and borderlands, producing an epistemic standpoint capable of holding tension, reflexivity, and transformation rather than coherence or purity. Anzaldúa, G. (2021). *Borderlands/La frontera: la nueva mestiza*. Capitán Swing Libros.

Indigenous research colleagues

Like all doctoral theses, I present a highly complex topic, perhaps with a particular nuance and a set of paradoxes in the development of South American Indigenous Knowledges carried out at a Scandinavian University. I find this paradox powerful and challenging, but still appropriate, as the task of promoting peace through emancipating human experience is a priority process with those who have forgotten their Indigenous heritage. Even if rejected or neglected, this profound relational wisdom of interdependence will remain present in people, rocks, rivers, territories, beings, and in family genes and genealogies.

This work contributes to the growing field of research on co-production for the sustainable use of forest fauna in the Amazon region, drawing on TEK and employing participatory emancipatory research methods. The participatory research process was guided by me, constantly supported by my advisor, Torsten Krause, and developed with teams of Indigenous researchers in two Amazon departments of Colombia (Vaupés and Amazonas). These indigenous colleagues were continuously involved in the research design and throughout the data collection. I coordinated the process and logistics, and Indigenous researchers collected data monthly throughout the research. In Puerto Nariño, Amazonas, the Airumakuchi Indigenous hunters' association, led by Edilberto Laureano del Águila and Milton Pinto, is a fundamental part of this research (Figure 1).



Figure 1. Work meeting with Airumakuchi hunters' association and local allies in Puerto Nariño, Amazonas.

In Tipisca, local agreements were possible through the work with Sirley Valentin, the Curaca (village Authority), and Teresa Suárez, who coordinated monthly community meetings (Figure 2).



Figure 2. Tipisca researchers group (Amazonas, 2023).

Front row from left to right: Juan Vásquez, Venilda Valentín, Serginho Silva, Luz Dari Coello (middle row), Elida Ahue, Belisario Macedo, Casilda Coello, Manuel Gómez, Eulogio Coello, Remberto Macedo. (back row) Carlos Hernández, Alicia Coello, Milton Pinto, Óscar Caldas, Eugenio V.

In Vaupés, we received great support from Luis Fernando Jaramillo from the SINCHI Institute, who recommended us to work with Ceima-Cachivera community. The local research team members were: Emson Estiven Hernández, Jacinta Uribe, Gilberto Gutiérrez, Jaime Gutiérrez, Franklin López, Francy Trujillo, with the captain's support (César Gutiérrez, Guillermo Yuremain) and their traditional elder leader Emilio Hernández and his family, who participated immensely in this research (Figure 3). I personally received vital guidance from my “cultural godfather”, the shaman Emilio Hernández. Together, we developed this study to understand and strengthen local biocultural knowledge of forest fauna management in their communities.



Figure 3. Ceima Cachivera researcher group (Vaupés, 2023)

From left to right: Franklin López, Jacinta Uribe, Francy Trujillo, Emilio Hernández, Jaime Gutiérrez, Refino Ávila, Gilberto Gutiérrez, 2023.

This study is an Amazon multi-sited case study, centred on the relational nexus that forms the IKS of forest-fauna-humans, and its connection to knowledge production in academic research for sustainability. The focus on this nexus and its relation to academia is rooted in critical thinking, aiming to expand the understanding of the Amazon Region by transforming research practices with Indigenous knowledges and territories. This approach aligns with action-oriented research that goes beyond analysing environmental problems to actively coproduce solutions for sustainability, connecting with Transformative Sustainability Science (TSS) ([Horcea-Milcu et al., 2024](#)).

I chose to sustain my previous relationships with the Vaupés and Amazon communities as a transformative practice, aiming to deepen them. Living in Vaupés shaped and transformed my paradigms and my knowledge of forest fauna, conservation, and sustainability. My whole research approach, methodologies, awareness and personal beliefs also changed, shaping how and with whom I decided to continue working on the Amazon, to redirect towards local and Indigenous communities. Therefore, returning to these regions was the right choice for starting this doctoral research. This personal insight influences my approach to sustainability, aligns with participatory research methods, and its theory of change towards societal transformation.

1. Introduction

The Amazon biome and its forests, wetlands and rivers are highly complex Social-Ecological Systems (SES) that can be studied and managed more sustainably through meaningful and respectful engagement with Indigenous Knowledge Systems (IKS). Despite increasing recognition of their importance, Indigenous and Local Knowledges (ILK)—including TEK²—remain structurally marginalised in academic research and environmental governance ([Albuquerque et al., 2021](#); [Bennett et al., 2025](#); [Nadasdy, 2003](#); [Tengö et al., 2014](#); [Whyte, 2013](#)).

I define TEK as a living and evolving knowledge system and way of being-knowing, rooted in ancestral teachings and sustained through oral transmission, practice, and direct experiences. TEK embodies a holistic understanding of the interconnected relationships among humans, more-than-human beings, and territory, accumulated over generations to guide wellbeing, environmental stewardship, and the maintenance of balance within the social-ecological world.

Many dimensions of this TEK have been, and continue to be, marginalised, with negative effects on sustainability outcomes. This marginalisation constrains not only the diversity of knowledges available to sustainability science but also the effectiveness, legitimacy, and justice of sustainability outcomes.

I approach the Amazon as an SES in which forest fauna, human livelihoods, and knowledge systems are deeply interconnected, coevolving with territorial limits and governance systems within ([Berkes et al., 2000](#)). Indigenous People and Local Communities (IP&LC) are embedded within these systems through long-term, place-based interactions that have generated detailed ecological knowledge over the years.

² In this thesis, Traditional Ecological Knowledge (TEK) plays a central role and is understood to exist within Indigenous and Local Knowledges (ILK) and Indigenous Knowledge Systems (IKS). Within TEK, I place Shamanic Knowledge (SK) and other specialised knowledges within Indigenous communities. My own TEK definition is inspired from Berkes Sacred Ecology 2017, but understood in this study in the Colombian Amazon as way of knowing, as a part of broader knowledge system, as an ongoing process, orally and “practice based” transmitted through generations, with detailed information of social-ecological dynamics, harvested through thousands of years of experimentation and directed by the knowledge given by the prime movers of the universe along its evolution stages and organising principles finally arriving to the first humans.

However, dominant scientific approaches continue to rely primarily on Western epistemologies, often overlooking or simplifying these relational knowledge systems ([Albuquerque et al., 2021](#); [Kimmerer, 2013](#); [Smith, 2016](#)). As a result, current understandings of forest fauna remain partial and interventions risk being ecologically insufficient and socially disconnected. This is why I chose to formulate the following aim and research questions.

Aim and Research Questions

The overall aim of my research is to enhance the current understanding of IKS and TEK within Transformative Sustainability Science (TSS) for forest fauna management. In achieving this aim, I promote a more inclusive scientific practice with a PAR approach by creating dialogues and co-producing knowledge between Indigenous communities in the Colombian Amazon, as local knowledge holders, and sustainability practitioners.

My main research approach has been knowledge co-production that promotes local processes of collective reflection on TEK, IKS, and other forms of local knowledge. I do this to advance their critical contributions and self-determination agency amidst the regional biodiversity and sustainability agenda.

This translates into the following research questions:

Main Research Question:

How can sustainability practitioners dialogue with Indigenous Knowledge Systems (IKS) holders in the transformative sustainable management of forest fauna in the Amazon?

- 1) How are IKS included in academic research on tropical forest fauna?
- 2) How is forest fauna represented in IKS in the Colombian Amazon?
- 3) What is the current state of IKS at local communities and its contributions to sustainability transformations in forest fauna management?
- 4) How and to what extent can PAR promote the weaving of IKS and non-indigenous knowledges for more sustainable, inclusive forest fauna management?

This thesis and its research questions are addressed through three interrelated dimensions, referred to as entry points (Entrances 1, 2, 3), that together define key gaps and social-ecological challenges in sustainability science. The entry points link

specifically to broader dimensions relating to the scales of organisms, knowledge and research/management practices: **1. Forest Fauna, 2. IKS and TEK, 3. Knowledge Co-production.**

I will use the term ILK initially in the introduction section as a broader concept to refer to knowledge systems held by IP&LC and, in the main arguments, to encompass non-indigenous communities. Later, when I describe and present my case studies, I will interchange them (ILK and IKS) and then focus solely on IKS and TEK upon arriving at topics of Amazon and Indigenous territories. The change to focus on TEK aligns better with the local Amazon categories and Indigenous territories that are the centre of my empirical work.

Figure 11 in the theoretical chapter explains in more detail how ILK, IKS, TEK, and Shamanic Knowledge (SK) are related to one another. I now turn to three key entry points to frame my PhD thesis.

Entrance 1: Forest Fauna

Forest fauna plays a central role in shaping the structure and functioning of Amazonian ecosystems through processes such as seed dispersal, pollination, and trophic regulation. Interconnections among species and their dynamics within the ecosystem are vital for ecosystem resilience, biodiversity, and the stability of ecological interactions. These dynamics are not only ecological but social-ecological, as they directly support human livelihoods and cultural practices, particularly for IP&LC.

In the Amazon, Indigenous communities are part of a complex relational system that links humans, animals and plants. Current scientific understanding of forest fauna remains incomplete due to the failure to incorporate IKS ([Watson et al., 2019](#)). Indigenous communities in the Amazon are constantly interacting with these ecosystems and therefore are better equipped to identify and respond to their changes ([Hernández-Vélez, 2026 in review](#); [Luzar et al., 2011](#); [Parry & Peres, 2015](#)). For this reason, Indigenous communities have occasionally been able to contribute their knowledge on forest fauna, which is unknown to the scientific community ([Barros et al., 2012](#); [DaviD W. Fleck, 2016](#)), but is crucial for addressing specific threats and drivers of biodiversity loss.

Defaunation (the loss of forest fauna) and deforestation have been found to be higher outside Indigenous territories, showing that most of the world's terrestrial biodiversity exists in areas traditionally managed, owned, used or occupied by IP&LC ([Alejo et al., 2021](#); [Bennett et al., 2025](#); [IPBES, 2019](#)). Biodiversity and the knowledge associated with its management are still deteriorating ([Bennett et al., 2025](#); [IPBES, 2019](#)). Halting

the loss of cultural and biological diversity is essential for maintaining ecological relationships that lead to positive outcomes across different socioecological levels. Climate regulations need to take into account these relationships for local, regional and planetary well-being ([Moraes et al., 2021](#)), including Sustainable Development Goals (SDGs) ([Krause & Tilker, 2022](#)). In this regard, forest fauna has significant and multidimensional importance for human well-being within SES.

The connection between ecosystems, forest fauna, and livelihoods is a key global discussion for sustainability in the Amazon. However, only in recent years have academic and national discussions begun to make visible progress on Indigenous land rights, ancestral territories, food autonomy, and, in general, a more serious dialogue with initiatives that aim to defend livelihoods and cultures ([Baptiste et al., 2012](#)). This recognition of the progressive interests in Indigenous livelihoods in the Amazon leads us to the second entrance.

Entrance 2: Indigenous Knowledge on Forest Fauna

The knowledge held by Indigenous communities about their ancestral territories and their forest fauna is immense and generally unacknowledged in Amazonian scientific and governmental discussions ([Nassar et al., 2020a](#)).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) defines knowledge as “a body of propositions that are adhered to, whether formally or informally, and are routinely used to claim truth” ([Díaz et al., 2015](#)). TEK has been used by Amazon Indigenous communities, both formally and informally, to assert truths about how to maintain healthy relationships with forest fauna within their territories ([Chacon, 2023](#); [Godo-Bakari, 2015](#)). Indigenous communities currently living in the Amazon region are holders of knowledge systems that have been learning and testing forest-fauna-human relationships for at least 12,000 years ([Roosevelt, 1999](#)). In many cases, their livelihoods and daily interactions continue to deeply depend on the direct and material use of Amazonian ecosystems, bringing them in constant and close contact with the changes and responses in ecological dynamics ([Becerra et al., 2021](#)).

Nonetheless, this connection between local livelihoods and forest fauna has been repeatedly left out of global, national, and regional agendas, mainly because dominant narratives have focused on tree cover and forest extent to advance carbon storage and climate change mitigation ([Krause & Nielsen, 2019](#); [Krause & Tilker, 2022](#)). Increased attention to the links needed to promote sustainable human livelihoods is also evident in global initiatives such as the IPBES, a relevant platform that currently aims to engage ILK ([Bennett et al., 2025](#)). Such efforts are vital for enhancing understanding, practice,

and ethics to progress towards sustainability at multiple scales ([Tengö et al., 2017](#)). This points to the vital need for decolonial reflexivity among sustainability practitioners (researchers, institutions and officers) to engage with the depth of the knowledge systems held by IP&LC ([Bennett et al., 2025](#); [Hernández-Vélez, 2026](#); [Lam et al., 2020](#); [van Maurik Matuk et al., 2023](#)).

Entrance 3: Coproducing Knowledge

The challenge and gap of coproducing sustainability knowledge encompass the previous two and are the main focus throughout the thesis. The urgency to respectfully address the knowledge exchange on forest fauna research and management practices with Indigenous communities is currently recognised and emphasised to connect diverse knowledge systems for enhanced ecosystem governance ([Gudde et al., 2026](#); [Tengö et al., 2014](#); [Tengö et al., 2017](#)).

The recognition of this inclusion challenge and methodological gap at the knowledge exchange dimension has been repeatedly pointed out and addressed by the IPBES ([McElwee et al., 2020](#)), the Convention on Biological Diversity (CBD) ([Reyes-García et al., 2022](#)), and the Intergovernmental Panel on Climate Change (IPCC) ([Ford et al., 2016](#)). Each platform explicitly recognises and calls for the inclusion of ILK in their assessments and guiding policies. All these platforms also recognise ‘science’ as a key actor for achieving pathways towards sustainability ([Beck et al., 2014](#); [Bennett et al., 2025](#); [Horcea-Milcu et al., 2024](#); [IPBES, 2021](#); [IPBES, 2019](#)).

Understanding how current science and IKS comprehend social-ecological systems in the Amazon, as well as how Indigenous communities understand and access forest fauna knowledge, requires a strong dialogical methodology, which is currently lacking or underdeveloped in scientific approaches ([Reid et al., 2021](#); [Root-Bernstein et al., 2023](#)). Dialogical, intercultural research methods are repeatedly proposed from other knowledge systems because Western scientific methods alone are inadequate for genuinely integrating Indigenous and scientific knowledge in social-ecological and fauna research ([Athayde et al., 2016](#); [Ban et al., 2018](#); [Johnson et al., 2016](#); [Krause et al., 2020](#)).

However, there are already a number of peer-reviewed studies that document and analyse this ILK and IKS inclusion, highlighting both progress and persistent gaps ([Lam et al., 2020](#); [McElwee et al., 2020](#)). Expanding and revising sustainability practitioners' understandings and management of forest fauna requires reflexive researchers and institutions that recognise the limits of their knowledge, methods, and historical biases

([Trisos et al., 2021](#)). A growing number of publications worldwide are proposing theories, frameworks, methodologies, tools, and processes to address these inclusion gaps and barriers in practice. Many of these proposals have built their plans from previous work coming from, e.g. “theorising from the borders” ([Anzaldúa, 2004](#)), border thinking ([Mignolo, 2012](#)), artistic approaches ([Athayde et al., 2017](#); [Strand et al., 2022](#)), inner-outer transformations ([Woiwode et al., 2021](#)), and Indigenous scholars ([Jacobs, 2025](#); [Johnson et al., 2016](#); [Whyte, 2013](#)).

These approaches and methodologies have been consolidated into research practices such as: Participatory Action Research ([Fals-Borda et al., 1986](#)), Two-Eyed Seeing ([Bartlett et al., 2012](#)), Coproduction ([Ostrom et al., 1978](#)), Participatory Mapping ([Gilmore & Young, 2012](#)), Ethic of equivocation from Viveros de Castro's work in the Amazon ([Viveiros de Castro, 2004](#)) and Weaving Knowledges ([Tengö et al., 2017](#)). Building from or alongside this body of knowledge, it is one of my contributions in this thesis to address the gap in respectful knowledge exchange by proposing the **Exchanging Research Seats Methodology** ([Hernández-Vélez, 2026 \(forthcoming\)](#)).

The previously mentioned work and authors represent clear action-based contributions to what I understand as Weaving of Knowledges (WK), shown in Figure 4. These resemble an ancient practice of Indigenous communities in Colombia (particularly the Arhuacos, Kogis, Wiwas, and Kankuamos ethnic groups) who weave fibres while discussing important community matters in a sacred form. The image shows a personal bag (called *mochila* in Colombia) being woven with patterns that reflect and symbolise the diverse conversations and conclusions occurring during the sacred use of the spoken word (known as *mambeaderos* in the Amazon region). Throughout my thesis, I define and apply WK as the careful action of bridging, integrating, complementing and engaging in bidirectional learning across different knowledge systems, as described in more detail in Chapters 2 and 3.



Figure 4. The Weaving Knowledges approach, associated with the weaving of a *Mochila* by Colombian Indigenous communities

Left image: Asoarhuaco & Artesanías de Colombia 2021; right image: iStock Images.

Weaving knowledge methodologies, either Indigenous or non-Indigenous, are needed to advance this mutual learning. Later in the methodology section (and Article 3), we propose the Exchanging Research Seats (ERS) as part of these WK methods. ERS could be seen merely as a methodological approach to include Indigenous knowledges in transformative sustainability research, it is much more than a new technique. It demands epistemic and ontological shifts and overcoming institutional and cognitive barriers that resist genuine dialogue between knowledge systems ([Chilisa, 2017](#)). This dialogue gap challenge depends on the conscious willingness to enter a new cycle within the scientific paradigm ([West et al., 2024](#)). I now turn to explore why this inclusion is not already taking place, or unfolding more naturally, among sustainability practitioners, nations, global governance systems, and the Amazon Indigenous communities, and what preexisting barriers prevent this inclusion.

The Inclusion, Participation, Dialogue and Co-production Gap

The failure of ILK inclusion and dialogue aspirations across different knowledge structures and competing paradigms is well documented in the literature as self-reinforcing mechanisms that fall back on their own knowledge paradigms, perpetuating the use of already known methods through path dependence or locking in a specific structure ([Stermann & Wittenberg, 1999](#)). Western science — similar to other formalised, institutionalised knowledge systems — often reproduces its own epistemic frameworks through self-reinforcing institutional and cognitive mechanisms, creating methodological and power barriers to meaningful coproduction with IKS ([van Maurik Matuk et al., 2023](#); [Watson, 2013](#)). These dynamics are therefore also present among sustainability institutions and practitioners and hamper participatory, dialogical, and co-production endeavours.

Attempts to dialogue and exchange knowledge often default to assimilating Indigenous knowledge into existing scientific frames rather than enabling reciprocal dialogue (understood here as the negative use of the term *knowledge integration*), reproducing colonial legacies in conservation practice ([Mignolo, 2011](#); [Yanou et al., 2023](#)). Several wildlife co-management cases demonstrate how mainstream ecological measurements and regulatory practices can erase Indigenous management practices and relational ontologies, highlighting the concrete difficulties science faces in engaging in genuine, reciprocal dialogue with non-Western ecological knowledge systems ([Watson, 2013](#))

Because the recognition of ILK has been long overdue, it causes increasing resistance, mistrust and miscomprehension between Indigenous communities towards science, government, and agencies. This implies the need for a comprehensive set of skills and

research methods to address these reactions and traumatic experiences, and to regain trust and mutual understanding.

Nonetheless, many of these dialogical approaches are paradoxically found within IKS, as they themselves are recipients of methods and practices that can reshape environmental and sustainability research ([Chilisa, 2019](#); [Weaver, 2023](#); [Wilson, 2020](#)). Multiple Amazon case studies and cross-cultural frameworks show that respectful engagement can yield new knowledge about forest fauna, and co-produced management ([Athayde et al., 2017](#); [Chapman & Schott, 2020](#); [Hernández-Vélez, 2026 \(forthcoming\)](#); [Hernández-Vélez, 2026 in review](#); [Nóbrega et al., 2023](#); [Trujillo et al., 2018](#); [Uribe Salgado & Uribe Salgado, 2012](#); [van Vliet et al., 2018](#); [Yoamara et al., 2020](#)).

Yet critical questions remain: How can research with non-academic partners become a standard in Sustainability Science ([Kramer et al., 2017](#))? What institutional characteristics enable PAR, and which methodologies best support knowledge dialogues? These important questions are relevant for global environmental governance ([Tengö et al., 2017](#)) and are exemplified in the latest IPBES report on indigenous knowledge and its role in transformative change ([Bennett et al., 2025](#)).

Although the need to include ILK, IKS, and TEK is widely acknowledged, significant challenges remain in sustaining dialogue and developing effective co-production methodologies. It is not enough to talk about inclusion if it does not follow a coherent, broader chain of steps and practices across management and research processes. That's why many inclusive research attempts fail. This reveals an interlinked gap in knowledge inclusion—across theories, methods, and behaviours—that I refer to as the **Inclusion-Participation-Dialogue-Co-production Gap** (IPDC Gap).

Urgent need to narrow the IPDC Gap

Not only nation states but also academic institutions remain at their “first steps” in transforming research in Amazonian Indigenous contexts. Methods and practices of research in Amazonian Indigenous contexts continue to be dominated by “Western” science and largely rely on top-down research approaches ([Schroeder & González, 2019](#)). These tensions are further intensified by the failure to recognise TEK within current institutional frameworks ([Nassar et al., 2020a](#)). This persistent disconnection between knowledge systems reveals a broader gap in recognising the relevance of the forest-fauna-human nexus in the Amazon.

The importance of addressing this IPDC Gap is synthesised from empirical research presented in Article 1 (13 global knowledge co-production cases) and in Article 2 (a

systematic review of ILK inclusion). Here, I point out four interrelated components of knowledge to support the need for inclusion, dialogue, and co-production with IKS and its holders: **i) epistemic justice, ii) explanatory power, iii) effectiveness, and iv) legitimacy**. Each of these carries distinct implications and consequences tied to the inclusion – or exclusion – in knowledge co-production in sustainability science.

First, social and environmental justice underpins sustainability science ([Grunwald, 2020](#); [Martínez-Alier, 2023](#); [Ott & Döring, 2011](#)). Addressing the historical oppression of ILK is therefore essential as it continues to shape sustainability outcomes, research practices, and epistemic justice ([Chilisa, 2017](#); [Mignolo, 2011](#); [Mignolo & Walsh, 2018](#)). Epistemological and decolonial perspectives emphasise the ethical dimensions of knowledge co-production, arguing that it should benefit IP&LC while also providing value to external institutions ([Chilisa, 2017](#); [Edwards & Heinrich, 2006](#)). These perspectives are grounded in socio-political commitments to the rights of IP&LC, including the recognition of their knowledge, identity, sovereignty, and self-determination ([Agrawal, 1995](#); [Aikenhead & Ogawa, 2007](#); [Bennett et al., 2025](#)). This recognition asserts that research should actively contribute to realising these aims and goals. Therefore, TSS must include relevant knowledge holders and aim for epistemic justice ([Meisch, 2020](#)).

Second, ILK — as approached in this thesis, and within Indigenous territories through IKS and TEK — offers significant explanatory capacity ([Brodnig & Mayer-Schönberger, 2000](#); [Castello, 2023](#); [Maffi & Woodley, 2012b](#)). This capacity lies in recognising the limits of any knowledge system when addressing complex phenomena. Such insight is particularly relevant for tropical forest fauna management, which directly affects the ecological integrity of forest ecosystems and thereby the global carbon cycle ([Berzaghi et al., 2018](#); [Fricke et al., 2022](#); [Galetti et al., 2017](#); [Gardner et al., 2019](#)).

Third, there is a practical need to engage ILK to enhance the effectiveness of transformative change within the knowledge-to-action boundaries. Practices and policies must be co-produced with ILK to generate information and solutions that are salient, credible, and legitimate ([Cash et al., 2003](#); [Matuk et al., 2020](#); [Pörtner et al., 2021](#)).

Finally, the legitimacy of results is essential in the production of knowledge and technology. For knowledge co-production to be considered legitimate, it must respect stakeholders' divergent values and belief systems, remain unbiased, and ensure fairness in engaging differing perspectives ([Cash et al., 2003](#)). Legitimacy is achieved when all participants—whether IP&LC, academics, or policy practitioners—recognise the outcomes as valid within the meanings and structures of their respective knowledge

systems ([Lam et al., 2020](#)). This validity, in relation to effective and legitimate actions, points out the critical importance of profound dialogues with ILK, including the translation of concepts, views, causes, and effects of sustainability challenges ([Hernández-Vélez, 2026](#)). This is clearly supported by the results in Article 2 of this thesis.

Article Compilation Structure

Article Landscape

Figure 5 shows the interdependent space of the SES that constitutes the Amazon biome, where my four-article compilation explores the human intersection with ecosystems, forest fauna, and other forest beings. At this intersection, practices, actions, and methods are arranged in a central circle that contains:

Article 1 (light orange): A comparative study that contrasts 13 natural resource co-production cases. Title: Advancing co-production for transformative change by synthesising guidance from case studies on the sustainable management and governance of natural resources. *Environmental Science & Policy* (2023).

Article 2 (white): A systematic review of academic publications in the tropics. Title: Indigenous and Local Knowledges' inclusion in Forest Fauna research - A Systematic Review in the Tropics. *AMBIO* (2026).

Article 3 (yellow): A study presenting a Weaving Knowledge Methodology within PAR processes with Amazon Indigenous Knowledges. Title: Exchanging Research Seats in the Amazon: Weaving Indigenous and academic methods in Participatory Action Research for sustainable forest fauna management. *Global Sustainability* (forthcoming 2026).

Article 4 (green): A collective publication with Indigenous researchers presenting our PAR process, reflection on the vitality of knowledge and the contributions of the Amazon TEK to forest fauna management in two communities. Title: Indigenous Knowledges for Sustainable Forest Fauna Management - Insights from Participatory Action Research in the Colombian Amazon. *People and Nature* (in review 2026).

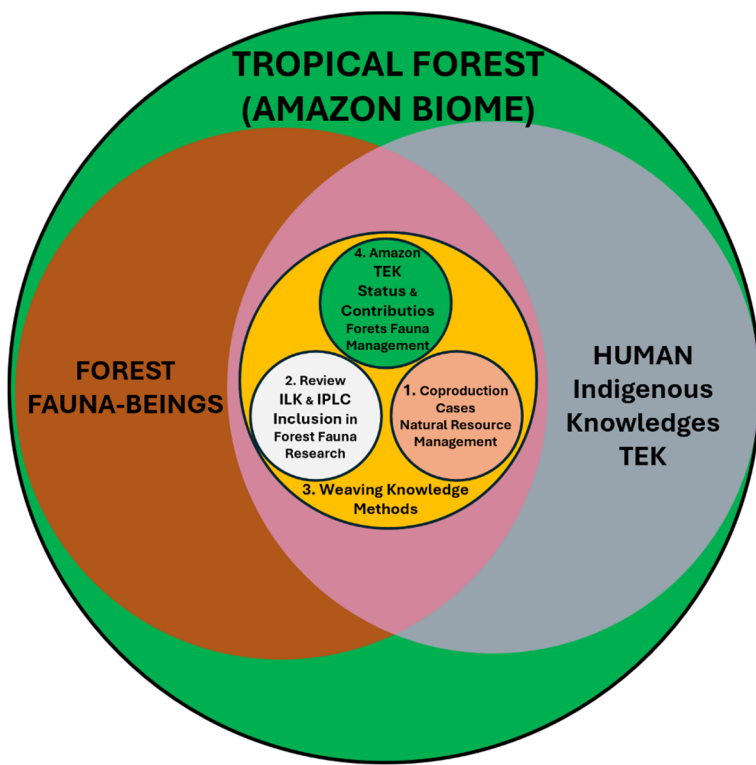


Figure 5. Thesis articles compilation embedded in the social-ecological framework.

Contribution of the Articles

I provide a holistic contribution to the enhancement of knowledge and understanding of forest fauna and their management in TSS. In the articles, I do this using theoretical and methodological entry points that aim to create and sustain respectful and productive dialogues with Indigenous Knowledges to transform the management of forest fauna in the Amazon. Rooted in the coproduction of emancipatory knowledge fostered by PAR, the articles focus on engagement with ILK, IKS and TEK to decolonise research practices in Amazon Indigenous communities. All articles deliver a unique message and contribution through their narratives, but collectively provide a stronger case for conceptual, methodological, and empirical proposals promoting IKS inclusion in forest fauna management.

Together, they exemplify how academic coproduction can enact change through research practices that learn from and complement TEK. Table 1 outlines each article's contribution, focus and methodological approach, which provides a foundation for a synthesis.

Table 1. Summary of the four articles and their main contributions to the research questions
Highlights of methodology and answers provided to specific research questions.

Article No.	Article description Method Contributions to Research Questions (RQ) (RQ1) IKS and Academia How are IKS included in academic research on tropical forest fauna? (RQ2) Forest Fauna in IKS How is forest fauna represented in IKS in the Colombian Amazon? (RQ3) IKS-TEK contributions, current and projected What is the current state of IKS at local communities and its contributions to sustainability transformations in forest fauna management? (RQ4) Weaving implications between TEK and TSS How and to what extent can PAR promote the weaving of IKS and non-indigenous knowledges for more sustainable, inclusive forest fauna management?
1	van Maurik Matuk, F. A., Verschuuren, B., Morsetto, P., Krause, T., Ludwig, D., Cooke, S. J., Haverroth, M., Maeesters, M., Mattijssen, T. J. M., Kefler, S., Lanza, T. R., Milberg, E., Ming, L. C., <i>Hernández-Vélez, C. A.</i>, da Silva, K. M. T., Souza, M. P. V., Souza, V. O., Fernandes, J. W., & dos Reis Carvalho, B. L. Advancing co-production for transformative change by synthesising guidance from case studies on the sustainable management and governance of natural resources. <i>Environmental Science & Policy</i> (2023). Article 1 promotes ILK recognition and co-production by analysing Indigenous Amazon communities and 12 global cases, drawing on input from scientists, practitioners, and IP&LC. It shows that TEK is often misused or marginalised and it reveals power imbalances that hinder outcomes, even in well-designed projects. Findings indicate credible knowledge emerges when co-production empowers participants, respects Indigenous worldviews, and links sustainability to local livelihoods, rather than rigid rules. The cases demonstrate ILK's role in local practice and its potential to foster sustainability, especially in forest fauna management. The article argues that effective co-production requires reshaping knowledge systems, building shared understandings, and recognising credibility as socially constructed. The article identifies PAR as a key method for integrating ILK and other knowledges into decolonial forest management. It emphasises structural changes for truly inclusive and decolonial knowledge co-production. Method: <i>Global Multi-Case Coproduction Analysis</i> RQ1 — is addressed in this article as it analyses 13 cases of academic–IP&LC collaboration that exposes power imbalances, failures, and contested definitions of TEK in environmental management RQ4 — is addressed in this article as it argues for reshaping knowledge systems, contextual credibility, and structural reform. The article positions co-production as a PAR-aligned mechanism for decolonial sustainability
2	<i>Hernández Vélez, C.A.</i>, Krause, Torsten, Jackson, Guy. Indigenous and Local Knowledges inclusion in Forest Fauna research - A Systematic Review in the Tropics. <i>AMBIO</i> (2026) Article 2 examines research on tropical forest fauna and Indigenous and Local Knowledge (ILK). It finds ILK is often poorly defined and used instrumentally for conservation, while communities value it for their livelihoods, culture, and social systems. These reveal biases and gaps between science and inclusive practices. RQ2 shows that including ILK and shared research affects knowledge, with a focus on birds and mammals. Insects and amphibians are overlooked. RQ3 notes ILK recognition increased since 2014 but remains mainly consultative. Involving knowledge holders in validation can transform

	wildlife management and epistemic justice. RQ4 discusses how PAR can foster co-production, with Indigenous and Local Peoples maintaining ownership and leadership, as well as shifting from studying to collaborating, and suggests recommendations for respectful and decolonial forest fauna management. Method: <i>Systematic Literature Review</i> RQ1—Is addressed, showing how academia can falsely define and instrumentalise ILK for conservation, while local communities see it as vital to their livelihoods and identity. Power imbalances and biases characterise academic–IP&LC relationships in forest research. A thought experiment is presented for reflexive sustainability practitioners to view ILK as a 'Door'. RQ2— Is addressed by showing how tropical fauna is categorised, used, and studied by researchers and within communities. Mammals and birds are preferred for study groups over insects and amphibians, which, although highly used in Amazon Indigenous groups, might not be included or linked to TEK and IP&LC exclusion. RQ3 — This article shows ILK engagement remains largely consultative and suppressed despite increased academic recognition since 2014. When knowledge holders become research protagonists, ILK has transformative potential for sustainable wildlife management and epistemic justice.
3	<i>Hernández Vélez, C.A.</i> Exchanging Research Seats in the Amazon: Weaving Indigenous and academic methods in Participatory Action Research for sustainable forest fauna management. <i>Global Sustainability</i> (forthcoming 2026). Article 3 demonstrates how the <i>Exchanging Research Seats</i> (ERS) methodology addresses critical dimensions of Traditional Ecological Knowledge in the management of Amazonian forest fauna. The article addresses RQ1 by revealing fundamental tensions in how TEK is conceptualised. Academia typically frames it as a cumulative, culturally transmitted body of knowledge, yet consistently fails to engage deeper Indigenous ontologies. Local communities, by contrast, understand TEK as an ongoing and practice-based relational process encompassing transcendental philosophies, spiritual worldviews, and reciprocal relationships with territory. Method: <i>Indigenous Methods and Ethnography</i> RQ3—Is addressed here by drawing on evidence from two Colombian Amazon territories, illustrating TEK's active role in shaping human–forest–fauna interactions and biocultural wildlife management. It projects that when TEK is integrated through dialogical and decolonial practices, it offers concrete and ethically grounded contributions to Transformative Sustainability Science RQ4—Is addressed here by presenting ERS practice directly operationalising PAR as a weaving mechanism, enabling external researchers and Indigenous communities to exchange knowledge roles through participatory and place-based processes. The article provides tested methodological guidance for TSS practitioners seeking to integrate TEK in ways that are both epistemically just and practically effective for decolonial forest fauna management.
4	<i>Hernández-Vélez, C.A.,</i> Torsten Krause, Airumakuchi Hunters Association: Edilberto Laureano del Águila, Milton Pinto Linares, Tipisca Community: Sirley Valentín, Teresa Suárez, Claudia Sadidt Grande, Remberto Macedo Ahue, Ceima Cachivera Community, Jacinta Uribe, Francy Ruth Trujiilo, Jaime Gutiérrez, Gilberto Gutiérrez, Emson Estiven Hernández, Emilio Hernández. Indigenous Knowledges for Sustainable Forest Fauna Management - Insights from Participatory Action Research in the Colombian Amazon. <i>People and Nature</i> (in review 2026).

Article 4, coauthored with indigenous researchers, examines IKS and TEK in forest fauna management through a four-year PAR process in two Colombian Amazon communities. It conceptualises TEK as inseparable from social, ecological, and cosmological dimensions, contrasting academic frameworks with lived Indigenous ontologies. Forest fauna are understood not merely as resources but as relational beings embedded in cultural, spiritual, and territorial systems, regulated through norms, ceremonies, and seasonal calendars. The study finds that TEK remains active but is increasingly threatened by socio-economic pressures, language loss, and weakening traditions, making its erosion a broader social-ecological crisis. Despite this, TEK continues to contribute significantly to sustainable practices and holds strong potential for future sustainability transformations. PAR emerges as a key approach for revitalising knowledge, strengthening governance, and enabling knowledge co-production between Indigenous and academic systems. Ultimately, the article argues that epistemic justice and Indigenous self-determination are essential for effective, decolonial, and sustainable forest fauna management. It merges IKS with SES and presents a qualitative evaluation of the SES principles as locally understood.

Method: Participatory Action Research

RQ2—Forest fauna are represented as relational and sentient beings embedded in cosmology, fulfilling roles beyond food (e.g., symbolic, medicinal, ritual), governed through norms, seasonal calendars, and territorial knowledge. Monitoring activities are presented here as one of the incoming co-produced activities that could be enhanced through collective rules and norms.

RQ3—The Tipisca and Ceima Cachivera communities demonstrate rich TEK on forest fauna, including species, behaviours, seasonal changes, and cosmological ties that support livelihoods. However, TEK transmission erodes due to market pressures and language decline. The article suggests that IKS can promote sustainable use of fauna, bolster Indigenous stewardship, and aid inclusive governance if well documented and valued.

RQ4—Is addressed here by presenting a four-year PAR process with 42 communitarian workshops structured around a five-stage reflective cycle to co-produce knowledge equitably with Indigenous researchers. Drawing on Freire and Borda, it operationalises PAR as a decolonial mechanism that bridges Indigenous and non-Indigenous knowledges through empowerment, self-determination, and institutional dialogue. Local researchers are positioned as co-authors and budget managers, embedding equity directly into the research architecture.

2. Biocultural Loss in the Amazon: Contexts, Pressures, and Exclusion

In this chapter, I establish the ecological, sociopolitical, and epistemic conditions that make transformative, participatory, and Indigenous-led sustainability research both necessary and urgent, amid escalating threats to biodiversity and the global transformation of social-ecological systems. Accordingly, this chapter is not intended to provide a comprehensive history of the Amazon. Critical approaches to science emphasise the need for research practices that prioritise action and reorganise research processes, rather than merely generating more knowledge on it ([Linnér & Wibeck, 2019](#); [Meisch, 2020](#)). This shift is now widely recognised as the “transformation turn” ([Blythe et al., 2018](#)), extending beyond sustainability science.

Although a detailed description of the historical evolution of solution-based approaches lies beyond the scope of my thesis, these approaches are broadly rooted in reflexive and transformative research, and have been described as mode 2-Science and post-normal science ([Funtowicz & Ravetz, 1993](#)), closely aligned with PAR ([Janes, 2016](#)) that is central to my study. Within sustainability science, this actionable and reflexive orientation is conceptualised as TSS framework ([Blythe et al., 2018](#); [Horcea-Milcu et al., 2024](#)), within which this research is situated.

A key related argument to socially committed science calls for a shift from research *on* IP&LC to research conducted *with* and *for* IP&LC ([Koster et al., 2012](#)). Advancing this shift requires recognising IKS as a valid and respected form of knowledge held by Indigenous Peoples and Local Communities. This inclusion also entails deeper implications, particularly a reparative dimension ([Sultana, 2025](#)), which calls for acknowledging the historical and ongoing forms of violence imposed on Indigenous communities by governments, companies, institutions, and universities. In doing so, epistemic inclusion becomes linked to peace-making processes ([Bhambra et al., 2018](#); [Peña, 2024](#); [Sultana, 2025](#)), which is an argument aligned with my thesis and thoroughly discussed in the literature ([Azam, 2026](#); [Freire, 2020](#); [Hallen, 1988](#); [Peña, 2024](#); [Shiva, 2013](#); [Sultana, 2025](#)). Overlooking, ignoring, or failing to address this gap could continue to produce epistemic harms, worsening sustainability outcomes and

rebuilding colonial conservation logic globally and in the Amazon ([Azam, 2026](#); [Peña, 2024](#); [Sultana, 2025](#); [Williams et al., 2021](#)), which could greatly affect Indigenous transformative processes in the upcoming years.

Threats and barriers to biocultural diversity

The need to include diverse knowledge systems in shaping the understanding and management of forest fauna indicates that Indigenous knowledge has been actively excluded from all these processes. While a comprehensive historical account of this exclusion gap in IKS and TEK—globally and across the Americas—would clarify its origins and persistence, it lies beyond the scope of this thesis. Instead, I highlight key dimensions of this marginalisation and oppression as: i) institutional-legal frameworks and ii) enduring forms of violence spanning pre-conquest, conquest and contemporary times. I also outline their implications for my thesis, which seeks to expand forest fauna management by including IKS in co-produced research on TSS practices in the Amazon.

The Amazon biome has long fascinated people, as a place of hidden wonders and immense ecological and cultural richness. Valued for both its material and immaterial wealth, it has become central for global environmental politics, particularly for its main role in climate regulation and as a reservoir of endemic biodiversity that is currently threatened by unsustainable human activities ([Arora, 2024](#); [Change, 1990](#); [Watson et al., 2019](#)).

Tropical forests—especially the Amazon—are critical for global climate mitigation, biodiversity conservation, and the preservation and well-being of local communities. Climate change increasingly threatens the social and ecological integrity of the Amazon and the long-term survival of its ecosystems and people. Studies increasingly highlight the risk of tipping points that can turn large swathes of the forest into savannah systems, causing an additional loss in species and carbon storage ([Flores et al., 2024](#); [Hajdu et al., 2025](#); [Lovejoy & Nobre, 2019](#)).

The Amazon biome, now at the centre of global political and economic interests, has sparked extensive debates on which governance systems are most effective for protecting its integrity, preventing species extinction, and promoting sustainable use of its benefits ([Fearnside, 2021](#); [Garda et al., 2010](#)). However, while these benefits extend globally, their distribution is deeply uneven. Indigenous communities, whose wellbeing, governance systems, knowledge and practices ([de Bessa Antunes, 2023](#)) remain insufficiently integrated and left out of the benefit scheme, are frequently marginalised by corporate, state, foreign countries and development interests.

This imbalanced distribution in Amazon development is accentuated by the ongoing deforestation and forest degradation, which seriously threaten the biome's long-term integrity and stability ([Gatti et al., 2023](#); [Unfccc, 2015](#)). Since 2023, deforestation across the Amazon basin has increased by 34%, with Brazil accounting for over half of the total loss, despite recent declines. Colombia, after reaching its lowest deforestation rate in 23 years in 2023 (113,608 hectares, Amazon region contributing to it by 69%), has experienced a marked reversal, with significant increases in 2024 and 2025 ([Global Forest Watch, 2025](#)).

Other factors contributing to this scenario are the significant loss of species diversity and abundance, widespread defaunation, wildfires, illegal mining, logging, land grabbing, cattle ranching and coca cultivation ([López, 2023](#); [Marques, 2024](#); [Myers, 2003](#)). These activities are heavily impacting the SES, resulting in significant biomass loss and reduced forest resilience. Rainforest resilience can be understood as the capacity of the ecosystem to recover after disturbance while maintaining its essential ecological functions, biodiversity, and structure, while also being capable of adapting and transforming ([Folke, 2006](#)). Since 2000, rainforest resilience has declined significantly, with pressures expected to intensify, with notable examples in Colombia, especially in post-conflict areas ([López, 2023](#); [Murillo-Sandoval et al., 2023](#)). This has been related to weak governance and expanding infrastructure, such as road network expansion in the Amazon ([Vilela et al., 2020](#)). This signals a critical transition in the Amazon, undermining the long-term integrity of the biome and posing major governance challenges ([Flores et al., 2024](#)).

Human disturbances, such as overhunting and wildlife trafficking, that lead to defaunation and forest fragmentation further erode wildlife abundance and biodiversity ([Benítez-López et al., 2019](#)). These pressures disrupt human-forest-fauna connections that are essential to ecosystem functioning, including forest regeneration and seed dispersal processes that depend on animal species ([Harrison et al., 2013](#)). Declines in large mammals, for example, affect seed dispersal, plant diversity and carbon storage ([Bello et al., 2015](#); [Estrada et al., 2017](#)). Losses of forest resources and defaunation also place great pressure on people who rely on these resources and wildlife as a source of food and income by jeopardising their subsistence and economic security ([Nielsen et al., 2018](#)). Forest-Fauna-Human interactions also carry global public health implications, as biodiversity loss and increased human-wildlife contact increase the risk of infectious diseases ([Allen et al., 2017](#); [Morand & Lajaunie, 2021](#)).

Alongside ecological degradation, cultural loss represents an even more critical yet often overlooked dimension. Language loss—commonly used as a proxy for cultural diversity (Davis, 2020)—suggests that half of the world's 7,000 spoken languages are no longer taught and may disappear in the coming decades ([Harrison, 2008](#)). Indigenous

languages in Colombia are experiencing significant decline. UNESCO classifies many of these languages as endangered, while the Colombian government estimates that nearly half of the country's 68 native languages are at risk of extinction due to reduced transmission across generations and increasing use of Spanish ([Uribe-Jongbloed & Anderson, 2014](#)).

Cultural and knowledge diversity reflects another layer of biodiversity under major threat. Addressing these threats and dynamics should be among the main interests of local and regional sustainability agendas.

Institutional-legal exclusions

Legal frameworks for Indigenous people across the Amazon countries, including Colombia, vary widely and their implementation depends on the government's alignment with the realisation of constitutional rights. An extreme example was Brazil during Bolsonaro's presidency (2019-2023), which systematically excluded Indigenous peoples and pursued violent agendas against them. From 2019 to 2022, the government failed to protect Indigenous rights, actively dismantling institutions like the National Foundation of Indigenous Peoples (FUNAI), stopping land demarcations, and nullifying demarcation laws. These actions exposed Indigenous lands to land-grabbers, agribusiness, and illegal extractive activities ([Nóbrega, 2023](#); [Risso et al., 2022](#); [Tourneau, 2019](#)). Furthermore, these anti-indigenous politics led to humanitarian crises that require criminal accountability, such as deforestation, illegal mining on Indigenous lands, community invasions, violence, and the Yanomami health emergency ([Da Luz Scherf & Viana da Silva, 2023](#); [Risso et al., 2022](#)).

Multiple scholars have moved beyond policy-failure framing to characterise this pattern as *necropolitical governance*, which is a state of exception that subjects Indigenous life to the "power of death", and as a *mass-atrocity structure* whose pillars of invasion, contamination, and deprivation of health care were not incidental but constitutive of the administration's political project ([de Belmont, 2024](#); [Rapoza, 2021](#)).

Across the region, forest-fauna-human relations are managed by various Indigenous and non-Indigenous institutions. These often experience tension asserting territorial autonomy through TEK and the imposition of national public policies on their lands ([Nassar et al., 2020b](#)). Such tensions manifest in numerous processes that disregard the diversity of knowledge within intercultural governance ([de Wit & Mourato, 2022](#)). Governance systems and an intertwined relationship between human and biocultural diversity are key to the post-positivist science mode, which seeks to include knowledge diversity that supports human livelihoods ([Agrawal, 2002](#); [Berkes et al., 1994](#); [Lam et](#)

[al., 2020](#); [Pimbert, 2017](#)). In this dissertation, I argue that biocultural diversity and the Indigenous governance systems within IKS can more accurately describe and address the social-ecological dynamics in the Amazon and facilitate participatory transformations in the region ([Perz et al., 2021](#)). Rather than treating ecological processes, cultural practices, and governance structures as separate domains, this perspective recognises their deep interdependence and co-evolution.

For the most part, South American and Colombian national institutions have constructed governance frameworks that systematically exclude and misrecognise IKS. These frameworks perpetuate colonial logics that privilege Western judicial, territorial, and epistemological categories over Indigenous cosmologies and legal orders and put Indigenous dispute resolution systems into survival mode rather than equitable coexistence ([Ruiz Morato, 2016](#)). This institutional negation reflects deeper ontological mismatches, as evidenced by REDD+ carbon-offset programs that impose carbon-centric frameworks fundamentally incompatible with Indigenous territorial ontologies and governance practices. Likewise, this negation reveals profound institutional ignorance about Indigenous conceptions of land and authority ([Schroeder & González, 2019](#); [Wright et al., 2024](#)).

The state's inability to engage Indigenous epistemologies reflects not just bureaucratic inertia, but enduring colonial continuities that are neither recognised nor reconfigured, thus sustaining structural exclusion ([Wright et al., 2024](#)). External agencies that translate TEK into global policy frameworks without negotiating Indigenous priorities reinforce asymmetrical power relations, ultimately threatening territorial autonomy instead of strengthening it ([Nassar et al., 2020a](#)). The U'wa Indigenous campaign (1995–2010) in Colombia is a case in point and shows how state and market interests overrule Indigenous governance. The campaign forces communities to mobilise transnationally after domestic avenues failed to protect their rights ([Rueda, 2012](#)). Far from random, these failures are structural, grounded in institutions that privilege assimilation over accommodating fundamentally different ways of knowing and governing.

In addition, protected-area regimes and state-led conservation narratives reproduce "nature without people" imaginaries, which justify restricting Indigenous practices and decision-making authority and effectively displacing the customary rules that have sustained wildlife populations for generations ([Macpherson et al., 2020](#)). These dynamics are evident in practice. Among East Tukano communities along the Papuri River, where external interventions and policies have ignored local cosmologies and wildlife consumption taboos, community-based regulation of fauna use is undermined ([Yoamara et al., 2020](#)). In the Colombian Amazon, market integration and extractive expansion have eroded hunting practices and the intergenerational transmission of

TEK, while formal management plans continue to omit customary hunting rules ([Krause et al., 2020](#)). Even progressive legal innovations, such as granting rights to rivers, can obscure Indigenous governance roles and tenure claims. These innovations shift focus to abstract ecosystem rights while displacing the locally grounded fauna management practices that depend on territorial authority ([Macpherson et al., 2020](#)).

Pre-“Conquest” waves of oppression

Conflicts within Abya Ayala—an ancestral Emberá name for the Americas—can be traced to pre-colonial dynamics prior to European conquest, including waves of external domination during the Inca expansion in the 15th and early 16th centuries. This expansion involved the construction of fortresses and garrisons to control access to resource-rich lowlands ([Alconini, 2016](#); [Siiräinen & Pärssinen, 2001](#)), disrupting local political economies and governance. Inca demands imposed on borderland polities led to partial subordination and the reorganisation of settlements, production systems, and leadership structures around tribute and ritual obligations ([Herrera, 2003](#); [Ogburn, 2011](#)). In addition, conflicts among neighbouring Indigenous groups that are often underreported or downplayed have also shaped regional dynamics and at times resulted in violent intercommunity encounters.

Spanish colonisation from the 16th to the 18th centuries compounded these pre-conquest disruptions through overlapping systems of violence and extraction. Colonial regimes imposed widespread forced labour through *encomienda* arrangements and outright slavery (see Figure 6), which displaced communities, overworked populations, and depopulated entire regions ([Regan, 2008](#); [Whitehead, 2011](#)).

Missionary projects, mainly operated by Montfortian, Capuchin, and Jesuit orders, reorganised Indigenous settlement patterns, dismantled local authority structures, and replaced them with ecclesiastical and colonial administration that eroded Indigenous governance institutions ([Cuvi et al., 2021](#); [Hechler, 2023](#)).

Epidemic diseases that were introduced after contact and compounded by labour exploitation and violence triggered a rapid demographic collapse that undermined the sociopolitical continuity of many chiefdoms and riverine polities ([Regan, 2008](#); [Roosevelt, 1993](#)).

Simultaneously, systematic extraction of plants and animals, alongside the imposition of new agricultural systems, transformed Amazonian resource regimes and produced long-term environmental change ([Lopes et al., 2024](#)).

Combined, Inca and Spanish interventions produced successive waves of territorial appropriation, political decapitation, and demographic collapse that reshaped

Indigenous life across the Amazon frontier. Recent work highlights the untold stories of Indigenous and colonisers in the Colombian case ([Langeback, 2021, 2023](#)), which have left enduring legacies of violence, including intergenerational trauma that persists today and is intensified by contemporary waves and forms of oppression.

Historical waves of oppression and the role of academia

Contemporary extractive dynamics in the Amazon can be divided into two periods: late 1940s–2000 and 2000–present. After World War II, European interest in oil exploitation spurred expansion into the region alongside new missionary projects (Figure 6), illegal settlements, and “boom economies” such as rubber, coca, and pelt trades. Since the 1990s, development projects have extended these dynamics through frontier expansion, land conversion to monoculture, and the enabling of illegal extraction, generating displacement, conflict, and environmental harm ([Berenguer et al., 2024](#); [Domingues & Sauer, 2021](#); [Urzedo & Chatterjee, 2022](#)). Large dams and infrastructure projects continue to prioritise state and corporate interests, often resulting in displacement and forms of what scholars call ethnocide ([Rodrigues & Lima, 2020](#); [Urzedo & Chatterjee, 2022](#)).



Figure 6. Examples of historical violence towards Indigenous people in the Amazon.

Two images exemplify the Indigenous people's enslavement for colonial resource extraction and the methodical, violent indoctrinations from religious boarding schools. The left image shows a 20th-century testimony in Colombia: “The priests and nuns, supported by police and *corregidores* installed within our territories by order of the central State, carried out sweeps in the communities to recruit all the children and young people they could find, just as when soldiers are recruited against their will”. When my mother was heard talking to *Uitoto* with her classmates, they tied a stick in her mouth for long hours or even the whole day, without being able to eat or drink; they gave them strict rules, forbade them to see their parents or relatives at the end of the year. Testimony by Lena Estrada Añokazi 2020. Indígena Uitoto Minika. Politóloga, PhD in Sustainability. Story Link: <https://elcomejen.com/2020/12/18/internada-en-la-selva-transmutando-entre-religiones/>. On the right, Amazon Testimony: Many Barbadians were imported to supervise the Indian workforce, which provided the raw material from which fortunes were being made. Explorers of the Amazon. University of Chicago Press. Picture taken in 1850 ([Smith, 1994](#)).

These recurring patterns are not accidental; they are actively reproduced by nation-states and institutions through policy capture, weak or corrupted regulatory frameworks, and institutional designs that favour licensing and extractive infrastructure and enable large-scale land conversion and socioenvironmental conflicts across Bolivia, Brazil, and Colombia ([Bonilla, 2022](#); [Marchand, 2016](#)). The concept of *coloniality of power* helps explain this persistence, as contemporary governance and development paradigms reproduce colonial hierarchies that rank land, knowledge, and peoples in ways that legitimise extraction and marginalisation ([Domingues & Sauer, 2021](#); [Mignolo, 2011](#); [Rodrigues & Lima, 2020](#); [Urzedo & Chatterjee, 2022](#)).

As a general trend—even in Colombia, where Indigenous land rights received constitutional recognition in the 1991 constitution—exclusionary and oppressive state and policy narratives persist, which frame Amazonian lands as empty or underutilised. This makes extraction appear legitimate, while legal and technical rationalities centred on “productivity” and modernisation routinely displace Indigenous ontologies and justify dispossession.

Academic and technical discourses are equally implicated in reproducing modern productivity ideals by prioritising market-oriented metrics, “effective obtention” of information and marginalising Indigenous knowledge, thereby reinforcing the same power structures that enable exploitation ([de Castro Leal et al., 2021](#); [Rodrigues & Lima, 2020](#)). Institutions and laws approve projects through licensing, land policy, and infrastructure planning that convert territorial claims into capitalised resources, placing colonial hierarchies in policy, law, and scholarly frameworks that sustain extractive violence into the present ([Blaser, 2008](#); [Bonilla, 2022](#); [de Castro Leal et al., 2021](#); [Mignolo, 2011](#)).

These exclusions and oppressive practices have also been observed in conservation, environmental, and sustainability-labelled projects, many related to global wilderness conservation, that displace Indigenous communities to maintain “pristine” ideals of nature which perpetuate colonial dispossession and undermine just and effective conservation outcomes ([Agnihotri et al., 2021](#); [Fletcher et al., 2021](#); [Rai et al., 2021](#)). On this matter, there is extensive literature documenting the contrast of Indigenous long-term landscape stewardship with colonial and extractive pressures and describing how outside exploitation has repeatedly undermined Amazonian sustainability and Indigenous sovereignty ([Posey & Balick, 2006](#)).

Even though this exclusion and oppression have been a common scenario for too long, there have been some changes in international, national, regional and academic agendas when facing this colonial inertia by acknowledging the negative consequences of knowledge extraction and the intimate connections between imperialism and academic

practices ([Carmona et al., 2023](#); [Escobar, 2007](#); [Ford et al., 2016](#)). This and more realisations from current academic endeavours are a clear challenge for sustainability practitioners and TSS interested in non-extractive practices, equitable and legitimate transdisciplinary research ([Blaser, 2008](#)).

Nonetheless, interest in addressing this challenge has increased over the last ten years. Sustainability practitioners and global governance systems have shown a significant increase in interest in decolonising research and a focus on Indigenous knowledges ([Breidlid & Krøvel, 2020](#)). This is a sign of a paradigm shift from exclusively positive to a growing post-positivist science production, which currently rethinks science terminology, categories and includes ILK, IKS and TEK into current discussions ([Bala & Gheverghese Joseph, 2007](#); [Broadhead & Howard, 2021](#); [Goduka, 2012](#); [Held, 2023](#)).

Relational barriers: Inclusion faces Trauma

All human beings experience trauma to varying degrees (see Gabor Maté's distinction between "capital T" and "lowercase t" trauma; Maté, 2022, pp. 23, 27). As a trauma and human development specialist, Maté defines trauma not as the external event itself, but as the lasting internal wound produced when overwhelming experiences occur without sufficient support. This trauma manifests as a constriction in emotional, cognitive, and bodily flexibility, limiting one's ability to respond authentically in the present, and often stems from chronic relational disruption rather than isolated catastrophic events ([Maté, 2022](#)). I have come to understand trauma as a collective, intergenerational survival adaptation that can outlast its context and be maladaptive. In Indigenous communities, this adaptation is closely tied to colonial violence through disrupted attachment, cultural suppression, and structural harm, rather than to individual pathology framed solely by genetics or upbringing, as dominant biomedical models suggest (personal communication with communitarian psychiatrist Dr Juan David Páramo, in Vaupés Hospital during 2022–2026 fieldwork).

My personal and research experience coincide with framings of Indigenous distress as an embodied response to enduring conditions of dispossession that weaken relational, cultural, and ecological connections ([Maté, 2022](#)). This aligns with scholars who view Indigenous trauma as collective, historically produced, and continuously reactivated through structural violence, rather than discrete psychological events ([Gone, 2023](#); [Heart & Chase, 2016](#)).

In Amazonian contexts, this trauma is inseparable from territorial dispossession, environmental destruction, and epistemic erasure ([Wolkmer et al., 2024](#)). At the same time, Indigenous-led healing practices—rooted in land, material culture, ceremony,

and intergenerational knowledge transmission—demonstrate resilience that challenges Western clinical models ([Duran, 2019](#); [Methot, 2019](#)). Various scholars, including the experience I collected during my own research, have shown that the actions and methods used for documenting ecological knowledge are inseparable from histories of dispossession and trauma ([Hernández-Vélez, 2026 \(forthcoming\)](#); [López Garcés & Robert, 2012](#))

Addressing sustainability or forest–fauna conservation in collaboration with Indigenous communities inevitably engages intergenerational trauma, as TEK is transmitted through kinship, memory, and lived relationships to land shaped by histories of violence and environmental disruption. TEK does not simply encode ecological knowledge; it also reflects cumulative experiences of displacement, loss, and resilience. Consequently, research engaging IKS must attend to processes of healing, care, and trust-building, recognising that knowledge-sharing itself may reopen or transform unresolved collective wounds ([Gone, 2023](#); [Heart & Chase, 2016](#)) for both Indigenous and non-Indigenous participants.

Inclusive Pathways Process

This section highlights calls to integrate Indigenous transformative processes and decolonising methodologies into sustainability science, presenting concrete methodological and governance approaches from scholars advocating epistemic pluralism and relational accountability. The cited works present examples of practice-oriented shifts in research and policy.

Only in recent decades have Indigenous rights been partially included in sustainability practice and their academic literature is shaping global governance debates, particularly regarding the need for inclusion and respectful engagement with local knowledge systems on both formal and informal governance institutions ([Beck et al., 2014](#); [Hulme & Mahony, 2010](#); [Maldonado et al., 2016](#)). However, in tropical fauna research, evidence from [Article 2](#) shows that only four of 62 studies included ILK and IP&LC in research decision-making ([Hernández-Vélez, 2026](#)). This persistent exclusion reflects colonial and modernist paradigms that continuously fail to recognise diverse worldviews and instead prioritise mainstream research and development agendas. This has been recognised as being driven by global market demands, often reproducing patterns of resource exploitation across regions ([Dore & Nogueira, 1994](#); [Escobar, 2007](#); [Ndlovu-Gatsheni, 2013](#); [Santos, 2016](#)).

Critical and propositional work has promoted methodologies grounded in African and Indigenous worldviews to challenge methodological imperialism, legitimise Indigenous

knowledge holders, and strengthen sustainability science through indigenised paradigms ([Chilisa, 2017](#), [2019](#)). Beyond methods, these approaches call for centring diverse knowledge systems, fostering partnerships based on consent and autonomy, and establishing institutional mechanisms that respect cultural–ontological systems and enable decolonial transformation, for instance in climate research ([Orlove et al., 2023](#)). They further show that place-based pedagogies can negotiate tensions and advance the collective work of decolonisation required for resilient social–ecological systems ([Williams et al., 2018](#)). This possibility of decolonial research is also demonstrated in **Article 4** as a collaborative publication with indigenous colleagues on our 4-year research process on TEK through adapting a SES framework ([Hernández-Vélez, 2026 in review](#)).

My thesis is an active proposal to challenge dominant knowledge hierarchies. I advance a more realistic, plural, and just landscape of knowledge; one that centres TEK, legitimises its diverse knowledge holders, and positions their epistemologies as indispensable to the sustainable use of the Amazon.

Researchers as Knowledge Mediators

While I emphasised the need to include IKS and TEK in global, national, and regional governance, closing this gap requires a shift at the level of individual researchers and research groups operating within these systems. The extent to which researchers engage in reflexive practice and recognise IKS as valid knowledge directly shapes their capacity to adopt participatory and co-production approaches, enabling more genuine dialogue and inclusion. I frame this as *inner–outer transformation*: changes in values, assumptions, and practices that can cascade into structural and policy shifts ([Wamsler et al., 2021](#); [Woiwode et al., 2021](#)). Through such transformations, sustainability practitioners and Indigenous communities can draw institutions into more inclusive and just forms of governance. In this sense, TSS practitioners can act as bridges between local and regional systems by advancing emancipatory research practices, rethinking conventional scientific methods, and aligning their work with an integrated view of sustainable SES that connects diverse ontologies into structural changes ([Ramcilovic-Suominen, 2025a](#)).

Despite pervasive institutional failures, evidence, **including this thesis and Articles 1, 3, and 4**, demonstrates that meaningful collaboration and co-produced research with IKS can be achieved when institutional actors undergo substantive transformation, shifting from instrumentalisation to genuine respect for Indigenous autonomy and biocultural integrity ([Hernández-Vélez, 2026 in review](#); [van Maurik Matuk et al., 2023](#)). These transformative practices are not isolated; they are gaining traction within national movements, though they remain fragmented and uneven.

Examples include the Colombian Constitutional Court's recognition of the Atrato River's legal personhood. This recognition represents a landmark judicial innovation and foregrounds Indigenous environmental relationships and biocultural rights while establishing a precedent for recognising non-human entities within state legal frameworks ([Nemogá et al., 2022](#)). Similarly, the La Tika fishermen's organisation secured formal co-management authority with Colombia's National Aquaculture and Fishing Authority (AUNAP) over the Yahuaraca Lake System in Leticia, demonstrating that equitable Indigenous–state collaboration can enhance both ecological and social outcomes when decision-making power is genuinely shared ([Sánchez-López et al., 2024](#)). In parallel, participatory biocultural community protocols developed by Emberá communities have strengthened forest relations and safeguarded biocultural heritage through locally driven protections that maintain Indigenous control over knowledge use ([Nemogá et al., 2022](#)). Initiatives such as “sabedores programs” of Bacatá schools in Bogotá, further institutionalise these approaches by embedding Indigenous epistemologies into formal education, reinforcing and protecting intergenerational knowledge transmission within formal education systems ([Pineda et al., 2020](#)).

Perhaps the most significant development is the entry of Indigenous and Afro-descendant “ethnic intellectuals” into state institutions, enabling the advancement of pluriversal governance and the recognition of non-human victim rights. This demonstrates that strategic representation, coupled with active confrontation of coloniality, can generate non-reformist reforms from within institutional structures ([Cárdenas, 2025](#)). These initiatives share key features; they uphold Indigenous autonomy, recognise ontological difference, redistribute decision-making power, and require institutions to transform their own frameworks rather than forcing Indigenous communities to conform to pre-existing state categories.

Across the Amazon, Indigenous agroforestry practices and ontologies have been shown to reshape governance priorities and provide durable strategies for biodiversity conservation and livelihoods, including explicit calls to integrate Indigenous hunting knowledge into forest governance and management planning in the Colombian Amazon ([González & Kröger, 2020](#); [Krause et al., 2020](#)). These successes are not incidental, as they rely on culturally grounded rules, such as taboos and ritual calendars, as management tools. They include participatory monitoring that generates locally credible data, legal recognition coupled with safeguards that reinforce rather than displace Indigenous governance, and co-production arrangements that enable joint research and capacity-building ([González & Kröger, 2020](#); [Jonas et al., 2017](#); [van Vliet et al., 2018](#); [Yoamara et al., 2020](#)).

3. Weaving Theories, Analytical and Empirical frameworks

In this section, I use the word “weave or weaving” in two senses: first, to refer to combining and relating theories and authors into a cohesive argument, and second, as it is used by Indigenous communities in Colombia and in Tengö's work in the Multi-Evidence Base Approach (MEB) as “Weaving Knowledges (WK)” ([Tengö et al., 2014](#); [Tengö et al., 2017](#)). My thesis is grounded in dialogical, participatory and emancipatory approaches that can Weave Knowledge (WK) among IKS and sustainability practitioners for forest fauna management. To do this, I propose and use different theories, approaches, and frameworks to advance knowledge and methodological inclusion pathways, thereby narrowing the previously described knowledge gap (IPDC gap) by various Weaving Knowledges practices that I present in Figure 8.

Addressing diverse sources of information, disciplines, and knowledge systems is commonly framed as an interdisciplinary challenge when integration occurs within academic fields, and as transdisciplinary when knowledge from outside academia—such as practitioners, local, or IKS—is explicitly included in the research process ([Kates et al., 2001](#); [Lang et al., 2012](#); [Pohl & Hadorn, 2007](#)). My thesis goes beyond knowledge exchange or production and aims to contribute to transforming knowledge exchange dynamics, interactions, and the collective reflexive cohesion of the SES by implementing solutions during the research process. As I established in the previous sections, in my thesis I draw on the weaving of theories and WK as a fundamentally transformative exercise.

In academia, WK has been understood as a holistic approach to mobilise knowledge exchange through equitable and empowering relations ([Johnson et al., 2016](#); [Tengö et al., 2017](#)). Rooted in ancestral Indigenous practices, it reflects decades of work by some scholars who have intertwined diverse epistemologies and methods ([Kimmerer, 2002, 2013](#); [Rist & Dahdouh-Guebas, 2006](#); [Seravalli, 2020](#)). I use WK to describe how actors, institutions, and worldviews can be bridged through continuous actions, creating visible interactions in co-produced practices. This weaving requires a socially

inclusive theoretical approach and a process-transformative methodology, which is why I use PAR, inspired by the work of Orlando Fals Borda and Paulo Freire ([Fals-Borda, 1987](#); [Freire, 2020](#)). In its multiple variations and theoretical evolution, PAR aims to decolonise research by prioritising local knowledge and fostering sustained dialogue and emancipatory action through genuine co-production.

Figure 7 is a representation of WK with my own modifications to Tengö's figure ([Tengö et al., 2014](#)), where two main threads of knowledge are separated: the green-blue threads representing ILK (community-based monitoring, local and Indigenous knowledge) and the yellow-orange threads representing externally originated knowledge (interdisciplinary, natural and social scientific knowledge), to present the MEB approach in favour of connecting diverse knowledge systems for enhanced ecosystem governance. Above the threads of knowledge, the role of Wise Elders (*sabedores*), Houses of Knowledge (*Malocas* or *casa ancestral*) and keystone species (jaguar) are also highlighted as contributing factors to effectively integrating the two sides of the threads.

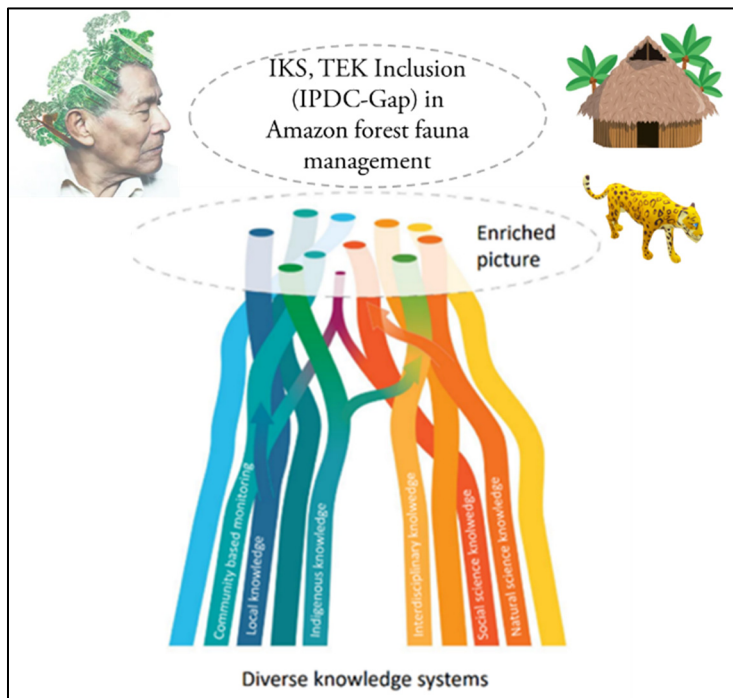


Figure 7. Weaving Knowledges in the MEB approach, modified from Tengö M et al. 2017.
Head Illustration by Abel Rodriguez- Indigenous artist. 2023

The streams weaved together represent my thesis's research interests and questions, and it is here that I can build on my theoretical, analytical, and methodological proposals. This is why I will return to this work to point out other areas where my work expands and fits in the WK-MEB.

In the following section, I weave the structural concepts of Collective Emancipatory Learning processes ([Fals-Borda et al., 1986](#); [Freire, 2020](#)), Decolonial ([Chilisa, 2017](#); [Mignolo & Walsh, 2018](#); [Wilson, 2020](#)) and Amazon Indigenous theories ([Godo-Bakari, 2015](#); [Wilson, 2020](#)) to address IKS and TEK ([Berkes et al., 2000](#)) in the Amazon Indigenous territories as Social-Ecological Systems (SES) ([Ostrom, 2009a](#)), using Participatory Action Research (PAR) practices with the communities ([Fals-Borda et al., 1986](#)), along with the Indigenous researchers, to WK about forest fauna in their territories (see Figure 8).

Theoretical Ensemble

WK is not a normalised practice in SS, and the interconnection between concepts, approaches, theories and methodologies is therefore still “under construction” in order to expand and diversify its research methods ([Johnson et al., 2016](#)). Assembling different theoretical structures into a cohesive research rationale is needed to show how I connect theories to concrete practices in fieldwork to answer the research questions in a highly complex, transformative scenario. In Figure 8, I present the main theories and frameworks I used, including broader concepts such as paradigms, fields of Inquiry, and theories and frameworks, inspired by the conceptual matrix proposed for structuring Sustainability Science ([Jerneck et al., 2011](#)).

At the top, the **first set of concepts** contains the *transformative paradigm* ([Mertens, 2008](#)) and its related branch/field of inquiry of this thesis, TSS ([Horcea-Milcu et al., 2024](#)), which respectively encompasses the **second layer of theories** used from *emancipatory pedagogies* ([Freire, 2020](#); [Wamsler et al., 2021](#); [Woiwode et al., 2021](#)), *decolonial research* ([Chilisa, 2017](#); [Mignolo & Walsh, 2018](#)), and *Indigenous theories* ([Godo-Bakari, 2015](#); [Wilson, 2020](#)). This level contains many overlaps and related work connecting the sociological participatory turns put into practice by F. Borda and P. Freire, e.g., with rural and Indigenous communities in Colombia and Brazil, as well as the many Indigenous proposals for decolonial research as advanced by Chilisa (2107). All this work is present in the research approach that guides the methodologies and aims of my work.

Other commonalities between this set of theories include the Inner-Outer work and the deeper reflexivity proposed by Shawn Wilson in “Research is Ceremony” (Wilson, 2020), as this literature also conceives of Inner-Outer work as a fundamental process for agency, empowerment, and emancipation. The relational and reflexive approach contained in this level enriched my personal and ethnographic reflections, providing bridges between biological and IKS understandings of the interconnectedness of life, and influenced my position toward research and research colleagues, fostering close relationships nurtured by a compassionate understanding of the research process.

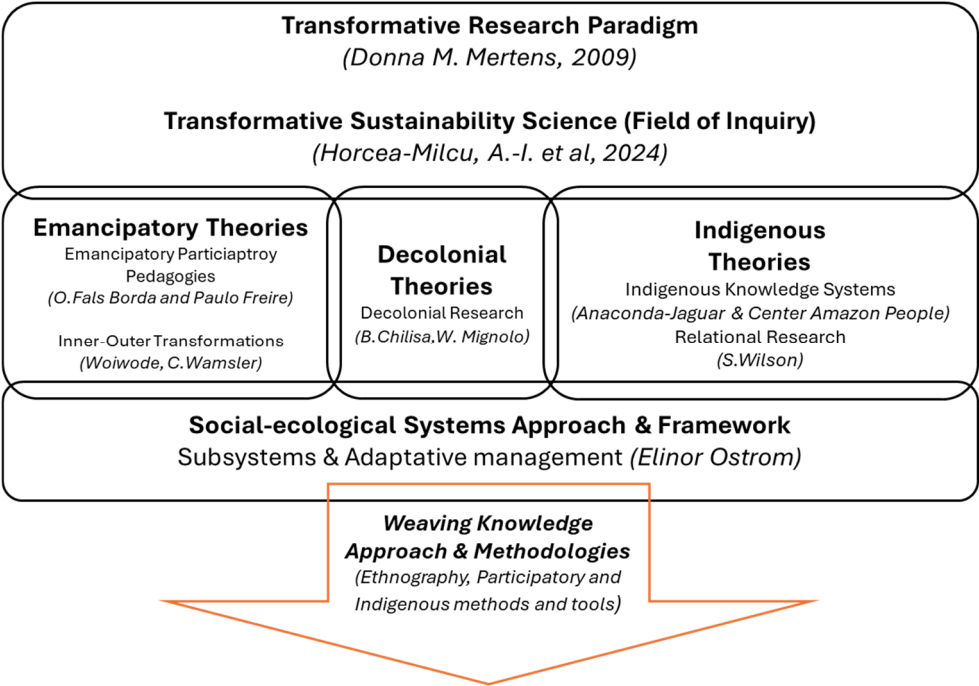


Figure 8. Theoretical framework overview of this thesis.
 This sequence of concepts structures and develops the WK with forest fauna IKS with Indigenous communities in the Colombian Amazon.

Moving down to the next set of concepts, I include the SES framework and Ostrom's (2009) approach in relation to the work on knowledge systems and TEK, rediscovered as adaptive management ([Berkes et al., 2000](#)). Drawing on Berkes' extensive work, I use TEK, extending its definitions, presenting variations in conceptualising TEK within IKS, and offering other descriptions in relation to Shamanic Knowledge, both of which are present in the contributions of Articles 3 and 4. I use the SES framework to structure the analysis of the Amazonian Indigenous territories, their related subsets,

and variables, while adapting Ostrom's categories, as discussed and developed with Indigenous researchers and communities and described in the methodology chapter.

The last set—methodologies, methods, and tools—will be presented in the methodology chapter, showing their alignment with these theories and frameworks. The next section will now focus on the primary concepts that structure my thesis: the Social-ecological Systems framework, Participatory Action Research, and the Multi-Evidence Base approach. Next, in the methodology chapter, I will describe in detail how they were implemented in the field.

Adaptive Complex Social-ecological System (SES)

My research draws on and further develops Ostrom's 2009 SES framework as a principal theoretical approach to forest fauna management in Indigenous territories of the Colombian Amazon. The SES framework conceptualises ecosystems and human societies as co-evolving and interdependent systems, making it particularly suitable for studying tropical forests where hunting, forest fauna management, livelihoods, culture and ecological dynamics are deeply intertwined ([Ostrom, 2009a](#)). I understand SES in the Amazon as a Complex and Adaptive System (CAS) mainly by its relational constitution and adaptive organising principles and its relation with TEK ([Berkes et al., 2000](#); [Preiser et al., 2018](#)).

Moreover, I approach forest fauna management not as a purely technical problem of regulating wildlife populations, but as a socially embedded practice shaped by Indigenous ecological knowledge, cultural norms, and local governance institutions ([Berkes et al., 2000](#)). The SES framework allows these elements to be systematically analysed by focusing on interactions among ecosystems or Resource Systems (RS), wildlife species or Resource Units (RU), Indigenous communities or Users (U) and both customary and formal governance arrangements or Governance Systems (GS). The diverse ways humans in Indigenous communities relate to and interact with forest fauna are here understood as Interactions (I), and the aims of our collective action within the PAR are seen as Outcomes (O) (Figure 9).

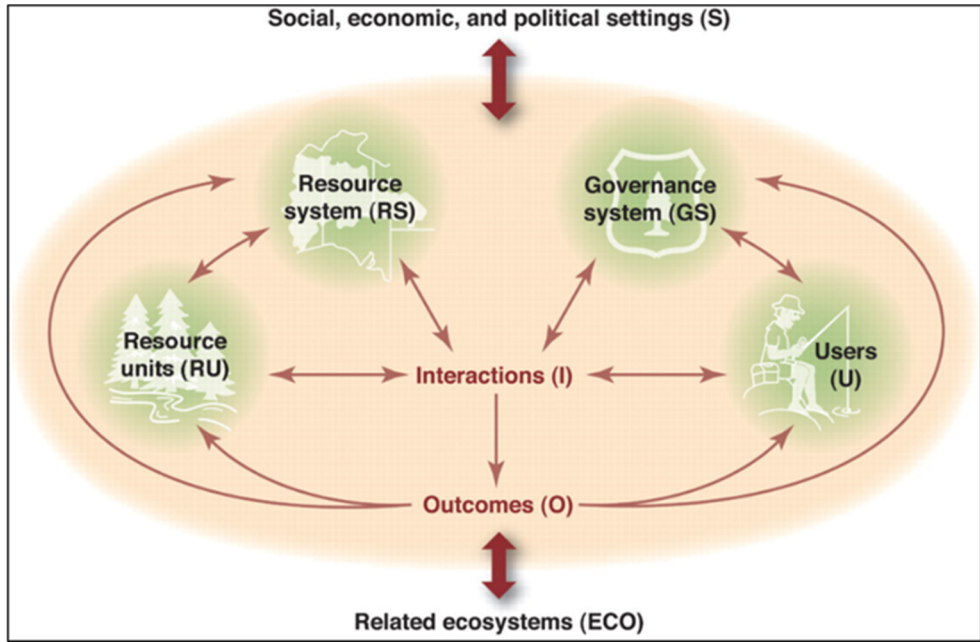


Figure 9. The core subsystems in Ostrom's (2009) framework for analysing SES.

In doing so, I recognise Indigenous cosmology, norms, hunting rules, taboos, and collective decision-making processes as legitimate institutions that actively regulate forest-fauna-human relationships ([Ostrom, 1990](#); [Yoamara et al., 2020](#)). This framework also supports context-specific and participatory wildlife research approaches as its diagnostic and flexible nature allows the integration of Indigenous knowledge—such as communitarian observations of species behaviours and abundance—alongside ecological assessments and social analysis. This approach is crucial for understanding how forest fauna management evolves over time in response to ecological feedback and social change ([Berkes, 2017](#); [Berkes et al., 2000](#); [Berkes et al., 1994](#)). This forest-fauna-human nexus is a traditional practise and an orally transmitted knowledge that has been represented in recent times as Indigenous socio-ecological calendars ([Yoamara et al., 2020](#)). SES also enables this research to situate human relationships with forest fauna as practices within broader multilevel and historical processes, including regional policies, market pressures, and territorial transformations in the Amazon. Here, I recognise Indigenous actors as adaptive managers and holders of expert knowledge, providing a comprehensive theoretical foundation for forest fauna management in the Amazon as a SES that links biodiversity, Indigenous livelihoods, knowledge dialogue, and territorial management ([Ostrom, 1990, 2009a](#)).

Variables in the System

The research questions addressed with PAR delineate the following subsets of socioecological approaches: Ecological System Variables, encompassing Resource Unit variables (RU1 to RU5) and Ecosystem Variables (RS1 and RS2), which elucidate ecosystem dynamics and species utilisation.

The second subset comprises Social System variables, including Actors (A1 to A4) and the Governance System (GS1, GS2, GS3), reflecting local understandings such as *Gobierno Propio* (Self-Governance) and *Gente de afuera* (People from outside).

These social variables analyse individual characteristics and behaviours, while the Governance System encapsulates institutional attributes, including formality, historical context, status, stability, and inter-institutional openness.

A third significant set of variables pertains to the Interaction subset (termed Relationships) and illustrates practices occurring during direct interaction between social and ecological systems, including harvesting techniques and cultural values linked to human-wildlife interactions. The knowledge underpinning these variables was predominantly local, yet co-produced with my external insights, integrating perspectives from conservation, decolonial methodologies, and Indigenous Knowledges.

Participatory Action Research (PAR)

Aligned with advancing forest fauna IKS, I adopted PAR as a core methodological approach, in combination with the Social-ecological Systems (SES) framework, to study forest fauna management in Indigenous territories of the Colombian Amazon. PAR is particularly appropriate for SES-based research because both frameworks conceptualise social-ecological dynamics as co-produced through human action, learning, and institutional change, rather than as externally controlled or purely technical processes ([Berkes et al., 2000](#); [Ostrom, 2009a, 2009b](#)).

PAR is grounded in the principle that those who live within a system are best positioned to understand, interpret, and transform it ([Chambers, 1998](#); [Fals-Borda et al., 1986](#)). This aligns closely with the SES framework's recognition of local actors as adaptive managers whose decisions, knowledge, and collective institutions shape socio-ecological outcomes over time ([Berkes et al., 2000](#); [Ostrom, 1990](#)). In Amazonian Indigenous contexts, forest fauna management emerges through situated practices such as hunting rules, species taboos, and shared monitoring of ecological change ([Godo-Bakari, 2015](#);

[Yoamara et al., 2020](#)). PAR then enables these practices to be studied with communities rather than about them, producing context-specific insights into how SES components interact and adapt, aligning to fill the inclusion gap and moving from research *on* to research *with*, and *by* ([Koster et al., 2012](#)).

Methodologically, PAR complements SES analysis by enabling iterative reflexive cycles when **agreeing, acting and reflecting on a research design that can go from a basic level of participation (informed, consulted, involved) to higher degrees of participation (collaborative, empowered)** ([Vaughn & Jacquez, 2020](#)). These cycles mirror adaptive governance processes central to resilience and sustainability theory ([Berkes et al., 2000](#)). In my work, through participatory methods — such as collective mapping, dialogue, community monitoring, and reflexivity — PAR allows us to examine SES variables (e.g., actors, institutions, resource dynamics) as dynamic and relational rather than static categories. This is especially important for Indigenous management of forest fauna, where ecological knowledge is cumulative, experiential, and continuously updated through practice.

PAR is also ethically and epistemologically appropriate for Indigenous research because it directly addresses power asymmetries in knowledge production ([Fals-Borda et al., 1986](#); [Whyte, 2017](#)). By positioning Indigenous participants as co-researchers rather than informants, PAR reduces extractive research practices and supports Indigenous autonomy over knowledge, research priorities, and outcomes ([Chilisa, 2019](#); [Whyte, 2017](#)). This ethical stance is consistent with contemporary SES literature, which emphasises legitimacy, trust, and participation as preconditions for effective and equitable environmental governance ([Ostrom, 2010](#)), also suited for advancing co-production as supported in [Article 1](#) ([van Maurik Matuk et al., 2023](#)), forest fauna ILK inclusion in [Article 2](#) ([Hernández-Vélez, 2026](#)) and narrowing the IPDC Gap mentioned in the introduction.

Above all, combining PAR with the SES framework strengthens the relevance of my research beyond academia. PAR produces actionable knowledge that can nurture local governance, conservation strategies and policy dialogues, while the SES framework provides a structured analytical language through which Indigenous management practices can be communicated across scales without being decontextualised. Together, PAR and SES constitute a coherent methodological–theoretical alignment for investigating forest fauna management as a living, adaptive social-ecological process rooted in Indigenous territories and knowledge systems.

Weaving Knowledges (WK): A Multi-Evidence-Based approach (MEB)

I previously introduced how I define Weaving Knowledges (WK) and how I draw on M. Tengö and her work on the MEB. Here, I describe how this proposal is linked with PAR as a reinforcing approach to working with Indigenous communities in the Amazon. These approaches (WK, MEB, PAR) address long-standing epistemological critiques of sustainability science by recognising that complex social-ecological systems cannot be adequately understood through a single knowledge system ([Cash et al., 2006](#); [Tengö et al., 2014](#)). By using them together, I want to enhance their aims and apply them as supporting approaches.

The MEB framework aligns with the epistemological grounding contemplated in PAR dialogues by treating Indigenous, local, and scientific knowledge systems as distinct yet equally valid sources of evidence, each providing complementary insights towards shared sustainability challenges ([Díaz et al., 2015](#); [Tengö et al., 2014](#)). In Amazonian Indigenous contexts, where forest and fauna management is shaped by historical continuity, territorial governance, and relational ontologies, the combined use of diverse knowledge systems in dialogical processes enhances analytical robustness, reduces epistemic injustice, and supports participatory research that is ethically grounded, policy-relevant, and aligned with Indigenous autonomy ([Berkes, 2017](#); [Whyte, 2013](#)). Weaving Knowledges emphasises dialogical, relational, and process-based engagement among knowledge systems, allowing Indigenous ways of knowing—embedded in lived practice, cosmology, and long-term ecological observation—to retain their integrity rather than being translated into external scientific categories ([Tengö et al., 2017](#)).

Within the Multiple-Evidence Based (MEB) approach, a set of core tasks (mobilise, negotiate, apply, translate, synthesise) is emphasised, necessary to WK between diverse knowledge systems (Figure 10).

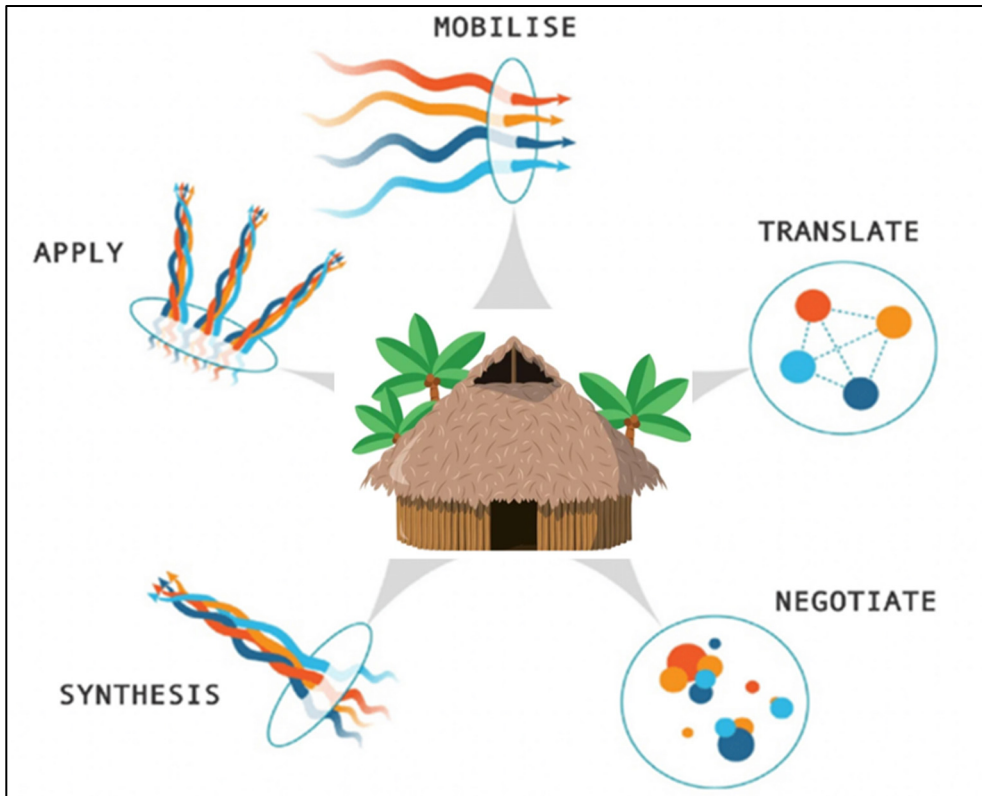


Figure 10. The MEB approach core tasks centered on weaving knowledge with TEK.

Modified image focusing on TEK (represented by a house of traditional knowledge) as a central institution in the Colombian Amazon (modified from Tengö et al., 2014).

These core tasks proposed in the WK-MEB can be defined in various ways. MEB definitions can be summarised as follows (Tengö et al., 2014): **Apply:** knowledge is applied first within the context, practices, and institutions of the knowledge system from which it originates, not immediately abstracted into policy or science. **Synthesis:** occurs after parallel validation, through triangulation, not integration or harmonisation. **Translation:** is not an epistemic conversion (i.e., turning local knowledge into science). It is limited to mutual intelligibility, while allowing each system to “speak for itself”. **Mobilisation:** means ensuring that diverse knowledge systems actively inform assessments, decisions, and policy processes, rather than merely being documented. **Negotiate:** knowledge interaction is inherently political and relational; therefore, legitimacy, transparency, and trust must be actively negotiated at interfaces.

The core purpose of these actions and their aims, in my view, is already present within PAR cycles but placed in action and defined at different stages of the research process. Therefore, PAR and MEB complement and reinforce each other when used together.

The **iterative cycle** within PAR, in which participants and researchers together **co-define** the problem, **identify** the priorities and objectives, and **agree** on possible actions grounded in local realities, finally **implementing** them through collective action, generates a validation of collective knowledge ([Vaughn & Jacquez, 2020](#)). This allows the integration of PAR as a container for respectful, reiterated, long-term dialogues and for developing priority tasks.

In this sense, PAR can activate the MEB approach by embedding its epistemological tasks within successive stages of collective inquiry and action. While MEB defines how diverse knowledge systems should relate without hierarchy, PAR provides the procedural structure through which problem framing, knowledge generation, validation, dialogue, and action are enacted in participatory and context-specific ways. Together, MEB and PAR form a coherent framework for Indigenous research in the Colombian Amazon that is both epistemologically rigorous and methodologically grounded. When combined with MEB, PAR helps me translate multiple evidence bases into situated insights that respect the integrity of Indigenous knowledge systems.

Nested Indigenous Ways of Knowing (IWK-IKS)

As already mentioned, the theories, concepts, approaches, and literature on SES, PAR, WK, and MEB are closely related to each other and to IKS. Many of them were developed while working with Indigenous and rural communities, and often drawing on concepts and methodologies from IKS to address the research challenges, such as the Inclusion Gap ([Johnson et al., 2016](#)). Having already explained “the why” for using these frameworks, now comes the “how to”: naming and defining IKS, which will present other reasons for combining these frameworks with a “new way of seeing” that reframes previous understandings of knowledge dialogues within forest fauna management in the Amazon.

To properly address the research aims and answer my research questions, I will now detail what Indigenous Knowledge is and how it is locally understood. I do this by outlining my understanding of differences and definitions in the terminology, referring first to the concept of Indigenous Ways of Knowing (IWK) and its equivalent, Indigenous Knowledge Systems (IKS), drawing on recent publications by Indigenous scholars across the world that critically examine TEK ([Jacobs, 2025](#)).

Figure 11 presents a nested knowledge system that moves from broader to more specific, from the “umbrella” set of ILK to IWK-IKS, then to Indigenous Science (IS) or Native Science (NS) terms, and finally to TEK and Shamanic Knowledge (SK).

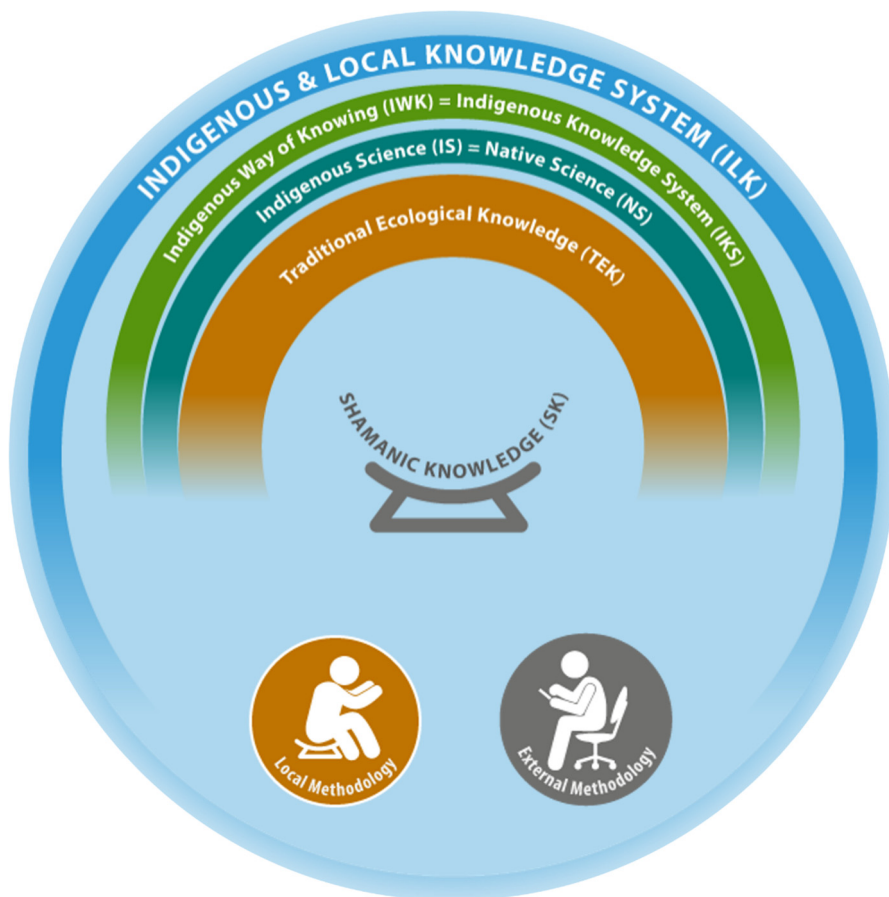


Figure 11. Nested ways of knowing (Hernández-Vélez, 2026)

Knowledges and knowledge holders are included in dialogue contexts using local and external methodologies.

TEK and ILK have been commonly used as synonyms for Indigenous Knowledge (IK), IKS, IS, and NS (Berkes, 2017; Jacobs, 2025). These terms can be more accurately differentiated by recognising their multidimensional aspects of Knowledge. Knowledge Systems (in this case, IKS) can have nested and interlinked dimensions (Jacobs, 2025; Nelson, 2014). These nested sets recognise ILK and IKS as systems that contain IS, which in turn contain TEK and SK. In this sense, not all IKS are IS or necessarily considered TEK; rather, they are subsets of IKS. On the other hand, in this nested system, all IS and TEK are embedded within IKS (Nelson, 2014).

This nested frame also recognises (diffused “permeable” lines) that knowledge contained in all dimensions does not exclusively originate from traditional pathways, but can also arise from complex external interactions that can be strategically incorporated, adopted for survival purposes, or appropriated in various possible modes of syncretism³ ([Berkes et al., 2000](#); [Gómez-Baggethun & Reyes-García, 2013](#); [Nelson, 2014](#)). This figure is already a conceptual contribution of my thesis to theoretical frames that can advance dialogues, inclusion, and the co-production of knowledge in TSS, and clarify some general misconceptions about TEK.

In this sense, I understand TEK to be part of what many Indigenous scholars recognise as Indigenous Science (IS) or Native Science (NS), both of which are part of IWK/IKS and ILK, the “umbrella” term in the nested ways of knowing. I will subsequently delineate the comprehensive information contained within TEK and its supplementary subsets.

Although there is an open debate on recognising IS and NS as science, which I do not aim to solve in this thesis, I do point at the fact that this science category exists in many Indigenous communities and it is used by Indigenous scholars ([Jacobs, 2025](#)).

Broadly, the literature identifies four main positions regarding Indigenous knowledge systems and their relationship to modern science: 1) Indigenous knowledge as Indigenous Science ([Cajete et al., 2018](#); [Cajete, 2020](#); [Snively & Corsiglia, 2001](#)), 2) Indigenous knowledge as a parallel system complementary to Western science ([Berkes, 2017](#); [Díaz et al., 2015](#); [Tengö et al., 2014](#)), 3) critiques of extending the term “science” to Indigenous knowledge ([Haack, 2011](#); [Kitcher, 2001](#)) and 4) critical “middle-way” perspectives that challenge rigid dichotomies while rejecting romanticisation or essentialising of both modern science and Indigenous knowledges ([Agrawal, 1995, 2002](#); [Escobar, 2018](#); [Turnhout, 2024](#)). These positions help to locate the disciplinary and epistemic arenas in which dialogue between knowledge systems can be more or less productive. Here, productivity refers to the capacity of such dialogues to bridge inclusion gaps or, conversely, to widen them when debates become stalled at the level of recognition, thereby obstructing progress towards complementarity, contextual relevance, epistemic justice, explanatory expansion, effectiveness, and legitimacy.

Irrespective of terminological debates, IKS, TEK, and SK are ongoing adaptive systems grounded in specific epistemologies (ways of knowing and validating knowledge) and ontologies (conceptions of being and reality). Indigenous knowledge systems have historically employed systematic observation, experimentation, hypothesis testing, and

³ Syncretism is a term used in cultural anthropology to refer to the hybridization or amalgamation of two or more cultural traditions. It is also used to highlight the fusion and assimilation of different elements.

replication over long temporal scales ([Aikenhead & Ogawa, 2007](#); [Turner, 2014](#); [Whyte, 2017](#)). A key distinction from modern science lies less in methodological rigour than in the socio-economic and historical conditions of knowledge production: IKS developed largely outside industrial and capitalist feedback loops, giving rise to different technological trajectories, scales of inquiry, and modes of engagement with the material world.

In contrast to laboratory-centred modern science, IKS have relied on alternative “laboratories” and methodologies within livelihood practices, including, e.g., agroforestry systems, hunting and tracking practices, sophisticated plant-animal based pharmacology, venom preparation, and experiential testing involving *plantas maestras* (teacher plants) and shamanic practices. These are complex ecological and biological technologies that remain insufficiently recognised or poorly understood within dominant scientific paradigms.

A further source of perceived incompatibility concerns the ethical and value frameworks embedded in IKS, which explicitly integrate spiritual, moral, and relational commitments into knowledge production, in contrast to modern science’s enduring—though widely contested—claim to value neutrality.

While acknowledging this complexity, I adopt the position that some components of IKS may appropriately be described as scientific, while others may not, depending on context and practice. Variability also exists within and across communities, as in all knowledge systems. Because determining who qualifies as a scientist or what counts as science in a strict sense lies beyond the scope of my research, I focus on using the terms IKS, TEK, and Shamanic Knowledges (SK).

Advancing TEK definition

IKS, TEK, and SK embrace the interdependence of the visible and invisible worlds and are strongly connected to the natural laws given by the creating forces and entities that regulate the universal forces, allowing biological life to arise ([Godo-Bakari, 2015](#); [Yoamara et al., 2020](#)). Even though I draw on Berkes’ extensive and admirable work, I approach TEK differently from him. I do address the spiritual, transcendental and cosmological dimensions that Berkes chose not to delve into, but that many Indigenous communities consider crucial, as exemplified in Jacobs’s 2025 compilation “Indigenous Critical Reflections on Traditional Ecological Knowledge” and the diverse local terminologies registered in the Article 2 systematic review (e.g., Relational Symbiosis, Ancestral Knowledge, Local Wisdom, Interdependent Culture).

Berkes explicitly recognises that TEK includes cosmology, ethics, and belief systems; however, he also draws a methodological boundary by emphasising that scientific analysis should not attempt to evaluate or engage with transcendent or spiritual truth claims and therefore focuses analytically on those elements of worldview that shape observable practices, institutions, and adaptive management (Berkes, 2017, pp. 145–147).

I consider this boundary one of the barriers to the inclusion gap. However, this boundary is easily crossed by scholars, who have had the experience of immersing deeply in the field not as observers but as learners of the ways that Indigenous people see, define, and embody TEK in their daily lives ([Jacobs, 2025](#)).

Inspired by Berkes' 2017 definition and expanding it with my empirical comprehension reached in this study and my 13 years of research in the Colombian Amazon, I crafted this TEK definition, including its multiple dimensions of structure, transcendence, time, transmission, ontology, composition, epistemology, ethics, guiding principles and origin; without subjecting it to normal scientific verification or reduction.

Traditional Ecological Knowledge is:

i) a nested knowledge in a broader knowledge system, *ii)* a way of being-knowing, *iii)* an ancient ongoing developing knowledge, *iv)* an orally and practice based knowledge, *v)* held in differential degrees of appropriation by humans and more than human beings (visible and invisible), being shamans the most refined holders of it, *vi)* strongly dependent on oral and experiential transmission to new generations, *vii)* containing immense detailed information of the interlinked social-ecological dynamics *viii)* harvested through thousands of years of direct learning and plant-based experimentation of wellbeing outcomes *ix)* oriented by the knowledge given by the prime movers of creation throughout their evolutionary stages (manifestation, balancing, ordering), *x)* brought to ancient humanity by the epic work of the first ancestral couple who transferred it from underwater realms to land.

Accessing and understanding these TEK dimensions can be a complex task for researchers working in Indigenous contexts. I address this challenge by selecting and developing methodologies that enable dialogues to expand the comprehension of what can be considered a valid reality and knowledge. This challenge is not exclusive to TSS; it is also present in physics, where experimental conclusions depend heavily on the methods and instruments used, as is the case of “The operational or measurement paradox”, described, e.g., in philosophy and physics as Niels Bohr's work ([Heisenberg, 1958](#)). This method-dependence paradox affects the possibility of accessing and

constructing knowledge, pointing to the strong connection between Knowledge, Access, Epistemology, and Ontology.

To address this paradox in social sciences, I draw on the term onto-epistemology to frame the methodology chapter, discussing reality in relation to this key concept.

Onto-epistemology refers to the co-constitution of ontology (being) and epistemology (knowing), rejecting the assumption that knowledge is produced through neutral observation of a pre-given reality ([Barad, 2007](#)). From this perspective, ways of knowing are understood as materially and relationally entangled with the worlds they help to enact, such that knowledge practices are simultaneously practices of world-making.

This stance is particularly relevant for expanded conceptions of TEK, which do not treat knowledge as detached information about nature, but as emerging from ongoing relationships among humans, more-than-human beings, ancestors, spiritual presences, and places ([Berkes, 2017](#); [Manuel-Navarrete et al., 2025](#)).

An onto-epistemological framing of knowledge, therefore, situates Indigenous beliefs, practices, and ceremonies not as auxiliary or “cultural” dimensions added to ecological knowledge, but as constitutive of relational realities in which knowing, doing, and being are inseparable. Adopting this perspective has methodological implications, as it calls for research approaches that attend to participation, relational accountability, and the co-production of knowledge rather than the extraction or representation of an external reality ([Barad, 2007](#); [Romm, 2024](#)). According to this, the methods used to build knowledge about forest fauna can also determine how the whole system is perceived and managed (while the concept appears across many traditions, Karen Barad is known for formalising onto-epistemology as a unified framework, highlighting that acts of knowing shape reality).

In my research I adopt an onto-epistemological perspective that views knowledge and reality as interconnected and mutually shaping. Over time and through exploring IKS methodologies, this perspective can broaden its understanding of reality into what is referred to as an expanded onto-epistemology.

Recognising humans, animals, and forests as a shared world rather than separate entities, I developed the following methodology section that addresses various existing tools from Indigenous methodologies, including an innovative personal proposal for non-Indigenous or external researchers to access the multiple dimensions of TEK through a Method called Exchanging Research Seats.

4. Methodology: landing theories in praxis

Research Areas and Indigenous Study Sites

This thesis draws on more than four years of collaborative research conducted with local Indigenous communities across two Indigenous territories (called *Resguardos Indígenas*⁴, in Spanish) in the Colombian Amazon. The decision to work in two distinct territories was motivated by the aim of moving beyond a single PAR case, thereby enabling a more robust exploration of the possibilities and challenges of dialogue between sustainability practitioners and IKS in the context of Amazonian forest fauna management. An additional motivation was the commitment to sustaining long-term research and personal relationships with Indigenous communities in the region, in response to well-documented critiques of extractive, short-term, and insufficiently accountable academic engagements. As previously mentioned, I lived for one year in a multiethnic community in Vaupés (between 2012 and 2015), and in Amazonas, I previously met a unique Indigenous association at a wild meat symposium in 2014. Therefore, it made sense to deepen the existing relationships to develop real-life scenarios to test and apply sustained empowering dialogues that foster IKS inclusion in Amazon forest fauna management.

Both sites are among some of the world's most bioculturally diverse regions ([Maffi & Woodley, 2012a](#)) and share a common history of exploitation booms during the 19th and 20th centuries ([Whitehead, 2011](#)). Despite the horrors of the rubber, balata, pelts and cocaine booms and systemic discrimination and assimilation by governments and church interests, many local communities continue to keep indigenous practices, beliefs, ceremonies and livelihoods in a modern and interconnected era.

⁴ Indigenous *Resguardos* in Colombia are inalienable territorial units that recognise the communal property and sociopolitical structures of Indigenous communities. They were created to ensure control over their lands, although historically they have also been a tool for land concentration and dispossession. The 1991 Constitution recognizes these territories as collective property and guarantees Indigenous peoples their own rights

The selection of two cases is also intended to identify commonalities, contrasts, and potential forms of collaboration across geographically distant yet bioculturally related regions, specifically the Vaupés and Amazonas departments of Colombia. While initial engagement was sought with a broader range of communities across these regions, alignment in timing, priorities, and research interests proved decisive, and the deliberate limitation of PAR initiatives was necessary.

PAR requires more time, sustained commitment, continuous reflexivity, broader budgets, or at least more active retributions for communities and co-researchers, and iterative engagement, demanding substantially greater investment than non-participatory approaches. At the same time, these relationships and forms of cultural vitality are increasingly threatened by the expansion and normalisation of non-Indigenous livelihoods, governance frameworks, and socio-economic pressures that risk eroding Indigenous modes of relating to forest ecosystems and forest fauna.

The focus on indigenous reserves as study sites is particularly relevant because these territories are legally recognised, collectively owned, and governed (to some degree) by Indigenous authorities. This institutional configuration provides a distinctive context for examining how communities jointly manage resources, maintain and adapt TEK, navigate formal and informal rules, and develop new institutional arrangements for managing commonly held lands and wildlife. Working within two *resguardos*, therefore, offers critical insights into how social processes, collaboration, and governance structures influence both forest fauna management and the practice of inclusive, participatory research in Indigenous territories.

The first study area shown in Figure 12 is the TICOYA *resguardo* in the Amazonas department (yellow area). Leticia is the capital, the closest urban centre, Puerto Nariño, and the study site Tipisca. The second study area is the Gran Resguardo del Vaupés (pink area), showing its capital, Mitú, and the study site, Ceima Cachivera. Basic data on the areas, capital, and nearby towns and villages are presented in Table 2.

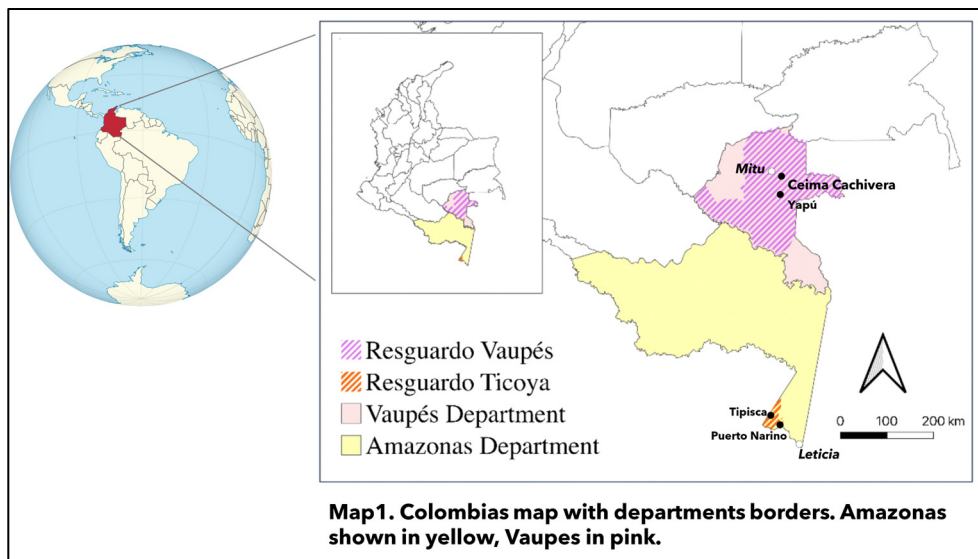


Figure 12. Map of study areas and communities in the Colombian Amazon.

(map created by N. Ponta).

The Amazonas department is highlighted in yellow, featuring the Tipisca and Puerto Nariño communities as dots.

The Vaupés department is shown in pink, with the Ceima and Yapú communities represented as dots.

Table 2. General Information on Study Areas and Sites.

Area 1. Amazonas, Area 2. Vaupés and the respective study sites, Tipisca and Ceima Cachivera communities, are participating in the research.

Town, villages and Resguardos information	Area 1 Resguardo TICOYA Amazonas	Area 2 Gran Resguardo del VAUPÉS
<i>Department name</i>	Amazonas	Vaupés
<i>Indigenous Associations to which communities are related</i>	Association of Tikuna, Cocama and Yagua communities (ATICOYA)	Association of Traditional Indigenous Authorities near Mitú (AATIAM)
<i>Name the nearest urban settlement</i>	Puerto Nariño	Mitú
<i>Population of the town</i>	11,000 (2026) approx.	32,000 (2026) approx.
<i>Town Elevation meters over sea level (mosl)</i>	82 mosl	183 mosl
<i>Main rivers</i>	Amazonas and Loretoyacu	Vaupés
Main Indigenous groups at the town (attributive Name)	Tikuna, Cocama and Yagua	Cubeo, Barasano, Desana, Piratapuyo, Tatuyo, Tukano, Bará.
Community Village Name and population (Study Sites).	Tipisca (63 families, population of 299, in 2026)	Ceima Cachivera (66 families, population of 280, in 2026)

The Resguardo TICOYA, Puerto Nariño, and the Tipisca community are part of the department of Amazonas, located in southern Colombia along the borders with Perú and Brazil. Puerto Nariño is located on the northern bank of the Amazon River. The average monthly atmospheric temperature in Puerto Nariño ranges from 23 to 28°C, with a maximum of 37°C and a minimum of 16 °C. The annual precipitation average is 3,325.2 mm, with a monthly average of 277.4 mm ([Rangel & Luengas, 1997](#)). Rainfall regime registers a multi-annual behaviour of a monomodal type, presenting a period of low rainfall in July and August, a time of greater rainfall that usually occurs between December and April and two transition periods, one between September and November, in which the intensity of the rains gradually increases and another between May and June, in which the transition towards low precipitation ([Rangel & Luengas, 1997](#)).

In the Amazonas department, we (my advisor Torsten Krause and I) work with Tikuna, Cocama and Yagua communities, Indigenous groups who live in the tri-frontier zone with Brazil and Perú. We are building on previous research relationships with a local hunter association, Airumakuchi, a group that has been working since 2014 to revive TEK and new forms of collective decision-making regarding the local and traditional use of forest fauna. I first learned about the hunter association in 2014, and in 2022, we approached them with a proposal to continue working together. They responded positively to the current research invitation. Through the association, we reached various members of the ATICOYA reserve and ended up working more closely with the Tipisca community. Both Puerto Nariño and Tipisca can be reached by boat from Leticia. It takes two hours to reach Puerto Nariño, with a population of 8,000 inhabitants, most of them indigenous, and then take the Loretoyacu River for another 3 hours in a small boat to reach Tipisca, a small indigenous village of 299 members, the majority being ethnic Tikuna.

The other study area, the Gran Resguardo del Vaupés, is located in the department of Vaupés (capital: Mitú), in southeastern Colombia, along the border with Brazil. The region is characterised by a humid-tropical climate with an average of 3583 mm per year and an average temperature of 25.4 -26.3°C. Typical rainfall patterns occur during the rainy season between April and July, with a second rain period between September and October ([Rudas Lleras, 2009](#)). The department also contains major areas that are part of the larger Río Negro basin rock formations, commonly composed of sedimentary and metamorphic rocks that belong to the Pira Paraná formation, part of the Guyana Shield ([Hernández et al., 1992](#)).

Connecting methods with communities

Based in emancipatory, participatory, Indigenous, and SES theoretical frameworks, I understand knowledge production as a collective and world-constituting practice, rather than a neutral representation of reality. PAR provides the overarching methodological framework and ethical compass, within which the MEB, Weaving Knowledges, and ERS methodology were implemented and adapted through iterative cycles of collective learning with Indigenous communities. The following sections describe how these approaches were implemented.

First, an overview of the research process is presented in Figure 13, which connects topics, scenarios, data harvesting, analysis, results, methodologies, and publications throughout the research process. In Figure 13, I present a description of the levels at which methodologies were applied, connecting my methodological contributions to institutional dialogue, community knowledge exchange dynamics and focus group work with local researchers.

Next, a PAR description and ERS methodology are presented, and finally, a detailed overview of the methods and tools applied is shown in Table 3, along with the set of forest fauna topics developed in community workshops (Table 4).

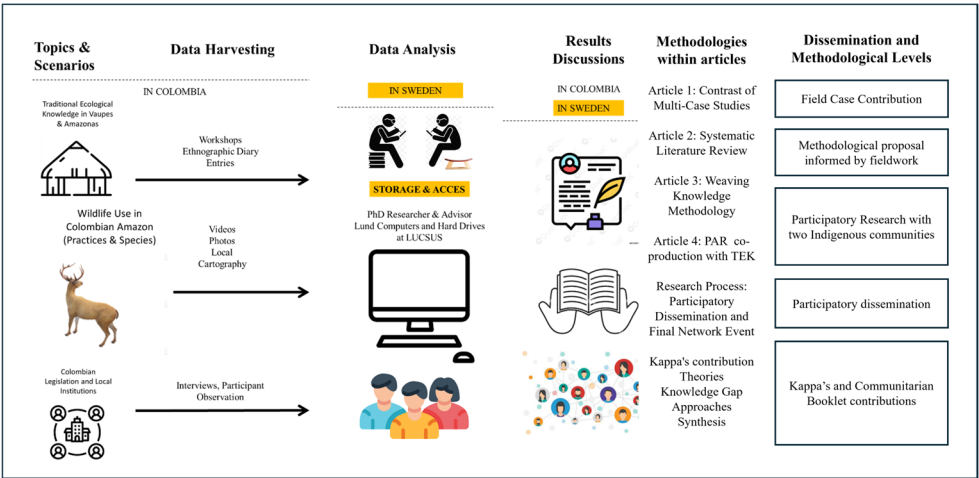


Figure 13. Overview of the whole research stages and process.

Figure 13 provides an overview of the entire research process, connecting the various stages, scenarios, data types, places of analysis, result types, article methodologies, and

result dissemination strategies. In addition to the four academic articles, additional printed materials were presented to and returned to the communities. Also, our agreements include the forthcoming creation of a Spanish-Indigenous language booklet, as a key community commitment to returning information and disseminating their own results in non-academic publications.

Amazon Participatory Action Research

My methodological approach focuses on local knowledges and methods to understand, interpret, and act within transformative research that enhances dialogical and co-produced research with IKS to enrich Indigenous inclusion in sustainability practices. Reflexivity is a key aspect of co-producing knowledge, and it is highly promoted by PAR, considering local knowledge at every step.

Participatory Action Research (PAR) is an approach in social sciences, defined as a process which emphasises a dialogical, self-reflective, and participatory approach to knowledge ([Fals-Borda et al., 1986](#); [Freire, 2020](#)). PAR distances itself from neat hierarchical distinctions between the researcher and researched, with the explicit purpose of empowering the oppressed and helping them to overcome their oppression ([Kindon et al., 2007](#)). PAR definition is adapted and informed from Fals Borda and P. Freire's work; for the purpose of this study, I define it as:

- i) a collective learning process, praxis-centred methodology in which community members and an external researcher (me) jointly produce and apply local knowledge (TEK) through iterative cycles of collective reflection and action. ii) a way to cultivate critical consciousness, iii) a possibility to transform oppressive social, political, and structural conditions, and iv) an approach that favours emancipation related to inclusion of IKS and TEK, including discussions and regional actions to manage forest fauna.

The origins of the current work are based on my cultural immersions (2012-2015) in the region, which inspired me to continue my relationships with local indigenous groups. My transformative personal process served as the basis for my current research design and is grounded in the recognition of the importance and need for dialogue and inclusion of IKS in forest fauna research. I presented this initial proposal to communities that had previously shown openness to working together, and adapted it to incorporate their ideas, aims, and methodologies. For that reason, I consider my study as “Researcher-Initiated with Shared Decisions of participants” ([Radermacher, 2006](#)).

I designed methods of intervention and collaboration, considering four principles of PAR, also described by Indigenous and feminist researchers (Chilisa, 2019; Mohanty, 1984). The first emphasises the **authority of direct experience**, valuing expertise gained through practical engagement. Marginalised or affected individuals possess vital experiential knowledge needed for sustainable, more effective, inclusive, and legitimate decision-making regarding forest fauna management in this case. The second principle involves **knowledge in action**, where PAR gains understanding through the implementation of local knowledge empowerment and the criticism of external knowledge domination. The third principle considers **research as a transformative process** that aims to create empowering relationships throughout the project. The fourth stresses **collaboration via dialogue**, leveraging diverse expertise through critical collective discussion.

PAR also contributes to the intention and action to move away as much as possible from “Extractive type of research”: that which extracts information and exploits relationships, places and people, producing benefit for scholars or external institutions, and depleting resources at the sites of the research ([Cornish et al., 2023](#)).

Local Researcher Groups and Community Inclusion

This process relies on active participation and collaboration with members of the two areas of study and their communities, where a group of local researchers was selected by the community.

The Local Researcher Group (LRG) had four members in Tipisca and six in Ceima Cachivera, committed to monthly duties and receiving monetary recognition for the duration of the research (2022-2026). They were selected by the community based on TEK interests, multilingual skills, responsibility, and strong relational skills, as outlined in the invitation letter (Annex A). Each researcher received a monthly payment for their work, usually requiring three days (1 day of preparation, 1 day of development, and 1 day for presenting results) of approximately 83 USD/300,000 COP (total monthly budget: 417 USD/1,500,000 COP).

We used a variety of techniques, including methods and specific tools, to gather information for a coherent PAR (Figure 14). We developed this in a collective process, coordinating with the local research groups (LRG), who recurrently aligned with me on the PAR's methodologies, methods, and tools.

Basic details of the three levels where methodologies, dynamics, and tools were used (LRG, Community, Institutions) are shown in Figure 14. This image presents a picture of each LRG during community workshops and basic data on community participation.



Figure 14. Implementation levels of methodologies.

Both LRG, Community and institutional levels within the two PAR processes.

Community Contact: Invitation, Dialogues and Agreements

We made sure the first stage of agreements was fully completed before starting any activity with local communities and their selected researchers. There are basic legal requirements for working with Indigenous communities in Colombia that involve presenting and providing a written invitation with a detailed description of objectives and community benefits. Also, presenting it to the community leader and the formal community plenary, who meet weekly. Once evaluated by them, they can give or reject permission.

In this case, we received an acceptance letter expressing informed consent and permission for entering their territory through their legal representatives (Annex A, B, C). Agreements on working dynamics and the purpose of the research was aligned with their wellbeing concepts and "Planes de Vida" ([AATIAM-ASATRIZY, 2024](#); [ATICOA, 2008](#)). The agreement included: the projected products and results; who would be visiting the community; on what frequency and for how long; what products the community, school, and LRG would receive; and when. In these meetings, we also discussed how this PAR was an opportunity to potentialize other local processes like strengthening their intercultural medical service, defining their territorial delimitation and promoting dialogues with external authorities.

The legal authority received and evaluated the invitation letter, and an assembly was organised to formally introduce us (my advisor and I) to the community. Then, we explained the roles of the Local Research Group (LRG): To coordinate, activities, to establish collaboration with the consulted communities, to update local colleagues or allies about the research purpose, objectives, characteristics, to establish direct communication with local leaders and to consult the *sabedores* (shamans) to include their knowledge in the research.

After receiving a positive response and being asked to provide details on the project structure, I visited the community and stayed at a local researcher's house. Whenever we organised field trips and visits that aligned with the communities' schedules, I stayed and slept in the *Maloca* (house of traditional knowledge) or at LRG houses. Additional pedagogical meetings with the LRG were needed to discuss and develop more detailed explanations of the possible roles, methods, methodologies, and remuneration, presenting to them the possibility to have a voice and decision on all these matters and arrive at collective consensus on roles, strategic invitation to the community, equitable payment agreements, rotation of specific roles to expand inclusion and participation, among other topics.

Our initial goal was to establish clear agreements within the research group and promote community participation in monthly core activities of the PAR process, focused on participatory workshops as the backbone of the research. Over four years, we maintained multiple levels of agreement with individual leaders, research group members, schoolteachers, elders, shamans, the LRG, and the community.

These co-produced agreements and commitments include the delicate process of synthesising ideas, translating diverse scientific concepts to the community, and receiving bidirectional clarification and negotiation (tasks from the MEB approach). These are critical steps that occur in earlier stages of developing PAR, but the MEB tasks are also present within the co-produced research processes.

This process of reiterated collective learning is known in PAR as the “heart pump” dynamic that regulates and boosts collective and reflexive actions, including conflict resolution, problem solving and creative thinking. The process relates unseen events to empowering and emancipatory purposes, placing IKS in an equal, dialogical stance with other forms of forest fauna knowledge (Figure 15).

PAR in Action: cycles and tasks

In May 2022, after concluding the agreement phase, the LRG, community, and an external researcher (me) walked through what I call “the initiation stage” of the PAR first cycle.

Figure 15 presents the PAR-reiterated cycles, consisting of four key participatory stages

1. Define 2. Act, 3. Observe, 4. Reflect and 5. Refine

1. Define common interests: Learn about TEK related to Forest Fauna management, document its use and promote its transmission.

2. Plan actions on Agreed Paths: Organise monthly community workshops and visits to elders and sacred sites to learn, question, contrast, and reflect on forest fauna TEK.

3. Observe & Harvest: Observations, experiences, stories, narratives, and information were gathered within the community, among elders, and during seasonal abundance ceremonies. These were also written down and registered in research notebooks that all co-researchers had throughout the process.

4. Analyse & Reflect: Reconvene and compare interpretations; express misunderstandings; resolve conflicts; reorder questions, methods, logistics and responsibilities. ‘

5. Refine & Reorient: Arrive at a new way of seeing the common interests, walking a renewed path, sustaining the process and gaining confidence in the group dynamics to express questions, doubts and needs for open resolution, before moving into the next cycle.

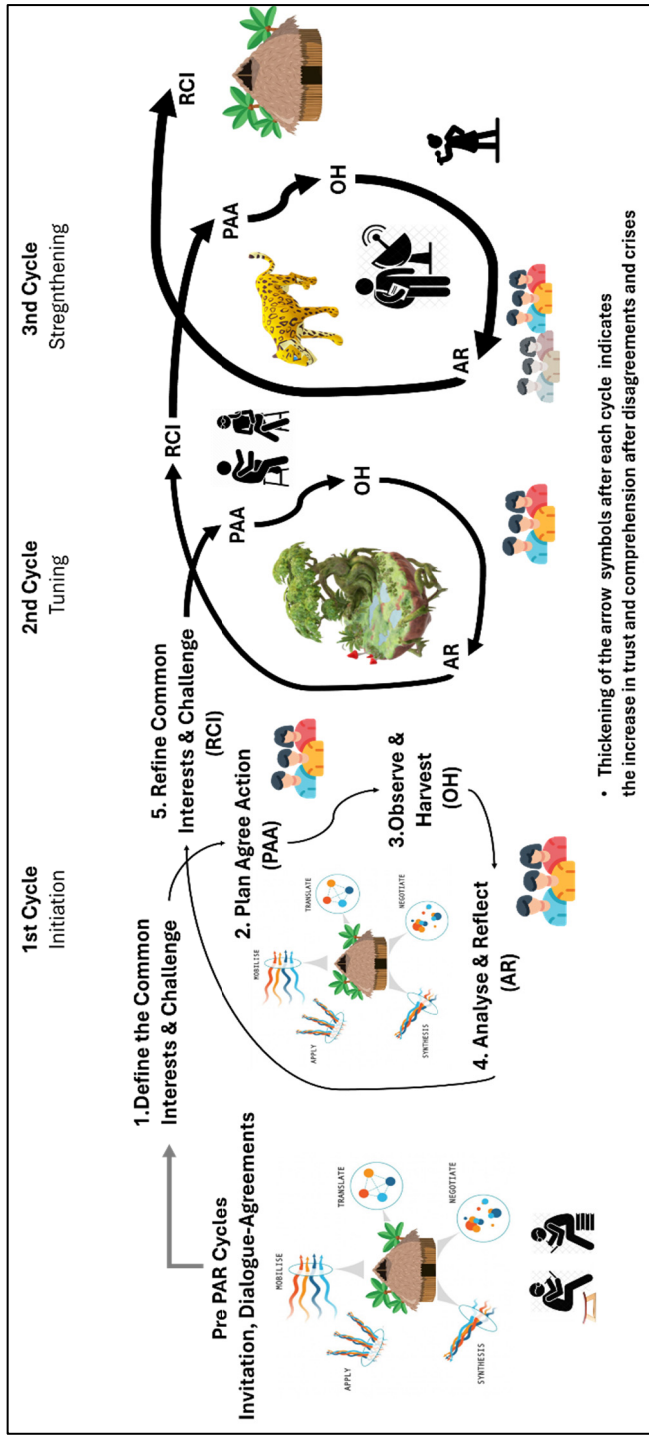


Figure 15. Synthesis of PAR cycles developed with local researchers and community members. Reiterated collective learning through a five-step process (Define, Act, Observe, Reflect, Refine).

Challenges and Conflicts within cycles

The biggest concern with long-term participatory and co-produced research is bridging contrasting contexts, group dynamics, and personalities across diverse communication methods and differing access to them (such as cell phones), as well as addressing power imbalances and community hierarchies. The complexity of these differences cannot be addressed here; however, I mention in Articles 1, 3 and 4 some cases and how we, as a group, and I, as an individual, faced and overcame barriers and conflicts to achieve our proposed goals.

In the **initiation cycle**, a recurrent challenge was achieving effective bidirectional communication, since misunderstandings commonly occurred within the group and in the process. When these were addressed through mediation and dialogue, the process could be taken further into a second stage: **The tuning cycle**.

This cycle is characterised by a sense of teamwork achieved after overcoming the initial abrupt obstacles. However, new challenges arise, and mutual corrections occur among the group members, not only within the communities but also from their side to me, teaching me how to be more careful and respectful of local ways and behaviours and helping us all to gain a sense of trust.

Then we reach the **strengthening cycle**, where the groups and processes that have already experienced confusion and strong conflicts realign their terms and aims, reaching a state of flow in which a sense of companionship and belonging arises, nurturing the daily lives of individuals and, as a consequence, the dynamics of the research processes. Patience, repetition, and finding value in the mistakes and learning processes are fundamental to addressing the conflicts that arise. Of course, not all conflicts get resolved, and many of them continue throughout the process.

Managing expectations within the external and LRG in sustained dialogues is of immense importance, as well as in private, reflexive spaces, where the external researcher can put into practice their inner-outer reflections, decolonial processes and weaving knowledge skills.

Also, it is of great importance to use pedagogical approaches to address misconceptions that often arise from differences in cosmology, livelihoods, literacy levels, personal and collective trauma, and even language. It is very likely that historical epistemic oppressions favour the reinstatement of external ideas over local expressions, and it is up to the researchers to continually challenge their own power, agency and criteria to promote collective local proposals aligned with the PAR process.

This is the main reason why, while immersed in fieldwork and dealing with the complexity of a participatory initiative, I saw the necessity of including another methodology to complement PAR. A new approach was vital for overcoming challenges and conflicts and having a successful journey through the different cycles.

Exchanging Research Seats: including indigenous technology

Over the long years living in the Amazon, I was invited several times to the Houses of Ancestral Knowledge for the night, sharing stories around the fire. These long hours of listening to the elders were spent sitting on a low seat, close to the ground, which initially could even be very uncomfortable for a person coming from a city like me. What I could see at some point was that those gatherings were, in reality, moments of study and learning for the community, listening and sharing stories that would last for hours, explaining topics about spirits and animals that provided information for hunting or eating, agriculture, fishing, and social norms or taboos. All this exchange of deep information, orally preserved for thousands of years, could not be transferred in the context of a classroom with chairs, tables and lights. The information itself was linked to a particular scenario. Traditional knowledge was dependent on a local spatial arrangement, including a wooden seat to sit on. My conclusion then was that, if we want to really talk about TEK, we would have to include its own technology for sharing information.

The **Exchanging Research Seats (ERS)** dialogical methodology (see details in **Article 3**) emerges as a weaving of knowledge practices specifically designed to facilitate respectful knowledge flow and exchange between Indigenous and non-Indigenous perspectives in the context of collective forest fauna management in the Amazon. ERS involves adopting new mind-body postures — sitting in Indigenous "*thinking seats*" and non-Indigenous "*academic seats*" — creating reflexive spaces for learning dialogues and understanding diverse worldviews ([Hernández-Vélez, 2026 \(forthcoming\)](#)).

The mechanisms through which body-mind postures translate into epistemic effects are multiple and mutually reinforcing. Understanding them methodologically is essential for any research design that aspires to genuine onto-epistemological dialogue. This ERS concept recognises that ritualised embodied practices operate as performative enactments (actions, speech or behaviours that produce reality rather than merely describing it), so that the posture adopted within knowledge dialogues is itself an act of world-making ([Loppie, 2007](#); [Zegarra-Parodi et al., 2025](#)).

The approach is visually represented in Figure 16, showing both ways of seating and actively proposing bidirectional learning with an emphasis on IKS.

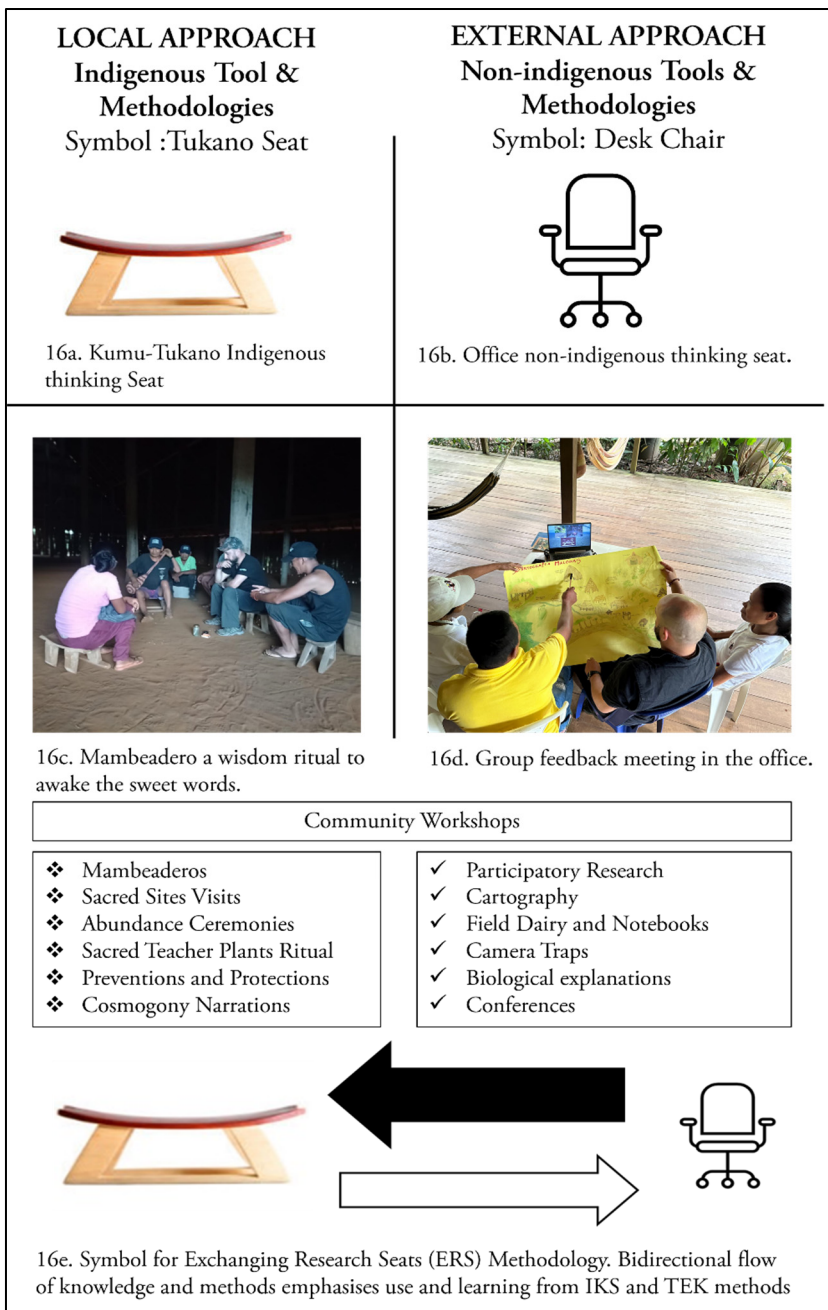


Figure 16 a-e.Exchanging Research Seats methodology resume.
Guidance in methods and tools practice.

Here, I propose seeing, relating to, and using seating postures and bodily arrangements as an active part of knowledge production, not as a neutral condition for dialogue. Drawing on cognitive semiotics, ritualised sitting practices are understood as performative acts that shape what can be perceived, spoken, and recognised as valid knowledge ([Mendoza-Collazos, 2022](#)). In Amazonian Indigenous Knowledge Systems, posture and spatial arrangement orient attention and sensing toward relationships with forest fauna and other-than-human beings. These practices reflect embodied epistemologies, such as *sentipensar* (feeling-thinking), where knowledge arises through affective and somatic atonement rather than abstract reasoning alone ([Pacheco Bejarano, 2023](#)).

Methodologically, Indigenous seating practices—particularly the ritual use of seats and the *mambeadero*—are here approached as dialogical technologies that mediate cognition, agency, and accountability. They anchor knowledge claims in place-based relations among humans, animals, plants, and ancestral presences, supporting situated dialogue essential for transformative sustainability.

This seating-based dialogue is a method I have practised and refined since 2012, demonstrating its capacity to structure complex conversations, expand perceived realities, and support conflict transformation in contexts where meaningful intercultural and multispecies dialogue is required.

Ethnography as a guiding compass

Throughout my research, I practised ethnography as a collaborative and reflexive method that supports collective learning with Indigenous communities, rather than as an extractive technique applied to them. Aligned with decolonial and PAR approaches, I use ethnography *with* and *for* Indigenous partners to strengthen their agency in shaping research questions, interpretations, and outcomes. Moreover, I understand and approach knowledge production through ethnographic tools (e.g., recording, field diaries, etc.) and as a shared process in which IKS guide what is observed, discussed, recorded, and acted upon in relation to the forest–fauna–human nexus.

Participant observation and field diaries function as tools for mutual reflection rather than unilateral documentation. Local and external researchers jointly record daily experiences related to communal activities, ceremonies, rituals, and everyday practices such as cooking, harvesting, and dialogues about forest fauna. Entries also include mediated communications (voice and text messages, images, meeting calls), recognising these exchanges as a part of an ongoing relational work. Field diaries document the

date, time, topic, and experiences, along with reflexive notes on emotions, tensions, and learning moments. This shared ethnographic practice reinforces accountability, makes positionalities visible, and supports continuous dialogue, ensuring that ethnography contributes to community-led reflection, action, and transformative sustainability pathways.

My personal approach to ethnography is closely related to my personal position on reflexivity and interest in remembering my mestizo heritage⁵. This was openly proposed to the LRG as a method for reflection, while observing, participating in, and recording “the obvious” daily activities. I see reflexive participatory ethnography as a broad methodological guiding practice that constantly reminds the researchers of their aims to include IK.

Space for Knowledge, Unity, and Multi-meaning Reality

I adopt an **ethnographic approach** as a methodological learning space for engaging knowledge plurality and relational unity. Grounded in the premise that knowledge is situated, embodied, and inherently partial (Haraway, 1988), ethnography enables the researcher to position themselves within the interplay of material, collective, and individual realities, recognising that different knowledge systems—including academic and Indigenous knowledge—offer distinct and valid interpretations of a shared, yet layered, Reality⁶. Through sustained immersion and attention to narratives, practices, translation processes, and experiences, ethnography provides a space in which multiple meanings can coexist without immediate reduction or epistemic assimilation (Götsch & Palmberger, 2022; Qutoshi, 2024).

Ethnography is used here and potentiated by Indigenous dialogue methodologies (*mambeaderos*) and the ERS practices as a methodological learning space for engaging with knowledge plurality, unity, and multi-meaning realities.

Such encounters involve not merely differing viewpoints, but potentially coexisting ontological realities that must be engaged on their own terms (Blaser, 2009). From this

⁵ I relate more deeply to Gloria Azaldúa definitions of mestizo positionality as: a *state of consciousness* formed by living within contradictions and borderlands, producing an epistemic standpoint capable of holding tension, reflexivity, and transformation rather than coherence or purity. Also read as an embodied way of knowing that emerges from inhabiting multiple worlds at once, where contradiction becomes a source of critical awareness, ethical responsibility, and creative transformation; in Anzaldúa, G. (2021). *Borderlands/La frontera: la nueva mestiza*. Capitán Swing Libros.

⁶ I refer to the layered Reality and relative realities. Inada, K. K. (1988). The range of Buddhist ontology. *Philosophy East and West*, 38(3), 261-280. , Poli, R. (2015). Nicolai Hartmann’s Theory of Levels of Reality. *Objects and Pseudo-Objects: Ontological Deserts and Jungles from Brentano to Carnap*, 62, 223.

perspective, ethnography supports my exploration of knowledge unity as a relational and emergent process grounded in interaction across plural realities, rather than as the reduction or homogenisation of diverse knowledge systems ([Romm, 2024](#); [Wilson, 1999](#)).

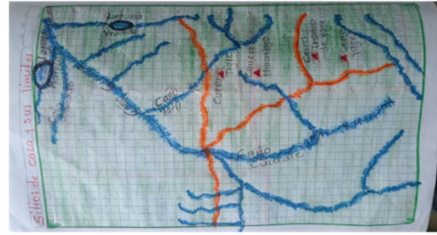
Methods and Tools Overview

To address the forest fauna TEK questions guiding my research, twelve complementary techniques were developed and applied, generating diverse forms of knowledge, participant insights, and ecological understanding. Together, these approaches provided complementary perspectives and generated evidence that informed the answers to my research questions while supporting the iterative, collaborative, and reflective processes characteristic of PAR. The following section presents an overview of these methodologies, outlining their descriptions, applications, and contributions to the overall research design.

Figure 17 a-g presents images from the main methods and tools I employed during my empirical research. Table 3 shows each method classified by its epistemic origin (Indigenous, External, or Combined), leadership structure, temporal rhythm, and transformative purpose. Together, they constitute a decolonial research architecture that honours ancestral protocols while engaging institutional and scientific frameworks, cultivating critical consciousness and shared management capacities among Indigenous researchers, communities and sustainability practitioners in the Colombian Amazon.



a. Territorial Walks



b. Research Notebook



c. TEK Cartography



d. Camera Traps



e. *Mambeaderos*.
Dialogue Indigenous ritual



f. Ceremonies in the House of
Traditional Knowledge (*Maloca*)



g. Community Lead and Co-designed Participatory Workshops.

Figure 17 a-g. Image samples of methods and tools in practice.

Table 3. Methodology, methods and tools Overview.

Twelve techniques applied in this PAR developed diverse methodologies, methods, and tools that contributed to answering my dialogical and forest fauna knowledge questions.

Name		Leadership	Purpose and data	Description and Characteristics
(occurrence number) Origin Frequency	<i>Communitarian Meetings (10 general assemblies)</i>	Led by the Capitán with the local council (assembly) and community members	Organise community activities, decide on projects and needs, and promote collective agreements through consensus	Held in community meeting house; food sharing integral; combines traditional consensus-building (offerings, collective voice, elder wisdom) with modern organisational structure (10 thematic groups: Education, Culture, Sports, Environment, Women, Children, Youth, Communications, Health, Work); decisions on infrastructure, rituals, project management.
	Indigenous Weekly (every Saturday)		Obtain permission, participation and information on local governance.	
	<i>Mambeadero (80)</i>	Usually led by a traditional Elder or authority (Kumu or Capitán); also promoted and requested by CAHV	Dialogue for study, consultation, investigation, and resolution; understand elders' advice rooted in ancient knowledge, songs, stories, healing practices, and dietary habits.	Traditional ritual of spoken and unspoken word in circular arrangement using Kumu seats (low benches); consumption of Mambe (coca leaf powder with Yarumo ash) promotes introspection, genuine listening, oxygenation, and reduced hunger; inhalation of tobacco (rapé) clears mind; occurs in maloka (House of Traditional Knowledge) or elder's house; preparation includes plants, firewood, traditional seats, translator; physiologically mild stimulant, emotionally promotes serenity and wisdom in speech.
	Indigenous Daily			
	<i>Communitarian Workshops (80)</i>	Mostly led by LRG; also led by CAHV during fieldwork	Promote, gather, and organise collective and individual knowledge of forest fauna management; foster local expressions and critical thinking about TEK and Indigenous self-governance.	Held in 9 am–12 sessions at the community meeting house with food provided; LRG prepares with me topics, guidelines, materials (stationery, cardboard, markers, booklets, banners), and invitations for community members, guideline questions, along with 25 topics shown in Table 5.
	Combined Monthly			The workshop collects a participation list; the reflection and decision-making processes focus on forest fauna and local TEK. Tables and chairs were arranged in circles to enable talking, inclusion, group writing, drawing and physical performance. Community members invited by the LRG served as local cooks and got paid. Materials provided include stationery, cardboard, markers, booklets, and banners (Annex B, C). The external researcher (me) joined and led this season to develop specific topics chosen by me, or that presented methodological challenges to the LRG (shown in * in the thematic table).

<i>Group Meetings (64) in-person meetings</i> Combined Monthly by phone; seasonal during fieldwork	Mostly led by CAHV, also initiated by LRG	Decision-making, logistics, and scheduling of activities; align process, gather suggestions, resolve tensions, set collective agreements	Meetings with local researchers (women and men) and families during field visits; address financial sharing, team roles, communication, food preparation, ceremonies, conference presentations; structured format: greeting/catching up, reviewing previous month, assessing what worked/didn't work, proposing options, new agreements, next steps following PAR stages and cycles; video calls rare due to unreliable internet; conflicts addressed through basic communication structure.
<i>Life Story Interviews (12 interviews)</i> Combined	Led by CAHV, applied to LRG	This method gathers detailed individual knowledge about SES variables by emphasising personal experiences that workshops might miss. Particularly valuable in Indigenous contexts, where oral traditions dominate narratives of change over time—e.g. migration paths, food and hunting practices, relationships with TEK, and present and future views on governance.	Interviews were led by the external researchers and conducted with LRG members — as community insiders — to ensure cultural safety and interpretive trust. Each session lasted between 45 minutes and 2 hours, conducted at times convenient to participants, and recorded in audio format for subsequent analysis. This approach enabled the documentation of longitudinal, place-based knowledge held within individuals that is not formally codified but is central to understanding changes in SES dynamics in the communities (Annex B, C).
<i>Walking the Territory (20 walks)</i> Indigenous Daily during local livelihood activities; seasonal during fieldtrips	Led by LRG, and externally requested	Recognise, feel, and sense the territory; its sites and beings present in TEK; embody knowledge of sacred places	Group walks (3–5 hours from the village) to sacred caves, mountains, and trees linked to origin stories, allowing experiences of local livelihoods, challenges, and governance. Elder Kumu uses traditional Carayuru paint, activated by prayers, to prevent snake bites and accidents. Paintings help forest beings recognise locals. Visits include rocks, trees, animals, lagoons, food sites, trails, and households.
<i>Research Notebooks (5 active)</i> External Continuous (personal use)	Led by CAHV, applied by LRG	Tool used for personal reflection, field notes, documentation through writing, drawings, tables, maps, and stories	Each local researcher received a notebook for diary-style reflection and workshop activities. Personal interviews were conducted with elders and villagers. Researchers' approaches to appropriation vary widely, with women displaying more consistent use. Some participants used multiple notebooks, while others found it unappealing. It is speculated that injuries from hunting or construction, which can affect fine motor skills, may restrict usage for some men, despite both genders being taught writing in school and being skilled painters.

<i>Camera Traps</i> (4 times, 3 cameras installed on each community over 15 days) External Two seasons Led by CAHV, monitored by LRG A tool used to collect forest fauna Images for monitoring and management. Images provide ecological, behavioural, abundance, and location data, complementing workshop visualisation.	Introduced via a participatory workshop to facilitate community decision-making regarding tool use, installation sites, and timings; elders provide permission. Installation was performed by local researchers who continued monitoring activities. The project involves a partnership with the Airumakuchi hunter association in Tipisca, Amazonas, part of a decade-long collaboration with CIFOR. Five cameras capture still and video images. This approach aligns with regional fauna-monitoring practices, such as those of the SINCHI institute in Vaupés, to address conflicts in forest-fauna management, especially regarding large felines.
<i>Phone communication</i> (180 meetings) Monthly Led by both types of researchers Served to communicate updates, define logistics, and communicate across distance and time zones	A personal phone number was shared at the beginning. There are frequent messages from about 10 members per community, including the research team and leaders. The 7-hour time difference between Sweden and Colombia, along with intermittent internet, requires extra effort. WhatsApp groups were created for monthly updates, such as questions, guidelines, and budgets. Researchers preferred personal communication over group chats. The platform was used for workshop logistics, fund transfers, pedagogical materials, queries, sharing personal events or needs, emergencies, real-time images of fauna, territory, and people, and learning Indigenous languages. Communication mainly involved audio, text, and images rather than calls.
<i>Ceremonies of Nature Cycles</i> (10) Indigenous Four seasons; monthly Led by Indigenous researchers: local elders, community leaders (<i>aspitanes</i> or <i>curacas</i>), experienced Payes/Kumu (shamans) Balance relationships with the forest to secure collective wellbeing; manage socioecological changes through Traditional Ecological Calendars	Seasonal rituals marking life transitions and forest dynamics: <i>Peldazon</i> (childhood-to-adulthood in Tikuna, Cocamas, Yagwas cultures); <i>Yurupary</i> puberty initiations and <i>Dabucaris</i> (seasonal fruit/fish abundance ceremonies in Vaupés); Yagé preparations (<i>Banisteriopsis spp.</i> mixed with <i>Psychotria viridis</i> or <i>Diploperis spp.</i>) consumed during ceremonial dances; community-led cleansing and balancing of soil, forest, and air to make it suitable for human interaction; enhances reading of natural cycles and management of spaces, species, and forest beings.
<i>Strategic Presentation and Conferences</i> (6) with LRG Combined Planned by CAHV and TK, developed by LRG This divulgation strategy was chosen to enhance TEK recognition, bridge interinstitutional gaps, and address communication gaps between	Conference speeches and meetings on forest fauna governance; challenges dominant colonial powers; previously unknown/rare opportunities for Indigenous researchers to present ideas to audiences or address non-

Twice a year	Indigenous communities and regional institutions	indigenous officers as equal partners; practice public speaking with high-resolution printed banners created by community; participation in 6+ regional/international conferences (SALSA Conference, IA Anthropology Leticia 2023, CIMFAUNA Santa Marta 2023); tailored meetings with regional sustainable development institution (CDA) presenting 10+ banners on traditional knowledge; first-time mambadero experience for CDA director/staff enabling equal engagement on sustainable hunting, trade, shamanic practices
<i>Compassionate Inquiry</i> <i>(7) interventions mostly with individuals</i> External When a personal crisis developed	Recognises and incorporates the trauma-related reactivity in Indigenous communities. PAR uncovers historical violence and trauma, helping identify, confront, and manage trauma reactivity within the LRG. This raised awareness of harmful behaviours linked to past experiences and improved conflict resolution. In TSS, trauma-informed strategies support decolonial research by emphasising Indigenous sovereignty, minimising harm, and creating safe spaces for sharing.	Compassionate Inquiry (CI) is a trauma-informed therapeutic framework to gently access and integrate unresolved emotional pain and somatic memory, fostering self-awareness and healing (Polat, 2025). The role of unconscious trauma in shaping behaviour has been applied in clinical contexts alongside Indigenous healing traditions, including ceremonial and psychedelic-assisted settings (Maté, 2014). In PAR with Indigenous communities, CI aligns with culturally grounded, land-based healing modalities that address intergenerational trauma through collective and relational processes (Panofsky et al., 2023 ; Willmot et al., 2024). This study used CI as a supportive method during personal crises among LRG members, with seven interventions primarily delivered to individuals. This practice maintains PAR's commitment to holistic, relational care during trauma triggers, offering compassionate responses that foster mutual care beyond data collection.

This methodological ensemble—integrating participatory workshops, field walks, camera traps, ceremonial participation, strategic presentations, and continuous relational communication—was deliberately designed to answer the question of how TEK contributes to sustainable forest fauna management through praxis rather than extraction. The combination of embodied, technological, ceremonial, and institutional methods honours the holistic nature of IKS while creating legitimate spaces for TEK-WK dialogue within regional governance structures.

I acknowledge that my positionality as an external researcher, despite long-term relationships and collaborative authorship, inevitably shapes knowledge co-production processes; furthermore, methodological adaptations (e.g., the implementation of field notebooks) reveal the ongoing negotiation between introduced tools and existing cultural practices.

Participatory adaptation of social-ecological framework

As this research is aligned and guided by PAR cycles and WK key actions, we are in a constant collective learning process that requires translation, synthesis, negotiation, and mobilisation of knowledge co-production. Using Ostrom terminology in the field with local communities and researchers necessarily opens the door to revision or local interpretations. Although I understand and initially mentioned this terminology, we as a research group adapted the major subsets of the SES framework to local categories aligned with and commonly associated with IKS in the communities (Table 4).

Table 4. Adaptation of SES to the locally agreed terminology.

Ostrom's SES Terms	Local Indigenous Terms Short description, <i>Local term</i> (equivalent term in English)	Agreed Terminology In Spanish (in English)	Variable of focus
Users (U)	The ones who are using and capturing: Community, Hunters, Shaman	<i>La gente, nosotros</i> (Local People)	(U1) Knowledge of Forest Fauna
Resource Units (RU)	The creatures that the community are interested in: Animals, Birds, Insects,	<i>Aves, animales y seres del bosque</i> (Birds, Animals, Forest Fauna)	(RU1) Lifecycles (RU2) Behaviours (RU3) Relationship with Humans
Resource Systems (RS)	The Places in the community where humans and life exist: Sacred Sites, <i>Chagras</i> (agroforestry area), <i>Rastrojos</i> (secondary forest), <i>Monte Bravo</i> (primary forest), Invisible sites.	Zonas del Territorio (Territorial Zones)	(RS1) Typology (RS2) Distribution (RS3) Practices (RS4) Rules
Governance System (GS)	The new and ancient ways of managing the territory: Shamanic work, Indigenous Association, Community Coordination, <i>Gente de afuera</i> (external people), <i>gente blanca</i> (white people).	<i>Gobierno Propio</i> (Local Indigenous Government)	(GS1) Actor and Institutional Typology (GS2) Their Interest towards TEK
Interactions (I)	Types of Uses, Encounters, Practices, Behaviours, Dreams, Signals, Omens	<i>Relaciones</i> (Relationships)	(I1) Typology (I2) Priorities (I3) Projections
Outcomes (O)	Effects, Consequences, Healings, <i>Dabuccuri</i> (Abundance), Wellbeing, <i>Buena Vida</i>	<i>Enfermedad, Buen Vivir</i> (Consequences) Sickness & Wellbeing)	(O1) Research Group (O2) Interinstitutional (O3) Contributions to Self-Determination

These categories allowed us to establish a comprehensive dialogue during fieldwork and workshops, generating a recurring map of actors and visualisations of the institutions and their local view of the system.

Our main method, which structured a progression of thematic development in forest fauna TEK topics over time, was the communitarian monthly workshops. Together with the LRG, we successfully developed more than 45 workshops in each community, creating a modular “TEK pensum” that served as a “backbone” structure for developing the rest of our inquiries and sustaining our PAR.

The workshops' themes included 25 forest fauna topics, selected, discussed, and agreed with the LRG (Table 5).

Table 5. Outline of Communitarian Workshops on Forest Fauna TEK.

45 workshops covering 25 topics across 12 categories, based on the SES framework and co-designed with local groups.

*** Shows the months I was in the community and guided the workshop during field entrances.

Year	Month	No.	Topic	SES categories and variables (U, RU, RS, GS, I and O)
2022	Ago***	1	Presentation and Agreements	Common Grounds 1. Users (U) 2. Resource Units (RU) 3. Resource Systems (RS) 4. Governance System (GS) 5. Interactions (I) 6. Outcomes (O)
	Sept	1	Purpose, dynamics and workshops	
	Oct	2	Village Cartography	Users Livelihoods (RS1) Typology (RS2) Distribution (RS3) Practices (RS4) Rules
	Nov	3	Animals for Consumption	Fauna Relations (I1) Typology (I2) Priorities (I3) Projections
	Dec***	4	Handling Camera Traps	Fauna Relations (I1) Typology (I2) Priorities (I3) Projections Governance System (GS)
2023	Jan	5	Food Areas	Territory Relations (RS1) Typology (RS2) Distribution (RS3) Practices (RS4) Rules
	Feb	6	Eatable Fauna and Other Uses	(I1) Typology (I2) Priorities (I3) Projections
	Mar	7	Community Timeline	(GS) History (GS1) Actor and Institutional Typology (GS2) Their Interest towards TEK
	April	8	Fauna Drawings and Tracks	(RU2) Behaviours
	May	9	Fauna Drawings and Tracks	
	Jun	10	Community Past and Present	(GS) History
	Jul	11	Local History	(GS1) Actor and Institutional Typology (GS2) Their Interest towards TEK
	Ago***	12	Consumption Rules	(I1) Typology (I2) Priorities (I3) Projections
	Sept	13	Ecological Calendars	
	Oct	14	Ancestral Knowledge	(GS1) Actor and Institutional Typology (GS2) Their Interest towards TEK
	Nov	15	Ancestral Knowledge 2	Users Knowledge

	Dec***	16	Reflections and Conference Presentations	(O1) Research Group (O2) Interinstitutional (O3) Contributions to Self-Determination
2024	Jan	18	Socialising Process and Results	(O1) Research Group (O2) Interinstitutional (O3) Contributions to Self-Determination
	Feb	19	Hunting Trails	(RS1) Typology (RS2) Distribution (RS3) Practices (RS4) Rules
	Mar	20	Fauna Preventions and Signals	(I1) Typology (I2) Priorities (I3) Projections
	Aprl	21	Knowledge and Transmission	Knowledge Origins
	May	22	Forest Fauna Local Narratives	(U1) Knowledge of Forest Fauna (RU1) Lifecycles
	Jun	23	Ceremonies and Ritual Calendar	(RU2) Behaviours (RU3) Relationship with Humans
	Jul***	24	Knowledge of the House of Traditional Knowledge	(U1) Knowledge of Forest Fauna
	Ago***	25	Knowledge of House of Traditional Knowledge 2	Relational Reflections (RU1) Lifes Cycles (RU2) Behaviours (RU3) Relationship with Humans
	Sept	26	Knowledge Status and Representation	
	Oct	27	Traditional Instruments	
	Nov	28	Healthy and Unhealthy Relationships with Territory	
	Dec***	29	Healthy and Unhealthy Relationships with territory 2	
2025	Jan	30	Healthy and Unhealthy Relationships with territory 3	Relationships (RS1) Typology (RS2) Distribution (RS3) Practices (RS4) Rules
	Feb	31	Institutional Relationships	People and Institutions (GS1) Actor and Institutional Typology (GS2) Their Interest towards TEK
	Mar	32	Institutional Relationships 2	(GS1) Actor and Institutional Typology (GS2) Their Interest towards TEK
	April	33	Community Organisation	(GS1) Actor and Institutional Typology (GS2) Their Interest towards TEK
	May	34	Terminology	(U1) Knowledge of Forest Fauna
	Jun***	35	Perception of local and external actors	(RU1) Lifes Cycles (RU2) Behaviours (RU3) Relationship with Humans
	July***	36	Booklet Agreements and Design	(O1) Research Group (O2) Interinstitutional (O3) Contributions to Self-Determination
	Ago	37	Prioritised TEK Calendar	(RU1) Lifecycles

	Sept	38	Prioritised TEK Calendar	(RU2) Behaviours (RU3) Relationship with Humans
	Oct	39	Forest Fauna Use Agreements	(RU1) Lifecycles (RU2) Behaviours (RU3) Relationship with Humans
	Nov	40	Possible Pathways	(O1) Research Group (O2) Interinstitutional (O3) Contributions to Self-Determination
	Dec***	41	Reflection and Projections	(O1) Research Group (O2) Interinstitutional (O3) Contributions to Self-Determination
2026	Feb***	42	Results Exchange and Alliances - in Bogotá	(O1) Research Group (O2) Interinstitutional (O3) Contributions to Self-Determination

Together, these methods enabled the generation of a rich and situated empirical corpus grounded in Amazonian Indigenous practices while remaining analytically connected to broader sustainability and governance debates. The research material emerging from fieldwork — across workshops, ceremonies, territorial walks, interviews, and everyday interactions — was later revisited through iterative analysis, where theoretical frameworks, comparative literature, and analytical synthesis were mobilised to interpret patterns, tensions, and convergences. The following results synthesis chapter brings these strands together by integrating field experiences with systematic analytical reflection, showing how Indigenous Forest fauna knowledge, practices, and more-than-human relations collectively inform pathways for forest fauna management.

Finally, key results from community workshops, comprising local cartography, circular calendars, drawings, and photographs, were printed on large-scale, high-quality materials and returned to both communities to be used at local schools and community meeting offices to disseminate the results to other community members and neighbouring communities. These products are already being used to support and strengthen local governance agendas and provide insights and knowledge for external and state institutions that work on environmental, health and sustainability issues.

5. Results & Findings

In this chapter, I synthesise the findings from the preceding chapters and article compilation to provide an integrated answer to the research aim and questions. I address here the overarching question of how respectful dialogues between IKS, and sustainability practitioners can be enhanced in Amazon TEK forest fauna discussions. To do so, the chapter revisits the four interrelated research questions:

(RQ1) How are IKS included in academic research on tropical forest fauna? (RQ2) How is forest fauna represented in Indigenous Knowledge Systems in the Colombian Amazon? (RQ3) What is the current state of IKS in local communities and its contributions to sustainability transformations in forest fauna management? (RQ4) How and to what extent can PAR promote the weaving of IKS and non-indigenous knowledges for more sustainable, inclusive forest fauna management?

I do this first by describing the main results brought by each article's findings. Then I highlight key findings that go beyond the article's results, grouped under thematic subtitles.

Article Results

Article 1: Co-production is a global challenge ([van Maurik Matuk et al., 2023](#))

In advancing co-production for transformative change, this article synthesises guidance from case studies on the sustainable management and governance of natural resources, making a significant contribution to TSS by offering an empirically grounded, practice-oriented understanding of knowledge co-production with IP&LC. Drawing on thirteen diverse case studies—including several from the Amazon—this first article demonstrates that sustainability transformations depend less on the technical integration of knowledge systems and more on the relational, political, and ethical conditions under which knowledge is co-produced ([van Maurik Matuk et al., 2023](#)).

A central contribution of this article is its expansion of the widely used credibility–legitimacy–usability (CLU) framework by explicitly linking these attributes to

effectiveness, understood as the adoption of co-produced knowledge in practice to enhance sustainability outcomes. We show that knowledge becomes effective when IP&LC perceive co-production processes as fair, inclusive, and empowering, and when the resulting knowledge aligns with local values, livelihoods, and governance arrangements. This insight directly supports this research's overall aim of advancing inclusive forest fauna management by strengthening Indigenous agency within sustainability processes.

In relation to the main research question—how sustainability practitioners can engage in dialogue with IKS in the transformative management of forest fauna in the Amazon—the article demonstrates that such dialogue is not primarily a matter of translation between knowledge systems. Instead, it is a process of negotiating epistemological differences and power relations, often shaped by colonial histories and institutional asymmetries. Across cases, co-production was most effective when scientists and practitioners abandoned rigid postures and shared decision-making power, adapting research goals, methods, and temporalities to Indigenous priorities and ways of knowing. These findings strongly resonate with my findings from Colombian Amazon case studies and contexts, where forest fauna management is embedded in Indigenous cosmologies, subsistence practices, and customary governance systems.

This article also contributes directly to the four specific research questions. First, regarding the inclusion of IKS in academic research on forest fauna, the synthesis reveals that many co-production efforts reproduce extractive dynamics when Indigenous knowledge is selectively mobilised to fit scientific classifications. Such practices undermine the legitimacy of knowledge production and limit the long-term effectiveness of sustainability interventions. The findings of the article reinforce the need for critical reflection on how forest fauna research engages IKS, a gap further addressed in Article 2.

Second, Article 1, in at least two case studies, highlights how Indigenous worldviews hold that animals are spiritual and intelligent entities from whom Indigenous peoples learn and to whom they have ethical obligations. This challenges the dominant ecological framings that treat animals primarily as managed resources. In several Amazonian cases, sustainability improvements emerged only when these Indigenous ontologies were recognised as valid foundations for management decisions, rather than as supplementary cultural perspectives. This is a direct contribution from our case study and the other case studies informing my investigation of forest fauna representations within Amazonian IKS. Thirdly, while examining the varied examples of IP&LC and their contributions to sustainability transformations, my work documents both resilience and vulnerability. While Indigenous practices such as rotational hunting,

customary norms, and community-based monitoring (in my study cases) continue to support biodiversity and food security, these systems are increasingly threatened by market integration, policy constraints, and knowledge erosion. Co-production processes that revitalised IKS — rather than merely documenting them — were shown to strengthen collective reflection, intergenerational transmission, and Indigenous self-determination. Finally, article 1 provides strong empirical grounding for PAR as a means of weaving Indigenous and non-Indigenous knowledges.

Practices such as reciprocal learning, the use of boundary objects⁷, Indigenous-led data collection and collective deliberation enabled the co-creation of knowledge perceived as legitimate and usable by all actors. These insights directly underpin this dissertation's methodological approach and the development of a WK methodology for forest fauna management in the Colombian Amazon.

Overall, this first article advances SS by shifting attention from abstract co-production ideals to the everyday practices, power negotiations, and ontological pluralism that enable transformative change. My research here provides essential conceptual and empirical support for engaging IKS and TEK through PAR, situating forest fauna management as a biocultural and political process central to inclusive sustainability transformations.

Article 2: Tropical research is still not inclusive (Hernández-Vélez, 2026)

In this systematic review, we examine how ILK and IP&LC are incorporated into academic research, particularly in publications on tropical forest fauna. Its results are attributable to patterns of inclusion, representation, and participation. Based on 62 peer-reviewed publications published between 2000 and 2022, our results show a clear increase in the number of studies on ILK since 2014, coinciding with global policy processes such as those of IPBES. However, this increase does not correspond to deeper or more inclusive research practices. Less than half of the reviewed studies (25 out of 62) explicitly define ILK or related concepts, but terminology varies widely, including ILK, TEK, Local Ecological Knowledge, and non-specified references to “local knowledge” (Hernández-Vélez, 2026). Studies that did not define ILK were more likely

⁷ Boundary objects refer to concepts, tools, or representations that are sufficiently flexible to be interpreted differently across social groups, yet robust enough to maintain a shared identity that enables coordination and collaboration. In SS, they are understood as ambiguous artefacts that bridge diverse knowledge systems and worldviews—without resolving their differences—thereby facilitating dialogue, mutual learning, and collective action across. Franco-Torres, M., Rogers, B. C., & Ugarelli, R. M. (2020). A framework to explain the role of boundary objects in sustainability transitions. *Environmental Innovation and Societal Transitions*, 36, 34-48.
<https://doi.org/https://doi.org/10.1016/j.eist.2020.04.010>

to treat it implicitly as auxiliary information rather than as a distinct knowledge system. In these cases, we found that ILK is often used to support scientific datasets or conservation objectives without influencing research design or analytical frameworks.

Our review demonstrates a strong taxonomic bias that contributes to answering RQ2 relating to forest fauna representations. Mammals are the most frequently studied fauna group (82.3% of publications), followed by birds (59.7%), reptiles (43.5%), invertebrates (16.1%), and amphibians (9.7%). Nearly half of the publications focus on a single fauna group, and 23 studies focus exclusively on mammals ([Hernández-Vélez, 2026](#)). Forest fauna is primarily described in relation to human use, with edible uses reported in over 90% of studies. Other uses include medicinal, ceremonial, commercial, ornamental, and spiritual roles. While this demonstrates that many studies acknowledge multiple human–fauna relationships, the results show that ILK representations are often restricted to utilitarian categories. Relational, spiritual, governance-related, and ethical dimensions of fauna—central to Indigenous cosmologies—are less consistently documented or analytically engaged with.

These patterns suggest that, even when ILK is referenced, representations of forest fauna tend to align with dominant scientific and conservation framings rather than reflecting the full ontological and cultural diversity of Indigenous knowledge systems.

Article 2 contributes to answering RQ3 by presenting our results on the degree of IP&LC participation in research. By adapting the participation framework, I proposed to classify studies according to levels of involvement ranging from informative to shared decision-making ([Vaughn & Jacquez, 2020](#)). Our results show that most studies involve IP&LC at consultative or contributory levels. IP&LC participation typically includes interviews, species identification, or the provision of local information, without influencing research questions, methods, or interpretation. Only four studies explicitly report shared decision-making or participatory action research approaches in which IP&LC were involved in shaping research objectives, methodologies, and outcomes ([Hernández-Vélez, 2026](#)). These cases are exceptions rather than the norm. Most studies retain epistemic and methodological control within academic institutions, even when research is conducted on Indigenous territories or focuses on Indigenous practices.

This pattern indicates that IP&LC involvement in forest fauna research remains largely procedural rather than transformative, with limited implications for local governance, self-determination, or long-term sustainability practices.

Regarding RQ4 on implications for knowledge co-production, the results in article 2 also reveal substantial gaps in the use of participatory and co-productive research approaches. Although many studies acknowledge the value of ILK for conservation and

sustainability, few adopt methodologies that enable the weaving of Indigenous and scientific knowledges. Participatory Action Research, co-design, and shared governance mechanisms are rarely employed.

Consequently, the article documents a persistent disconnection between normative calls for inclusion in sustainability research and actual research practice in forest fauna studies. This absence of co-production limits the legitimacy and contextual relevance of research outputs, particularly in socio-ecological systems where forest fauna management is closely tied to Indigenous livelihoods, governance institutions, and cultural values.

Article 2 also introduces the “ILK as a door” metaphor as a device to interpret the resulting empirical patterns identified in the systematic review. The door metaphor presents a range of ILK engagement rather than a binary category ([Hernández-Vélez, 2026](#)), as described next.

As noted, our results show that most forest fauna studies either do not define ILK or do so only superficially. These patterns mirror situations in which researchers either do not see the ILK door or see it without naming it, rendering ILK epistemically invisible despite working in Indigenous territories. A second, more common pattern involves studies that recognise the ILK door as valuable but limit engagement to interviews or consultations (researchers who see the door but do not enter it), acknowledging ILK while maintaining scientific control over research design and interpretation.

A few of the studies showed shared decision-making or participatory action research. These cases align with scenarios in which researchers not only see the door but actually open it and enter, engaging with Indigenous ontologies, governance norms, and knowledge validation processes. The metaphor makes it clear that these studies are not simply more participatory but qualitatively different in how epistemic authority is distributed. It also highlights a form of symbolic inclusion evident in the results: studies that adopt ILK terminology do so without altering underlying hierarchies. By distinguishing between naming the door and crossing it, the metaphor helps identify epistemic tokenism that participation metrics alone cannot capture.

Overall, my “ILK as a door” metaphor strengthens the findings of Article 2 by translating quantitative and qualitative review results into a relational model of ILK inclusion. It shows that the ILK inclusion gap is driven less by lack of awareness than by limited willingness or capacity to cross epistemic thresholds. This interpretation directly informs the need for participatory and co-productive approaches developed in subsequent articles, where crossing the door becomes a deliberate methodological choice rather than an exception.

Article 3: New knowledge, new methods (Hernández-Vélez, 2026 (forthcoming))

In this single-authored article, I provide the empirical and methodological response to the ILK inclusion IPDC Gap mentioned in the Introduction and addressed in Articles 1 and 2. While Article 2 demonstrates that ILK inclusion in forest fauna research is largely consultative and instrumental, and Article 1 identifies co-production as necessary but often under-specified in practice, Article 3 shows how meaningful inclusion can be operationalised through PAR using the Exchanging Research Seats (ERS) methodology.

In relation to the overall aim of enhancing inclusive and transformative forest fauna management in the Amazon, Article 3 demonstrates that shifting epistemic authority—by deliberately exchanging researcher and Indigenous roles, spaces, and methods—enables IKS to shape research agendas, knowledge validation, and management priorities. With respect to RQ1, the article shows how ILK, IKS and TEK can be included in academic research not as supplementary data, but as a guiding epistemic framework embedded in Indigenous governance, ritual practices, and learning spaces. Regarding RQ2, it documents how forest fauna is represented relationally within Indigenous cosmologies—through territorial categories, ceremonies, and multispecies ethics—thereby addressing the taxonomic and utilitarian biases identified in the systematic review. In relation to RQ3, the article provides evidence that IKS remain active, adaptive, and generative when research designs support intergenerational transmission, collective reflection, and local leadership. Finally, addressing RQ4, Article 3 operationalises knowledge co-production by demonstrating how PAR, grounded in Indigenous dialogue technologies (e.g., *mambeaderos*, territorial walks, ceremonies), enables sustained knowledge weaving and legitimises Indigenous authority in forest fauna governance. In doing so, Article 3 empirically demonstrates what Articles 1 and 2 conceptually and diagnostically call for: the transition from research *on* and *about* ILK to research *with* and *from* IKS.

Article 4: TEK is still alive and co-producing (Hernández-Vélez, 2026 in review)

This final article, coauthored with Indigenous researchers, consolidates and extends the thesis by empirically demonstrating how IKS operate as complete, living systems for sustainable forest fauna management when supported through long-term PAR. In direct response to the overall aim of advancing inclusive, transformative sustainability science for forest fauna governance, Article 4 shifts the analytical focus from the need for inclusion (Article 2) and inclusion mechanisms (Articles 1 and 3) to the substantive

content, structure, and governance of Indigenous knowledges themselves. The four-year PAR with two Indigenous research teams in the Colombian Amazon documents how forest fauna management is embedded in relational practices, territorial zoning, ecological calendars, ceremonies, and collective norms that pre-existed conventional conservation frameworks.

In relation to RQ1, Article 4 provides empirical evidence that IKS are not supplementary information sources but internally coherent systems of knowing, managing, and governing forest fauna, integrating ecological, spiritual, social, and territorial dimensions. This directly addresses the conceptual gaps identified in Article 2, where ILK was often undefined or used instrumentally, by explicitly mapping the nested structures of IKS, TEK, Indigenous Science, and ceremonial knowledge as they function in practice.

Regarding RQ2, the article demonstrates how forest fauna is locally categorised, named, and understood relationally—particularly through the distinction between birds, animals, and other forest beings—thereby advancing the taxonomic and utilitarian biases documented in the systematic review (Article 2). These findings emphasise that Indigenous representations of fauna are multidimensional, species-rich, and grounded in long-term ecological observation and cosmology. In Tipisca, nearly all the 33 mentioned forest fauna species were used for food, medicine, or symbolic purposes, indicating high functional integration. In Ceima Cachivera, 37 of 74 species were used by the community, reflecting broader diversity but more selective engagement. Species-specific norms reveal relational depth: The tapir (*Tapirus terrestris*) is subject to pregnancy taboos, the opossum (*Didelphis marsupialis*) is medicinal, and the jaguar (*Panthera onca*) holds a complex symbolic status, often requiring shamanic mediation. Ontological distinctions between “human animals” and “animal animals” further structure interactions. Camera trap data, interpreted collectively, reinforced local monitoring and improved understanding of predator dynamics, reducing conflict.

Addressing RQ3, Article 4 shows that IKS remain dynamic and adaptive when collective learning spaces, intergenerational transmission, and ceremonial practices are actively supported. While the article documents processes of erosion linked to language loss, market integration, and institutional marginalisation, it also demonstrates that PAR can strengthen knowledge transmission, local governance, and community self-determination. This complements Article 3 by showing not only how epistemic authority can be redistributed through methods such as ERS, but what becomes visible and actionable once that redistribution occurs. In relation to RQ4, Article 4 provides concrete evidence that knowledge co-production, when grounded in Indigenous methodologies and learning rhythms, enables meaningful dialogue with regional environmental authorities and supports inclusive forest fauna governance across scales.

Outcomes such as jointly developed ecological calendars, fauna use agreements, and interinstitutional exchanges demonstrate how woven knowledges translate into governance-relevant results that can be used across the region.

Taken together with Articles 1 to 3, Article 4 completes my thesis's integrative logic. While Article 1 establishes the conditions for transformative co-production, Article 2 diagnoses the structural barriers to ILK inclusion, Article 3 operationalises methodological transformation through Exchanging Research Seats, and Article 4 demonstrates the substantive sustainability contributions of Indigenous Knowledge Systems when those barriers are effectively removed.

Findings beyond the articles

The previous results from articles 1 to 4 reveal a long process of fieldwork, intensive reading and writing, questioning myself and others and, of course, mutual cooperation from the communities, my advisors and colleagues I was working with over the years. The articles served the purpose of taking me step by step to the construction, or, better said, the weaving of a complex view of my topic, throughout the 4 years of research. Now, being able to look at my doctoral work as a whole, I can see clearly beyond the specific results and propose new contributions to Sustainability in two ways. First, the identification of the need to address Inclusion in a connective manner as a multi-dimensional process of participation, dialogue, and co-production to respectfully and effectively include IKS; and second, the proposal of a conceptual framework that addresses how to develop this inclusion process. This Inclusion framework, which addresses the IPDC Gap, is described as follows and shown in Figure 18:

First, the Inclusion-interested actor (researcher, community, institution) is invited to consider inclusion as a process comprising Participation, Dialogue, and Co-production of the topic at hand. Diverse literature either focuses on the specific terminology of each of the previous actions or fails to reflect how the other dimensions contribute to the desired aim of inclusion. Once this first step is completed, the interested actor can self-diagnose the level of experience on its entry dimension. As an example, if my project is labelled as a “dialogue project”, I can reflect on one of the five degrees of expertise or commitment that I am or my team is (none-0, required-1, basic-2, developed-3, expert-4).

These two steps give the actor the opportunity to rethink and consider the connection with literature, individuals or methodologies from the other dimensions (Inclusion, Participation, Dialogue, Co-production). The design of any Inclusion endeavour, if it

acknowledges the multi-dimensional nature of Inclusion, will benefit from this framework, enabling the design of team profiles, budgets, literature, methodologies, and dissemination stages.

In the image of the framework, individuals, communities and institutions are placed in the centre (in my case supported by the traditional thinking seat), to show the collective process of integrating the multiple dimensions of Inclusion and reflecting on their degrees of expertise and commitment. As this group undergoes this reflective process, links between what could have been considered unconnected approaches can be woven for the common aim of inclusion, in my case, forest fauna TEK and IP&LC inclusions in research and management. The approaches that can be woven together can be many. I illustrate four main approaches connected to my thesis (Transdisciplinarity, Justice & Legal Participatory, Participatory & Decolonial and Weaving Knowledges approaches)

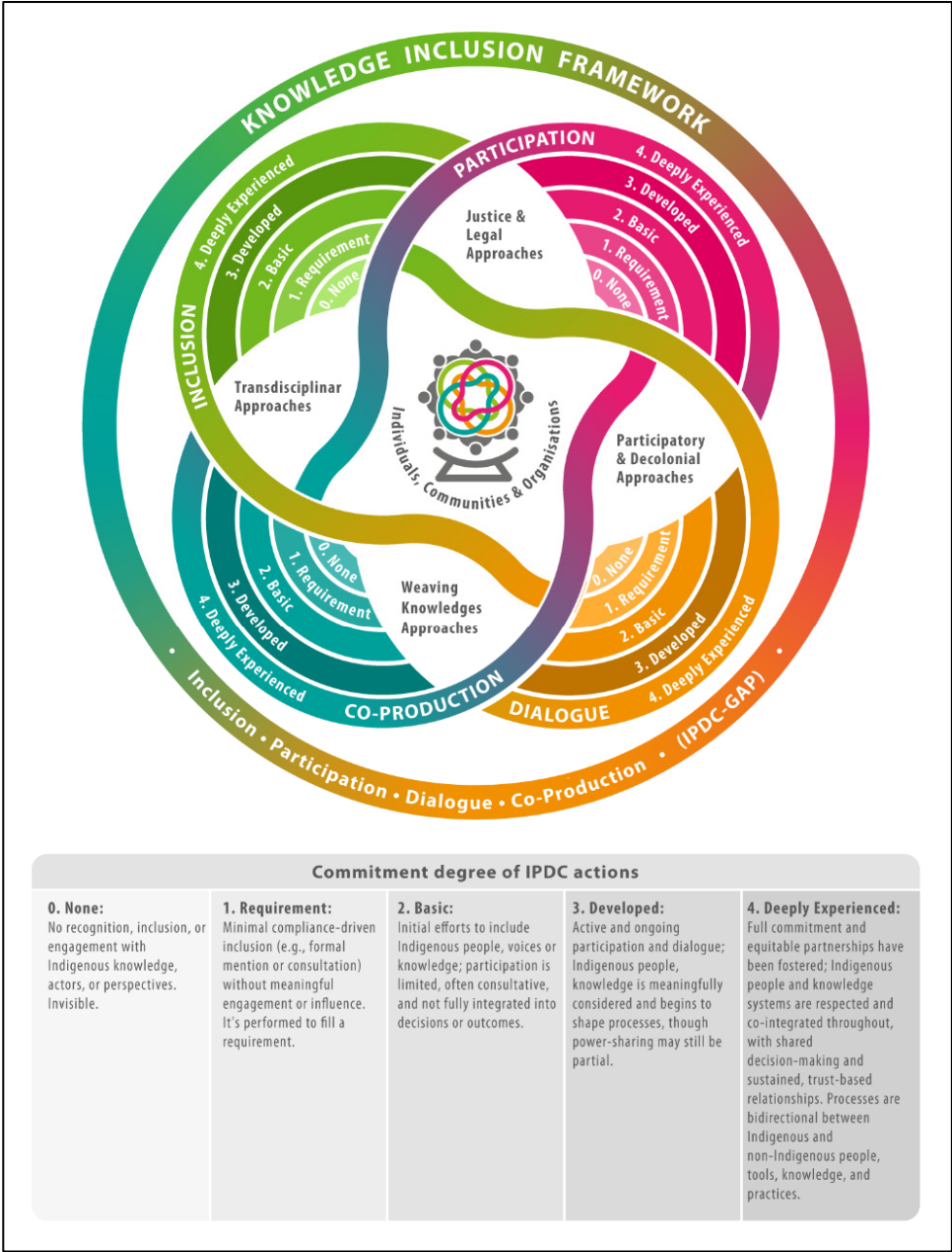


Figure 18. Inclusion Framework to narrow the IPDC Gap (Hernández-Velez, 2026).

Reflecting on this framework can constructively address the persistent challenge of meaningfully including IP&LC and ILK in sustainability research and management practices across diverse contexts and foster more effective and legitimate Transformative Sustainability outcomes.

The visualisation of this framework naturally developed over time and allowed me to see how many of these elements were present in my thesis and articles. Although I did not have it clear at the beginning, it helped me present my findings cohesively, and it will be useful for my next Knowledge Inclusion endeavour. I hope this can also serve other scholars, actors, and institutions in moving forward and narrowing the IPDC Gap.

Forest Fauna in review and study sites

This section synthesises patterns in taxonomic focus, use diversity, and community-level interactions with forest fauna across the reviewed literature and field observations.

Results from the systematic review of 62 publications reveal a markedly uneven and taxonomically skewed landscape of forest fauna research involving ILK. Mammals dominate the literature, appearing in 51 documents (82.3%), followed by birds (37 documents, 59.7%) and reptiles (27 documents, 43.5%), while invertebrates (10 documents, 16.1%) and amphibians (6 documents, 9.7%) remain consistently underrepresented. This distribution reflects a strong concentration on vertebrates—particularly mammals—pointing both to their prominence within ILK systems and to a persistent research bias toward larger, more charismatic fauna. Study designs reinforce this imbalance: although 32 publications consider multiple taxonomic classes, single-group studies (30) overwhelmingly focus on mammals (23), with only limited representation of birds (5), invertebrates (3), reptiles, and amphibians (1 each).

At the species level, most studies (55) adopt a multispecies perspective, emphasising broader ecological and cultural assemblages. However, seven monospecific studies focus on high-profile or conservation-relevant species, including the Tapanuli orangutan (*Pongo tapanuliensis*) and the Indian pangolin (*Manis crassicaudata*), further illustrating the selective attention given to emblematic taxa. Together, these patterns highlight significant gaps in the representation of less visible or less studied groups.

In parallel, nine categories of forest fauna use were identified, underscoring the multifunctional role of fauna in Indigenous Peoples' and Local Communities' (IP&LC) livelihoods. Edible use is nearly universal (56 documents, 90.3%), confirming its centrality for subsistence. At the same time, fauna is deeply embedded in economic, medicinal, and cultural systems, with commerce and medicine each reported in 29

documents (46.8%) and ceremonial uses in 27 (43.5%). Less frequently documented roles—such as ornamental use (19.4%), companionship and tourism (9.7% each), and functions as indicators or tools (8.1%)—reflect more context-specific practices.

This diversity of uses underscores the integration of material and non-material dimensions of fauna within tropical forest social-ecological systems. The prominence of medicinal and ceremonial roles, alongside subsistence functions, highlights the importance of fauna for both physical and psychosocial well-being. Overall, these findings demonstrate that forest fauna sustain interconnected systems of food provision, health, cultural identity, and livelihoods, although this complexity is only partially captured in a literature that remains taxonomically and functionally selective.

At the community level, marked differences in species recognition and use further illustrate this variability. Ceima Cachivera reported a substantially higher diversity, identifying 74 species, compared to 33 in Tipisca. However, this broader knowledge base does not translate into more extensive use: in Tipisca, nearly all identified species (31 of 33) are actively used for food, medicine, or symbolic purposes, indicating a highly integrated system. In contrast, only half of the species recorded in Ceima Cachivera (37 of 74) are associated with consumption or cultural uses, suggesting a broader but more selectively applied knowledge system.

Differences are also evident in specific practices. Insect consumption, although present in both regions, was explicitly documented only in Vaupés, including the leaf-cutter ant (*Atta laevigata*), the termite (*Syntermes spinosus*), and the beetle larva *mojojoy* (*Rhynchophorus palmarum*). This uneven reporting likely reflects variation in cultural practices, ecological availability, and the depth of documentation. These patterns point to distinct configurations of knowledge: one characterised by high diversity and selective use, and another by lower diversity but near-complete functional integration.

Field observations further illustrate the lived dynamics of these relationships. In Tipisca, documented events include the capture of howler monkeys (*Alouatta* sp.) and woolly monkeys (*Lagothrix lagotricha*) for companionship among elders, caiman harvested with harpoons for food, and domesticated trumpeters (*Psophia crepitans*), alongside subsistence hunting of collared peccaries (*Pecari tajacu*) and tapirs (*Tapirus terrestris*) using shotguns. In Ceima Cachivera, observed practices include hunting lowland pacas (*Cuniculus paca*) with dogs and firearms, capturing agoutis (*Dasyprocta* sp.) with machetes and sticks, and the defensive killing of a jaguar (*Panthera onca*).

Across both sites, these accounts highlight the coexistence of traditional and modern hunting techniques and the flexible adaptation of capture methods to species and context. Importantly, fauna use extends beyond subsistence to include companionship and protection, underscoring the social and emotional dimensions of these interactions.

Finally, the prioritisation of fauna-related functions reveals distinct value hierarchies. In Ceima Cachivera, tourism ranks first, followed by food and ritual ornament, indicating stronger integration into external economic dynamics. In contrast, Tipisca prioritises food, local trade, and companionship, reflecting a more subsistence-oriented and locally embedded system. These contrasting hierarchies demonstrate that human–fauna relationships are not only multifunctional but also differently structured according to socio-economic context and community priorities.

Overall, these results reveal both the depth and variability of human–fauna relationships within IKS systems. While fauna underpin complex and interconnected livelihood systems, their representation in research—and their prioritisation in practice—varies significantly across taxa, uses, and communities.

Documenting Social-Ecological Rhythms and Nature’s Space-times

Social cartography and participatory mapping identified key socioecological spaces, including sacred sites, *chagras* (agroforestry plots), rivers, trails, hunting areas, and fauna habitats. These maps documented the perceived distribution and abundance of mammal, reptile, and bird species based on each community's TEK, alongside Indigenous ecological calendars that organise temporal dynamics, seasonal variation, and human practices.

The socioecological calendars produced with Ceima Cachivera (Vaupés) and Tipisca (Amazonas) capture annual ecological rhythms through locally defined seasonal frameworks. Tipisca distinguishes five rainfall-based seasons, while Ceima Cachivera identifies four, named after fauna such as shrimp, river dogs (*Pteronura brasiliensis*), and armadillos. These naming systems reflect a relational understanding of time, in which animals act as key temporal indicators.

Both calendars emphasise fish phenology as a central organising axis. Seasonal fish abundance events (*piracemo*) structure subsistence and social activities, linking fish abundance to river dynamics, fruiting cycles, and wildlife behaviour. Avian phenology is similarly detailed, with records of nesting, migration, abundance peaks, and acoustic signals (e.g., *Nyctibius spp.*), while Tipisca identifies seasonal markers such as “Parrot Time” and synchronised turtle nesting. Mammalian behaviour—including mating cycles, migrations, and predator presence (e.g., *Panthera onca*)—is also integrated, with some entries explicitly linking ecological stress to both animal and human well-being.

Invertebrates further function as key seasonal indicators, with the emergence of ants, termites, and larvae such as *Rhynchophorus palmarum* marking environmental transitions and resource availability. Across both calendars, ecological processes are

inseparable from spiritual and ceremonial practices. Sacred sites in Tipisca are described as sources of animal abundance regulated through seasonal cycles, while in Ceima Cachivera, ceremonies such as *Yagé* rituals and *Dabuccuri* festivals are closely synchronised with ecological events.

Despite structural differences, both systems share a common epistemological framework: ecological time is organised around faunal behaviour, and human activities respond to environmental cues rather than fixed dates. Together, these calendars function as high-resolution, community-based monitoring systems that integrate ecological, social, and spiritual knowledge, supporting adaptive and sustained relationships with forest ecosystems.

Building on this foundation, social cartography and annual TEK-guided calendars informed the targeted installation of camera traps by the LRG. Guided by shamans and community leaders, camera-trapping generated extensive visual records of forest fauna, capturing a broad range of taxa, including lizards, birds, rodents, marsupials, bats, anteaters, tapirs, jaguars, and cougars. This approach not only complemented experiential knowledge but also enabled the identification of species not readily recognised by local nomenclature (e.g., *ulaman*, corresponding to *Eira barbara*) and confirmed the presence of species not recently encountered, such as jaguars and cougars.

Integrating camera traps with Indigenous knowledge systems demonstrates a complementary monitoring approach in which Indigenous expertise guides placement and interpretation, while technology contributes additional temporal and spatial evidence. Documenting rarely observed species reinforces existing knowledge of species presence and distribution, highlighting how participatory monitoring can strengthen both scientific understanding and locally grounded ecological knowledge systems.

Shamanic Knowledges. Management and Governance Systems

Shamanic knowledges and cosmological frameworks emerged as central to regulating human-fauna relationships and governing resource use. Shamans—known as *kumús*, *payés*, *sabedores*, *taitas*, *curanderos*, and traditional healers—interpret signs of imbalance, such as unusual animal behaviour, illness in people's bodies, and hunting accidents, and prescribe interventions, including healing plant-based ceremonies, dietary restrictions, and harmonisations of beverages and food. Shamanic governance relies on cosmological knowledge, spiritual communication, and community consensus-building.

Knowledge holders vary by gender and role, with shamans holding specialised knowledge across multiple domains. In both Vaupés and Amazonas, shamans possessed

the highest levels of knowledge regarding invisible animals, animals for ceremonies, and animals used for healing, while knowledge of edible animals and construction materials was more widely distributed across genders. However, Shamanic Knowledge faces significant threats from religious conversion, criminalisation of plant medicines, and loss of elder shamans.

Managing the territory and the house of traditional knowledge

“The house of ancestral knowledge is alive, and it is where knowledge comes from, and it is where we remember, transmit and learn our culture”.

Emson Hernández, the youngest son of Ceima Cahcivera’s shaman
(open communication during *mambeadero* session in December 2024)

“It is for me evident that the use of TEK in Ceima Cachivera is more alive, as the role of *sabedores* and their teachings was not properly happening in Tipisca, weakening the house that was built for this purpose, as the community was not able to sustain it and keep it alive”.

Curaca Sirley Valentin from Tipisca
(open communication during the network event in February 2026)



Figure 19. The “*Ipanoré*” house of traditional knowledge in Ceima Cachivera.
(Photo by Hernández-Vélez, 2025)

The role of the community, guided by the elder or shaman, is to practice and teach TEK within these houses of traditional Knowledge. Emilio Hernández is currently guarding the Ipanoré house of traditional knowledge, supported by his wife and sons, other elders, local leaders, and the whole community that participates in the annual ceremonies required to maintain social-ecological balance (Figures 22 and 23).

“Following the rhythms of the forest and keeping human practices aligned with the ecological calendars guided by the elders is what keeps our good life strong and independent from the need for money to buy food and from becoming like the people in the city who don’t have *chagras* to harvest or creeks to fish from. This is what I try to teach my daughters, although they are also becoming less interested in culture, but they will remember what I said”.

Jacinta Uribe Ceima Cachivera Dessana, researcher
(personal communication during fieldwork, Dec 2025)

Emilio, elder guardian of the Ipanoré house of traditional knowledge, taught the researchers during many *mambeadero* sessions how he and other shamans managed the forest fauna, plants and territory in the seasonal ceremonies. I learned and complemented with field notes what I recall from his explanation transmitted in Barassano and translated to Spanish by his youngest son:

“He says his work while in the house of ancestral knowledge yields an abundance of harvest for the community, whatever is in abundance for the season. Inside the traditional house, he has a particular place in the first column to the right of the men’s entrance. Here, it is his duty to practice what he was taught by his father and follow the process that was originally taught and brought to this world by *Wai Pino*, the snake elder, and the first couple, *Yawirá* and *Yebá*. They were the first to learn that the world, in its raw form, carries dust, toxins, and illness. That is why he needs to clean it out....

.... The venom (*r-má*) he has to absorb and blow it out to a safe place. This column of the house is the one that sustains the world (*ûmû ari botá*), and that is where he sends all that is not good for us humans.... he says I have to take out the venom of the world (*Ûmûâri rîma wetá*). If not then the babies and the people will get sick from eating those fruits, or meat or fish that is carrying that toxin. Every time a baby is born and starts feeding from things from the territory, I have to clean this. I have to make it sweet for us, make the world bitterness sweet. While I am doing this, I need help from others to protect and “take care” (*~inaŕunûré*) of me and my back while I am in this process”

Emilo Hernández's teachings during *mambeadero* with the research group in July 2025.
Translated by his youngest son, Emson Steven Hernández (Pakú)



Figure 20. Ritually cleaning food offerings by Ceima Cachivera Kumú and elders.
(Photo by C.A.Hernández-Vélez July 2025).



Figure 21. Women organising the forest harvest (fish, meat, fruits).
After the shamans' cleaning, they distribute them to community members (photo by C.A.Hernández-Vélez July 2025).

Within these socioecological systems, shamans play a central role in regulating relationships between humans, forest ecosystems, and invisible beings. Rather than acting only as spiritual authorities, they function as mediators who interpret ecological signals and maintain balance across interconnected domains. They engage directly with both ecological processes and spiritual entities, ensuring that human activities remain aligned with environmental cycles and cosmological norms (Figures 20-22).

A key dimension of this role is managing imbalances or “unhealthy” conditions affecting humans, animals, and the forest. Through collective ceremonies involving singing, chanting, and dancing, shamans work to remove harmful influences that accumulate across beings and the territory. These practices are not symbolic alone but constitute active processes of ecological and social regulation. During these rituals, shamans invoke and name specific territories, rivers, and sacred sites where ecological cycles occur, reinforcing spatial awareness of resource systems and their governance.

At the same time, these ceremonial performances serve as narrative acts through which historical migrations and origins are retold. Shamans recount the foundational moments when rules, norms, and restrictions governing human–fauna interactions were first established. By embedding these laws of origin (within the given cosmogonic order) in ritual practice, they reaffirm the connections among ancestral mandates, present-day behavior, and the continued health of individuals, communities, and territories.

This form of governance directly shapes the collection and distribution of forest products. Access to fauna and other resources is mediated by cosmological principles, in which invisible beings are considered custodians of abundance. Shamans negotiate with these entities to determine appropriate times, locations, and conditions for harvesting. In turn, this regulates extraction and supports equitable distribution within the community, preventing overuse and maintaining ecological equilibrium.

Through these practices, shamanic knowledge operates as both a monitoring and regulatory system. By linking ecological observation with ritual action and collective memory, shamans ensure that resource use remains responsive to environmental conditions while grounded in cultural norms. Their role reinforces social cohesion and transmits ecological knowledge across generations, embedding sustainability within everyday practices.

Overall, the shaman occupies a pivotal position in maintaining socioecological balance, integrating ecological processes, spiritual relations, and social organisation. This system demonstrates that forest management in Indigenous contexts is not merely a matter of resource use, but a relational process sustained through continuous negotiation between humans, non-human life, and invisible forces.

Knowledge Transmission and Erosion

A critical finding revealed that knowledge transmission and reproduction depend on collective processes and ceremonies that are experiencing varying degrees of erosion. Historical and contemporary socioeconomic pressures, increased dependence on the market economy, declining Indigenous language fluency, and weakening adherence to traditional norms are driving this erosion. My research documented that knowledge transmission occurs through multiple pathways, including direct instruction, observation, participation in ceremonies, and storytelling, however, these pathways are increasingly disrupted by external and internal pressures that diminish the use of local language, local livelihoods and transmission of knowledge and skills to new generations.

Erosion of traditional leadership is reported in both communities, with greater severity in Tipisca. This was evident and repeatedly expressed, as no cohesive, recurring gatherings of the community around one or a group of elders occurred, even though we knew they were present. They served as teachers more to particular families and individuals rather than be traditional leaders of the community. This role was more evidently being practised by community leaders, who, in this case, were Sirley Valentín, one of the few women leading a community in ATICOYA. The menarche ceremony (*pelazón*) was the most common and recurrent traditional ceremony that celebrated and marked the passage of young women into adulthood. They are taught in private by older women to navigate these changes in their bodies and within the community, equipping them with the knowledge they will need to survive as adults. The community offers the girl food and forest meat, which is carried in a wooden structure when she comes out of this immersion, to be presented to the community as a new woman.

Ceima Cachiveras' socioecological calendar showed a greater richness of local categories of star constellations, weather seasons named after animals, and specific ceremonies for each seasonal transition, including the preparation of plant-based beverages (e.g. *Banisteriopsis caapi* mixed with *Pshycothria viridis*, commonly known as *Yagé*) and complex rituals such as the *Yuruparí* ceremony. All this is part of maintaining the traditional house of knowledge, expressing a strong commitment to resist and revitalise local traditions. Our regular meetings with the LRG created a space for expressing needs, where learning from other elders and a desire to visit each other's territories to help remember songs, dances, and rituals were noted. This PAR process itself became a mechanism for knowledge revitalisation, creating spaces for intergenerational knowledge exchange and documentation, which generated changes and reflections most evident at the individual and LRG levels.

Expanded Onto-epistemologies to advance IKS inclusion

One of the major advances, as a group and as individuals, occurred during the *mambeadero* sessions, where we established a shared understanding of our common interests, which pleased the elder, seeing the group's comprehension progress after each reiterative PAR cycle. This allowed the group to reflect together before meeting the elders and to arrive at the dialogue space with an advanced, shared question. We found that many of the forest fauna topics presented explicitly linked forest fauna to the Law of Origin, including prescriptions for healthy practices and the purposes of current ceremonies that maintain social-ecological balance in the community.

Understanding how cosmological narratives are linked to current forest fauna management has taken me many years to openly access Indigenous multidimensional concepts, where one thing has multiple meanings at the same time. This was, for me and for the LRG, one of the most gratifying achievements of our learning process with the elders. Sharing this understanding here aims to advance Amazon forest fauna TEK for non-indigenous ontological reflections.

This happens with many concepts and forest fauna species, like the jaguar (*Panthera onca*, sometimes called tiger in indigenous communities), which is represented across Amazon Indigenous cultures in many forms, sometimes as an animal, as a figure that keeps order and chaos in the universe; other times as a shaman with human-animal qualities; and at other times representing the sun.

This unified multi-meaning representation is present in many other species and types of animals, with the concept of snakes being of particular importance. Snakes are locally named in the Amazon as *Güüios*, *Boas* and *Anacondas*, and they are a crucial creature symbolising many important meanings in global and Amazon IKS and TEK.

Figure 22 shows three narrative levels in IKS, both in Vaupés and Amazonas, that refer to serpents.

Level 1: shows one biological level (terrestrial), where snakes are referred to as organisms and described in various species, habitats, and diets, and are also mentioned as living in places they guard, such as special dark ponds in rivers.

Level 2: shows historical events, mentioning a special sacred ancestral anaconda when migration and occupation is discussed. This history mentions a giant anaconda canoe to explain how ancient populations migrated from the Amazonas river mouth upstream, disembarking in a specific order and knowledge at different sides and affluents of the Amazonas, Yavaraté, Rio Negro, and Vaupés rivers. In this case, rivers are categorised between the underground and middle levels of the world.

Level 3: shows an upper level containing narrations that mention the white stellar stream visible at night, referred to as the milk lagoon in the sky (commonly known as the milky way), and the cosmic serpent that inhabits that dimension.

Snakes (although not exclusively) also appear as a connective element across these three planes, the upper (sky), middle (land), and underworld (subaquatic) dimensions, in the narratives of shamans and local historians, who mention a snake, a vine, or a tree when questions about the origin of knowledge, life, and the seat of thought are posed. This connective concept has previously been described in anthropology as the *axis mundi*.

In this case, the serpent *axis mundi*⁸ also appears in narrations as a ladder, a vine or an ancient, massive tree (Eliade, 1959), which I recognise in Amazon IKS and TEK as the Tree of Abundance (animals and fruits), the Tree of Life, or the Tree of Knowledge, named in Vaupés as the *Uku* (Figure 22).

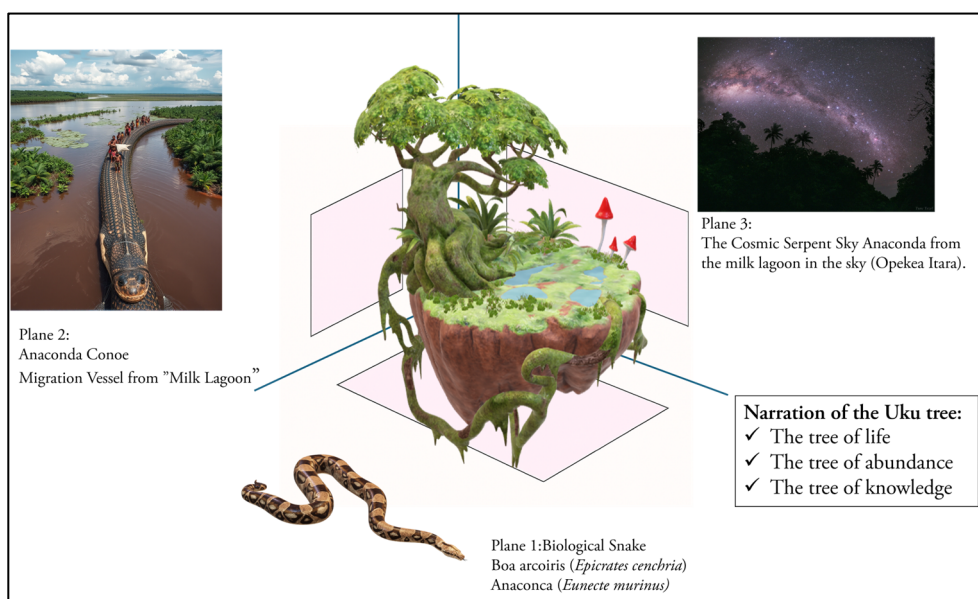


Figure 22. Overview of Amazon onto-epistemology linking cosmology, history, and forest fauna

In Amazonian IKS, the Uku tree story has various versions that narrate an immense tree connecting the lower, middle, and upper dimensions (*axis mundi*), which was cut

⁸ In anthropology, the *axis mundi* is understood as a symbolic and spatial center that organizes cosmology and human–environment relations (Eliade, 1959).

down to unblock water and life forces, creating the first interconnected water path, an event that led to the emergence of biological life.



Figure 23. Illustration of the Origin of Life and the Seat of Knowledge.
Story of the Uku Tree (see Annex D):

For positivist science, this multi-reality is often difficult to grasp, as an anaconda is clearly only a biological organism, a product of evolutionary processes, and the Milky Way and human migration are entirely different topics. Common scientific thinking is not trained in metaphor analysis or in decoding symbolic interpretations that contain multilayered, unified knowledge. These understandings within positivist science and environmental academia can go unseen, be belittled, or be dismissed as anecdotal or fantastical when TEK is not yet integrated. Key literature advancing this topic has been explained by previous authors ([Århem, 2003](#); [Echeverri & Candre-Kineraï, 1993](#); [Micarelli, 2020](#); [Rodríguez & van der Hammen, 2021](#); [Rodríguez et al., 2007](#)).

Transformative Outcomes

The PAR approach led to multiple transformative outcomes: (1) a collective learning process where community members and external researchers jointly produced and used local knowledge through iterative cycles of collective reflection and action; (2) cultivation of critical consciousness regarding the value and legitimacy of IKS; (3) deliberate transformation of oppressive social, political, and structural conditions; and (4) emancipation related to inclusion of IKS in forest fauna discussion and regional action to manage it; (5) a Weaving Knowledge and Forest Fauna Network Event, organized at the end of the process to foster knowledge exchange between Indigenous researchers and alliances with regional environmental institutions.

My study demonstrates that IKS are living, dynamic systems essential for transformative sustainability and that they challenge dominant conservation paradigms that often marginalise Indigenous perspectives. The structural integration of TEK and SK within broader cosmological and social systems revealed that Indigenous approaches to forest fauna management are inseparable from cultural identity, spiritual practices, and territorial governance. Thus, my research emphasised that the biodiversity of the Amazon cannot be sustained without the cultural diversity of Indigenous peoples, and vice versa, highlighting the fundamental interconnectedness of epistemic justice and biocultural conservation.

To conclude the four-year process, a regional meeting and an Indigenous fauna research network were convened by bringing together, for the first time, Indigenous researchers from both study sites. We met in the rural outskirts of Bogotá from 16 to 21 February 2026, also hosting regional and national NGOs and research institutes such as Tropenbos Colombia, Sinchi Institute, Amazon Conservation Team, FAO, Etnollano, researchers from Lund University, as well as Indigenous artists.

The main goal was to enable Tipisca and Ceima Cachivera members to meet, share their research experiences, and present their Ecological Calendar results. This included highlighting similarities and differences, particularly in how they name and manage their forest fauna. The event also aimed to create future possibilities for support between the two communities, as the groups' knowledge strengths differ and complement each other's learning.

A key day occurred on February 19th, when external agencies also came to hear from community members about their processes, with the goal of creating Strategic Alliances between governmental or private organisations and the communities, to ensure the continuity of our work over the past four years. This exchange initially took place in a plenary presentation that showcased the maps, camera-trap photos and ecological calendars of both communities. Later, the conversations deepened, utilising the thematic fire methodology and thinking seats, where the invited agencies and Indigenous researchers grouped by their interest around the fires: Territorial Norms, Knowledge at Risk, Weaving Knowledge, and Shamanic Knowledge. The outcomes of these fires included new networks, ideas, and exchanges of contact, as well as concrete proposals for future cooperation, including the construction of a *Casa de Partería*, a place to teach women the traditional knowledge of childbirth in the traditional way, knowledge that has been weakened in recent decades (Figure 26).

At the closing ceremony, we planted several trees using the ashes from the four fires where our conversations and alliances took place. This is a collective symbol of planting the words, thoughts, and agreements on the ground as seeds to be nurtured and grow.



24 a. Indigenous Research Network of Forest Fauna Event: Four thematic fires developed challenges and alliances: 1. Weaving Knowledges, 2. Territorial Normatives, 3. Local Skills and abilities, 4. Shamanic Knowledge (Organismo-Tenjo Febrero 2026)



24 b. Local Research Groups (Ceima on the left and Tipisca on the right), present with me our main forest fauna result and reflections to the invited Amazon research network (Organismo-Tenjo Febrero 2026)



24 c. Local Research Groups, Shamans and NGOs representatives reflect on focal group outcomes. Four thematic fires developed challenges and alliances:1. Weaving Knowledges, 2. Territorial Normatives, 3. Local Skills and abilities, 4. Shamanic Knowledge (Organismo-Tenjo Febrero 16-212026)

Figure 24 a,b,c. Images from the Indigenous fauna research network meeting outside the Amazon.

6. Discussion

Throughout my research, I sought to address a central question: how can sustainability practitioners dialogue with IKS in the transformative sustainable management of forest fauna in the Amazon? I have argued that sustaining Amazonian forest fauna is inseparable from sustaining the IKS that have co-evolved with these ecosystems over generations. Across the four articles, I describe how biocultural loss encompasses the decline in biodiversity, language loss, governance systems, and knowledge practices. Consequently, meaningful engagement with IKS requires more than inclusion; it demands a fundamental shift in how sustainability science understands knowledge authority and environmental governance.

This discussion examines how recognising Indigenous knowledge systems as living foundations of biocultural stewardship contributes to more legitimate and transformative approaches to forest fauna management.

IKS as a biocultural “Keystone Species”

The four articles of my dissertation converge on a single diagnostic logic: biocultural loss in the Amazon is not the sum of two parallel crises—one ecological, one epistemic—but a single coupled process in which each dimension amplifies the other. Biodiversity decline and the erosion of Indigenous languages, governance institutions, ceremonial practices, and intergenerational transmission systems are mutually constitutive ([Maffi & Woodley, 2012c](#); [Reyes-García, 2009](#); [Sterling et al., 2017](#)). Addressing one without the others is structurally insufficient.

This diagnosis has clear implications. My article compilation has shown that treating IKS solely as a tool to meet external conservation goals, without supporting Indigenous governance or intergenerational learning, can unintentionally accelerate their erosion. This pattern has been noted in sustainability science ([Díaz et al., 2015](#); [Nadasdy, 2003](#); [Tengö et al., 2017](#)), and it is further empirically grounded in my work, concluding that extractive epistemology not only fails to protect; it actively erodes the relational substrate that makes Indigenous knowledge viable.

Empirical grounding: territory as a condition of biocultural persistence

Article 4 deepens TEK as a living biocultural epitome by mapping the historical and living relationships between Indigenous communities and forest fauna across the Amazonian case studies. These relationships are not residual or nostalgic; they constitute functioning regulatory systems sustained by TEK and, in several cases, by shamanic knowledge, whose ontological premises fundamentally diverge from those that govern modern extractive livelihoods. Their persistence is ecologically consequential. Converging evidence from forest cover analyses, biodiversity assessments, and carbon storage calculations confirms that biodiversity outcomes, including fauna density and canopy integrity, are systematically better inside Indigenous territories than outside them ([Alejo et al., 2021](#); [FAO, 2021](#)). **Indigenous territorial presence is therefore not merely a cultural or political fact; it is an ecological variable.** The communities involved in this dissertation are not only knowledge-holders; they are, in ecological terms, active regulators of Amazonian SES.

Conceptual proposition: IKS as a biocultural keystone species

This empirical pattern licenses a stronger conceptual claim. **I propose that Indigenous Knowledge Systems—understood as the inseparable unity of peoples, knowledge, practices, and relational livelihoods—function as a biocultural keystone species within Amazon SES.**

The keystone species concept in ecology designates organisms whose disproportionate impact on ecosystem structure and function far exceeds what their biomass or numerical abundance would predict. Their removal triggers non-linear, systemic collapse, rather than gradual adjustment ([Estes et al., 2016](#)). A related development of the trophic cascade theory extended this logic to the cascading effects that the presence or absence of a single functional entity generates across multiple trophic levels ([Estes et al., 2011](#)). These concepts are not metaphors chosen for rhetorical effect; they offer a precise ecological grammar for what the integrated data in my articles reveal.

The closest precedent in the conservation literature is the notion of **Cultural Keystone Species (CKS)**, developed in the context of forest-dependent communities in Canadian territories, to designate species that play a disproportionately large cultural and ecological role in sustaining human-nature relations ([Garibaldi & Turner, 2004](#); [Lukawiecki et al., 2024](#)). The concept already incorporates the relational dimension, i.e., the survival of the animal species and of the human community that manages them is co-constitutive. I retain this relational logic but invert its direction of application; rather than a *species* anchoring a culture, I propose that an Indigenous knowledge and

practice system anchors both the ecological and cultural integrity of the SES in which it is embedded.

Formally stated: IKS can be defined as a biocultural organism—a relational and livelihood entity—whose structural and regulatory functions within its ecosystem are disproportionate to its demographic or spatial extent. Removing this organism from the territory does not produce a linear reduction in ecosystem services; it triggers a biocultural trophic cascade that simultaneously restructures governance, land use, biodiversity dynamics, and intergenerational transmission.

Differential cascades: regulatory versus extractive livelihoods

The cascade logic also allows for comparative differentiation. The functional role of IKS within a given SES depends on its relational and regulatory qualities. The degree to which it performs ecosystem governance, e.g., spatial and seasonal restrictions on hunting, shamanic regulation of species relationships, and the degree to which it differs qualitatively, not merely quantitatively, from the alternative livelihood systems that could replace it. A modern, market-integrated and extractive community occupying the same territory does not simply reduce the abundance of the IKS; it substitutes a regulatory system for an extractive one, replacing stabilising feedback loops with destabilising ones. The cascading effects of this substitution can be tracked at multiple scales: within-community behavioural change, species population dynamics, forest cover, and ultimately carbon and biodiversity outcomes. The evidence base assembled across this dissertation points in this direction.

Visibility and the problem of structural exclusion

Recognising IKS as a Keystone Species—whether as a component of biodiversity itself or as the structural support of SES dynamics—requires confronting a prior obstacle: its systematic invisibility within the dominant frameworks of conservation and environmental science, sustainability governance, and research practice. My systematic review on tropical fauna and ILK inclusion ([Hernández-Vélez, 2026](#)) documents the institutional and epistemological veils that render IKS structurally illegible, operating simultaneously at the level of individual scientific assumptions, organisational mandates, and societal worldviews. The Keystone Species framing does not automatically dissolve these veils; it provides a functionally precise argument, anchored in ecological theory, on why IKS/IP&LC “removal” is structurally undesirable, not merely a social justice argument.

The deeper historical dimension cannot be set aside. The biocultural Keystone Species discussed here was deliberately removed from vast areas of its ancestral range by colonial and extractive political economies and continues to be eroded by their contemporary successors, including, in some configurations, the research practices this dissertation aims to transform. Understanding the role of IKS within Amazon SES, therefore, requires holding two analyses together: one of its ecological and epistemic functions when present and one of the structural forces responsible for its ongoing exclusion. The argument for IKS inclusion in more sustainable governance is inseparable from a structural critique of the mechanisms that have made such inclusion the exception rather than the rule.

Inclusion Paradox: We cannot include what we cannot see

IKS inclusion bears several paradoxes. One paradox present in my work is the Inclusion Gap, **conceiving Inclusion as requiring the “inclusion” of other concepts, actions, and practices to be truly “inclusive”.**

By framing Inclusion as an integrated path of Inclusion-Participation-Dialogue and Co-production (IPDC), I argue that it synergises and collaborates across varied approaches that aim for congruent outcomes, although commonly labelled as different isolated concepts.

A second inclusion paradox is that one can include only what is visible and recognised. Inclusion, then, depends on visibility and recognition.

In my view, this second paradox is more problematic, as the “invisibility of ILK and Indigenous people, termed here as the ILK blindness paradox, is present in many individuals, societies and organisations, as reflected and discussed in my systematic review. Even when researchers were directly dealing with IP&LC and the fauna in their territories, the knowledge of IP&LC and IP&LC themselves were, in many cases, not included in concept definitions, analysis, or research development. This is developed across the four articles, in which I show that the problem is not merely a shortage of documentation but a structural failure in how knowledge is produced, validated, and governed.

When ILK is extracted to serve externally defined conservation goals—without transforming the epistemic authority of Indigenous communities—research does not slow biocultural erosion; it accelerates it ([Díaz et al., 2015](#); [Nadasdy, 2003](#)). This is a significant starting point from prevailing historical approaches to fauna management, urban planning, or disciplinary frameworks, which tend to treat ILK inclusion as a

technical problem of data integration rather than a political problem of knowledge governance ([Lopez et al., 2024](#); [Milanese & Sibilla, 2025](#)).

This reframing has direct implications for TSS's understanding of inclusion. My systematic review confirms what critical scholars have long argued—that most studies involve IP&LC at consultative or contributory levels ([Latulippe & Klenk, 2020](#); [Nadasdy, 2003](#); [Whyte, 2017](#)). The "ILK as a door" metaphor, developed in Article 2, names a specific epistemic threshold that most research never crosses: ILK is acknowledged as an idea (theory), but does not shape research questions, methods, or interpretation ([Huntington & Watson, 2012](#); [Löfmarck & Lidskog, 2017](#)). The consequence is that knowledge enters academic discourse while losing its grounding in territory, ceremony, and collective practice ([Escobar, 2018](#); [Kopenawa & Albert, 2013](#); [Wilson, 2020](#))—disembodied from the SES that gives it meaning and sustains its transmission. This is not only a critique of individual researchers' intentions and awareness but also a structural diagnosis of how modern science can reproduce epistemic exclusion even under the banner of inclusion and may be passively satisfied. Thus, halting biocultural loss requires transforming sustainability science itself ([Fazey et al., 2020](#); [Norström et al., 2020](#)), rather than improving inclusion strategies alone.

Invisible Knowledges - invisible fauna

An additional dimension of the inclusion paradox emerges from this study's systematic review and fieldwork. The review shows that forest fauna research that reflects a taxonomical and utilitarian logic typical of modern scientific practice is dominated by studies of mammals and birds with a strong focus on material use and resource value. In contrast, fieldwork in the Ceima and Tipisca communities revealed a fundamentally different ontology: fauna are understood not as resources but as relational beings, embedded within cosmology, seasonal cycles, and territorial belonging ([Århem, 2001](#); [Chacon, 2023](#); [Descola, 2004](#)).

This divergence is not merely descriptive. It demonstrates that scientific representations are also epistemic filters that shape which knowledge systems become legible. When birds are treated solely as biodiversity indicators, their roles in ceremony, ethics, and governance are rendered invisible ([Natcher et al., 2025](#); [Tidemann & Gosler, 2012](#)). Thus, dominant research practices reproduce a form of ILK blindness by privileging certain classifications while excluding the relational and governance dimensions of knowledge.

PAR, however, offers a pathway beyond this limitation. My findings demonstrate that PAR can support Indigenous representational systems, such as through ecological

calendars, territorial zoning, and ritual cycles. PAR thus enables fauna knowledge to function as a vehicle for cultural continuity rather than as a dataset for external analysis ([Akumsi, 2003](#); [Gilmore & Young, 2012](#); [Rodríguez & van der Hammen, 2021](#)).

Rooted in South American emancipatory traditions, PAR provides a bridge from inclusion to co-production by redistributing epistemic authority. The four-year research process generated outcomes beyond conventional outputs, including strengthened governance systems, intergenerational knowledge transmission, and the emergence of combined Indigenous methodologies and researchers as co-authors (Articles 3 and 4). These findings align with Indigenous methodologies emphasising reciprocity and accountability ([Wilson, 2020](#)) and with calls in transformative sustainability science to address power and justice explicitly ([Horcea-Milcu et al., 2024](#)). Nonetheless, PAR's transformative potential depends on conditions often absent in dominant academic systems, including long-term engagement, flexible funding, and institutional openness. Without these, inclusion remains limited.

More fundamentally, I argue that the representation of fauna is not neutral but ontological, spiritual, and political. How fauna is defined shapes biocultural trajectories, influencing processes of erosion, persistence, or renewal of knowledge systems.

To advance more inclusive practices, I propose an integrated framework of Inclusion, Participation, Dialogue, and Co-production (presented in the findings beyond the articles section). These are not discrete steps but interdependent processes; co-production requires meaningful inclusion, participation depends on dialogue, and all are necessary for epistemic transformation ([Fazey et al., 2020](#)). Their adoption depends on both external conditions (institutional, political) and internal dynamics (individual and collective agency).

Together, these findings indicate that overcoming the IKS inclusion paradox requires moving beyond technical inclusion toward transforming the representational and governance foundations of research. Only then can sustainability science engage Indigenous knowledge systems as autonomous, living systems of governance, rather than as supplementary inputs.

Co-production contribution to Amazon SES continuity

The co-production literature has grown substantially in the past decade, generating principles, typologies, and frameworks for integrating diverse knowledge systems into TSS ([Bennett et al., 2025](#); [Fazey et al., 2020](#); [Norström et al., 2020](#); [Pohl & Hadorn,](#)

[2007](#); [Tengö et al., 2026](#)). Another missing aspect of co-production (less theorised) is the specific mechanism by which co-production either reproduces or dismantles epistemic hierarchies. My work addresses this gap.

Articles 1 and 3 show that co-production becomes transformative not when knowledge is shared at a table but when the conditions of knowledge production are reconfigured—who holds the research role, in whose territory the learning space takes place, whose validation counts as evidence ([Fazey et al., 2020](#); [Norström et al., 2020](#)). ERS methodology, developed in Article 3, operationalises this reconfiguration by inverting the standard researcher–participant relation. Through ERS, Indigenous researchers become the epistemic authorities and the non-Indigenous researcher occupies a learning position grounded in Indigenous dialogue technologies, territorial walks, and ceremonial pedagogies ([Chilisa, 2017](#); [Escobar, 2018](#); [Hernández-Vélez, 2026 \(forthcoming\)](#); [Hernández-Vélez, 2026 in review](#)). This is not merely a methodological innovation; it is a demonstration that the redistribution of epistemic authority is possible in practice, not only in theory ([Pohl & Hadorn, 2007](#); [Rathwell et al., 2015](#)).

My work with communities documents the outcomes of this reconfiguration at the governance level, including jointly developed ecological calendars, fauna use agreements, strengthened Indigenous governance structures, and substantive dialogue with regional institutions. These outcomes exceed those typically produced by conventional co-management arrangements, in which Indigenous knowledge is incorporated into externally governed management plans without altering the governance architecture itself ([Nadasdy, 2003](#)). My contribution here is to show that co-production, when grounded in Indigenous self-determination rather than integration into external frameworks, generates governance **legitimacy and cultural continuity simultaneously**, which are two outcomes that the literature has tended to treat as separate ([Escobar, 2018](#); [Norström et al., 2020](#); [van Maurik Matuk et al., 2023](#)).

Threatened and Enduring Knowledges



Figure 25. Weaving Knowledges illustrated by a local artist.
Image by Tikuna-Magüta artist Luz Adiel López Ahué. Puerto Nariño 2026.

Excerpts of *mambeadero* teachings from Emilio Hernández (shaman) on child development, knowledge transmission and TEK loss and vitality.

Registered and transcribed by Hernández-Vélez.
Ceima Cachivera, December 2025

“Every time a child is conceived, I have to protect the gifts that the baby is carrying, by taking care of the mother's food and diet, and protect the child's knowledge through its upbringing, doing different initiations, so he doesn't lose this knowledge and can be open to receive and practice what we can teach... Later, as an adult, this person will have to decide whether to keep this knowledge, practice and transmit it or forget it and replace it with other knowledge.”

“Either boy or girl, they need their initiations in ceremonies, with sacred objects, sacred plants, dances, songs and teachers so they can narrate their own territory and use what our ancestors with immense effort brought to this earth for having a good life with the forest and the people.”

“When there is no teacher, no ancestral house, no feathers, no songs, teaching is very, very hard.... when diet is not adequate, also knowledge enters the ears, but it doesn’t stay in the body, and then memory escapes...”

My work provides empirical evidence that IKS in the Colombian Amazon are dynamic yet unevenly protected and supported, rather than uniformly declining as has been more discussed in the literature in the last decade ([Becerra et al., 2021](#); [Berkes, 2017](#); [Reyes-García & Benyei, 2019](#)). The findings challenge a persistent dichotomy in conservation and environmental literature that frames Indigenous knowledge either as static and pristine or degraded and disappearing, which is critiqued as analytically inadequate and politically problematic ([Berkes, 2017](#); [Reyes-García, 2009](#)). At the same time, processes of knowledge erosion are real, common and uneven.

Knowledge domains closely tied to language, ceremony, and shamanic practice are under particular pressure due to language loss, market integration, institutional marginalisation, and disruptions to intergenerational transmission ([Maffi & Woodley, 2012a](#); [Nassar et al., 2020b](#); [Sterling et al., 2017](#)). **This finding directly counters deficit narratives that implicitly attribute knowledge loss exclusively to community failure, instead relocating responsibility to the broader socio-political systems that constrain Indigenous agency.**

Most importantly, this research shows that knowledge erosion and knowledge evolution are not mutually exclusive processes. While some domains are under threat, others—particularly those linked to territorial practice and collective governance—demonstrate strong resilience and adaptive capacity. Articles 3 and 4 reveal that when collective learning spaces, ceremonial practices, and local leadership are actively supported, IKS is not only maintained but renewed and transformed. These findings dialogue with Indigenous pedagogies, collective learning processes and adaptive systems literature ([Berkes, 2017](#); [Berkes et al., 2000](#); [Berkes & Turner, 2005](#); [Blöse & Ndlovu, 2025](#); [Pandit, 2025](#); [Wyborn et al., 2019](#)). These findings also shift the analytical focus from documenting loss to understanding the conditions under which IKS can shape their own trajectories of change.

These conditions for Indigenous self-determination are fundamentally relational and practice-based. Knowledge persistence depends less on external preservation efforts and more on the existence of spaces where knowledge is enacted, contested, and transmitted, including ceremonial, territorial, and intergenerational contexts ([Chilisa, 2019](#); [Reyes-García & Benyei, 2019](#); [Reyes-García & Fernández-Llamazares, 2019](#); [Tengö et al., 2017](#)). In this regard, PAR did not function as an external mechanism for safeguarding knowledge, but rather as a methodological approach that helped sustain and expand these internal conditions. By strengthening Indigenous researcher roles and

facilitating intergenerational exchange, PAR contributed to renewed engagement in forest–fauna governance while supporting processes of autonomy, empowerment, and collective agency as proposed by critical action research and alternative onto-epistemology authors ([Escobar, 2007](#); [Stephen Kemmis & Robin McTaggart, 2014](#))

A key contribution of this research is therefore to reconceptualise knowledge erosion as a governance issue rather than a cultural deficit. While individual and collective agency remain important and shaped by specific social-ecological conditions as discussed in Article 4, agency is exercised within broader systems that either enable or constrain knowledge transmission and transformation. This perspective aligns with critical literature on co-management and knowledge integration, which demonstrates how dominant institutional frameworks often require Indigenous knowledge to be translated into external categories, thereby limiting its continuity and authority (Nadasdy, 2003).

A key methodological contribution of my work is the demonstration that time, trust, and relationships are not peripheral but constitutive conditions for knowledge continuity. Long-term engagement through PAR supports the intergenerational processes through which knowledge is reproduced and adapted ([Berkes, 2017](#); [Chilisa, 2019](#); [Ligtermoet, 2024](#); [Reyes-García & Fernández-Llamazares, 2019](#); [Stephen Kemmis & Robin McTaggart, 2014](#)). While participatory approaches are widely advocated in sustainability science, they are rarely implemented at temporal scales sufficient to sustain these processes. This research provides empirical evidence of their importance.

Finally, my study makes a paradigmatic contribution by demonstrating that Indigenous methodologies, such as knowledge weaving, ceremonial learning, and role exchange, are not context-specific alternatives but globally relevant epistemological contributions to sustainability science ([Escobar, 2018](#); [Thaman, 2013](#); [Turnbull, 2007](#); [Watson & Huntington, 2008](#)). Halting biocultural loss, therefore, depends not on documenting or preserving knowledge as static content but on supporting the social, political, and ecological conditions that enable its ongoing evolution and practice.

It has also been my direct experience that within academic and general society, e.g., in Colombia and Sweden, colonial and pre-colonial history is largely ignored. Meanwhile, commonly known narratives on IKS are heavily colonised, making it very difficult to achieve a consensus on the recognition of historical losses of human lives, knowledge, and ecosystems. Several university colleagues, friends, and many family members remain unaware of the atrocities involved in the extermination of Indigenous peoples. They continue to demand scientific proof for colonial assertions and often dismiss community claims as political constructs or conspiracy theories. This issue is deeply

concerning and underscores persistent deficiencies within national educational systems, decolonial initiatives, and country branding efforts.

Limitations and Future Possibilities

My research operates from an explicit recognition that both Indigenous and non-Indigenous knowledge systems are, to varying degrees, historically and structurally colonised ([Mignolo, 2009](#); [Quijano, 2007](#); [Smith, 2021](#)). This is not a rhetorical gesture toward reflexivity; it is a substantive epistemic condition. Colonial logics are not only external to academia as they have been internalised and reproduced within academic practices, including within Indigenous contexts shaped by centuries of missionary education, state governance, and extractive research. My own positionality as a mestizo researcher working within Indigenous territories is part of this condition, not outside of it. My research cannot claim epistemic neutrality, nor does it try to.

A second limitation is institutional. The paradigm shifts this thesis calls for—toward epistemic justice, meaningful co-production, and Indigenous-led knowledge governance—are unlikely to emerge from the centre of what Kuhn (1962) called "normal science," which remains governed by disciplinary boundaries, performance metrics, and extractive research conventions. This thesis, therefore, deliberately positions itself at the margins of established academic authority, aligned with border theories which are intercultural, decolonial, transdisciplinary, and practice-based ([Escobar, 2007, 2018](#); [Mignolo, 2009](#); [Pohl & Hadorn, 2007](#)). The generative power of these marginal positions is real, but so are their constraints in limited recognition, difficult scaling, and unequal institutional support. Acknowledging this is not pessimism, but rather a realistic opportunity for sustainability science to act upon and expand.

There is a deeper limitation in the literature on sustainability science that has been insufficiently developed as the Inner dimensions of change ([Fazey et al., 2020](#); [Ives et al., 2020](#)). The interconnected crises of our time encompassing ecological, social, epistemic and political crises cannot be resolved through methodological innovation alone ([Bennett et al., 2025](#); [IPBES, 2019](#); [Steffen et al., 2015](#)). They require what I call transcendental commitments within academia, which entail reflexive, ethical, and affective transformations that disrupt internalised hierarchies, epistemic violence, and learned forms of domination already pointed out in decolonial literature ([Chilisa, 2017](#); [Escobar, 2018](#); [Ramcilovic-Suominen, 2025b](#); [Williams et al., 2018](#); [Willmot et al., 2024](#)). Science can cultivate rigorous reflexivity by acknowledging positionality,

emotional entanglement, and moral responsibility as constitutive of knowledge production ([Roth & Lee, 2004](#); [Watson & Huntington, 2008](#)). My thesis demonstrates this through practice, not only through arguments.

In this respect, IKS offer something that Western sustainability science has not yet fully reckoned with: comprehensive frameworks for holding ontological plurality, ethical responsibility, and relational accountability together. The framing of Indigenous and scientific knowledge as oppositional systems, which still organises much of the co-management and multi-evidence literature, obscures more than it reveals. My work demonstrates that these systems share more methodological, moral, and relational elements than is commonly acknowledged. Their differences are less about fundamental incompatibility and more about asymmetries of power, legitimacy, and historical authority ([Mignolo, 2011](#); [Mignolo & Schiwy, 2002](#); [Nadasdy, 2003](#); [Quijano, 2007](#)). Recognising this is not a concession to relativism; it is the precondition for genuine dialogue.

Looking forward, I can foresee that TSS would benefit from incorporating psychological, therapeutic, and pedagogical capacities into its practice, as has been developed particularly in contexts marked by collective and intergenerational trauma ([Fast & Collin-Vézina, 2010](#); [Maté, 2022](#); [Willmot et al., 2024](#)). My publications and personal experience within and out of academia have proven that trauma reactivity is widespread across the nations, academia and especially within indigenous communities. My work aligns directly with the academic literature term of Inner–Outer transformations, which are necessary to sustain the kind of long-term, respectful, mobilising knowledge dialogues that generate knowledge perceived as credible, salient, and legitimate across diverse worlds ([Cash et al., 2003](#); [Ives et al., 2020](#); [Wamsler et al., 2021](#); [Woiwode et al., 2021](#)). This thesis cannot fully model that transformation, but it demonstrates what becomes possible when research is grounded in relational ethics, reflexivity, and sustained engagement.

My work is, to a degree, partial. It's biased towards normative and pedagogical emancipatory approaches and prioritises Indigenous methods. This is, however, a deliberate choice, not an oversight. Future research may build on this work by exploring how the Indigenous way of knowing shares extensive pedagogical strategies across nations and cultures while simultaneously highlighting the specificity and context dependence of cases. Doing this would not be an attempt to diminish or belittle the uniqueness of each IKS, but rather a reality in which differences can find commonalities to sustain complex dialogues.

7. Conclusion

My thesis began with a question about inclusion, dialogue and Indigenous Ways of Knowing. I conclude it with a deeper insight: biocultural loss is not primarily the result of missing knowledge, but of misplaced authority. Forest fauna decline and the erosion of IKS are not parallel crises, but they are mutually reinforcing processes produced by research, governance, and development practices that continue to privilege certain ways of knowing while marginalising others.

My work has shown that, despite increased recognition of ILK and IKS in sustainability science, meaningful inclusion remains rare. Knowledge is often collected without being respected, cited without being shared, and invoked without being lived. I have learned how most forest fauna research stops at the threshold of IKS, by merely opening the door without entering. My results revealed that this pattern persists not because transformative approaches are unknown, but because they are difficult, relational, and disruptive to preestablished epistemic hierarchies.

What my thesis ultimately contributes to is not another call for inclusion, but an argument for transformation. Through PAR and ERS, I show that sustainability research can move beyond extraction when researchers deliberately reposition themselves physically, epistemically, and ethically. Exchanging seats is not a metaphorical gesture; it is a practice of accountability. It requires time, humility, and the willingness to learn in ways that cannot necessarily be controlled or standardised.

At the same time, my research also reveals the enduring tensions of pursuing epistemic plurality within contemporary academia. Meaningful co-production requires time, trust, and sustained engagement, yet academic knowledge production remains shaped by project deadlines, funding cycles, and pressures for rapid outputs. These tensions were particularly evident in a Scandinavian research environment, where discussions of Indigenous realities are often mediated through literature rather than long-term lived experience and direct collaboration. As a result, Indigenous knowledge may be recognised in principle but still interpreted through familiar academic frameworks in practice. Addressing this contradiction requires not only institutional support for slower and more relational forms of research but also greater reflexivity regarding

Europe's own histories of disconnection from land, plants, and ancestral knowledge traditions.

Reconnecting with these often-overlooked lineages may create new possibilities for engaging Indigenous knowledge not as an external object of study, but as an invitation to rethink what it means to belong. In this broader sense, Indigenous knowledge challenges the modern separation between humans and the living world, reminding us that knowledge emerges through relationships with territory, more-than-human life, ancestors, and future generations. Such reflection does not seek to universalise Indigenous identities, but to open space for more reciprocal, place-based, and ethically grounded forms of knowing and being, both within sustainability science and beyond.

The aspired transformations in TSS are visible in the collective publication with Indigenous authors, where this co-production emerges when epistemic authority is genuinely shared. With this approach, IKS appear not as fragmented datasets, but as coherent systems of governance that are capable of sustaining forest fauna through relational ethics, territorial zoning, ceremonial cycles, and collective norms refined over generations. These systems do not merely conserve species, but they sustain relationships between humans and animals, ancestors and descendants, territory and responsibility.

Taken together, the article compilation and the kappa findings answer the research questions: sustainability science can help halt biocultural loss only if it stops positioning itself as the centre of knowledge production. Protecting biodiversity while allowing languages, ceremonies, and governance institutions to erode is not sustainability—it is cultural displacement in ecological terms. The findings demonstrate that biocultural conservation demands epistemic justice, long-term engagement, and research practices that strengthen, rather than extract from, Indigenous living worlds.

I hope that my work contributes to sustainability research by showing possibilities for self-development, emancipation and relational practice. Participatory methods alone are insufficient without shifts in authority, validation, and care. Knowledge co-production is not about harmonising epistemologies, but about creating conditions in which multiple knowledge systems can coexist without domination. In this sense, Indigenous methodologies are not alternatives to science; they are critical contributions to its transformation.

A further path for future research concerns the role of the researcher's positionality in relation to psychology, trauma, and emotional reactivity. Despite growing recognition of reflexivity within qualitative and participatory research, the influence of individual and collective trauma on knowledge production remains underexplored. How

researchers perceive, avoid, interpret, or engage with difficult realities may be shaped not only by epistemological assumptions but also by emotional and embodied responses. Greater attention to trauma-informed and psychologically informed research practices could therefore deepen understanding of the often-unacknowledged barriers to transformative collaboration, particularly in contexts that challenge dominant worldviews, identities, and ways of knowing

This has important implications for forest governance, fauna management, and sustainability research more broadly. Decisions about conservation, species management, territorial governance, and ecological restoration are shaped not solely by evidence but also by the values, fears, assumptions, and institutional cultures through which evidence is interpreted. Avoidance of uncertainty, discomfort with non-Western ontologies, or attachment to familiar scientific frameworks may contribute to the dismissal of relational and place-based forms of knowledge, even when they offer valuable insights for maintaining ecological integrity.

In practice, this can limit opportunities for more pluralistic approaches to forest stewardship and reinforce management systems that focus on controlling ecosystems rather than cultivating reciprocal relationships with them. Future research could therefore explore how psychological dimensions of knowledge production influence environmental decision-making, e.g., understudying insects due to repugnance towards them, and how greater awareness of these processes might support more inclusive, adaptive, and ecologically grounded forms of governance.

The responsibility that emerges from my work is clear. Researchers cannot claim neutrality while benefiting from systems that marginalise the very knowledges they seek to engage. Institutions cannot demand rapid outputs while undermining the slow, relational processes through which knowledge, trust, and responsibility are cultivated across generations. Nor can sustainability science fulfil its transformative aspirations while remaining epistemically selective. The implications extend beyond questions of representation or participation.

What is at stake is not only the continuity of forest fauna and ecological processes, but also the continuity of cultural practices, livelihoods, territorial governance, and the relationships that have sustained the Amazon biome for generations. To lose these relational systems of knowledge is to lose ways of understanding and caring for the living world at a time when such capacities are needed most. The challenge, therefore, is not simply to protect biodiversity but to create the conditions under which diverse ways of knowing, belonging, and stewarding life can continue to exist and evolve together.

Crossing the door of ILK, IKS, TEK, and SK is not the end of the journey; it is the beginning of the possibility to commit to staying, listening, and being changed by what is learned. With this work, I am not offering a universal blueprint, but I do offer a grounded pathway: one in which forest fauna, Indigenous peoples, and sustainability science are no longer managed separately but understood as intertwined futures.

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Annexes

ANNEX A

Community Research Agreements

Public summary of research agreements

"Knowledge Beneath the Trees"

PARTICIPATORY RESEARCH ON INDIGENOUS KNOWLEDGE AND
WILDLIFE MANAGEMENT IN THE COLOMBIAN AMAZON

Ceima Cachivera in Vaupés and Tipisca Amazonas



Ceima local research group:

Francy Ruth Trujillo Gonzales, Jacinta Uribe Salgado, Franklin López Rodríguez, Jaime Gutiérrez Castaneda, Gilberto Gutiérrez Castaneda, with the support of the entire community of Ceima Cachivera, the teacher of the educational center and the wise Emilio Hernández and his son Daniel Hernández.

External researchers from Lund University: Carlos Alberto Hernández Vélez and Torsten Krause. 2025

Tipisca LRG: Sirley Valentin (Curaca), Edilberto del Aguila Milton Pinto (Airumakuchi), with the support of the entire community of San Pedro de Tipisca.

Researcher/student: Carlos Alberto Hernández Vélez.

Addressed to: Indigenous population in Vaupés interested.

Project Name: Bajo el Docel: Traditional Ecological Knowledge and Consumption of Wildlife in the Colombian Amazon.

Location: Vaupés and Amazonas

Researcher affiliation: Lund University.

Foundation: The life plans of the indigenous associations expose the need to strengthen traditional knowledge, learn from the Western world and know to conserve the sustainable consumption of wildlife for the good life.

In an integrated way with the livelihoods and rights of indigenous communities, this relationship between conservation and human well-being is also included in the Sustainable Development Goals (SDGs).

In the interest of knowing and contributing locally to the sustainable management of resources and the protection of the ancestral knowledge of the indigenous communities of Colombia, the following objectives are proposed to be developed during the next 4 years:

Objectives

Know and describe the ways in which Traditional Ecological Knowledge (TEC) regulates the consumption of wildlife.

To make a general diagnosis of the current state and vitality of this knowledge.

Locate and describe the organisations or entities that are contributing and those that generate a negative effect on the TEC.

Promote practices that contribute to the use of wildlife and that promote TEC.

Methodologies

Face-to-face work in Vaupés territory 2 times a year for 20 days on each visit for a total of 8 visits over 4 years.

Interviews focused on Traditional Knowledge and consumption of fauna with knowers.

Surveys of residents (school principal, hunters, wildlife users)

Wildlife Simulation Games (8-10 young, adult, female and male players).

Products/Benefits of Sharing

The research aims to produce digital and printed material in Spanish and the local language that describes the process and results of the research. This product will reflect the essence of TEK and wildlife consumption findings.

The research also aims to conclude by inviting different local and regional institutions and members to assist at a meeting where the community will present and discuss the results in the light of the local context for the Colombian Amazon.

Research results for the community

- Printed booklet with research results in the local language
- Printed community maps in waterproof material.
- USB with digital archives of the research (photos, booklets, maps, etc.)

ACTA DE REUNION

El día 24 de Agosto de año 2022, los habitantes de la Comunidad Indígena de CEIMÁ CACHIVERA se reunieron en la Casa Comunal con el señor CARLOS HERNÁNDEZ VELAZ, Investigador de la Unidad de LUND, y aceptaron participar la Investigación sobre los conocimientos Tradicionales y Contorno de FAUNA.

De igual manera se conformaron los siguientes grupos de Coordinadores e Investigadores:

COORDINADORES: Francisco López Rodríguez
CC.Nº [REDACTED]
Francis Trujillo
Francis Ruth Trujillo Gonzalez
CC.Nº [REDACTED]

INVESTIGADORES LOCALES: [REDACTED]
GRUPO 1, [REDACTED]
CC.Nº [REDACTED]
[REDACTED]
Bilberto Gutierrez Castañeda
GRUPO 2, [REDACTED]
CC.Nº [REDACTED]
[REDACTED]
Diana Patricia Abadía
CC.Nº [REDACTED]
Cel: [REDACTED]
Correo: dianaarbelaez@gmail.com

Cada coordinador e investigador recibirá por igual a 200.000 pesos como participación como comunidad.

CARLOS ALBERTO HERNÁNDEZ VELAZ
Cel: [REDACTED]

Republica de Colombia
departamento del amazonas
municipio de puerto nariño

Resguardo indígena Hixuna cocama y yagua de puerto nariño.

Comunidad indígena [REDACTED]

Fecha 08 - Junio del año 2022.

Siendo las 3:30 pm de fecha 08-Junio año 2022 se reunió la comunidad en general junto con los Cabildo de la comunidad para convocar las persona que va hacer parte del proyecto conocimiento ecologico tradicional y consumo de fauna silvestre

Nº	Nombre	Apellido
1	[REDACTED]	[REDACTED]
2	[REDACTED]	[REDACTED]
3	[REDACTED]	[REDACTED]
4	[REDACTED]	[REDACTED]
5	[REDACTED]	[REDACTED]
6	[REDACTED]	[REDACTED]
7	[REDACTED]	[REDACTED]

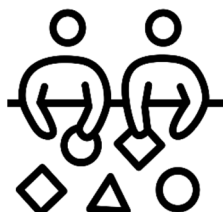
Para mas constancia Firmen las lista de asistencia la comunidad.

[REDACTED]

:::: COMMUNITY SIGNATURES INFORMED & CONSENT CAN BE SHARED UPON REQUEST AND PROTECTION OF PRIVATE INFORMATION DATA REQUIREMENTS:

ANNEX B

Participatory Workshops guide & consent



PROJECT NAME

BENEATH THE CANOPY: THE ROLE OF TRADITIONAL ECOLOGICAL KNOWLEDGE (TEK) AND SUSTAINABLE WILDLIFE USE IN COLOMBIAN AMAZON.

LUND UNIVERSITY RESEARCHERS

Torsten Krause Professor and Carlos Alberto Hernández Vélez. LUCSUS PhD candidate.

carlos.velez@lucsus.lu.se, Phone in Colombia: +57 300-2894986

LOCATION

Colombian Amazon region (Vaupés and Amazonas departments).

COMMUNITIES PARTICIPATING IN THE RESEARCH

Multiethnic indigenous communities interested in TEK.

Brief for Participants and Informed Consent

The following description is a guideline to develop participatory workshops in the participant's communities from July 2023 with a periodic frequency decided by the local coordinator with the participants. The workshops mentioned here aim to harvest information with the participants around their own knowledge, with local researchers and Carlos Hernández around Traditional Ecological Knowledge present in the community. All participation is voluntary and will happen only after previous discussions and explanations of the research objective, with members that are interested in the protection of indigenous livelihoods and sustainable use of the forest resources *Annex C. Project Invitation for local communities.*

These participatory workshops aim to record drawings, tables, diagrams, and graphics of knowledge that contribute to the comprehension of how locals understand and describe their territory and the use of traditional knowledge when using wildlife. Workshops will develop 4 main topics.

I. Life Story and Learning Process (Village and Household Distribution).

II. Using wildlife and hunting knowledge (Local Cartography).

III. Changes over time in the community traditions (Timeline and Perception of Abundance).

IV. Institutional relationship and TEK future (Actor Relational Maps).

Introduction Paragraph to read to all workshop participants.

My name is Carlos Alberto Hernández Vélez. I am a researcher at Lund University who has made an agreement with the community and now with you to ask you some questions about your knowledge of the forest, the animals, and the plants you use in your daily life. We will present this information to the community and other audiences if you give us your permission.

Do you agree to participate and be photographed in this workshop? Yes ___ No ___

Do you prefer to remain anonymous? Yes _____ No _____

PARTICIPATORY WORKSHOPS GUIDELINES

The use of a Participatory framework and methods is based on the project's interest in communitarian learning processes or community-based projects, interested first of all and mostly in people's knowledge, views, opinions and ideas of themselves referred to a specific topic, in this case their knowledge about wildlife consumption. The workshop's interest is to reflect, discuss, and harvest the information that the participants have on these 4 main topics:

I. Personal Life Story and learning process (Village and Household distribution).

II. Using wildlife and hunting knowledge (Local Cartography).

III. Changes in time of the community traditions (Timeline and Perception of Abundance).

IV. Institutional relationship and TEK future (Actor Relational Maps).

To place this knowledge in concrete form, different tools will be used; from the creation of visual objects to actively making categories on whiteboards or cardboards, creating collective drawings of the local territory, known as “local cartographies or speaking maps”; collectively filling tables with marks that sign perceived resource abundance and direct drawing of wildlife species with specific characteristics. These methodologies allow the participants to discuss and choose what information to share and in which ways, creating an open space to reflect on their own “knowledge construction” the value of this knowledge and reflect on its purpose and possible future.

Setting Characteristics

The Following workshops should be developed in a comfortable place for the participants, placing a table, chairs, and the needed didactic aids in a visible position. The meeting place should be spacious enough for participants to have individual space, with good illumination, ventilation, and resting options such as chairs agreed to be used by the community. Lund researchers will organise with local researchers the place that the community chooses for these meetings.

General invitation and offerings

Participants in these meetings will be offered water or local juice, appetisers, and a shared communitarian lunch afterwards. The local researchers will organise the needed materials and food with contributions from the research budget, complemented by participants' contributions of some local ingredients. The invitation and project description format will be read and translated into the local language using the form:

ANNEX C

Picture & video consent



PROJECT NAME

BENEATH THE CANOPY: THE ROLE OF TRADITIONAL ECOLOGICAL
KNOWLEDGE (TEK) AND SUSTAINABLE WILDLIFE USE IN COLOMBIAN
AMAZON

LUND UNIVERSITY RESEARCHERS

Torsten Krause, Professor, and Carlos Alberto Hernández Vélez. LUCSUS PhD candidate.

carlos.velez@lucsus.lu.se

Phone in Colombia: 300-2894986

LOCATION

Colombian Amazon region (Vaupés and Amazonas departments).

COMMUNITIES PARTICIPATING IN THE RESEARCH

Multiethnic indigenous communities interested in TEK.

This research works in agreement with the local communities' interest in understanding, describing, and promoting dialogues about traditional ecological knowledge between local communities and Lund University researchers at the LUCSUS Centre for Sustainability. We aim to work side by side with local indigenous communities to address questions regarding Traditional Ecological Knowledge and create communication pathways with local institutions that favour indigenous livelihoods and governance, including the consumption of wildlife. If you decide to participate, you will always be asked to accept orally or with a signature (if you use one) the use of your experiences in this study. You can also give or refuse your consent to appear on audio, video, or photo recordings. Your experiences and images if accepted to be registered, will be used to develop the following objectives:

Research Objective 1 (RO1)

Know and describe formal and informal forest governance institutions, norms and Traditional Ecological Knowledge that determine hunting of forest fauna.

(RO2)

Know and describe the implications of hunting for livelihoods and availability of other forest products, biodiversity, and the ability of tropical forests to store carbon.

(RO3)

Know and describe the extent to which Traditional Ecological Knowledge can be leveraged in forest governance across multiple levels to support long-term sustainable resource use in tropical forests.

Hereby I _____

Member of the community (Captain) Cesar Gutierrez and Sirley Valentin, (Cultural Coordinator) Emson Hernandez, (Traditional Authority) Emilio Hernandez and (Airumakuchi Director) Edilberto del Aguila.

Permission is granted to take pictures and video recordings and use them for the project's purpose and its dissemination and outreach objectives. None of them can be used for profit or used in any way that is not referred to in the research.

Signature of person taking photos or video material: ENDÉMICA.

Signature of person operating the camera: ENDÉMICA.

ANNEX D

The Story of the Uku Tree: Origin of life and the Thinking Seat

This story is a short version of the original recording, narrated in Vaupés in 2012 by Bua Bayá (Cándido Muñoz), a *Umuercomaja* (Tatuyo) traditional *Kumú* (shaman) and founder of Yapú village. Cándido relationally adopted me as his grandson and *Padrino Cultural* during my first cultural immersion in Yapú. He passed away in 2017 but is present all around this work, as he is responsible for my cultural initiations of the *Yuruparí*-complex of cultures.

Before life could truly arise on the planet, invisible beings, matter, objects, plants, animals, and humans existed in spirit. They were not yet human-humans or animal-animals; they were spirit-humans and spirit-animals and so on. At this time, there was a huge, giant, enormous tree, whose trunk was so big that not even a big community holding hands could revolve around it. [This tree in Tatuyo is named the Uku Tree]. The branches of this tree had such an immense canopy that it held all the water from the sky and did not allow it to fall into the middle and lower worlds, so there was no water to drink in rivers for fish to swim. Some spirit-humans noticed this and wanted to do something to allow this water to reach the other layers of the world and allow life to flourish, so they decided to start talking and analysing how to bring this tree down and gathered sharp rocks to fabricate a rudimentary but strong axe. Both humans took turns and supported each other in the intense, hard work of chopping pieces of the trunk bark.

After a day of committed work, they were exhausted and went to sleep elsewhere. Their work was hard, but their progress compared to the tree's enormous size was minuscule, so they knew this would take sustained work for years.

The next day, after a long sleep, they gathered again and returned to their long-term project, and while facing the place where they had previously worked, they were stunned to discover that there were no traces of their chopping, not in the tree trunk, not on the floor, nothing! All the wood pieces that had been scattered around the area were somehow reattached to the tree. The humans, confused by this, started to imagine who could have intervened in this bark reattachment. Maybe the ants did this! Although the squirrels could also have been involved!... Maybe someone else was hiding behind the bushes and collecting the wood when

we left! Maybe there is an evil spirit that does not want life to flourish, and with its magic healed the tree trunk when we left!.

Many theories arose from the conversation, but no conclusion was reached; they agreed to try again and resumed their project. The exhausting cycle of hard work, sleep, and returning to find no progress had happened a couple of times, leaving the spirit-humans more confused each time. The next idea was to stay hidden behind the bushes after work, waiting to see who or what was behind the sabotage. So they did, waiting until the early hours of the day to discover that they had fallen asleep and their project was again at a standstill. Why did you fall asleep? One recriminated the other... No, it was not asleep. I was distracted from taking the ants out of my butt, but as they were sitting on the floor. Apparently, we weren't prepared to stay awake, and we finally collapsed.

One of them resumed its chopping practice and started building a small Seat specific to its body and size, with the idea of making it proper to support him during the vigilant quest to find the truth.

The other human was also inspired, understood the purpose of this action, and followed his project partner, fabricating a second seat suited especially for him. With these seats, we can stay focused, stay small and invisible to others and remain concentrated without feeling uncomfortable sitting on the floor. Now we will see clearly who is behind this sabotage!

The seats worked perfectly. Both humans stayed awake all night and saw nothing. No one came. There were no squirrels, there were no ants, no evil spirits, no enemies. The only change they made was to put what was being cut to proper use, allowing them to have a better life.

This story continues until they cut down the tree, and another chapter explains how the river was formed by following the tree trunk and branches, and how their positions on the tree influenced the distribution of animals in the territory as it fell.

Paper I





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Advancing co-production for transformative change by synthesizing guidance from case studies on the sustainable management and governance of natural resources

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ABSTRACT

Co-production has become paramount for scientists, practitioners and social groups of Indigenous peoples and local communities of rural and urban areas to deliver transformative changes that enhance sustainability. Co-production should result in knowledge that is credible, legitimate and usable to enable sustainable outcomes effectively. However, this is not always the case due to challenges related to differences between scientific and Indigenous and local knowledge, as well as inherent power imbalances. The literature emphasises that these challenges are often triggered by rigid scientific theories and postures, dominant practices, and time-money limitations that co-production projects involve. This happens despite the adoption of guidelines recommended in the literature. We investigate the role of these challenges and guidelines in the generation of credible, legitimate, usable, and effective knowledge. We analyse this role in 13 co-production cases focused on sustainable transformative changes linked with the management and governance of natural resources across the globe. Despite challenges varying between groups and contexts, credibility, usability, and effectiveness are promoted simultaneously, especially when co-production empowers social actors via legitimate processes. Scientists and practitioners do so, through creative and flexible reshaping of existing knowledge and worldviews with a focus on common goals that link sustainability and livelihoods. They conceptualise a mutual understanding of knowledge and that is deemed trustworthy feasible to use in their socioecological context. Our findings complement existing scholarship on co-production, exploring the credibility of situated knowledge and its practical effectiveness together with its commonly addressed legitimacy and usability. A focus on the practices

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of different actors, including dynamics that are external to co-production, and changes in the scientific and social *status quo*, are needed to advance co-production effectiveness.

1. Introduction

The collaborative production of knowledge and practices (co-production) is inherently part of participatory or transdisciplinary research and projects that span science, policy, and social interfaces (Tengö et al., 2017; Chambers et al., 2022). Co-production is used to include both scientific knowledge and 'Indigenous and local knowledge' systems (ILK) (Díaz et al., 2015) in several activities, for instance project design (Wheeler & Root-Bernstein, 2020), environmental assessments (Sutherland et al., 2017) and planning (Matuk et al., 2020). Such activities aim for transformative changes through which 'Indigenous Peoples and Local Communities' (IPLCs) improve the management and governance of natural resources and mitigate environmental problems such as climate change and loss of biodiversity (Wyborn et al., 2020). For example, in a project related to 'Reducing Emissions from Deforestation and Forest Degradation' (REDD+), Indigenous peoples co-produced an assessment with practitioners to ensure that local livelihoods were not jeopardised by efforts to reduce deforestation (Amaral et al., 2021). In another example, scientists and local citizens planned to improve the selective collection of solid waste to reduce biodiversity loss resulting from pollution (Rada et al., 2020).

In this study, we draw upon various scientific fields that address sustainability literature (Tengö et al., 2017; Chambers, 2022) – i.e., Science and Technology Studies (STS) (Wyborn et al., 2019, 2020), participatory (action) research (Freire, 1996; Almekinders, 2009); ethnocoecology, ethnopedology (Toledo and Barrera-Bassols, 2009), ethnobotany (Albuquerque et al., 2014), citizen science (Bonney et al., 2009), circular economy (Marra et al., 2018), postcolonial (Latulipe and Klenk, 2020), and feminist studies (Sato and Alarcon, 2019). We stipulate that to be effective, co-production should result in knowledge that is credible, legitimate, relevant, usable and accepted for all involved. This includes scientists, practitioners (e.g., actors who work with policy or non-governmental organisations (NGOs)), and IPLCs. By credible and legitimate, we refer to the co-produced knowledge that all these actors accept as trustworthy and inclusive (see Cash et al., 2003a, 2003b; Matuk, 2020; Schuttenberg and Guth, 2015). By relevant, we mean that this knowledge is theoretically and practically fit to address the actors' needs within the social-ecological context in which co-production is addressed. Finally, this knowledge is accepted by actors when it enhances the sustainability of the impacts and outcomes in practice (cf. Matuk, 2020). This knowledge improves the understanding of how to manage resources more sustainably and increases the chances that IPLCs will endorse transformative changes together with other actors (Hanson and Polk, 2018). Therefore, it creates space for these actors to move beyond the exclusive recognition of the credibility and usability of scientific knowledge and challenge epistemic inequalities grounded in colonial hierarchies among actors (Latulipe and Klenk, 2020). It also invites them to be critical of co-production processes and uncertainty of it leading to ecological sustainability in practice (Brix et al., 2020).

While knowledge credibility, legitimacy and usability (CLU) are central to co-production effectiveness, its achievement is often challenged by knowledge differences that exist between and within different knowledge systems, and by power imbalances among knowledge holders (Turnhout et al., 2020). These differences relate to epistemologies (how to know), ontologies (what is there to know) and associated axiologies (values support what and how we know) (Woolgar and Lezaun, 2013; Ludwig and El-Hani, 2020), which may be reflected in differences in problem conceptualization, classification categories, needs, goals, worldviews, values, beliefs, and interests. For instance, different groups of scientists and local communities may differ in how they respectively validate land use indicators they know and use

towards achieving their goals. These differences might be, in some cases, hard to reconcile during co-production processes of bringing knowledge systems together – i.e., mobilizing (exchanging, bringing out, selecting), weaving (bridging, braiding, combining), translating (into a common language of communication, and synthesizing (reframing) commonly accepted knowledge (Tengö et al., 2014, 2017). In turn, power imbalances constrain this reconciliation (Matuk et al., 2020). These imbalances originate from scientists and practitioners who usually hold more power than IPLCs to influence what knowledge is adopted or implemented for change (Agrawal, 1995; Turnhout et al., 2020). Therefore, scientists tend to engage with IPLCs and their ILK in a hierarchical manner, believing that science is better equipped to solve problems.

Challenges related to knowledge differences and power imbalances during co-production processes are largely ascribable to the rigidity of theories and postures and to dominant methodological practices (Matuk et al., 2020b; Simon et al., 2018; Turnhout et al., 2019, 2020). Moreover, time-money limitations that are common in co-production projects serve as another major challenge (Lemos et al., 2018; Chambers et al., 2022). The literature recommends practical guidelines for the co-production actors to adopt towards overcoming these challenges: 1) reciprocal engagement and flexibility; 2) mutual understanding and deliberation; and 3) trust and creativity (Tengö et al., 2017; Matuk, 2020; Chambers et al., 2022). (Ayana et al., 2015; Matuk et al., 2020b). For example, the premises of scientists and rigid formality can prevent the participation of IPLCs in participatory methods, making it difficult to develop mutual understandings to reconcile knowledge differences. Additionally, much of what is proposed in these guidelines comes mainly from scholars from the global South and to some extend from the scholars from the global North. Meaningful engagement with IPLCs and ILK remains mostly absent in the literature focussing on the practice of co-production (Turnhout et al., 2020). Finally, the time-money limitations of co-production processes tend to limit the space for actors to identify and engage more deeply with knowledge differences. This may lead to scientists and practitioners dominating co-production decisions during project design, environmental assessment and planning with IPLCs. This is done to pursue project planning and project activities needed to meet project objectives (Meehan et al. (2018); Cockburn et al. (2017)). The outcome is an extraction of ILK, used and interpreted to match scientific data, yet detached from the meaning and use it has for IPLCs (Klenk et al., 2017). These outcomes lead IPLCs to question the CLU of the knowledge generated and to hamper its effectiveness. This indicates the need for studies that help to understand the role of these challenges and guidelines in co-production and how they affect co-production effectiveness (Díaz et al. (2018); Djenontin and Meadow (2023); Wyborn et al. (2020); Wheeler and Root-Bernstein (2020); Matuk et al. (2020b)).

We investigate the role of the aforementioned challenges and guidelines in co-production. Specifically, we explore whether and how these guidelines enable actors to overcome these co-production challenges and achieve knowledge CLU and effectiveness. We do so by applying a conceptual framework to 13 diverse cases of co-production from around the globe. We explain the selected cases in Section 3, but different types of IPLCs – urban citizens; modern and traditional farmers (or peasants), traditional communities that rely on customary practices aimed at subsistence and Indigenous peoples. In this context, we contribute to the flourishing scholarship on co-production in two main ways. First, the existent literature focuses on the legitimacy and usability of co-produced knowledge, which involves a debate on the credibility of this knowledge for different actors and on its effectiveness (Lemos et al., 2018; Díaz et al., 2018; Wagner et al., 2023). We complement this literature by exploring the emergence of the knowledge attributes CLU

and their role in the ‘effectiveness’ of co-production. Second, we enrich existing literature that theorises on practices that help scientists to tackle knowledge differences and power imbalances with society (Tengö et al., 2017; Turnhout et al., 2020) with an exploration of how this occurs in practice. These contributions enable us to share insights on principles and practices that help advance the effectiveness of co-production.

2. A conceptual framework to assess knowledge credibility, legitimacy, usability, and effectiveness

Our conceptual framework draws on ‘CLU’ and ‘effectiveness’ as the core attributes of knowledge. We understand legitimacy as resulting from the perception that the production of knowledge or information has been respectful of “*divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests* (Cash et al., 2003a, p. 8087).” Credibility refers to the validity and trustworthiness of knowledge (Cash et al., 2002, 2003; cf. Schuttenberg and Guth, 2015). Usability refers to the relevance and appropriateness of applying knowledge to address actors’ needs and contexts (Cash et al., 2003b; Clark et al., 2016; Lemos et al., 2018). While explaining usability, Cash et al. (2003a), (2003b) focus on salience which they explain relates to whether mobilized knowledge address the problem central to co-production. We apply a broader framing for the concept of usability to emphasize that this knowledge should be relevant and fit to address the needs prioritized by the various actors in terms of feasibility, practice, and social-ecological context (cf. Matuk, 2020).

CLU are often entwined, linking knowledge and action or practice. They are thus considered to affect the effectiveness of co-produced knowledge. Effectiveness refers to knowledge and co-production that generate social and environmental impacts or outcomes; specifically, when knowledge is adopted in practice to enhance sustainability (Matuk et al., 2020b; Lemos et al., 2018). The problem is that holders of different knowledge systems can have different interpretations of the knowledge that bears CLU (Wheeler and Root-Bernstein, 2020). In the attempt to inform social practices with information that scientists and practitioners consider credible (according to science), they often compromise the legitimacy and usability it has for IPLCs, thus reducing its effectiveness (Turnhout et al., 2020). We assume that co-produced knowledge should have its CLU attributes evaluated by different actors participating in co-production in a non-hierarchical manner that is shaped according to the situated context of its application. This knowledge should enhance the effectiveness of actions and sustainable solutions (cf. Hansson and Polk, 2018; Matuk, 2020; Leino and Peltonmaa, 2012). We recognise these definitions are based on scientific concepts, and may be counterpoised in co-production involving actors that draw upon other knowledge systems.

We consider the way knowledge holders characterise, validate and use knowledge should be subject to reflection during co-production (Matuk, 2020; Hill et al., 2020). For instance, many scientists portray their systems of classifications and conceptualizations as being neutral from ontologies and universally applicable (Bowker and Star, 2000; Woolgar and Lezaun, 2013). Nevertheless, other scientists recognise that research design involves subjective choices and that the experiential knowledge of scientists interferes with research processes and findings (Collins, 2001). Scientists usually identify CLU when knowledge is produced following systematic empirical methods and is published in peer-reviewed outlets (Cash et al., 2003b). Practitioners also have scientific knowledge, although the literature stresses their technical and professional knowledge. However, scientists and practitioners with a background in social and natural sciences validate knowledge using different qualitative and quantitative methods (Turnhout et al., 2019).

In accordance with the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), we define that ILK includes diverse knowledge systems and is “*a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including*

humans) with one another and with their environment. It is also referred to by other terms such as, for example, Indigenous, local or traditional knowledge, traditional ecological/environmental knowledge (TEK), farmer or fisherman knowledge, ethnoscience, indigenous science, folk science (Díaz et al., 2015, p. 13).”

We emphasise that ILK systems differ from each other in some respects and vary within their own domains, which implicates that each approach and methodological process used for co-production needs to be adapted not only according to the type of knowledge but also to each case and context. Overall, Indigenous knowledge is inseparable from Indigenous practices and holistic ontologies. It is orally transmitted via storytelling, music, and traditional practices (Parsons et al., 2017; Latulipe and Klenk, 2020). It is intricate to long-term relations to the lands of these original inhabitants of global areas and to animist values and worldviews, also referred to as cosmologies (Scoville-Simonds, 2018; Man Han Chit Htoo et al., 2022). These worldviews imply that animals are spiritual and intelligent entities from whom Indigenous peoples learn and have ethical obligations to (Man Han Chit Htoo et al., 2022). Shamans and local cultural leaders are influential in knowledge transmission, but communities also validate knowledge based on their values, morals, needs, and circumstances (Lickers, 1997). Although Indigenous knowledge is rooted in traditions, its holders adapt it in response to environmental change (Hitomi and Loring, 2018). Concurrently, Indigenous knowledge varies with Indigenous ethnicity and context (Nascimento and Vieira, 2015; Matuk, 2020). Additionally, co-production with Indigenous peoples must take into consideration aspects related to identity, land, and intellectual rights, and to cultural heritage as recognised by international treaties and national laws (e.g., Mauro and Hardison, 2000; Cittadino, 2019). Co-production must also contemplate the benefit sharing arising from the utilization of Indigenous knowledge (see Nagoya Protocol of the CBD; Wright, 2020).

Finally, despite the fact that the groups holding local knowledge vary considerably across the globe, studies indicate that the adoption of co-produced knowledge depends on it meeting their values, needs, and contexts (Klenk et al., 2017; Matuk et al., 2017, 2020a). Specifically in the Global South, co-production often addresses peasants and citizens who draw their knowledge mostly from place-based experiences and values (Freire, 1996; Coelho, 2014). Co-production also addresses traditional communities (e.g., formed by marooned escaped slaves or tappers) who base their knowledge on multigenerational land use and holistic ontologies, and on exchanges with IPLCs (Matuk et al., 2017). Yet, co-production with traditional communities must account for needs insufficiently covered by policies and often relating to the colonial histories in their lives (Santos and Meneses, 2010). Unlike in the Global North, co-production with Southern peasants often addresses citizens and modern farmers, who next to scientific knowledge usually rely more on situated and experiential knowledge (Strasser et al., 2019). Moreover, co-production with these groups should also elevate their needs and knowledge to be included in decisions that will affect their lives (Brix et al., 2020).

2.1. Challenges and guidelines that affect credibility, legitimacy, usability and effectiveness in co-production

The literature on sustainability and co-production emphasises that scientists, practitioners and IPLCs should use good practices to achieve CLU. We synthesize three key guidelines, associated with overarching triggers that make knowledge differences and power imbalances emerge during co-production processes (Fig. 1).

Below, we exemplify how the triggers manifest and we point at possible strategies to deal with knowledge differences and power imbalances, based on the three guidelines of our framework.

1) Rigid theories and postures: Reciprocal engagement and flexibility to reshape.

The rigidity of the premises of scientists and practitioners reinforces pre-existing power structures. This limits the ability of scientists and

practitioners to elicit and understand ILK and IPLCs perspectives (Chambers et al., 2022; Turnhout et al., 2020). Furthermore, it inhibits their ability to make sense of knowledge differences between IPLCs and their own scientific knowledge. For instance, a disciplinary approach to address IPLCs may prevent them from meaningfully engaging in co-production as their knowledge is holistic and as such requires an interdisciplinary approach (Matuk et al., 2020). Scientists and practitioners strive to move beyond these structures and premises when they empower IPLCs to reshape pre-given concepts, classifications, and models. They do so by developing a reciprocal engagement with IPLCs and being flexible to do this reshaping (Wyborn et al., 2019). For example, scientists being transparent when explaining the objectives of their project and the purposes of their methods. Another example is scientists embracing a plurality of values and knowledge that enforce sustainability (Kenter, 2018). This guideline is followed when all actors, including scientists and practitioners: i) reflect and learn from tensions or insights, to reshape their postures (Klenk, 2018); and ii) change the *status quo* of their practices towards supporting changes in the sustainable management and governance of IPLCs (cf. Chambers et al., 2022).

2) Dominant methodological practices: *Mutual understanding and deliberation*.

When scientists and practitioners dominate the steering of co-production, they may generate unintended (uncontrollable or performative) dynamics that compromise knowledge CLU (Turnhout et al., 2020) - e.g., when they lack facilitation skills. However, they can also negotiate and reframe methods with IPLCs to develop mutual understandings of knowledge differences (i.e., correspondences and complementarities between concepts, classifications and goals) and deliberate on changes that enhance sustainability with them. One possible strategy is that they can help IPLCs bring out ILK, and decide together on distributional justice aspects (who decides and benefits from decisions). The use of this strategy is detectable when actors: i) rely on boundary objects - e.g., livelihoods (Clark et al., 2011); ii) make inter- and transdisciplinary efforts to grasp the reasons behind knowledge choices (Léle and Norgaard, 2005; Ingold, 2011); and iii) 'inherit' or appropriate elements of each other's knowledge (Meehan et al., 2018). For example, scientists accept the sacred value that locals attribute to lands where their ancestors are buried as a credible or valid indicator to decide governance. The resultant outcomes of these processes combine knowledge systems allowing IPLCs to recognise ILK, and align project goals and local needs (cf. Matuk et al., 2020b).

3) Limiting time and money resources: *Trust and creativity*.

The lack of time and material resources reflects the structural limitations of academia and commodified research that underfund co-production while putting emphasis on competition between its actors, including IPLCs. The same limitations are found in projects of policies and NGOs that address co-production with IPLCs. Although these limitations require structural responses, scientists are challenged to mitigate them by cultivating trust and creativity. Participatory processes take

time and money - e.g., to organize and carry out meetings, build trust, and achieve a shared understanding of ILK (Lemos et al., 2018). Often, scientists and practitioners do not limit their own space. This goes at the expense of the voices of IPLCs and ultimately sharing power, for instance when selecting the criteria for water governance (Oliver et al., 2019; Wyborn et al., 2019). Studies also show that when scientists and practitioners take a less rigid approach towards IPLC and invest in building trust this optimizes time and money (Evans, 2006; Matuk et al., 2019, 2020a). They do so by readjusting research methods and objectives to the local needs and goals of all actors involved. Trust is often identifiable when project activities ensure the participation of IPLCs. In turn, creativity is tangible when the development of creative solutions minimises these limitations and enables lower-cost changes (Matuk et al., 2019). For instance, trust and creativity reduce constraints to time and costs when different researchers facilitate different fieldwork activities simultaneously or adapt their interviews and workshops to incorporate ILK-related information and methods proposed by IPLCs.

The suggested guidelines can enable co-production to generate knowledge CLU, thus yielding the foundation for effective changes related to natural resource management and governance carried out by IPLCs.

3. Material and methods

The location and characteristics of our 13 study areas are presented in Fig. 1 and Table 1. Four of these cases addressed Indigenous peoples and nine of them addressed local communities, of which four included rural participants and five included urban or mixed groups.

3.1. Data collection and analysis

Following applicable local and/or international protocols, we present the free and prior informed consent and the ethical procedures used for data collection in Table 1. In addition, Fig. 2 illustrates data collection across research fields, methods, and IPLC and other groups in specific cases. The first author invited the co-authors to contribute data based on case studies and publications. This enabled an analysis across common characteristics but also delivered a variety of aspects for broader reflection on co-production processes and effectiveness. The cases were selected from scientists that actively facilitated the co-production of environmental assessments and planning processes with the participation of IPLCs, NGOs and/or policy practitioners. The intention was to generate credible and legitimate knowledge for implementing sustainable transformative changes in the management and governance of natural resources.

Qualitative data analysis was carried out through two rounds of 'thematic coding' (Nowell et al., 2017) of data from the different cases such as notes on fieldwork activities; recorded and transcribed interviews that had followed a different structuring pertinent to each project. The first author guided the co-authors in gathering and synthesizing data from their respective research via e-mails and online dialogues. She structured the data (based on the headlines of Fig. 1 and Table 1) in order to gather similar information across cases needed for comparative analysis. Overall, this information focused on: 1) how co-production was facilitated; 2) how co-production decisions prioritised and included research framing, assessment, planning and data analysis - e.g. problem conceptualizations, classification categories and indicators, needs, goals, worldviews, values, beliefs and interests; and 3) whether and how co-production processes generated knowledge CLU and led to effective outcomes.

In each case, the form of participation of practitioners and IPLCs was classified as 'active' or 'informative' (Table 1). Active participation refers to actors adding their knowledge to co-production process and decisions; by evolving and aligning research methods with environmental assessment and planning activities. Informative participation refers to actors not participating or participating shortly in these decisions (cf.



Fig. 1. Triggers related to challenges of knowledge differences and power imbalances with guidelines for actors to address them.

Table 1

Projects, roles of actors, research field and form of participation, location, general characteristics and problems addressed in each context, and methods and activities involved in co-production. References cited in the research field relate to publications and projects that case studies have been derived from.

Project focus	Co-production: role of actors + participation (active/informative)	Research field	Location	Social-ecological issue	Methods/activities & project duration
With citizens and local knowledge (LK).					
1) <i>Establishing a program for selective solid waste collection</i>	<u>Scientists (active)</u> : program design/planning and uptake <u>Policy practitioners (active)</u> : program design/planning and uptake <u>Citizens and Peasants (informative)</u> : Deployment of LK; knowledge exchange on waste management	Transformative research (Freire, 2017 ; Lam et al., 2020)	São João Evangelista in the Atlantic Rain Forest (Minas Gerais, Brazil)	Poor and polluted region with solid waste management issues and low levels of education level	4 Environmental campaigns in public spaces (130 people/average); 10 interviews - 1,5 years
2) <i>Searching for new pocket parks in Amsterdam</i>	<u>Scientist (active)</u> : assess locations for small-scale green spaces <u>Policy and NGO practitioners (active)</u> : co-producing indicators with scientists; facilitating process or urban greening; engaging citizens <u>Citizens (informative)</u> : planning locations and implementation of parks	Urban greening, Citizen Science (Bonney et al., 2009)	Amsterdam (The Netherlands)	Growing urban expansion in an intensely used landscape causes declining green space and urban biodiversity loss combined with a need for climate change adaptation	2 Workshops; 4 focus groups; Geographic information science (GIS); 86 site visits by local citizens and practitioners - 2 years
3) <i>Updating the management of a cultural stream by citizens</i>	<u>Scientists (active)</u> : mediate management update/ biocultural conservation <u>Policy/Water Board practitioners (Hydrology, Ecology) (active)</u> : collaborative advise/ implementation <u>Citizens (active)</u> : bringing in management history/practice and co-producing changes	Nature Conservation; urban greening, Ecology, Hydrology, Cultural History.	Driebergen (The Netherlands)	Citizens have managed a green space for 25 years, conserving a springwater system/greenblue infrastructure now under threat from climate change, dropping water levels and water quality	2 Workshops; 2 technical visits for ecological measurements; 2 joint walks to learn about, and plan management - 4 years
4) <i>Avoiding the harm from salt mining in the urban environment</i>	<u>Scientists (active)</u> : mediating a safer measurement of mining impacts <u>Policy/Ministry of Economic Affairs practitioners (active)</u> : support scientists and citizens <u>Citizens (active)</u> : creating a new framework to measure mining impacts to be licensed <u>Mining company (informative)</u> : collaborating to prevent harm	Environmental conservation, Cultural heritage conservation	Harlingen (The Netherlands)	Citizens prevent salt mining impacts in urban residential areas, i.e., loss of houses and heritage buildings under threat from soil subsidence	20 Interviews, participant observation - 4 years
5) <i>2000 m² for sustainable agriculture</i>	<u>Scientists (active)</u> : supporting practitioners with co-production <u>Policy and NGO practitioners (active)</u> : engaging citizens in setting the course for the national transition to resilience/zero-carbon emission by 2050 <u>Citizens (active)</u> : to adopt or improve agricultural sustainability; uptake healthy diets	Circular economy (Marra et al., 2018)	Kockelscheuer, Luxembourg City (Luxembourg)	Most citizens have unhealthy/ unsustainable diets and do not have a home garden. Most local farmers could produce more sustainably under climate change	2 Workshops (25 people/ average); 42 seminars in demonstration gardens/ agricultural sites - 3 years
With farmers and traditional communities and local knowledge (LK)					
6) <i>Advancing participatory research oriented to sustainability with agroecology</i>	<u>Scientists and graduate students (active)</u> : providing agroecological technical support <u>Policy practitioners (informative)</u> : supporting peasants to increase food productivity and diversity while maintaining their sustainable practices <u>Peasants (active)</u> : co-creating problem understanding and	Action research (Almekinders et al., 2009); Agroecology (Gliessman, 2001)	São João Evangelista in the Atlantic Rainforest (Minas Gerais, Brazil),	Poverty, low productivity, and low food diversity in the municipal food market	5 Workshops (30 people/ average); 24 interviews - 1 year

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Table 1 (continued)

Project focus	Co-production: role of actors + participation (active/informative)	Research field	Location	Social-ecological issue	Methods/activities & project duration
7) Knowledge and power in transdisciplinary research with traditional fishers	solution, and raising income and sustainability <u>Scientists (active)</u> : studying LK and enhancing mangrove biodiversity, learning together <u>Traditional fishers (active & informative)</u> : reshaping LK, learning together and co-creating school materials	Participatory research (Chevalier and Buckler, 2013; <u>Sato and Alarcon, 2019</u>)	Siribinha in the Atlantic Rainforest (Bahia – Brazil)	Poor population; low policy support; balance conservation and livelihoods in the mangrove estuary	5 Workshops with participatory activities (12 people/average); ethnographic participant observation; 50 interviews - 4 years
8) Grape marc - From underrated waste to premium fertilizer	<u>Scientists (active)</u> : mediating co-production of a pilot-project/strategy to close carbon cycles in the country <u>Policy and NGO practitioners (active)</u> : implementing the 'Yes We Care' -program <u>Winegrowers (active)</u> : co-creating the fertilizer and program	Circular economy (<u>Marra et al., 2018</u>)	Schwebsange in the Moselle River valley (Luxembourg)	Winegrowing region affected by climate change and carbon pollution that can become carbon storage in soils	14 Workshops (5 people/average); demonstration site - 3 years
9) Reducing turtle bycatch in a small-scale fishery	<u>Scientists (active)</u> : mediate bycatch mitigation, keeping fish livelihoods/trade <u>Policy and NGO practitioners (informative)</u> : regulate turtle protection <u>Fishers / fisheries managers (active)</u> : reducing/supporting the reduction of turtle bycatch	Participatory research on sustainability (<u>Larocque et al., 2020</u>), Biology, Social Sciences.	Eastern Ontario (Canada)	Biodiversity loss and livelihood dependency in a region of important turtle biodiversity involves turtle bycatch by fishers' hoop nets	2 Workshops (20 people/average); 40 interviews conference calls - 4 years
with Indigenous peoples	and Indigenous knowledge (IK)				
10) Assessing the legitimacy and effectiveness of co-production to mitigate climate change with Amazon Kaxinawás	<u>Scientists (active)</u> : analysing co-production <u>Policy practitioners (active)</u> : providing technical support and SISA (REDD+) <u>Kaxinawás (active)</u> : problem understanding/solutions to rescue/enforce traditional practices/conservation	Ethnoecology (<u>Toledo and Barrera-Bassols, 2009</u>)	Kaxinawá Nova Olinda Indigenous Land in the Amazon Rainforest (Acre, Brazil)	Traditional IP activities (fishing, gathering, hunting, agriculture etc.) under pressure from <u>climate change and deforestation. A return to REDD+ funds with a growing population puts pressure on biodiversity</u>	3 Workshops, participatory mapping (35 people/average); participant observation; 20 Interviews - 4 years
11) Reinforcing traditional food and medicinal practices with Amazon Kaxinawás	<u>Scientists</u> : helping locals conserve food practices and security/sovereignty <u>Policy practitioners (active)</u> : providing technical support and implementing SISA (REDD+) <u>Kaxinawás (active)</u> : exchanging and rescuing traditional knowledge and practices	Ethnobotany (<u>Albuquerque et al., 2014</u>)	Kaxinawá Nova Olinda Indigenous Land in the Amazon Rainforest (Acre, Brazil)	Important agrobiodiversity foresees in the growing consumption and demand of urban food	60 Interviews, 35 technical visits to home gardens/crops, including participant observation; several guided tours/cataloguing IK - 4 years
12) Conserving ecosystem services, agrobiodiversity and human health with Amazon Puyanawas	<u>Scientists (active)</u> : supporting practitioners and <u>Puyanawas</u> <u>Policy and NGO practitioners (active)</u> : technical support and implementation of SISA (REDD+) <u>Puyanawas (active & informative)</u> : assessing soils/ natural resources and planning practices to enhance sustainability/health	Ethnopedology; Ethnobotany (<u>Albuquerque et al., 2014</u>)	Puyanawa Indigenous Land in the Amazon Rainforest (Acre, Brazil)	Growing population induces urban food consumption which causes health issues and pressure on biodiversity	4 Workshops, demonstrative gardens, participatory mapping (8 people/average), 10 Interviews - 4 years
13) Wildlife management with Airumakuchis in the Colombian Amazon	<u>Scientists (active)</u> : understand the role of local governance norms and IK on wildlife management sustainability <u>CIFOR practitioners (active)</u> : collaboration with scientists and <u>Airumakuchis</u> <u>Airumakuchis (active)</u> : hunters/fishers who aim to secure livelihoods and sustainability	Social-ecological systems/ILK (<u>Folke et al., 2016</u>)	Santa Teresita Village in the Amazon Rainforest (Puerto Narino/Leticia, Colombia)	Growing livelihood demands affect the consumption of wildlife for subsistence and trade as Indigenous knowledge and governance erodes	5 Workshops (10 people/average), 15 interviews - 4 years

van Koppen and Spaargaren, 2015; Rosen. and Painter, 2019). In general science appears key to all co-production projects as science actors always have an "active" role.

Data was coded in two rounds and involved a reflection by the co-authors on which information and situations emerged, during their co-production process. Initial coding focused specifically on information related to questions 1 and 2 presented above, and with the three 'triggers' and 'guidelines' presented in Fig. 1. This coding supported the analysis of the emergence and mitigation of the challenges of knowledge differences and power imbalances, during co-production processes.

A second coding focused on the reasons why actors met challenges and/or successes to generate CLU knowledge and achieve sustainability. For example, when an interviewee stated that she did not adopt a change in resource management as planned during co-production, we checked whether this resulted from the 'rigid postures' of scientists and whether there were attempts at *deliberation* and *trust*. We analysed CLU based on our definition of these three concepts. We pay attention to manifestations of trust in co-produced knowledge (see Fig. 3), the extent of the inclusiveness in co-production, and the extent to which knowledge was deemed appropriate and feasible to be used. The effectiveness of sustainability implementation was not measured. As the cases focused on a qualitative analysis of co-production, we instead verified if transformative changes were in motion.

Finally, data from the cases were systematised per type of IPLC group, aiming to compare the specifics of co-production with different ILK systems. We then analysed the interplay between different challenges and guidelines with knowledge CLU and effectiveness and distilled principles and practices that led to co-production effectiveness.

4. Results

In this section, our analysis of the case studies is guided by focussing on the objective of this research, assessing the impacts of knowledge CLU on co-production effectiveness and the practices that help scientists to tackle knowledge differences and power imbalances. In all the cases, actors involved in co-production faced challenges related to knowledge differences and power imbalances. Furthermore, there was evidence in successful generation of knowledge CLU that these attributes yielded benefits for the adoption of changes in the management and governance

of natural resources that have enhanced sustainability (Table 2). In table two we outline the challenges and successes of actors in achieving credible, legitimate, usable, and effective knowledge for each case, which we explain in more detail thereafter. We consider the challenges related to knowledge differences and power imbalances and the guidelines used to tackle them. These guidelines are used to structure the discussion following the results section.

In **Case 1**: Selective solid waste collection program in Minas Gerais, Brazil, scientists co-produced this program by working separately with citizens, as practitioners avoided engagement with them. Practitioners disregarded part of the scientific and local knowledge that citizens had assessed as credible and usable. Despite the efforts of scientists to sensitize citizens to the program (e.g., citizen-to-citizen method; see Case 5), practitioners did not disclose and monitor the changes afterwards, making its adoption ineffective so far. In addition, the knowledge and values of citizens affected their inclination to adopt changes in their practice or not (Table 2).

Cases 2 and 3 are both 'science shop' projects, where universities fund and conduct sustainability research to address the demands of practitioners and citizens. In **Case 2**, New pocket parks in Amsterdam, The Netherlands, practitioners selected indicators to assess potential park locations, which scientists integrated into a GIS model at the city level. Scientists indicated which indicators the models could include, but practitioners had the final say in deciding on this. Practitioners validated these data on site and discussed future park management separately, with citizens. The effort to inform planning with knowledge that was usable to citizens was an important follow-up aimed at generating effective knowledge. In **Case 3**, Citizen management of a cultural stream in Driebergen, The Netherlands, scientists and practitioners co-produced an assessment with a small citizen group. They generated data that would help them update the management of a stream and its banks with Water Board practitioners. The project combined scientific knowledge with the knowledge developed by citizens who have managed and governed the stream for 25 years. Co-production resulted in knowledge that citizens found trustable and usable and that they are adopting in the revision of their management. However, the effectiveness of this adoption was not investigated and was recognised to be relatively fragile, as the practices of actors who were not involved in the process may influence falling water levels and poor stream water quality.



Fig. 2. Map with locations of the study areas where thirteen co-production case studies explored in the article were carried out.



Fig. 3. Co-production activities and/or their contexts. A: Case 1; B: Case 2; C: Case 3; D: Case 4; E: Case 5; F: Case 6; G: Case 7; H: Case 8; I: Case 9; J: Case 10; K: 11; L: 12; M: 13.

In **Case 4**, Salt Mining impacts on settlements in Harlingen, The Netherlands, citizens contested the insufficiency of the Dutch system to measure mining impacts (see also Meesters et al., 2022). After extensive inter and transdisciplinary dialogue with scientists, citizens proved the inability of the system to establish causality between mining activities and future environmental damage. Through campaigns based on the idea of fair mining, the citizens persuaded the Ministry of Affairs and the mining company to adopt a (co-produced) monitoring system that can capture this causality and establish accountability (Table 2). Both citizens and the Ministry consider this system more credible, usable, and effective than the previously used. The monitoring system is now required and feeds into a national process to enhance environmental security. In contrast, in **Case 5**, Sustainable agriculture in Kockelscheuer, Luxembourg, a pilot project promotes the production and consumption of regionally grown food with citizens and farmers, to support the national 'resilience-zero carbon health transition' program (Kebler et al., 2022). Scientists and practitioners advocate that agriculture should be widely adopted in urban and rural areas. When dividing the agricultural area of Luxembourg by its population, we find 2000 m² of arable land per citizen that would be sufficient for them to cultivate food. The process was intended to be informative, but citizens and farmers pushed for co-production to create meaningful education and training initiatives. Citizens considered the co-produced knowledge credible and usable for them, since it had meaning for their well-being and their environment. Most farmers recognised the ecological importance of the suggested changes but did not find them credible and usable for themselves, in view of the reduction of profit these changes could bring.

Additional cases focus on modern farmers, peasants and traditional communities, **Case 6**: Participatory agroecological research with peasants in São João Evangelista, Brazil stresses the need for creatively optimise project resources with rural communities to overcome geographical distances, see Cases 1, 7, 10 and 11 (Table 2). Also, as in these cases, scientists achieved a knowledge CLU in Case 6. This was

verified as the social groups involved indicated to find the knowledge co-produced trustable, inclusive, and appropriate to enhance sustainability in their contexts. This success was met by the facilitators of co-production understanding local knowledge and needs first, and then deciding with IPLCs about scientific knowledge that was relevant for them, and by them reshaping project goals to align with these needs. The adoption of co-produced knowledge by peasants has taken place slowly. Although some of them argue that this is due to (youth) labour evasion and low income, others seem to increasingly regard their work as a hobby rather than as a full-time occupation. However, since the project lasted one year until now, more changes might still occur during its subsequent year of duration.

In **Case 7**, The community worked on co-producing sustainable practices in Siribinha, Brazil (see also Ludwig and El-Hani, 2020). Despite respectful dialogues and the treatment of local knowledge, scientists were not clear enough about research goals, (personal) motivations and in the benefits that fishers would have by participating in co-production. As fishers did not fully grasp the former, it limited their ability to co-create common goals or manifest their thinking about the process. Additionally, their focus on collecting objective data and local knowledge sometimes prevented them from including local concerns. This approach led many fishers to not see the value in participating in the project. Scientists did not know how to manage the situation and deal with the hierarchical relation that emerged, and the demotivation of fishers, limiting their participation in co-production. This constrained the generation of CLU. While CLU was achieved in co-produced practices, only few fishers of the community shared this view.

In **Case 8**, Making grape marc fertilizer in Schwebbsange, Luxembourg, scientists and winegrowers co-produced a new fertilizer technology based on composting grape marc. Scientists established and maintained reciprocal engagement and trust with winegrowers by including local knowledge in the process of co-production and supporting winegrowers to adopt change - cf. Cases 2, 4, 6, 9–12.

Table 2

*Challenges and * *successes that actors met in each case to achieve credible, legitimate, usable, and effective knowledge, in view of challenges related to knowledge differences and power imbalances and of guidelines used to tackle them.

Challenges	Rigid theories/postures		Dominant methodological practices		Limiting time and money resources		Outcoming effectiveness
Guidelines Case	Reciprocal engagement	Flexibility to reshape	Mutual understanding	Deliberation	Trust	Creativity	Sustainability changes
<i>Citizens and Local knowledge (LK)</i>							
1) <i>Establish a selective (solid waste) collection programme</i>	* *Scientists interacted with citizens as equals but practitioners did not. *Practitioners avoided contact/ being confronted with citizen demands; and only partially accounted for the knowledge co-produced with them	*The lack of local social mobilization and political engagement required scientists to co-produce an assessment of problems/solutions with citizens and do planning with practitioners separately	* *Knowledge exchange and 'inheritance' between scientists and citizens were enabled by 1) the use of non-technical language; 2) by creating symmetrical relations and 3) through raising awareness and sensitization	*Practitioners disregarded key points which scientists asked them to consider (e.g. program monitoring and citizens' need of garbage containers in poor areas).	*Practitioners lack funds and time to divulge and monitor the program and as a result it doesn't get done and citizens lose trust in it	* *Scientists' creative solutions contributed to the acceptance of the program (e.g. educative traffic/market interventions; games; electronics/oil collection points). *Practitioners did not divulge these creative aspects of the program sufficiently.	* *Citizens adopted the program (when they were aware of it or found it relevant) or * Waste management/ governance changed little because of deeply rooted values (faith in God's will), disbelief in its relevance and lack of time.
2) <i>Searching for new pocket parks in Amsterdam</i>	* *Scientists and practitioners interacted as equals. *Practitioners engaged separately with scientists and citizens	* *Scientists and practitioners co-produced GIS indicators that could support the selection of locations to introduce small parks in urban areas of Amsterdam. *The complexity of modelling meant that programming was the exclusive work of scientists	* *Range and criteria for the indicators were discussed based on suggestions from the scientists; but the practitioners had the final say on the indicators used, based on their practical perceptions of the locations. *LK was only brought in through the practitioners during the modelling.	* *Scientists and practitioners shared power to co-produce indicators. *Citizens were not involved in the assessment. They *participated in the validation of the model while selecting the top locations and in planning their implementation	* *Trust was cultivated by practitioners with scientists (during the assessment) and citizens (during the planning)	* *Practitioners involved citizens in the assessment of locations. *When scientists could not visit locations due to COVID, practitioners decided to visit and select locations only with citizens and through online conferences.	* *Practitioners are creating/managing parks in the chosen locations with citizens *without the participation of scientists. *Scientists do not know how these parks are managed
3) <i>Updating the management of a cultural stream by citizens</i>	* *Representatives of all local actors actively involved in co-production	* *Research questions, goals, and methods (i.e., the content of questionnaires) were reshaped with citizens. Scientific measurements were linked to the knowledge of practitioners and the experience of the citizen in the history / practice of management.	* *All actors inherited knowledge from each other based on dialogue. A joint understanding to make decisions focused on the common goal of sustainable management. Citizens with a minority view (e.g., we should cut most trees) were not represented in decisions	*While evaluating management/ governance options, citizens sometimes wanted to lead decisions. Scientists negotiated with them, stressing their scientific independence	* *Trust was motivated by scientists and practitioners who valued citizen practices/ cultural heritage and listening to them	*The scientists did not participate in planning to update the management of the stream. *Citizens and practitioners took responsibility for this and made planning decisions based on the previous advice of the scientists.	* *The management plan is being revised by practitioners and citizens. *It remains uncertain how many citizens will actually adopt the planning and whether the water levels and quality will change.
4) <i>Avoiding harm from salt mining</i>	* *The citizens' status/lobbying campaign and the regional history of protests for better mining impacts measurements made the company engage/change	* *Via inter- and transdisciplinarity, citizens and scientists discredited and replaced the measurement system adopted in Dutch regulations to better account for mining impacts (soil	* *The co-produced 'Security Framework for the City' was based on a collective trust in scientific knowledge, a shared valuation of cultural heritage sites and	* *Citizens persuaded Ministry officials to allow the use of their framework arguing its validity/ usefulness as a pilot framework to guide mining licenses	* *Trust of the Ministry and the company was enabled by reciprocal trust among co-production actors, and since citizens wished for a fair procedure but did not pose a	* *Citizen creativity in lobbying and participation in the media enabled change (i.e., in proposing a pilot-frame/inter-/transdisciplinary learning/ lobbying) for an adjusted mandate	* *Increased safety (e.g. mining stops if soil subsidence extends the prognosis). *Other citizen groups draw on the frame, and the procedure is presented as exemplary for other

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Table 2 (continued)

Challenges	Rigid theories/postures		Dominant methodological practices		Limiting time and money resources		Outcoming effectiveness
		subsidence/ house damage/)	openness to dialogue.	*The audit committee did not engage due to its commitment to stay objective *Deliberation occurred, but is expected to evolve towards strongly implement/ monitor changes in the future	significant threat/ opposition to mining	for the audit committee	cases in the Netherlands
5) 2000 m ² for sustainable agriculture	* *Actors increasingly engaged to see meaning in changing their lives/being the precursors of the national transition	*Dialogues involved tensions (e.g., when actors felt criticized in their practices) *but these were managed and informed practice reshaping.	* *Growing awareness, problematizing / creating a solution at a demonstrative site; common goals on health/ sustainability united actors to evaluate/plan transition diets/ pathways		* *Trust was created/ maintained with efforts towards listening to others, inheriting knowledge, and respecting differences/ values before tensions	* *Actors co-created ideas to further the group and national transition, i.e., to engage young people, via social media; adopt community gardens; involve family/friends	* *Some citizens/ farmers are adopting organic horticulture and diets based regionally and seasonally and low in dairy/meat. *Conventional farmers see more profit in not changing to (certified) organic agriculture but are adopting agroecological techniques
Farmers and traditional communities, and LK							
6) Advancement of participatory research oriented to sustainability with agroecology	*Peasants' low education/political neglect required scientists to "stress research benefits to attract them. *Some peasants did not engage as the project involved policy practitioners who they do not trust	* *Scientists were flexible to translate technical terms into a simple language; address social/ economic/ environmental sustainability; and reframe methods before the temporalities of citizens/farmers	* *Scientists understood LK/ problems/needs with peasants to mobilize agroecological knowledge of peasants is valued as valid and relevant. Lab analysis added precision to deliberation	* *Knowledge exchange on problems/ current solutions followed by mutual deliberation/ practice demonstrations made co-production valid/relevant for peasants	* *A friendly relationship forged trust and participation.	* *Technical visits to peasants; spelling booklets and knowledge exchange in the market optimized co-production	* *Some peasants enhanced the productivity and diversity of their already sustainable practices, beginning to produce seedlings/ natural fertilizers and pesticides. *Project deadline and lack of peasant funds/labour limited changes
7) Knowledge and power in transdisciplinary research	* *Scientists expressed respect for LK/routines and were introduced by a locally trusted scientist; *but did not explain research goals in a way fishers understood and became motivated	* *Scientists drew on local nomenclature and valued LK, but "dominated co-production in the process (not making agreements on methods/goals). Some locals felt motivated to participate but many others did not.	* *Scientists mirrored LK/ taxonomies with scientific correspondences, to communicate with locals; *but did not deliberate enough why	* *Often, agreement on how to change practices flew spontaneously. When it did not, *scientists avoided debate/ impose SK; to remain neutral	* *Scientists did not have the ability to discuss power imbalances openly. This broke the trust of many fishers in co-production, Interpersonal skills helped gain/regain trust of the community	*The Brazilian political context led to the reduction of funds and time for fieldwork creating focus on gathering data	*Only a fraction of the community stayed involved and motivated. *Those that remained are using the materials created and adapting practices (e.g., to conserve fishes/birds and cleaning beaches/ mangroves from rubbish)
8) CO ₂ MPOSITiv Grape marc - from underrated waste to premium fertilizer	* *Winegrowers had the impetus to adopt the program/ project; established reciprocal engagement of practitioners/ scientists.	* *Knowledge inheritance and efforts from scientists/ practitioners to negotiate composting license with the government enabled co-production	* *Despite providing technical support, *it was hard to encourage the commitment of winegrowers to composting (it takes weeks, with repeated tasks every 2–3 days) * *Scientists worked alongside the fishermen to learn about their practices and also	* *Non-hierarchical decisions enabled actors to create the (practical) knowledge that is being used by other actors	* *Practitioners stimulated trust by persisting in helping winegrowers install composting in their proximity and obtaining legal approval for it	* *Creativity was key to inventing a fertilizer using grape marc as a raw material	* *Winegrowers are producing fertilizer / increasing soil carbon storage. Composting is attracting winegrowers nationally. *Compliance with legal requirements remains a challenge
9) Reducing turtle bycatch with small-scale fisheries	*Scientists created engagement despite actors' different priorities (avoid turtle bycatch/	* *Flexibility to reshape postures, practices, and law was a common goal given the potential		* *Deliberation on management/ governance options included	* *Scientists enabled trust by moderating dialogue and making explicit	* *The solution adopted was to provide air spaces for turtles in the nets; however, its	* *Most fishers/ managers/ practitioners are using the co-produced

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Table 2 (continued)

Challenges	Rigid theories/postures		Dominant methodological practices		Limiting time and money resources		Outcoming effectiveness
	maintain fishing rates high) by working both together and independently	for gains if the research results led to regulation, practices that maintained livelihood/profits and were actually adopted	interacted with the fisheries managers to find a mutual understanding of the problem and possible solutions.	all knowledge holders and was ultimately based on solution feasibility / use in conjunction with regulations.	that the sustainability common goal could benefit all, if all cooperated and bridged knowledges	impact was not measured. *Bycatch still happens, but turtles are more likely to survive	knowledge. Compliance is enforced by regulations and more frequent net checks (e.g., in reproduction seasons)
Indigenous peoples and Indigenous knowledge (IK)							
10) <i>Legitimacy and effectiveness of co-production to mitigate climate change with Amazon Kaxinawás</i>	* *Practitioners established a fluid intercultural relationship with Kaxinawás by showing respect for/interest in understanding IK/ context/culture	*When translating IK mobilized with Kaxinawás, practitioners framed it to match scientific classification/ analysis; generating reports/maps that did not include IK as locals recognize it	* * Practitioners drew on IK classifications to weave soil classes with them and reflect on changes with them *Practitioners did not respond to the resistance of Kaxinawás to their form of translating IK;	* *Mutual reflection on changes/ common goals (biocultural diversity) and the feasibility of changes' feasibility (i.e., ecological state; local income) generated a planning the locals found valid/relevant	* *Reciprocal trust between practitioners and Kaxinawás optimized co-production, despite time/ money constraints (i.e., remoteness of the area)	* *Practitioners' creativity of practitioners (participating in local practices) optimized understanding of problems and solutions. Scientists managed *temporality differences by adjusting the methods and recalling their timeframe	* *Knowledge agents supported Kaxinawás to adopt practices/rules (i.e., agroforestry; agriculture focused on deforested areas). *Population growth/ neighbours' practices still pressure biodiversity/ climate
11) <i>Reinforcing traditional food and medicinal practices with Amazon Kaxinawás</i>	* *Scientists created a 'reciprocal' commitment by being friendly and respectful of IK; children also engaged / learned	*The vast experience of the ethnobotany team helped weave knowledge correspondences/ differences/goals and adapt to the temporality of IPs	* *Scientists departed from dialogue on local nomenclature indicators and weaved them with scientific taxonomies, via mutual understanding and knowledge inheritance.	* *All co-production processes and decisions were made with Kaxinawás. *Women engaged little in this case, as it was guided by male researchers. Man represented them	* *Co-production departed from creating trust with Kaxinawás (by being introduced by practitioners they trusted in; respecting local routines)	* *Practitioners optimized (split) the teamwork to assess/plan plants production/ consumption; created spelling booklets/and interactive games with the identified plants	*More changes could have been mediated if the area had not been so remote. * *Changes included new crops, revalorization of IK/identity/ practices that were viable in cropped/ forested areas
12) <i>Conserving ecosystem services, agrobiodiversity, and health with Amazon Puyanawás</i>	* *Practitioners created engagement by agreeing with leaders to use a different methodology than the one they planned *as they preferred to transfer the co-produced knowledge to other Puyanawa	* *Practitioners reshaped methods before local: political dynamics of leaders); focus on cassava trade; Indigenous temporality. Locals adapted IK/values/ goals to change before gain of awareness/learning in demonstration areas	* *Practitioners relied on interdisciplinary/ experiential knowledge (of previous co-production with IP) and Puyanawas *were already empowered (by previous projects), leading to dialogue based on IK	* *Deliberation was facilitated by Puyanawas, who were interested in sustainability / preservation of traditional practices (common goal); REDD + supports	* *Trust was developed by practitioners with respect to IK/governance and being introduced by practitioners, Puyanawas trusted	* *Actors raised cassava/ flour production, liberating labour to diverse agriculture; created community gardens; re-valored/ rescued medicinal IK	* *Local knowledge agents and schools/ youth are supporting the adoption of changes and re-signifying agricultural practices. *Urban food consumption remains strong
13) <i>Wildlife management with Airumakuchis in the Colombian Amazon</i>	* *Engagement was obtained by scientists being introduced by people the locals trust and ensuring that IL/ expectations/ needs/practices are included throughout the process	* *Scientists reshaped the conceptual/ methodological premises to support the initiative of local leaders/ researchers to co-steer the process; and supported the setup of the 'Hunting Association of Airumakuchis'.	* *actors manage differences and created new knowledge/ capacities *Despite intracommunal conflicts (about the access to/ benefits from the project and the perception of appropriation of resources by associated members),	* * supporting the sustainable management and governance of wildlife secures an important regional food resource *Scientists dealt with the local trade of game meat (which contradicts conservation science/ Colombian laws)	* *Scientists frequent site visits (2-3 times/year) and transparent communication ultimately helped built trust with Airumakuchis *Despite efforts to build engagement, Airumakuchis distrusted scientists (thinking they wanted to exploit them/ their resources).	*Budget limitations stimulated new ideas - e.g., local leaders guide monthly workshops with other Airumakuchi members) and get compensation for this work. Updates have been sent through social networks (postings/videos).	*Documentation and valorisation of IK/practices that maintain access to wildlife resources are stimulating Airumakuchis to commit more to local rules and change management practices. The hunting association has strengthened the representativeness of hunters before public authorities

Winegrowers considered this knowledge credible, usable, and resultant of legitimate iterative processes. Winegrowers are also increasing the storage of soil organic carbon, and the generated knowledge inspires other winegrowers, evidencing co-production effectiveness. In **Case 9**, Reducing turtle bycatch in small-scale fisheries in Ontario, Canada, scientists, fishers, and fishery managers collaborated to minimise turtle bycatch (see also [Larocque et al., 2020](#)). They reached mutual understanding about bycatch while allowing fishers to continue their activities. Co-production efforts were felt as fair (legitimate) by the actors involved and led to a solution that was considered credible and usable by them, cf. Cases 3–6, 8, and 10–13. The adoption of this solution in practice was mediated through the enforcement of government regulations and conservation officers, as well as by the education of fishers and managers. Nevertheless, the effectiveness of this solution to enhance sustainability – in this case, by avoiding turtle bycatch – seemed to be questionable ([Table 2](#)).

In the cases involving Indigenous peoples, scientists and practitioners stressed the need to adapt to local processes of dialogue, deliberation, and decision-making (cf. Cases 6, 7). Respecting local norms and dynamics required scientists to put effort into establishing agreements with Indigenous leaderships. Distinct local temporalities were perceived to slow down scientific production and to be managed by interspersing different types of data collection (e.g., workshop activities and interviews) to optimise time (cf. [Matuk et al., 2020a](#)). While Indigenous peoples, scientists and practitioners could speak in a shared language, the latter learned and used the local language and classification the former employed to identify soils, fauna, and land management indicators to plan sustainability based on Indigenous knowledge cf. Cases 1, 6, 7.

Case 10 deals with the co-production of climate change mitigation in the Indigenous Land of *Kaxinawá* Nova Olinda, Brazil (see also [Matuk et al., 2020b](#)). Here, scientists and practitioners used IK-based oral communication and considered local needs. For this reason, *Kaxinawás* considered that the knowledge generated with them had CLU. They also adopted many changes (cf. Cases 11, 12). Almost all *Kaxinawás* quit cattle grazing (a non-Indigenous practice that damaged crops) to focus on game meat consumption. They also adopted rotative hunting practice to avoid increasing the pressure of hunting over the biodiversity of their fauna. Such changes have been considered effective in improving sustainability. However, practitioners also produced graphic materials (i.e., reports and maps) that represented Indigenous knowledge in ways that were unrecognisable and unusable to *Kaxinawás*. Although the former alleged that these materials were meant to be presented for other scientists, this lack of recognition indicates that these materials involved knowledge extraction (see also [Matuk et al., 2020b](#)). Additionally, *Kaxinawás* expressed that it would have been helpful for themselves to use these materials to transfer the co-produced knowledge to community members who did not participate in co-production. **Case 11** was also carried out with these *Kaxinawás*. Here, a different group of scientists planned how to support them in rescuing food and medicinal practices and improving sustainability (see [Lanza et al., 2018](#)). Although power issues did not emerge, this case was more aimed at documenting Indigenous knowledge and providing some support to locals in rescuing traditional practices. The challenge encountered was that although some *Kaxinawás* adopted changes to improve sustainability, the consumption of urban food and the internal migration of youth to study and work in the city limited the adoption of this direction.

Case 12 is about the preservation of ecosystem services, agro-biodiversity and health in the indigenous *Puyanawa* land, Brazil (see [Amaral et al., 2021](#)). In this case, practitioners and scientists applied a REDD+ policy while jointly searching with *Puyanawas* on how to enhance local sustainability and Indigenous health. Co-production respected *Puyanawa* norms of engagement. Leaders preferred to co-produce knowledge with the former alone and to transfer it to the rest of the community members later on. While this preference centralised the co-production decisions on leaders, to the detriment of the inclusion

of other community members in these decisions, the co-production facilitators trained leaders as ‘knowledge agents’ to do this transfer in a way that could be adapted to the needs of different community members (cf. Cases 11–13). Although these arrangements were made, the challenge of adopting changes remained: *Puyanawas’* focus on cassava trade and is already widely used to consume processed foods imported into the community (cf. Case 10). This leaves little space for traditional polyculture and changing diets to minimize the consumption of urban food and the health issues that they have (e.g., obesity and diabetes). While the *Puyanawa* leaders considered the knowledge generated to have CLU, the exclusion of other community members from the process prevented them from being legitimately included. Ultimately, some members manifested to find meaning in the knowledge transferred to them, to improve their practices and the conservation of their livelihoods in their context. So, they consider this knowledge credible and usable. However, those *Puyanawas* who value more to focus on the cassava trade and the consumption of urban food do not see usability in this knowledge for themselves.

Finally, **Case 13**: Wildlife management with *Airumakuchis* in the Colombian Amazon covers challenges related to trade and consumption of game meat and the loss of traditional hunting practices in an Indigenous territory (see [Hernández-Vélez et al., 2020](#); [Krause and Tilker, 2022](#)). Scientists dealt with this practice (usually considered unsustainable) by studying how it contributes to livelihoods and diets and supporting local approaches for sustainable management and governance. Scientists also found creative strategies to monitor fauna and harvest rates ([Table 2](#)). The inclusion of *Airumakuchis* in collecting and applying the obtained data generated knowledge CLU for them and led to effective outcomes.

5. Discussion and conclusions

The application of our conceptual framework to our 13 cases shows that challenges of knowledge differences and power imbalances arise during co-production processes in an intertwined manner. As we had argued, these challenges are indeed triggered to emerge when scientists and practitioners adopt rigid theories, postures and dominant practices during co-production (cf. [Chambers et al., 2021](#); [Matuk et al., 2020a](#); [Turnhout et al., 2020](#)). Moreover, when these triggers are present, they tend to reduce the ability of these actors to deal with the time and money limitations of co-production projects (c.f. [Evans, 2006](#); [Matuk et al., 2019, 2020a](#)). Likewise, the guidelines ‘reciprocal engagement and flexibility to reshape’, ‘mutual understanding and deliberation’, and ‘trust and creativity’ enforce each other. Using one of them enables the other and helps co-production actors to work collaboratively to achieve knowledge CLU successfully.

Overall, knowledge CLU and co-production effectiveness are achieved in co-production processes by means of sharing of power between groups of scientists and practitioners and groups of IPLCs (cf. [Matuk et al., 2020a](#)), independently of the research field and methods used for participation. The cases show that sharing of power helps these actors reshape pre-given methods and frameworks to fit the co-production context e.g. type of the social group, the knowledge involved, the context specifics etc. By doing so, they get to better understand the knowledge and values of different actors and to align or deliberate on knowledge differences (cf. [Lélé and Norgaard, 2005](#); [Clark et al., 2011](#); [Ingold, 2011](#); [Tengö et al., 2017](#); [Klenk, 2018](#)). This helps them identify knowledge that is credible and usable in the situated context of co-production that goes beyond their previous conceptualizations of the said. Their understandings are then based on achieving ecological sustainability in practice, in each socioecological context (cf. [Matuk, 2020](#)).

Additionally, the challenges faced during co-production vary depending on the context of co-production itself, on the group of IPLCs, and on the ILK involved. This leads to differences regarding which knowledge content they find credible, legitimate, and usable (cf. [Wheeler and Root-Bernstein, 2020](#); [Matuk, 2020](#)). It is important to

distinguish that collaborating successfully with Indigenous peoples indispensably requires efforts to establish trust and develop agreements that respect local socio-political and temporal dynamics (Matuk, 2020), interdisciplinary and holistic thinking, and needs - Case 10–13 (cf. Lelé and Norgaard, 2005; Matuk et al., 2020b). Nonetheless, our data show that these agreements are also needed when co-producing with citizens, peasants, and traditional communities, especially in the Global South (Cases 1, 6, 7). In addition, co-production with actors from the Global North requires an emphasis on creating bonds of trust, agreements on goals and methods, and acquaintance with knowledge, worldviews, values, and needs of social groups. These agreements become more challenging as the actors involved in co-production often belong to different cultural backgrounds. They often hold different epistemologies, priorities, interests and goals. The key to transpose knowledge differences then, is to understand environmental problems in their social-ecological contexts. This requires navigating possible sustainable transformative changes with IPLCs, in ways that are feasible to be endorsed and executed in practice.

Below, we synthesise the insights we gained from our cases with a focus on the overarching objective of advancing the effectiveness of co-production in delivering sustainability transformative changes. Scientists, practitioners, and IPLCs working with co-production in other cases can use these insights as a set of effective principles and practices.

- **To generate knowledge CLU, scientists and practitioners need to empower IPLCs, by enabling the creation of a reciprocal engagement and trust with them.**

When scientists and practitioners leave their 'rigid postures' and 'dominant practices' and share power with IPLCs in unbiased and friendly ways, this may contribute to higher chances of success (check Table 2). Generating an equal playing field for different knowledge systems contributes to inclusive ways of doing assessment and planning that promote sustainable outcomes (Díaz et al., 2015; Hill et al., 2020). The former can do so by being 'reflexive' to improve the process (cf. Klenk and Mehaan, 2017) and 'flexible' to shape forms of engagement, methods, and ideas (Chambers et al., 2022) – e.g., Cases 4–6 and 8–13. When they make space and give voice to IPLCs, they motivate participation. They, moreover, co-steer co-production by listening, reflecting together and giving credit to IPLCs. This guideline brings in reciprocity, optimises the time and money available, and triggers other elements of guidelines that tackle knowledge differences and power imbalances (cf. Matuk, 2020). By doing so, it generates knowledge CLU, which IPLCs are more likely to use in practice. Oppositely, when scientists and practitioners remain rigid, objective and exclude IPLCs from decisions, the "collaboration" stays conceptual and IPLCs might not engage (cf. Meehan et al., 2018) (Case 7). However, IPLCs do not remain passive to the former's approach - e.g., they may not be fully open to engaging themselves or using the knowledge generated in the process (Cases 1 and 5).

- **CLU, and effectiveness are raised by involving IPLCs in the co-production of both environmental assessment and planning processes.**

Assessments co-produced by one group tend to be insufficiently legitimate and usable for another group (cf. Nadasdy, 2003; Ayana et al., 2015). In Case 2, citizens did not participate in the co-producing assessment and planning. In Cases 2 and 3, scientists only participated in the assessment and not in the planning. However, the lack of scientists participating in the planning also prevented them from validating knowledge and witnessing co-production effectiveness. Despite these pitfalls, these cases importantly indicate an increasing use of co-production in Citizen Science and in other fields that address citizens (cf. Ottinger, 2009; Rosen, and Painter, 2019), to include citizens and their knowledge more fairly in the decisions that affect their lives.

- **Scientists and practitioners need to use more graphical materials (e.g., maps, reports, and booklets) in addition to the oral communication they use with IPLCs to systematise and divulge co-produced knowledge for both scientific, policy, and social audiences.**

Case 10 illustrates that co-production can be mediated by oral communication of practitioners with Indigenous peoples based on the latter classification nomenclatures. This communication can result in knowledge that is considered legitimate and usable by Indigenous people. However, it can simultaneously involve the production of graphical reports and documents that show knowledge extraction. This extraction could have been prevented if practitioners would have responded to the resistance of *Kaxinawás* against their way of framing their knowledge to match scientific classifications (see also Matuk et al., 2000a). Doing so, would have allowed them to produce materials that were legitimate and usable also for *Kaxinawás* and not solely for themselves. In addition, we saw the use of graphic materials in co-production with Southern peasants, traditional communities, and Indigenous peoples (Cases 1, 7, 10 and 13). These materials help transmit knowledge exchanged and co-produced with IPLCs for community members who did not participate in co-production. Furthermore, some Indigenous peoples (Case 12 and 13) are seeking to rescue or support the wider adoption of traditional knowledge that is in the process of being abandoned by most locals. This knowledge can be registered graphically to help prevent this loss. In sum, graphic materials are a useful means of documenting knowledge and supporting changes.

- **Actors sorting out knowledge differences need to deliberate on differences in an explicit manner, which requires facing divergences, focusing on common goals, and/or shifting values.**

As Haraway (2016, p. 1) states, actors must 'stay with the trouble' of differences in order to co-produce meaningful results. They do that, by reconciling differences - e.g., on conceptualisation of methods (Cases 4, 12) and solutions (Cases 5, 12–13) - or by making concessions that benefit the majority involved in (e.g., Cases 3, 4). In our cases, the actors 'mutually understood' and unravelled the reasons behind the differences that emerged. Usually, this took place during demonstrations of practices and while developing inter- and transdisciplinary collaborations. The actors generated new knowledge on management and governance strategies (Cases 8, 9, 12, 13) by 'inheriting knowledge' from each other (cf. Klenk, 2018). This resulted in shifting worldviews and values (e.g., Cases 4, 10) that crucially sensitised actors to deliberate on 'common goals' and fuelled their commitment to change practices (cf. Kenter, 2018; Matuk et al., 2020a).

- **Strengthening the effectiveness of co-production requires involving more broadly in co-production actors from various spatial scales and sectors whose status quo of practices and institutions influence the ecosystems that IPLCs manage.** Environmental conservation, climate change, and biodiversity loss involve actors at different scales whose practices may affect the areas addressed with co-production. However, co-production usually includes actors located in local or regional areas – e.g., Cases 4, 5, 7, 8–10 and 12. The participation of external actors in these areas could enhance the change in areas addressed with co-production, incentivizing these actors to also adopt changes that prevent them from affecting IPLCs' ecosystems (cf. Matuk, 2020; Chambers et al., 2022). Additionally, the participation of external actors could lead them to adopt changes in their practices that would support IPLCs to improve the sustainability of their practices (Case 5). Especially in Case 4, actors engaged in co-production in a way that generated changes in both social, policy, and entrepreneurial practices. Cases 5 and 9, in turn, demonstrate that changes can be limited when the goal of maintaining profits or existing practices is expected to lead to enhancing

sustainability. This is made clear through examples of conventional farmers who preferred to stick to organic agriculture and fishers who remained using nets that cause bycatch. Furthermore, despite the fact that Indigenous people generally focus on subsistence, some of these peoples focus on trade, restricting the adoption of sustainability changes (Case 12, 13). These cases call for transformations in the *status quo* of science, policy, and social practices to support IPLCs enhancing sustainability. They also call for technologies that ground economic profit in sustainability (cf. Chambers et al., 2021). However, these transformations must carefully consider the dangers of commodifying the resources and knowledge involved (cf. Buscher and Fletcher, 2020).

- **While generating knowledge legitimacy and usability leads to greater credibility and effectiveness, ensuring effectiveness requires co-production projects to extend their time, resources, and goals towards consolidating changes.**

Scientists and practitioners generated legitimate knowledge when they provide opportunities for IPLCs to take part in co-production decisions. As these decisions bridge elements of scientific knowledge and ILK that are relevant for needs and contexts of IPLCs, the legitimacy of this knowledge is interdependent with its usability (Cases 4 and 6–13). Legitimacy is also required to address knowledge credibility and usability and therefore a key quality of co-production. Moreover, legitimacy works intertwined with effectiveness e.g., together, ILK and scientific knowledge enhance sustainability in its social, economic, and ecological dimensions (Cases 2, 3, 5, 7, 8, 10–13) (cf. Folke et al., 2016). However, the changes adopted indicate the potential rather than ensuring sustainability. We saw our cases neither analyse the long-term effects of changes nor measure the enhancement of sustainability.

In conclusion, challenges related to knowledge differences and power imbalances vary by group and context. Nonetheless, knowledge CLU and effectiveness are promoted simultaneously, mainly when co-production empowers society via fair and respectful processes. These processes should treat IPLCs and ILK in a non-hierarchical manner and generate knowledge that is legitimate to both scientists, practitioners and society. To do so, the holders of scientific knowledge and ILK unravel their epistemological and ontological differences by reciprocally reshaping the methods, knowledge, worldviews and practices involved in co-production. An attentive, proactive, enlightening, and friendly attitude towards IPLCs greatly supports this. In general, knowledge that different actors find credible and usable is often considered legitimate and effective. Knowledge that is credible, usable, and effective can be the result of a process that does not directly include all IPLCs' community members and that is partially legitimate. Therefore, effectiveness is relatively independent of legitimacy (cf. Cash et al., 2003) if it succeeds in generating knowledge that is credible and usable to address the specific needs and context of the actors who will use this knowledge to improve sustainability in their contexts. Legitimacy, however, is the key quality of co-production and the means, we conclude, to address knowledge credibility and usability. Rather than focusing on scientific criteria to validate knowledge CLU, actors should focus on criteria that are situated in the context of co-production and address common goals that link sustainability and livelihoods.

Two shifts are urgently needed to advance co-production effectiveness. First, elevating society before science-policy interfaces to create legitimate co-production processes. This equal treatment of different knowledge systems will generate credible, usable, and effective knowledge. Efforts to be flexible and accept IPLCs' ways of validating knowledge CLU and effectiveness are of the essence. Second, scientists need to shift the focus from co-production conceptualization to its practice, and from idealizing ways of categorizing knowledge that bears CLU to identifying knowledge that is feasible to be adopted and to enhance ecological sustainability in each context of management and governance practices. A better understanding of the effect of the changes

adopted by IPLCs on ecological sustainability is lacking. There is also a lack of broader inclusion of actors whose practices affect these changes. This shows that a sustainable future on Earth calls for social-science-policy interfaces, with a deeper collaboration among social scientists (who study co-production practices), natural scientists (who study ecological sustainability) and IPLCs (who traditionally transform resource management and governance).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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Paper II



REVIEW

Indigenous and local knowledge inclusion in forest fauna research: A systematic review in the tropics

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Abstract Indigenous and Local Knowledge (ILK) is an expression of biocultural diversity and is vital for inclusive and sustainable forest management and epistemic justice. We examine how researchers studying tropical forest fauna engage with ILK and the Indigenous Peoples and Local Communities (IPLC) who are holders of this knowledge. We conducted a systematic review of 62 articles that focus on tropical forest fauna and ILK. We used a category-based quantitative and qualitative content analysis on the types of forest fauna studied and how research engages with, defines and represents ILK. We also evaluated the varied forms of inclusion of IPLC in the research. We find that less than half of the reviewed studies (25) explicitly define ILK, and only four studies reported including IPLC in the decision-making processes. Our findings reveal that science has not fully acknowledged and understood the depth of ILK and we suggest ways to address this in future research.

Keywords Biocultural diversity · Indigenous and local knowledge · Knowledge co-production · Tropical forest fauna

INTRODUCTION

The role and use of forest fauna in tropical forest ecosystems are increasingly prioritised in research (Krause and Tilker 2022). Tropical forests hold more than half of the known vertebrate species (Pillay et al. 2022) and are

crucial for regulating global environmental processes (Khanna et al. 2017; Alves de Oliveira et al. 2021; Boulton et al. 2022; Smith et al. 2023; Flores et al. 2024). Because of their ecological importance, tropical forests have been a focus of ecological, conservation and environmental research, but such research has often obscured that people inhabited and thus shaped these ecosystems for millennia, acquiring profound and sophisticated locally adapted knowledges about these ecosystems and how to use and manage the floral, faunal and other types of material and immaterial resources (Cummings and Read 2016; Marin et al. 2017; Aswani et al. 2018; Paneque-Gálvez et al. 2018; van Vliet et al. 2018; Fonseca-Cepeda et al. 2019; Pironon et al. 2024). These vast knowledge systems and epistemologies can be approached and defined using diverse terminologies. To best capture this diversity, we draw on the broad and inclusive term Indigenous and Local Knowledge (ILK), which was defined by Diaz et al. (2015, p.13) in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework as “A cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. It is also referred to by other terms such as Indigenous, local or traditional knowledge, traditional ecological/environmental knowledge (TEK), farmers’ or fishers’ knowledge, ethnoscience, Indigenous science, folk science”. This inclusive definition highlights the sophisticated knowledge of Indigenous and Local Communities (IPLC) that inform and shape the diverse strategies of IPLC to manage, use and interact with the living and non-living entities in the biosphere.

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Given the growing recognition of ILK's importance in biodiversity and conservation research, we carried out a systematic review of how ILK is recognised, conceptualised and defined by researchers working on tropical forest fauna. Moreover, through this review, we want to highlight why it is important for researchers and policymakers to understand that ILK is a crucial biocultural and social-ecological element which is fundamental for epistemic justice and sustainable forest fauna management. Biocultural diversity as a term and framework refers to the variety of life in all its forms: biological, cultural and linguistic, which are interconnected (and possibly coevolved) within a complex socioecological adaptive system that includes the diversity of human cultures and languages (Maffi 2007). This diversity does not exist independently or in isolation; instead, it engages with and influences each other in complex ways. This biocultural dimension of the social-ecological systems (SES) contains diverse knowledge systems, with sophisticated ecological knowledges and management practices historically evolving from independent livelihoods and customary interactions of IPLC with tropical forest fauna (Berkes 2017).

Based on our own research, we approach ILK as a form of knowledge of self-identified individuals and communities, who maintain intergenerational connections to places and nature through their livelihood practices, cultural identity, worldviews, institutions and ecological knowledge (Watson et al. 2019; Krause et al. 2020). We also understand ILK as situated knowledges (Nazarea 1999) and as part of local and informal institutions and norms that shape SES, where people and nature, for instance forests, are intricately linked through direct, indirect and spiritual connections (Berkes et al. 2000; Cajete 2020).

Historically, ILK has been suppressed by states and religious institutions and has been undervalued and underrepresented in scientific studies (Jacobs 2025). As a result of numerous historical reconfigurations, colonisation, persistent colonial practices and rapid social and environmental changes, ILK is increasingly being lost. There is evidence that this loss of ILK follows a general trend that correlates with forest degradation and deforestation, as well as the loss of local languages (Chiblow and Meighan 2022) and the disappearance of entire ethnicities (Aswani et al. 2018; Hua et al. 2019; Cámara-Leret and Bascompte 2021; Bromham et al. 2022). Moreover, the oral intergenerational transmission of ILK has been severely disrupted by broadly expanded colonial structures at the development-education-religion link (Mignolo 2011; Chilisa 2017). Concrete and horrifying examples include religious boarding schools, e.g. Canada, USA (Holiday 2025) and Colombia (Zapata 2008), which led to a severe decline in the relationship between different generations and the transmission of knowledge between elders and young people (Callison

et al. 2016). Even though current research is approaching ILK as resilient systems that can also generate new knowledge (Berkes et al. 2000; Gómez-Baggethun and Reyes-García, 2013; Jacobs 2025), it is crucial to recognise that the threats and losses that these systems and their holders have been experiencing for centuries are still ongoing (Tang 2012).

Across the world's tropical forests, people still draw on ILK to use resources and interact with their surroundings. When coupled with associated cultural values, local traditions and spiritual beliefs, these interactions may support the sustainable use of wildlife in tropical forests (van Vliet et al. 2015; de Mattos Vieira et al. 2019; Smith et al. 2019; Krause and Tilker 2022). Indeed, the management of tropical forests, particularly viewed through the SES perspective, which recognises an interdependent dynamic between humans and ecosystems, can benefit by incorporating biocultural dynamics by understanding ILK and including its holders in forest fauna management, starting from research practices.

Many scholars have argued that it is essential to recognise and engage with ILK in forest management and conservation efforts (Trosper et al. 2012; Smith et al. 2019; Sunderland and Vasquez 2020; Yoamara et al. 2020; Krause and Tilker 2022). The crucial role of IPLC and their knowledges has also been emphasised by the IPBES and IPCC (Ford et al. 2016; McElwee et al. 2020), which underlines the need for decolonial research approaches where these knowledges are not only recognised and receive more attention, but where the knowledge holders are protagonists in co-production and in the validation of the representations of their knowledge (Whyte 2013; Schröter et al. 2023; Jacobs 2025; Subramanian et al. 2025). Nonetheless, this is only possible if knowledge co-production and epistemic justice are assured and prioritised (Meisch 2024; Jacobs 2025).

Other key co-production proposals use "weaving of knowledge" as a term proposed in Tengö et al. (2017), which refers to co-production processes based on respectfully recognising and bringing together both ILK and Western knowledges in collaborations that respect the integrity of each knowledge system towards societal challenges. Increasingly, sustainability scientists have argued that solving current social-ecological crises requires an iterative process of societal change that values and centres different ways of knowing, being and acting (Wyborn et al. 2019). Sustainability practitioners are also increasingly recognising fundamental principles of co-production in research and management, which are defined by Nostrom et al. (2020, p.183) "as an iterative and collaborative process involving diverse types of expertise, knowledge, and actors to produce context-specific knowledge and pathways towards a sustainable future".

Social and environmental justice underpins sustainability science (Ott and Döring 2011; Grunwald 2020; Martínez-Alier 2023). Thus, there is a need to recognise and address the systematic oppression and exclusion that ILK has suffered over centuries, which have lasting consequences for sustainability, transdisciplinary research practices and the ability to address epistemic injustices that continue to this day (Mignolo 2011; Chilisa 2017). Therefore, transdisciplinary and transformative sustainability research must ensure that knowledge co-production includes relevant knowledge holders and meets the aspiration of epistemic justice (Meisch 2024). With regard to our own research, the ILK of tropical fauna must inherently be part of knowledge co-production processes for its sustainable use and management in tropical forests. ILK of forest fauna is the overarching approach that we used in this review as its inclusion in research has implications for the management of forest fauna—both from within an ILK perspective and local resource users (hunters, fisher communities, etc.) and for a conservation managers or national authorities who seek to align objectives of ecosystem protection and sustainable resources management with local needs and forms of use.

While we are not Indigenous scholars and do not claim any insider knowledge of ILK, we seek to answer the following research question: How are researchers studying tropical forest fauna and management engaging with IPLC and their respective ILK? We answer this question through our systematic review by first outlining (1) geographical distributions and frequencies of studies, including forest fauna types, and then considering (2) how ILK on tropical forest fauna is defined and approached in the studies and (3) to what extent research on ILK is based on collaboration and co-production with the knowledge holders and IPLC in places where the research is carried out. By doing so, we provide a state-of-the-art approach in the field and provide evidence, gaps and omissions that scientists and practitioners can use to advance a research agenda grounded in and encouraging deeper engagement with the ILK of IPLC in research on tropical forest fauna.

MATERIALS AND METHODS

Defining the review, terms and filters

We conducted a systematic literature review and used a four-stage process to identify, obtain, save and process data (Fig. 1): (1) we carried out an exploratory search in EBS-COhost and Scopus to get an overview of the extent of research on the topic and developed a comprehensive search string; (2) we designed a specific and targeted screening process to identify relevant articles in Scopus;

(3) the relevant articles were selected and extracted using Sysrev © 2025 Insilica LLC Software; and (4) in a final step, we read the selected articles in Sysrev and extracted data according to pre-defined categories related to the research objectives and then analysed the data in Microsoft Excel.

After testing various search strings, which refer to different combinations of search terms, we selected a search string that yielded a sufficiently extensive and relevant list of forest fauna literature from the past twenty years. After the Exploration Stage 1 (see Supplementary material S1), the Search String Selection and Screening (Step 2) used the following combination in Scopus search engine looking for titles, abstract and keywords containing the following terms: (*indigen*) OR (*local*) OR (*tradition*) AND (*wildlife*) OR (“fauna”) OR (“animal”) AND (*consum*) OR (*subsist*) OR (*commerce*) OR (*ceremon*) AND (*know*) AND (*forest*).

This yielded an initial set of 378 articles published between 2000 and 2022, which we then screened for relevance and duplicates, resulting in 108 articles after the second filter. We applied further exclusion criteria to filter out documents with incomplete or insufficient data, or where the content, topic or discipline fell outside our scope (e.g. traditional trade—commerce, indigenous species—phylogenetics and tropical and indigenous parasites—medical taxonomy, marine and fish industry).

We uploaded the final list of 108 documents to the Sysrev© 2025 platform and reduced the selection to 62 publications, published between 2000 and 2022, ensuring their relevance as they: (1) occurred in tropical regions; (2) addressed local knowledge of fauna; and (3) mentioned IPLC and ILK (Fig. 1).

Scope, inclusion and exclusion criteria

The screening process and selection of information were done using Sysrev © 2025 Insilica LLC Software, through a list of 51 labels grouped into seven categories to select and compile qualitative and quantitative information (Supplementary material S2). We obtained data according to the following predetermined categories and labels: (1) explicit definition and description of ILK, (2) authors' literal description in the document of the objective and methods that explain the degree of community participation and (3) description of diversity of fauna and the types of use given by the community. Publication information, such as author, funding, location and ecosystem categories, was also included. Once all the filtered publications were read and the respective information obtained, we transferred the data to Microsoft Excel for further quantitative analysis, including distribution, frequency, trends and visual representation. The qualitative categorisation of the

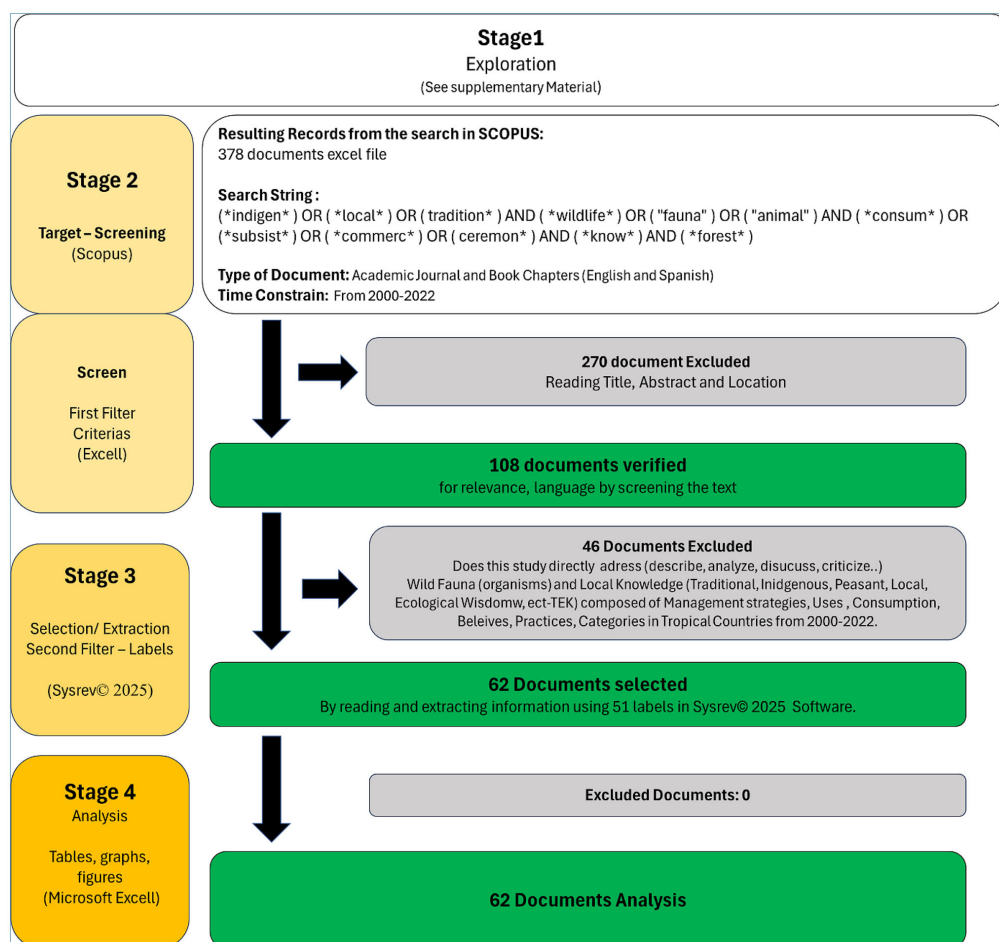


Fig. 1 Overview of Forest Fauna ILK Systematic Review Process

degree of participation was conducted by searching for, reading and quoting the author's direct descriptions of IPLC involvement, and the results were presented in comparative tables.

RESULTS

Distribution of publications in time

We found a clear trend of a gradually increasing number of publications about ILK on forest fauna over the last 22 years, with seven publications (11.2%) published between

2000 and 2013 and the majority from 2014 onwards (88.7%) (see Fig. 2). Although ILK gained some prominence in the wider environmental studies literature after 2000 (Berkes et al. 2000), there appears to be a delay before researchers working on tropical forest fauna began to engage with the concept. The rise of publications post-2014 demonstrates a consistent and growing interest in ILK. Although we cannot be certain, the marked increase in publications from 2014 may correspond to the work and attention of the IPBES, which has recognised and highlighted the importance of ILK of IPLC to manage and protect biodiversity sustainably.

Studied countries

The analysed studies were conducted in 22 tropical countries with an uneven distribution. Brazil was the most represented country, with 13 studies (20%), followed by Indonesia ($n = 8$, 13%), Mexico ($n = 6$, 9.8%), India ($n = 5$, 8%) and Cameroon ($n = 5$, 8%) (Fig. 3). The other 17 countries are represented by one or two publications each, with an evident absence of research occurring in Central America (except Mexico) and sub-Saharan Africa. In South and Southeast Asia, Indonesia (8) and India (5) were the most studied countries. This uneven geographical distribution highlights the need to expand research to understudied geographical ranges to ensure the representation of ILK of the thousands of different IPLC that live across the tropical forest realm. However, while we did not find publications from countries where one would expect this topic to be highly relevant, such as the Democratic Republic of Congo, Venezuela, Lao PDR or Myanmar, this does not mean that such studies do not exist, but they may be written in another language or published in journals not listed in Scopus. Another explanation may be the difficulties researchers encounter when conducting this type of research in certain countries. Brazil is the most represented country, likely due to its size, relatively well-established research infrastructure and the long-standing history of research on TEK and forest fauna in the Amazon Basin.

Fauna types and species

The different species of forest fauna that were studied in the selected publications are described using common (vernacular) and scientific names (binomial) (in two cases using local language), and grouped into five categories: Mammals species are named in 51 documents (82.3%), followed by birds ($n = 37$, 59.7%), reptiles ($n = 27$,

43.5%), invertebrates ($n = 10$, 16.1%) and amphibians ($n = 6$, 9.7%) (Fig. 4).

To understand how the differences in Fig. 4 are represented within each document and compared to the others, we present the fauna composition for each of the 62 publications in Fig. 5, listed in order on the x-axis (numbers 1–62). The figure illustrates variations in the type of fauna analysed, including studies focusing solely on one species.

While 32 documents describe more than one (> 1) fauna class, 30 publications describe only one class of fauna. Twenty-three publications exclusively focus on mammals, five documents exclusively focus on birds, three exclusively focus on invertebrates and one exclusively focuses on reptiles and amphibians. From the 62 documents, 55 referred to more than one species and 7 studies were exclusively describing a single species (monospecific publication—yellow triangle—see Fig. 5), such as document No. 10 on the Tapanuli orangutan (*Pongo tapanuliensis*) or document No. 16 on the Indian pangolin (*Manis crassicaudata*) (Fig. 5).

Types of uses of forest fauna

We analysed the selected publications regarding the different types of uses of forest fauna that were reported. Nine types of explicit use of forest fauna were registered in the 62 publications, ranging in frequencies from Edible, as the most common reported use of tropical fauna ($n = 56$, 90.3%), followed by commerce ($n = 29$, 46.8%), medicine ($n = 29$, 46.8%), ceremonial ($n = 27$, 43.5%) and ornamental ($n = 12$, 19.4%) categories (see Table 1).

These “fauna use” categories were also reported in different combinations (42 combinations in 62 documents) within the included studies. “Edible” is present in 56 publications and is often combined with other uses in 82% of the studies. Exclusive edible use is reported in 13 publications, followed by edible use in combination with commercial, medicinal or ceremonial uses ($n = 6$, 4, 2, respectively). The remaining combinations are reported only once (see Supplementary material S3). Table 2 illustrates examples with direct quotes from articles that describe different types of management and use of forest fauna.

Apart from these explicit uses, other variations and inferred uses were also reported. Some of these fauna values were either placed in the “Other” category or left unanalysed (see, for instance, “pest/spirit animal” (Harahap and Ridwan 2022) and “trophy hunting” (Zafra-Calvo and Moreno-Peñaranda 2018)). One example of these nuances is the intrinsic value of bats as an aesthetic experience, such as the “pleasure of seeing bats flying”, apart from their edible, medicinal and ornamental tourism uses, as reported by Rocha et al. (2021). Although forest

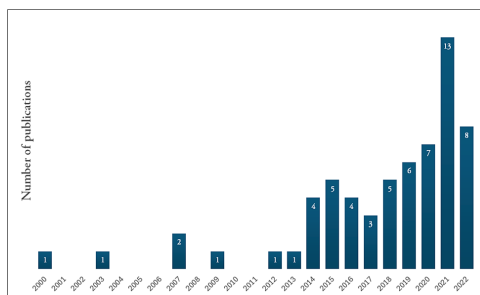


Fig. 2 Number of published articles studying tropical forest fauna, ILK within IPLC in peer-reviewed journals (62 articles between years 2000 and 2022)

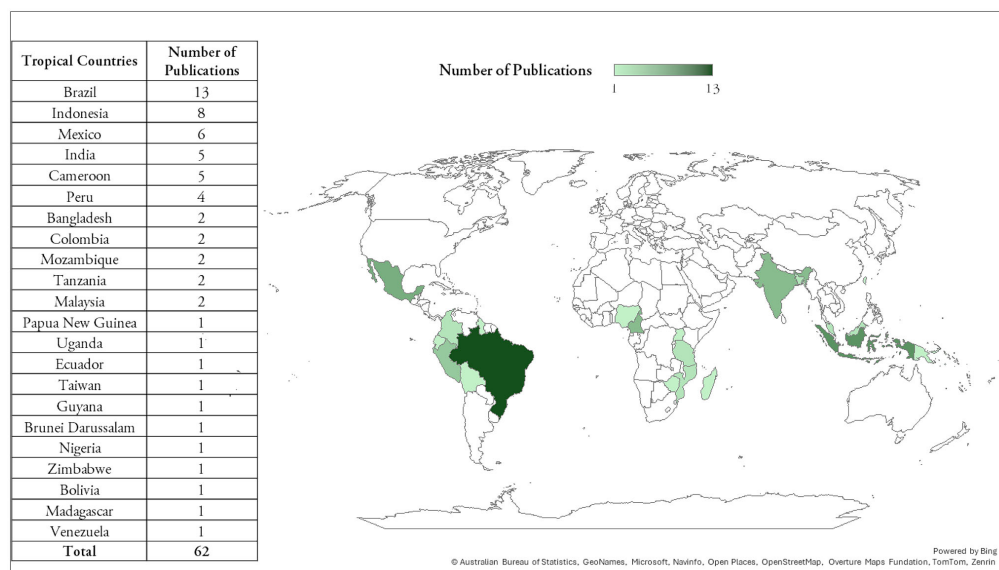


Fig. 3 Number of publications in tropical countries and their global distribution

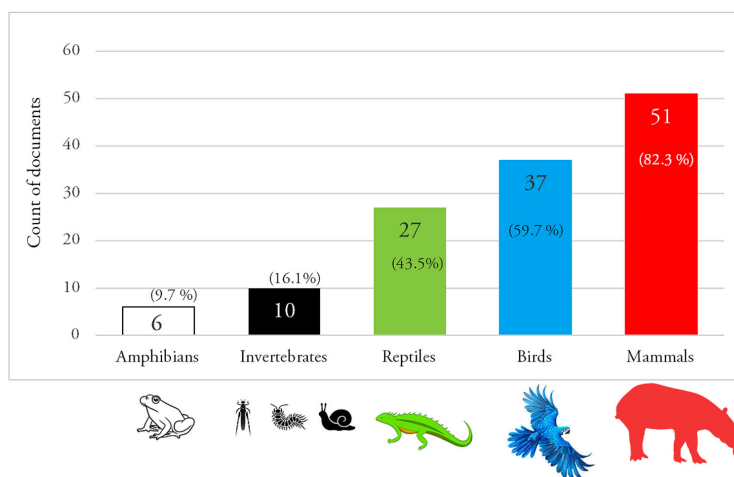


Fig. 4 Number of documents and percentage (%) mentioning each different classes of fauna

fauna was identified as being used primarily as a food resource, the variety of multiple material and spiritual uses exemplifies the intricate relationship between humans and animals in tropical forest social-ecological systems. The use of fauna as medicine and in ceremonies shows its spiritual importance for people who rely on their ILK to

manufacture these medicines and to perform diverse and sophisticated ceremonies that sustain their communities' physical and psychological well-being.

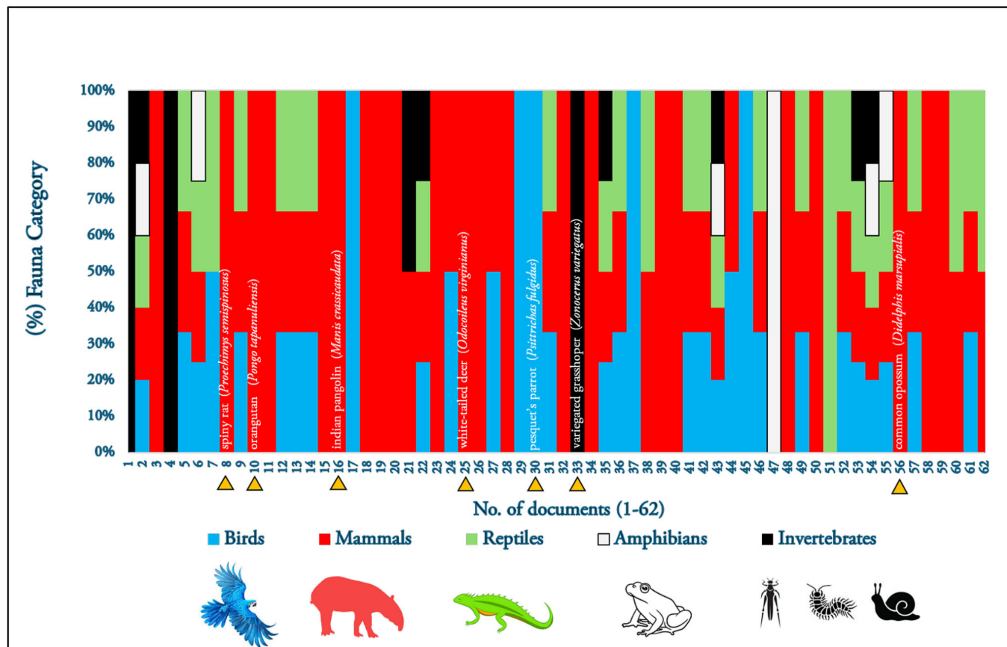


Fig. 5 Forest Fauna types' percentage composition for each study. Studies describing a single species are marked with a triangle and both vernacular and (*binomial*) names

Indigenous and local knowledge definitions and author's positionality

As previously noted by other authors, ILK lacks a unified, consistent definition or acronym, as reflected in our review (Whyte 2013; Berkes 2017; Khanna et al. 2017; Jacobs 2025). The 25 documents that made direct reference to ILK reveal a diversity of terminology when referring to ILK, with 10 distinct acronyms (43% of the total studies). Our understanding of ILK recognises this diversity and includes other terminologies such as Traditional Ecological Knowledge (TEK), Local Environmental Knowledge (LEnv.K) or Ecological Wisdom as part of ILK (see Supplementary material S4). More interestingly though, the remaining 37 studies provided no explicit definition of ILK or mention of other types of IPLC knowledge.

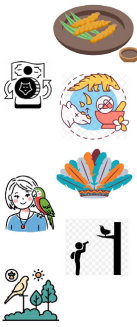
We observed a tendency that studies that did not explicitly define ILK were more likely to be less participatory and inclusive of IPLC. These studies primarily focused on scientific methods to analyse population dynamics of species of tropical forest fauna (Hallett et al. 2019) or measure the potential and actual impact of road development on these populations (Pattiselanno and Krockenberger 2021), but did not mention active

collaboration with IPLC nor engagement with ILK in their analyses.

Aligned with our objective to examine how ILK on tropical forest fauna is characterised and approached by academic publications, we searched for the author's position on ILK expressed directly or inferred from the selected publications. We present examples of the terms used or cited by authors, along with their positions and descriptions of ILK. We include details of the respective country of study, the specific references used in the document and the document number (see S6 for the complete list) in Table 3.

The opening lines of Agnihotri et al. (2021, p.1), stating "The traditional ecological knowledge (TEK) of Indigenous communities is nowadays regarded as a valuable resource in efforts to conserve biodiversity", capture the predominant relation many authors hold regarding ILK. Whereas ILK was widely considered a valuable tool for science, governments and NGOs in their efforts to halt biodiversity decline in tropical forests (e.g. Friant et al. 2015; Petriello and Stronza 2020; Piña-Covarrubias, 2022), little attention is given to ILK as an intrinsic component and expression of the biocultural diversity of tropical forests seen from a social-ecological systems perspective.

Table 1 Type of Uses reported for Tropical Fauna in 62 documents

	No.	Fauna use types	%	No. docs
	1	Edible	90.3	56
	2	Commerce	46.8	29
	3	Medicine	46.8	29
	4	Ceremonial	43.5	27
	5	Ornaments	19.4	12
	6	Companion	9.7	6
	7	Tourism	9.7	6
	8	Other	9.7	6
	9	Indicator of	8.1	5
	10	Tools	8.1	5
	11	N/A	1.6	1

Piña-Covarrubias et al. (2022), for example, recognise that TEK could be used for species conservation or sustainable development. In addition, Pangau-Adam et al. (2022) also recognise that traditional land conservation practices based on ILK are a valuable resource for managing introduced rusa deer populations in West Papua. These examples reflect the standard representation of ILK in the selected publications that recognised and named ILK or related terms. Although the recognition of ILK's value for research is a positive first step, such research also risks instrumentalising ILK and reducing its value to merely serving externally defined goals, such as Western ideas of conservation and sustainable development.

Only a few studies fully recognised ILK as more than just another data point. For instance, authors like Romero-Bautista et al. (2020) provided more profound insights and clear evidence of the value of such research, recognising the immaterial value of ILK and demonstrating a sensitive and keen awareness of the multidimensionality of fauna–human relations:

“To understand the various human–bird environmental interactions, it is necessary not only to address the utilitarian importance that species have in a specific place but also to address the importance of intangible cultural relationships and read the connection between these aspects, by resorting to it to the uses and to the system of beliefs and normativity that persist and resist”. (Romero-Bautista et al. 2020, p.12)

Thus, beyond the recognition of ILK as a scientific and expression of biocultural diversity of IPLC, it is part of the

local governance and management system that has enabled the sustainability of the use of fauna for medicine, food and tourism.

Inclusion of indigenous people and local communities in research

To answer our research questions, we have considered the degree of local or community participation as a variable that reflects the current ways in which academia approaches and interacts with ILK (Vaughn and Jacquez 2020). For this reason, we analysed the selected documents using five criteria of community participation adapted from the International Association of Public Participation (IAP2) spectrum of public participation (IAP2 2018) and Vaughn and Jacquez (2020). We scrutinised respective methodologies and categorised the documents according to the degree of local community participation. Figure 6 shows the level of inclusion of IPLC across our sample, and we provide examples of the distinct levels of participation we identified in the included studies (Supplementary material S5).

Agnihotri et al. (2021) and Akumsi et al. (2003), for instance, describe how IPLC were part of shared decision-making as follows:

“This paper is not intended as an objective, empirical investigation of Solega people’s attitudes toward, and practices regarding, conflict with wild animals. Instead, we present the following information with a two-fold aim. The first is to give a voice to Solega people, as Indigenous voices and points of view are often absent from discourses surrounding endangered wildlife, invasive species, and general biodiversity conservation” (Agnihotri et al. 2021, p.4).

“The development of the strategy emphasized the involvement of hunters and other traditional authorities, and the process involved adapting and testing existing local wildlife management systems” (Akumsi 2003, p.38).

In contrast, the study by Pangau-Adam et al. (2022), which we categorised as “Consulted” IPLC, states:

“Here, our aim was to assess the population status of rusa deer, and to investigate the extent of hunting practices on this mammal in West Papua...We conducted camera trapping and line transect surveys simultaneously to estimate...We also interviewed hunters (n = 134), informants (n=9) and households (n=91) to assess hunting patterns and socioeconomic importance of rusa deer across 15 districts of the Tambrau regency”. (Pangau-Adam et al., 2022, p.1).

Table 2 Details of the types of use and management of Forest Fauna

Type of Use Activity (Purpose)	Extracts of use and management of fauna as described in the articles	Country Document Number in S6 list
Edible Fauna Subsistence Hunting (Food and Crop Management)	“Because of their strong dependence on hunted wildlife for protein, the Mro have an intimate understanding of the relationships between these animals and their habitat”. p.61 The survey revealed that the Mro hunt for two purposes: for highly valued game meats and to protect their crops in the Jhum land from wild animals and birds” p.59	Bangladesh (Chowdhury et al. 2007) <i>No.2</i>
Edible Fauna Insect Harvest (Nutrition Well-being)	“We observed that Guajibo living at the savannah border (at Alcabala Guajibo, Amazonas, Venezuela) relied mostly on insects (especially grasshoppers and larvae of <i>Rhynchophorus palmarum</i>) during the rainy season of July to August and estimated that over 60% of their animal protein came from insects”. p.2251 “The Ye’ Kuana consumption of earthworms cannot be attributed to a lack of other animal protein resources because there is no shortage of fishes or game in their territory (Schlenkner 1974; Hames 1980). Rather, the Ye’ Kuana appreciate these species of earthworms as gourmet foods”. p.2249	Venezuela (Paoletti et al. 2000) <i>No.4</i>
Edible Medicine Tools Ornament Ceremonial Hunting (Food, Well-being)	“Thirty-nine species that provided raw materials (fat, bones, feathers, viscera, body fluids) for the production of zootherapeutics were mentioned, notably the fat of <i>S. merianae</i> ”. p.258	Brazil (Barbosa et al. 2022) <i>No.6</i>
Edible Commerce Hunting, Weddings, Funerals (Food, Well-being)	“They [two local communities of the Ruvuma landscapes] hunt small mammals for subsistence purposes (meat) or bigger animals (for example elephants) for income generation or traditional events (such as providing meat in weddings or funerals for a large number of people)”. p.858	Mozambique, Tanzania (Zafra-Calvo and Moreno-Peñaranda 2018) <i>No.42</i>
Medicine Signal of Ceremonial Capture, Observation, Interpretation (Well-being, prepared by Socioecological Predictions)	“The category of climatic and environmental changes predictors (ECP nine species) is understood as the reading and interpretation of a signal expressed from an unusual song or activity of the bird, which indicates a change in the weather or a specific climatic event” p.8 “Environmental Signal, Rituals, Omes, Medicine: e.g. help them to interpret rain announcements that allow them to prepare actions; for instance, the “salineros” rush the collection and protection of salt in the face of this rain forecast “. p.9	Mexico (Romero-Bautista et al. 2020) <i>No.29</i>

A representation of the distribution according to the degree of participation is presented in Fig. 6.

Many studies directly involved ($n = 26$) or consulted ($n = 23$) IPLC, but only four reached a level of inclusive and participatory scientific research where IPLC were able to influence decisions on the scope, content and methodology of the research. This distribution is, unfortunately, not surprising and repeats a long-standing pattern in ecological and biological field research, where scientists rely on IPLC logistical support to identify and access ecosystems for studying biodiversity. For this reason, we identified only four studies that explicitly employed a participatory action research approach, in which the research was co-designed and subsequently carried out in close collaboration with community members who retained ownership of the knowledge (Table 4).

DISCUSSION

In our review of 62 publications (see complete list in Supplementary material S6), we revealed how researchers studying tropical forest fauna engage with IPLC and their respective knowledges. While this topic has been receiving increasing attention over the past two decades, we noted a spike since 2014, coinciding with the release of the IPBES reports, which highlights the role and importance of ILK for biodiversity conservation (Díaz et al. 2015; Tengö et al. 2017; Pörtner et al. 2021). Nonetheless, the majority of studies focus on the instrumental value of ILK and not so much its intrinsic value, nor the significance and interconnectedness with biocultural diversity. While few studies are explicit about how the authors understand or engage with ILK in their research, our findings indicate that there

Table 3 ILK definitions and the author's approach to ILK

Knowledge Terminology Used	Direct quotes of the authors' approach to ILK	Country (Reference) Number of the reviewed document in list S6
Local Ecological Knowledge (LEK) "... can be defined as all the personal empirical experience that local people acquired through years of interactions with natural environments, which are transmitted to their communities" (Charnley et al. 2007; Brook and McLachlan 2008)	"Community-based management of natural resources has been considered the best available option for the local protection and/or recover [sic] of native biodiversity, in addition to socioeconomic gains in enhancing the living standards of rural populations" p.9	Brazil (Sampaio et al. 2022) No.7
Local Environmental Knowledge (LEnvK) "LEnvK linked to birds is transmitted generationally, from grandparents and parents to children and grandchildren" (Romero-Bautista et al. 2020)	LEnvK is needed: "To understand the various human-bird environmental interactions, it is necessary not only to address the utilitarian importance that species have in a specific place but also to address the importance of intangible cultural relationships and read the connection between these aspects, by resorting to it to the uses and to the system of beliefs and normativity that persist and resist" p.12 "This teaching-learning process is linked to experience and observation of the environment; it is transmitted while walking and working the field, through daily observation and the assessment, use and conservation of species" p.11	Mexico (Romero-Bautista et al. 2020) No.29
Local Traditional Knowledge (LTK)/Local Indigenous Knowledge (LIK) "most LTK themes focused on species-specific knowledge rather than the social and cultural contexts of campesino hunting" (Petriello and Stronza 2020)	"Rather, we recommend greater consideration of other marginalised and disenfranchised groups and their relevance to conservation" p.351	Mexico, Peru, Colombia (Petriello and Stronza 2020) No.31
Not Specific terminology (NST) mentions but does not describe LK "Local calendars were also related to religious and natural markers, acting as parameters for the livelihood activities" (Hanazaki et al. 2009)	"As stressed by (Redford 1991), native inhabitants should not be considered as ecologically noble savages, despite their deep knowledge about the environment. p.7 "The great challenge now is finding ways to cope [sic] the recent changes affecting these local people and changing their livelihoods and their values, with factors such as the maintenance of the social conditions of production of this local ecological knowledge and the improvement of their life quality". p.7 "Local Indigenous knowledge on native resources is important to promote local development in a sustainable way (Gadgil, Berkes et al. 1993), and help to conserve biodiversity, particularly if the resource is used". p.1	Brazil (Hanazaki et al. 2009) No.61
Not Specific terminology (NST) mentions but does not describe LK	"Conservation and public health interventions in such settings may be most efficient when they capitalize on local knowledge and target root socio-economic and cultural drivers that lead to hunting behaviour". p.1	Nigeria (Friant et al. 2015) No.62
No specific terminology (NST) "Detailed knowledge"	"The Indigenous people's strategy in the consumption of invertebrates indicates that they have a detailed knowledge of their environment, in the use and manipulation of forest resources to provide food for human populations, without the destruction of biodiversity, a practice that has been maintained through millennia" p.322 "Knowledge of the relationships between Indigenous populations and the ecosystem represents the basis for a natural and cultural preservation of biodiversity", p.322	Venezuela (Araújo and Beserra 2007) No.1
Traditional Ecological Knowledge (TEK) "Is a cumulative body of knowledge, practices, and beliefs that has evolved by adaptive processes and has been handed down through generations by cultural transmission" "It is about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1993)	"To successfully incorporate TEK into natural resource management, authorities should be concerned about the gradual loss of TEK, and we suggest that authorities should actively increase the investigation of TEK and documentation through written records, which is vital before it is lost forever". p.218 "Application of TEK to natural resources co-management with aborigines has recently become a policy trend. It is therefore necessary to know how TEK can contribute to natural resource management". p.214	Taiwan (Wu et al. 2014) No.57

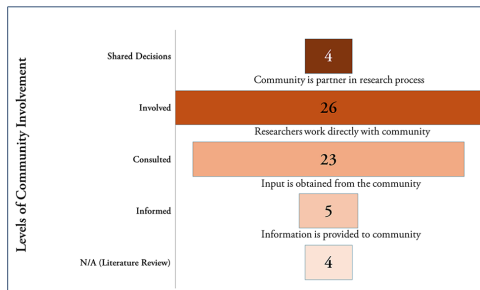


Fig. 6 Distribution of studies ($n = 62$) in our five categories of Community Involvement in ILK fauna studies

is considerable room for improvement in research studying the role and use of forest fauna in tropical forest ecosystems, even when ILK and its holders are claimed to be part of the research and management decisions.

In the fauna dimension, an interesting finding of our review is the focus of studies on mammalian and avian species, while most of tropical forest faunal biodiversity comprises invertebrates. This human lens and interest in species with hair and feathers have been observed in previous studies (Morris et al. 1995; Serpell 2004; Batt 2009; Byrd et al. 2017), but they may also portray a skewed picture of ILK in relation to tropical forest fauna as the mammalian and bird bias is likely enhanced by the non-inclusion of ILK. Based on our own experience and previous research (Rosso-Londoño, 2013; Yoamara et al. 2020), we are aware that a vast wealth of ILK on invertebrate species and amphibians exist, yet it is rarely reflected in the published literature.

We understand the uneven distribution of research in countries originates from complex dynamics unrelated to exclusively biological factors. If academic research were a direct match for biocultural diversity (a possible proxy for ILK occurrence), Cameroon, Colombia and Papua New Guinea would be competing for first place on the list (Maffi 2007). However, these highly bioculturally diverse countries (except for Brazil, which is the most studied country in our sample of 62 articles) appear only after the 4th position in the list (Cameroon, five articles; Colombia, three articles; and PNG, one article). A possible explanation for this can be the direct colonial relation of university structures and dynamics to its European origins, which contribute to unequal approaches to knowledge that replicate the subjugation of ILK in tropical territories and colonies (Carvalho and Flórez-Flórez 2014). Other factors, such as the country's position towards rural livelihoods, ethnic diversity and IPLC, can also be reflected in the interest and willingness to research ILK. Again, even though Brazil shares a shameful story of massive

destruction of its ecosystems and cultures, it has also been an example of “grassroots” social movements to protect Indigenous territories and the development and divulgation of ILK, which is demonstrated by the influential work of Ailton Krenak, Sônia Guajajara, Eduardo Batalha Viveiros de Castro and Davi Kopenawa. In many highly biodiverse countries throughout the tropics, violent conflict is also an important barrier to carrying out continued research on and with ILK and forest fauna. The past decades and current security situations in specific regions of Colombia or Cameroon are examples of how armed conflicts erodes the possibility of long-term research in regions with a high biocultural diversity (Weir et al. 2024; Garcês and Pires 2025).

Regarding ILK definitions, we highlight two tendencies in our review. The first shows diverse definitions of ILK, with TEK and combinations of Local Traditional Knowledge (LTK)/Local Indigenous Knowledge (LIK) being the most used. The second tendency relates to the non-definition or non-formal naming of ILK, as demonstrated by only 25 studies out of 62 that define it. When defined, however, we observed some interesting and uncommon terminologies, including Ancestral Knowledge, Local Wisdom and Strategic Relational Symbiosis. Each of these definitions attempted to highlight specific representations of ILK in the respective contexts. In our view, such definitions help illuminate the diverse understandings of the world, connecting knowledge with ancestry and fostering awareness of the interdependence of human life with other creatures. This diversity and focus on relational and transcendental descriptions of ILK are linked to how Indigenous scholars defined and described ILK, with a focus on relationship, responsibility and reciprocity to manage fauna (Jacobs 2025).

Lastly, we also found that the level and extent of inclusion and participation of IPLC in research on tropical forest fauna appear largely consultative, symbolic or superficial, rather than fully collaborative and co-produced. There may be several reasons for this, such as a lack of awareness, resources and time to engage in transdisciplinary research and knowledge co-production. Moreover, conducting co-production research requires interdisciplinary teams of researchers who can navigate the complex ethical, social, cultural and ecological aspects that this deeply collaborative research entails, as well as dedicating the time, energy and financial resources required for such a process (Viswanathan et al. 2004; Koster et al. 2012; Gitelsohn et al. 2020). The limitations set by traditional scientific research and its institutions are likely a major hurdle. However, we were nonetheless surprised that few papers even acknowledged these limitations and outlined a path for potentially more inclusive and participatory research.

Table 4 Details of sharing a decision-making approach in articles (co-production)

Article Author and Year Title (Number of the reviewed document in list S6)	Details of Shared Decision Studies (Communities are partners of study)
(Akumsi 2003) Community participation in wildlife management: the Mount Cameroon experience. <i>Unasylva</i> , 54(3), 37–42 (No. 3)	“The objectives of the strategy were: - to create village-based institutions and strengthen their capacity for managing wildlife sustainably - to develop locally defined rules and regulations that can support sustainable management efforts based on local realities and within the confines of the national wildlife legislation - to define community hunting areas and sustainable offtake - to develop a simple local monitoring and evaluation system with the participation of all stakeholders” p. 38
(Zafra-Calvo and Moreno-Peñaranda 2018) Exploring local people's views on the livelihood impacts of privately versus community managed conservation strategies in the Ruvuma landscape of North Mozambique–South Tanzania. <i>Journal of Environmental Management</i> , 206, 853–862 (No. 42)	“The aim of this study is to identify a strategy that achieves sufficient levels of nature protection while being perceived as acceptable by the communities in terms of livelihoods costs and benefits, and thus a strategy that communities would be willing to commit to” p. 854
(Franco and Minggu 2019) When the seeds sprout, the hornbills hatch: understanding the traditional ecological knowledge of the Ibans of Brunei Darussalam on hornbills. <i>Journal of ethnobiology and ethnomedicine</i> , 15, 1–14 (No. 37)	“Hence, we conceived this study to understand the TEK of the Iban community of Temburong in Brunei Darussalam on their hornbills and the cultural importance accorded to them” p. 2
(Agnihotri et al. 2021) Tiger becomes termite hill: Soliga/Solega perceptions of wildlife interactions and ecological change. <i>Frontiers in Conservation Science</i> , 2, 691,900 (No. 22)	“This paper presents aspects of the TEK of the Soliga/Solega community of southern India, who live in a forest habitat that is also home to tigers, leopards, elephants and sloth bears, among others” p. 2 ***This case was visited by one of the authors by coincidence, as the lead author was invited to the Soliga community by an ATREE college in January 2025, confirming the characteristics that make this process a collaboration between academia (ATREE) and Soliga Indigenous community

We found that research still lacks a co-production approach with IPLC and exemplify this with our review of studies on ILK and forest fauna. Knowledge co-production with IPLC is crucial for several reasons. Firstly, ILK can offer significant explanatory contributions to Western science (Brodnig and Mayer-Schönberger 2000; Maffi and Woodley 2012; Castello et al. 2024), which recognises the limitations of any particular knowledge systems in understanding and holistically addressing the complexity of any given phenomenon. This is the case for the use and management of tropical forest fauna that affects the functional integrity of tropical forests and their role in the global carbon cycle (Galetti et al. 2017; Berzaghi et al. 2018; Gardner et al. 2019; Fricke et al. 2022). Second, epistemological and decolonial arguments highlight the ethical and justice dimensions of knowledge co-production in research that must bring benefits to IPLC in addition to value for external institutions (Edwards and Heinrich 2006;

Chilisa 2017). Such arguments are underpinned by sociopolitical ambitions and the rights of IPLC, such as knowledge recognition, identity, sovereignty and self-determination (Agrawal 1995; Aikenhead and Ogawa 2007; Bennett et al. 2025) and claims that research can and should contribute towards achieving these goals. Third, and finally, there is a practical need for ILK for the efficacy of promoting transformative actions in the knowledge-to-action boundaries, where practices and policies need to engage and be co-produced with ILK to be able to produce salient, credible and legitimate information and solutions (Cash et al. 2003; Matuk et al. 2020; Pörtner et al. 2021). Considering our findings, these arguments on effective and transformative actions for sustainability must integrate explanatory, epistemic and legitimacy dimensions of ILK.

Legitimacy of data, and hence results, is crucial to produce information and technology. To be legitimate, knowledge co-production ought to be respectful of

stakeholders' divergent values and beliefs, be unbiased, and fair in its treatment of opposing views (Cash et al. 2003). Legitimacy occurs when all participants (e.g. IPLC, academics or policy practitioners) consider the outcomes of knowledge co-production to be valid according to the diverse meanings and contents of their knowledge systems (Lam et al. 2020). This validity in relation to effective and legitimate actions brings into clear view the critical importance of profound dialogues with ILK and the translation of concepts, views, causes and effects of the sustainability challenge addressed. This is clearly supported by our review results, which show that studies on forest fauna and ILK include wide topics ranging from food consumption, forest governance, to road development and tourism, all of which require knowledge co-production to achieve effective and legitimate solutions to the decline and loss of biocultural diversity.

To achieve all this, a profound and urgent transformation of research and research institutions is needed to recognise ILK and then to develop the skills required to see, engage with and understand ILK. The persistence of research *on* IPLC compared to research *with* IPLC (Koster et al. 2012) prompted us to engage in a thought experiment involving a non-Indigenous researcher (sometimes called an external researcher by Indigenous communities) conducting empirical research. We named this scenario "the ILK as a door metaphor".

Indigenous and local knowledge as a door to a pathway to inclusion

To conclude our discussion, we reflect on our understanding of the value of ILK in biodiversity and conservation research and beyond. Scientists working with tropical forest fauna should better recognise and engage with the incredible wealth of knowledge and multiple ways of understanding the complexity of tropical forest ecosystems, as well as how people are an integral component of these. Nonetheless, a substantial limitation that is slowly changing is the disciplinary boundaries set by research and educational institutions. Very few ecologists and biologists receive training in social sciences, such as anthropology or environmental sociology, and may be, what we call, ILK blind. ILK blindness is a very broad term that can be addressed through academic training that policy makers, natural scientists and ecologists could and should undertake to broaden their understanding of ILK. This would improve research and make science, as well as conservation, more inclusive and account for biocultural diversity and the profound social–ecological interactions.

Different scenarios related to individual researcher experiences, institutional constraints or project characteristics can be better addressed using what we propose here

as the metaphor of: ILK "as a Door" to IPLC knowledge systems. This metaphor can serve to understand a variety of research/researcher scenarios, with different aims and objectives, that engage, whether fully or partially, with ILK. We view the door as an entry point into various epistemologies, ontologies, human–nature relationships, values and knowledges about, in this instance, tropical forest fauna and its management. The following are our theorisations to this effect:

1. Researchers cannot see the ILK Door (e.g. ILK blind scenario), only seeing the other most common and visible doors, such as conservation, sustainability or its own disciplinary door of training (Fig. 7).
2. Researchers see the Door but do not describe it (e.g. project constraints)
3. Researchers see and move towards the Door but cannot access (context and consent constraints)
4. Researchers see the door, move towards, enter or are invited to enter the door and describe the shared understanding (willing and prepared)
5. Researchers already knew how to see the door, already knew it and have been inside before and visit or live inside (habituated)
6. Researchers have moved beyond merely seeing a door and moving between contexts, using the door's label to share with others without experiencing it (integrated).

ILK can serve as a door to a deeper understanding of IPLC ways of being and relating to each other and the world, and, in turn, tropical forest fauna and their management. Following this door metaphor, we found that while most studies saw the door and referred to it as ILK, they did not open it. Others did not appear to see the door or name it. Only a handful of studies saw, named and actually opened the door to pass through it. Our analysis of whether there are any observable characteristics that contribute to determining how authors have engaged with ILK can be of use for diverse scientific institutions and

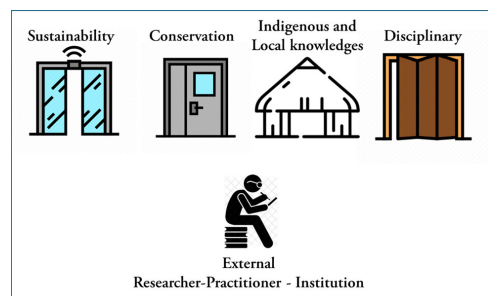


Fig. 7 Door metaphor for researchers entering and studying Forest Fauna with ILK and IPLC, among other doors

researchers to reflect on their own interest, preparedness and willingness to enter through this ILK door. As to the why—we can only speculate—but based on our own experiences and insights it is probably a combination of time, money, training and a traditional education in biology/ecology that largely excludes local people from scientific research processes.

Authors such as Bartlett et al. (2012), Hogue (2019) and Latuklippe and Klenk (2020) have come to similar conclusions and highlight that we first must bring attention to the “Two-Eyed Seeing” principle to weave Indigenous and mainstream knowledges together. The Two-Eyed Seeing principle refers to learning to see with one eye using the strengths of ILK and ways of knowing, and from the other eye, with the strengths of Western (mainstream) ways of knowing. Yet, and most importantly, learning to use both eyes together for truly informed vision (Bartlett et al. 2012; Hogue 2019). Second, the “Making a Room and Moving Over” principle is a critical position to knowledge co-production together with ILK, explaining why co-production scholars should move from merely “seeking to better integrate” ILK into Western science, but instead make way for IPLC research leadership (Latulippe and Klenk 2020). Third, we aligned with the research framework “Moving from research *on*, to research *with* and *for* Indigenous communities”, arguing that researchers need to move away from methods that perpetuate traditional ways of working *on* Indigenous and Local Communities to methods that work *with* and *for* IPLC (Koster et al. 2012).

In this sense, to continue this evolution from *on* towards *with* and *for* we need to become proficient at seeing with two eyes where ILK is an equal door through which we must go to ensure that equal knowledge authority is given to IPLC.

CONCLUSION

Based on our review, we see a need for a future research agenda on ILK of tropical forest fauna. There are numerous important benefits in committing to greater reflexivity and advancements in research that involve collaboration rather than isolation. We acknowledge that gaining a deeper insight into the significance of ILK regarding forest fauna requires an inter- and transdisciplinary approach. Actionable knowledge can be fostered at every level, even within specific fields of study. A substantial shift towards greater inclusion can enhance not just our comprehension but also the management of tropical forest social–ecological systems. This will, we argue, ultimately empower IPLC in their fight for greater autonomy and self-determination through data collection to the access and dissemination of research findings. Deeper self-reflection on the historical

patterns of knowledge system asymmetries and their connection to individual perspectives and ideologies is indeed needed for the transformation towards knowledge inclusion, plurality and justice. The diversity of labels and names currently referred to as ILK is indicative of the broad efforts for IPLC inclusion, one that is also confronted by the evident invisibility of ILK to many other researchers and institutions. Recognition of ILK value is closely related to respectful naming as a first step to consider respectful investigation and dialogue with IPLC. We consider this connection of practitioners and epistemic revision to be of fundamental importance, one that is closely related and addressed by decolonial studies. One positive development is the increasing number of publications that include non-Indigenous and Indigenous scholars referring to social–ecological paradigm shifts and methodologies that enrich our understanding of forest fauna, local management and resource use. More awareness and training of researchers can influence their willingness to dialogue with ILK that promotes reflexivity can help to ensure that the vast knowledge of IPLC, as well as their autonomy and right to self-determination, is respected and taken seriously. While only one concept of many, we identify that “weaving of knowledge” concept and practice is a crucial vehicle for working towards deep and sustained co-production in research.

As the pressure on tropical forest biodiversity continues to rise, pushing many populations and entire species towards extinction, we also need to recognise how wide-ranging environmental changes are intertwined with and are the result of socio-economic and political changes. Thus, the ongoing loss of biodiversity is in fact a loss of biocultural diversity, as it leads to the erosion and loss of ILK and the loss of local languages as living libraries. The invaluable knowledge of IPLC is not only a critical source of information revealing the intricacies of local social–ecological systems, but can also help in the struggle to safeguard tropical forest ecosystems from a biocultural perspective. Moreover, from a procedural and rights-based approach, IPLC have an inherent right to participate in research about them or that affects them, because they are rightful users and legal owners of territories located in tropical forest areas. From an instrumental perspective, we need to document, include, and centre ILK because it is a door that, if we dare to pass through, can provide us with an incredible source of information that, in turn, can promote a pathway to a more meaningful, inclusive and effective conservation of tropical forests as social–ecological systems.

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Declarations

Conflict of interest The authors declare no conflicts of interest.

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