Improving Biocultural Diversity Conservation: integrating the Multiple Evidence Base (MEB) approach and Co-Design

Sharon Yedid Valdez-Rentería, Omar Iván Huerta Cardoso, Yuriana Gómez-Ortiz, Leonardo Fernández-Badillo and Hublester Domínguez-Vega

Acknowledgments

We especially thank the authorities and people of the Matlatzinca community of San Francisco Oxtotilpan, as well as the directors and technicians of the Natural Reserve for the Protection of Flora and Fauna of the Nevado de Toluca, who collaborated in every phase of this study. We also thank the researchers and students who collaborated in creating the prototypes and identifying the species (Elisa González Fortino, Kenia Dayana Marcos Vázquez and Carlos Manuel Legorreta Garnica). We also thank the Consejo Nacional de Humanidades, Ciencia y Tecnología (CONAHCYT) for its financial support.

Conflict of interest statement

The authors have no relevant financial or non-financial interests to disclose

Abstract. The convergent extinction crisis —characterized by the simultaneous loss of biological and cultural diversity— poses a critical threat to the resilience of socio-ecological systems. To address this challenge, we adopted an approach that integrates the Multiple Evidence Base (MEB) and co-design methodologies. This study was conducted in the Matlatzinca community of San Francisco Oxtotilpan, State of Mexico, an area experiencing both language loss and a decline in local knowledge of amphibians and reptiles. This collaborative process enabled us to co-produce knowledge and co-create tangible solutions that foster biocultural valuation and conservation. Through this process, we co-designed an educational video to raise community awareness and encourage local conservation action. Our findings demonstrate that integrating MEB and co-design not only enriches herpetofaunal knowledge but also provides effective, community-centered strategies for revitalizing *Indigenous* knowledge and conserving biocultural diversity.

Keywords. Biocultural Diversity, Co-design, Conservation, Herpetofauna, Multiple Evidence Base Approach.

Introduction

Biocultural diversity —defined as the diversity of life in all its manifestations, including biological, cultural, and linguistic dimensions that are interrelated and possibly coevolved within complex socio-ecological adaptive systems (Maffi 2001)— recognizes the inextricable interconnection among these domains, as well as their interactions and feedback within local contexts (Maffi, 2007; Bridgewater & Rotherham, 2019). However, biocultural diversity faces unprecedented threats. Globalization and anthropogenic activities are among the primary drivers compromising its integrity (Cantes et al. 2024; Cantera et al. 2022). This "convergent extinction crisis" (Maffi 2018), which refers to the simultaneous loss of biodiversity and cultural diversity, has prompted the development of research approaches that integrate multi- and interdisciplinary perspectives for conservation. These approaches aim to understand and interpret social-ecological systems and human-nature relationships through culturally relevant strategies (Sterling et al. 2017; Bridgewater and Rotherdam 2019; Lukawiecki et al. 2022; Burke et al. 2023).

Historically, social disciplines such as environmental, ecological and cultural anthropology have examined the relationships between people and their environment from various perspectives (Pretty et al. 2009). However, social sciences have had difficulty integrating with the natural sciences, such as ecology and biology, which tend to address conservation from a technical approach, leaving aside social and cultural aspects. Conversely, natural sciences have focused primarily on models based on ecological systems for species and habitat conservation planning, but with limited engagement of local and *Indigenous* communities or traditional knowledge systems (Chengere et al. 2022; Tengö et al. 2014). This disciplinary divide has constrained the effectiveness of strategies aimed at conserving both biological and cultural diversity (Gavin et al. 2015; Franks and Small 2016; Chengere et al. 2022).

To address these limitations, collaborative and multidisciplinary approaches such as the Multiple Evidence Base (MEB) and co-design have emerged. Situated within transdisciplinary sustainability science, these approaches integrate different knowledge systems to address complex socio-ecological challenges (Lang et al., 2012). Their goal is to harness the strengths of varied disciplines and epistemologies to tackle multifaceted conservation issues (Sterling et al. 2017; McCarter et al. 2018; Hoyte 2021; Burke et al. 2023).

Multiple Evidence Base (MEB):

The MEB approach, grounded in knowledge co-production, facilitates equitable and respectful collaboration between different knowledge systems. It was designed to address sustainability challenges at multiple scales through five main tasks: mobilization, translation, analysis, synthesis, and application of new knowledge (Tengö et al. 2014; 2017; 2021). While MEB has demonstrated effectiveness in projects for protected area management and species monitoring (Austin et al. 2019; Torrents-Tíco et al. 2021), it faces challenges. These include the need for substantial time and resources (Malmer et al. 2020), as well as the lack of clear, practical guidelines, which can hinder implementation, limit replicability, and potentially lead to conflict if results are not properly managed (Austin et al. 2019).

Co-design:

Co-design is an iterative, hands-on, integrative process that uses people-centered design tools (IDEO.org 2015). It typically encompasses the phases of empathy, definition, ideation, prototyping, and testing (Hasso Plattner Institute 2010; Yadav et al. 2021), although alternative or additional phases may be incorporated depending on the context (Man et al. 2019). This approach fosters collaboration among different stakeholders to develop innovative solutions that are both creative and capable of producing tangible results in a short timeframe and with limited resources (Bowie et al. 2020; Wong et al. 2021). In biodiversity conservation and monitoring projects, co-design has been proven to achieve acceptability, feasibility, and efficiency among stakeholders (Hoyte 2017; 2021; Hölting et al. 2022). However, its application can be hindered by the disconnection between society and nature, which reduces the motivation of participants (Bowie et al., 2020).

The integration of MEB and co-design can provide a valuable methodological framework for biocultural diversity conservation, overcoming the limitations of each approach while building on their respective strengths. Specifically, we aim to leverage the enriched picture produced by MEB alongside co-design's capacity to foster collaboration and develop innovative solutions within short timeframes and under resource constraints. Our purpose is to develop an integrated methodological framework for biocultural diversity conservation projects that support researchers, community people and decision-makers to achieve conservation goals.

In this context, Mexican herpetofauna (amphibians and reptiles) represents an ideal case study for testing this integrated framework, given Mexico's exceptional herpetofaunal diversity (1,425 species; Balderas-Valdivia and González-Hernández 2024) and these species' close associations with traditional uses, knowledge, and practices of local and *Indigenous* communities (Sánchez-Núñez 2006; Pengüilly-Macías et al. 2010; Valdez-Rentería et al. 2023). However, amphibians and reptiles face serious threats from human activities such as habitat destruction and climate change (Böhm et al. 2013; Wilson et al. 2013; Suazo-Ortuño et al. 2023). Additionally, negative perceptions rooted in limited ecological knowledge contribute to the devaluation and decline of these species (Frías-Álvarez et al. 2010; Bohm et al. 2017; Domínguez-Vega et al. 2019; Fernández-Badillo et al. 2021; Valdez-Rentería et al. 2023). These challenges highlight the need for integrative approaches that bridge disciplinary boundaries and engage diverse social sectors to identify needs, challenges, and possible solutions for their valuation and conservation.

Therefore, the objective of this study was to analyze herpetofaunal biocultural diversity using integrated collaborative approaches to collaboratively generate knowledge and develop accessible solutions that promote its valuation and conservation. This approach was implemented with the Matlatzinca community of San Francisco Oxtotilpan, State of Mexico, Mexico.

Materials and Methods

Study area

This study was carried out in the last Matlatzinca community in Mexico, located in San Francisco Oxtotilpan, Temascaltepec, Mexico (Fig. 1). Historically, the Matlatzinca culture had a large distribution in the Toluca Valley or Matlatzinco Valley in central Mexico (Escalante and Hernández 1999). However, in the 16th century, during colonization, the Matlatzincas were geographically restricted to San Francisco Oxtotilpan (García-Hernández, 2004). Currently, this is the only place in Mexico inhabited by speakers of the Matlatzinca language, making this language critically endangered (INPI 2019). The Matlatzinca territory is located in the biogeographical zone of the Trans-Mexican Volcanic Belt, where three natural protected areas converge (Fig. 1). Its ecosystem is characterized by great biodiversity that is closely linked to its practices, beliefs, and traditional ecological knowledge.

The lack of collaboration between local, governmental, and academic knowledge systems has limited the creation of comprehensive strategies for understanding and conserving Matlatzinca biocultural diversity. The socio-cultural and socio-ecological context of San Francisco Oxtotilpan, combined with negative perceptions and conflicts associated with herpetofauna (including knowledge gaps, negative myths, and snakebite accidents) positions this community as an ideal model for the application of biocultural conservation approaches.

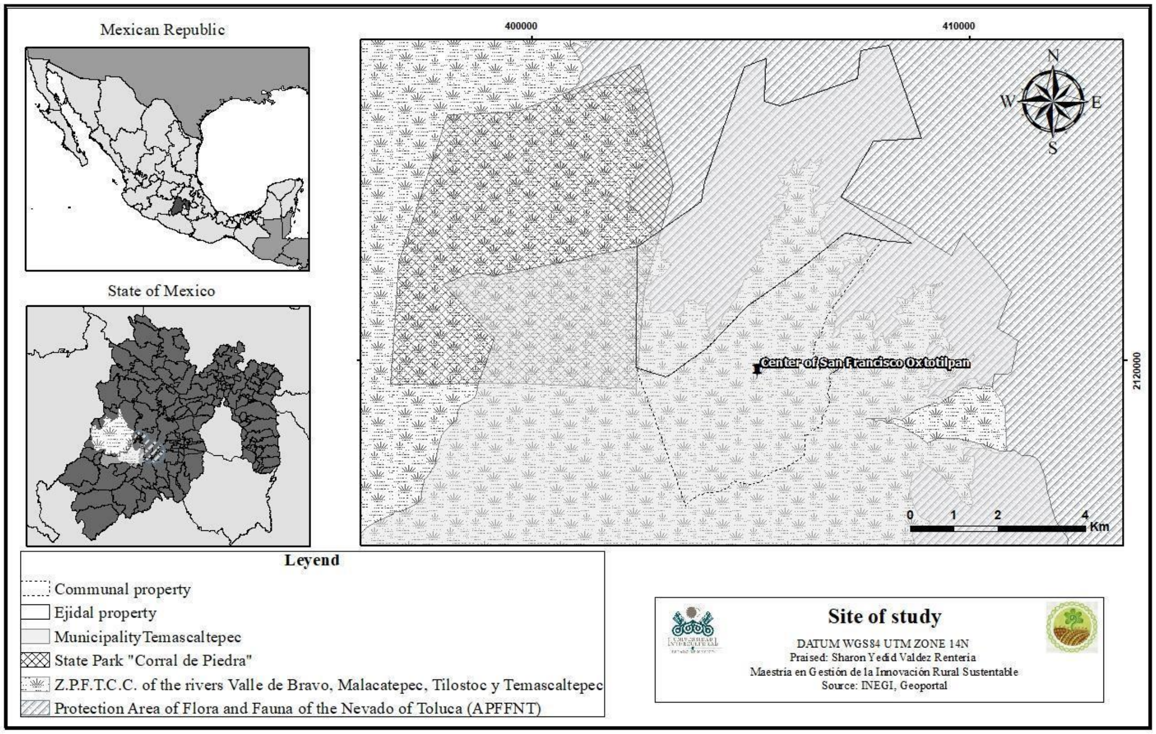


Fig. 1. Location of the Matlatzinca community of San Francisco Oxtotilpan, Mexico. This locality is administered by local uses and customs (norms regulating life within *Indigenous* communities and using their natural resources). Their territory is divided into communal and ejidal property (the communal property is the shared and administered collective land for the community, and ejidal property is granted by the government to the communities but not for transfer or sale). At this site, three natural protected areas converge.

Description of knowledge systems.

Three knowledge systems collaborated in this work: The Local Knowledge System (LKS), the Governmental Knowledge System (GKS), and the Academic Knowledge System (AKS). The LKS, represented by men and women who understood or spoke the Matlatzinca language, contributed important knowledge about the traditional uses, cultural relevance, and ecological dynamics of the herpetofauna in the locality. Each Matlatzinca collaborator contributed relevant information about the species, such as their local distribution, habitat, Matlatzinca names, and cultural value. The GKS was represented by managers and technicians from the National Commission of Natural Protected Areas (CONANP), who provided information on the species recorded at the Nevado de Toluca and the main policies, programs, and projects developed within this community. The AKS provided technical and specialized expertise on amphibians and reptiles, which enabled documentation and analysis of available information on this group. It also facilitated dialogs between knowledge systems, ensuring that the work carried out in the workshops was respectful and equitable.

To integrate MEB with co-design, the five phases of the MEB approach were implemented as follows:

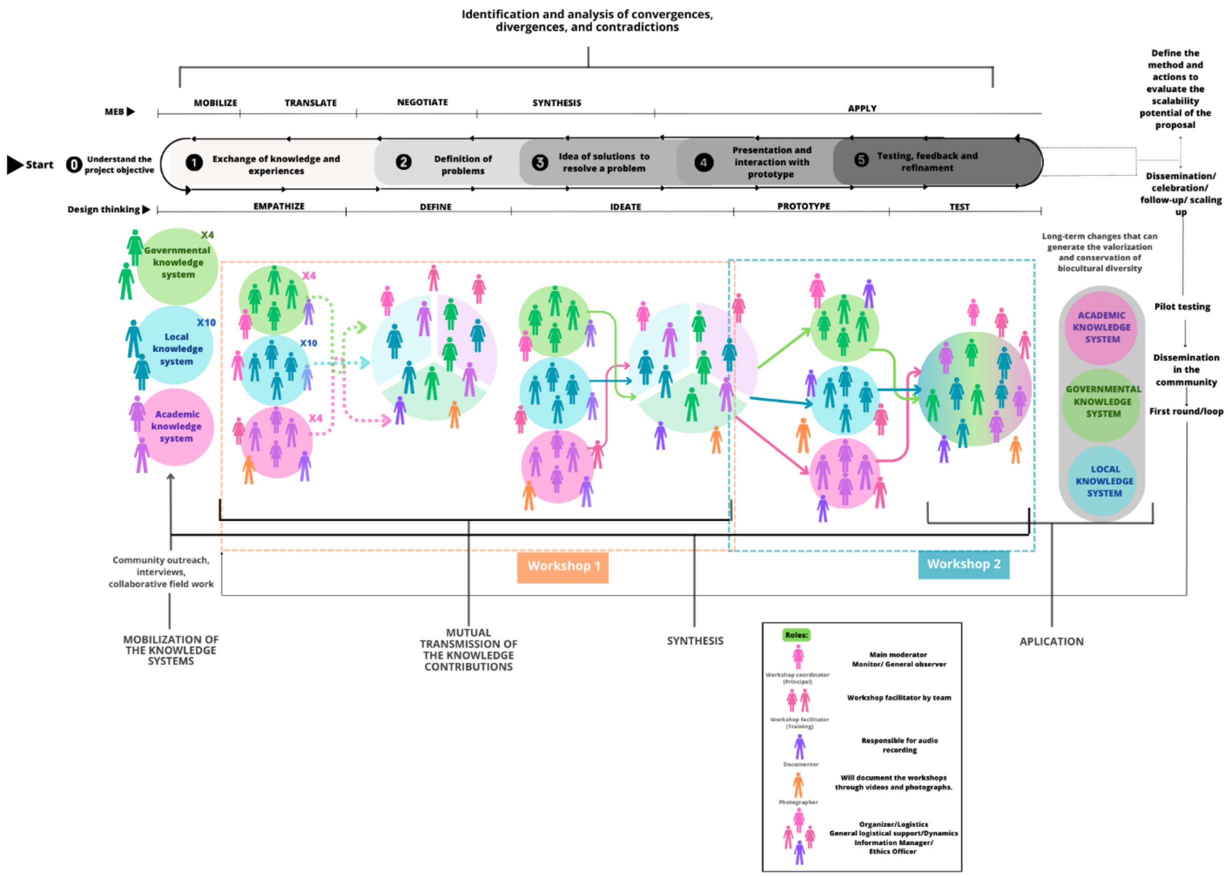
Mobilization: In this initial stage, outreach was conducted with the three knowledge systems (local, governmental, and academic) to gather information on the amphibians and reptiles of the study area. This process included interviews and a review of relevant information sources, including databases and literature. The collected data specific to each system included local names, traditional uses, management policies, and previous scientific studies in the locality.

Translate: During this phase, workshops were conducted with participants representing the three knowledge systems to elicit perspectives and identify convergences, divergences, and contradictions among their responses. This critical analysis enabled us to identify connection points and establish a common language, thereby enabling meaningful dialogue across knowledge systems. In the co-design methodology, this corresponds to empathize, define, and ideate phases, which enabled the generation of joint ideas grounded on shared knowledge. The divergences that emerged among the different knowledge systems were addressed through facilitated group dialogues during the workshops. In these spaces, participants discussed and exchanged their responses and perspectives, reaching consensus on the identification of the main problem and the selection of the most appropriate solution.

Synthesis: Once the information was translated and contextualized, the data were synthesized to co-create an initial prototype. This prototype represented a tangible solution or tool that combined the perspectives and contributions of the three knowledge systems.

Application: In this stage, the final prototype and synthesized information were presented to the collaborators of the three knowledge systems (Fig. 2).

157



158 **Fig. 2.** This scheme shows the integration of the Multiple Evidence Base (MEB) approach with the co-design and the compatibility that both
159 approaches had to overlap the stages of each one. It is also possible to observe the participation of the three knowledge systems in each stage and
160 the roles of the collaborators.

Mobilization of knowledge

This step is considered in the MEB approach but not in co-design. The mobilization of knowledge involved collecting information on the biological and cultural dimensions of the herpetofauna in the Matlatzinca area. For this purpose, semi structured interviews were conducted with LKS (10 interviewees) and GKS (4 interviewees) stakeholders. In the case of LKS, our interviewees were adult community members recognized for their extensive knowledge regarding biodiversity. To locate these individuals, we used the snowball sampling technique in combination with informal interviews with several members of the same community. For GKS, we included all individuals who have conducted activities related to the management of the protected areas located in the region. Likewise, to obtain information from the AKS, we reviewed databases (*i.e.*, Naturalista, Global Biodiversity Information Facility, Amphibia Web, Reptile Data Base, and Enciclovida), as well as specialized literature available on the herpetofaunal species distributed in the studied area and on the species with possible distribution in the locality.

In addition, fieldwork was conducted in collaboration with the residents of the Matlatzinca community. A total of sixteen field trips were carried out, with two trips per month, each lasting two days. Species were recorded using the Visual Encounter Survey (VES). This method involves systematically searching, in random transects, all potential microhabitats that may be used as refugia for amphibians and reptiles, including under rocks, logs, leaf litter, and vegetation (Domínguez-Vega et al. 2019). Sampling locations were identified through informal interviews with local people and a land cover analysis using digital layers of land use and vegetation cover (INEGI 2021).

Translate

This is the second step in the MEB approach, according to the co-design methodology, it includes the objectives of the empathize, define, and ideate phases (Figure 2). On January 13, 2024, a workshop was held at the Casa de la Cultura in San Francisco Oxtotilpan to achieve a multidirectional exchange of knowledge between governmental, academic, and local knowledge systems. The objective was to co-design a solution that promotes the valuation and conservation of herpetofauna in the Matlatzinca community. In this workshop, 16 people participated: 10 from the LKS (including community leaders, children, women, and elders), one representative from the GKS, and four researchers from the AKS. A detailed protocol was developed to guide the workshop, outlining the schedule, activities, guiding questions, and materials used (Supplementary Material S1).

Selection of participants

Workshop participants were selected using purposive sampling to ensure representativeness of the Local Knowledge System (LKS). Selection criteria included gender balance, age diversity, and recognized expertise in traditional practices (such as medicinal use of amphibians, storytelling, or interactions with herpetofauna). Priority was also given to individuals holding some form of community authority or leadership role that could strengthen the legitimacy and impact of the process. Children and young people were also involved to incorporate intergenerational perspectives, enrich the diversity of viewpoints, and foster long-term community engagement in conservation. For the Governmental Knowledge System (GKS), local authorities who had previously conducted flora and fauna monitoring within the community were invited to participate. Finally, collaborators from the Academic Knowledge System (AKS) were selected based on their expertise and experience with amphibians and reptiles to ensure that their contributions were directly aligned with the study's objectives.

The tools, presentation dynamics, and learning strategies were adapted based on the manual "Like the Salt in the Soup" (Grundmann and Stahl 2002) and The Field Guide to Human-Centered Design (IDEO.org 2015). The activities followed a structured process:

Identification of problems. Participants organized themselves into groups according to their knowledge systems to identify and prioritize the main problems affecting both the community and the herpetofauna. First, each group began by collectively brainstorming a list of perceived problems. Next, individually ranked the five most relevant problems according to their perceptions. Subsequently, each group provided their answers, and their perspectives were explained. Finally, in a joint dynamic, all participants identified and analyzed the similarities and differences between the responses of the three knowledge systems, grouping them into thematic "clouds of ideas" according to their similarities.

Voting. Using the dot voting technique (Dalton, 2018), each group received different colored stickers, with each color representing a knowledge system. The lead facilitator instructed participants to individually place a sticker on the problem they felt was most important to solve. To ensure fairness and minimize bias in the results, representatives of the LKS were asked to vote first.

Solution ideation. Each group was allocated five minutes to individually think of five solutions to the main problem identified in the previous activity. Participants then had 15 minutes to share and discuss their ideas as a team, working together to reach a consensus and selecting five final proposals. At the end of the session, each group had five minutes to present their proposals. These were collectively analyzed by all participants to identify points of convergence and divergence. Finally, similar responses were grouped into thematic “clouds of ideas”.

Voting. A point voting process was conducted to select the solution that each participant considered the best proposal. In this final evaluation, stakeholders were asked to consider three key constraints: short implementation time, minimum effort, and low cost. After the vote, a group discussion was held among the various knowledge systems. During this collaborative discussion, the strengths, limitations, and feasibility of the selected proposals were carefully analyzed. This exchange aimed to ensure that the chosen solution effectively addressed the identified problem while aligning with the established constraints.

Prototype. Following the consensus reached during the group discussion, the first prototype was developed: a video in MP4 format with a duration of one minute and thirty-nine seconds (Multimedia S1). The video was created using the free application CapCut and was based on a literary script. The script was developed based on the information collected during the knowledge mobilization and translation phases (interviews, fieldwork, workshops, and literature review). The video was produced by academics with support from students of the Universidad Intercultural del Estado de México; who specialize in communication and particularly in video production. The script was structured in three parts—introduction, development and resolution—to ensure a clear and engaging narrative.

Synthesis and application

These are the final phases of the MEB approach and correspond to prototype and test phases within the co-design methodology. All the content presented in this prototype was derived from the core findings of the knowledge mobilization and transmission. This first video was intended to convey a clear, concise message that could be easily integrated into people's daily lives (Lindholm 2023). Research suggests that the first eight seconds are crucial for capturing the audience's attention (Lindholm 2023). Therefore, efforts were made to optimize the content and duration of the video to achieve this goal.

A second workshop was held in March 2024 with the objective of presenting the prototype to the three knowledge systems to obtain feedback and improvements. A detailed protocol was developed to structure the workshop activities and guide the feedback process (Attached S2). Due to the participants' availability, the workshop was conducted face-to-face with six LKS and three AKS stakeholders. Subsequently, virtual meetings were held via the Google Meet platform with the collaborators of the three knowledge systems who were unable to attend the face-to-face workshop. Through virtual meetings, feedback was obtained from two more participants from the LKS and two from the GKS, thereby completing the participation of the three knowledge systems.

Activity 1: Contextualization. In both the face-to-face workshop and the virtual meetings, a short presentation was given to recapitulate and contextualize the results obtained in the first workshop.

Activity 2: Interaction. One by one, the prototype videos were shared in face-to-face meetings via Bluetooth and in virtual meetings via the WhatsApp application. During this process, collaborators were able to interact with the prototype to test its functionality and identify areas for improvement (Davies and Wilson 2023).

Data collection in the workshop. During the development of the activities, video and audio were recorded with the prior consent of all participants. The workshop documentation, facilitation, and evidence collection (i.e., photographs) were carried out by UIEM students and academics. During the team activities, an audio recorder or mobile device was placed at each table, and a designated documenter recorded participants' responses and interactions. During the plenary activities, a video camera was used to record the interactions and contributions of each knowledge system.

Evaluation of the data. The audio and videos from the workshops were transcribed to ensure accurate documentation of participant contributions. The information provided by each knowledge system was then organized and systematized into separate databases. To visualize the convergences and divergences among the responses from the different knowledge systems, Sankey diagrams were created using Power BI software. These diagrams provided a clear representation of the flow and overlap of ideas, facilitating the identification of shared perspectives as well as points of divergence.

Results

According to the results of this study, the MEB approach and co-design can be considered complementary in developing effective strategies for the conservation of biocultural diversity. Our methodological framework allowed the different knowledge systems to be woven from the initial phases of the work and jointly generate an enriched picture of the herpetofaunistic biocultural diversity in the studied area. This shared knowledge served as the foundation for subsequent steps, generating synergies to create a methodological and collaborative framework with tangible and actionable results within a short timeframe.

Movilization of knowledge

The mobilization of knowledge between the three systems demonstrated the value of their different contributions by producing a more comprehensive understanding of species richness and associated problems than could be achieved by any single knowledge system alone. For example, this exercise allowed the compilation of a biocultural inventory on the herpetofauna in the Matlatzinca region (Table 1). Beyond species records, the inventory incorporated the systematic documentation of uses and beliefs related to amphibians and reptiles in the community, thereby evidencing their biocultural significance and the interconnections between ecological, cultural, and symbolic dimensions (Table 2). When compiling the information from the databases available for the locality, only 11 species were recorded (representing current academic knowledge); LKS and GKS recognized 16 and 18 species, respectively. Through collaborative fieldwork and interviews, 23 species were ultimately documented, underscoring the value of joint efforts in expanding biodiversity knowledge within a relatively short timeframe.

Additionally, the information provided by the three knowledge systems enabled the compilation of additional information about local species. For example, 15 species names in Matlatzinca, the inclusion of species in the Mexican standard NOM-059-SEMARNAT-2010 for species conservation (SEMARNAT 2019), and the inclusion of species in the IUCN red list (IUCN 2023; Table 1). In our study, this information was used to build teaching material and subsequently used in the workshops. However, this knowledge and these materials can be used later in community meetings or in school lessons to improve people's connection with and valuation of local herpetofauna.

Table 1. Amphibians and reptiles registered in the municipality of San Francisco Oxtotilpan, Temascaltepec, State of Mexico, as recognized for the three knowledge systems and the species found in the collaborative fieldwork.

No.	Family	Genus	Specie	Name in Matlatzinca	Identification for each knowledge system			Field work	NOM-059-2010	Red list
					LKS	GKS	AKS			
1	Craugastoridae	*Craugastor*	*Craugastor sp.*				X	X		
2			*Craugastor cueyatl*[*,1] (Jameson, Streicher, Manuelli, Head & Smith, 2022)					X		
3	Hylidae	*Dryophytes*	*Dryophytes eximius*[1] (Baird, 1854)	*Cho´kwa*	X	X		X		LC
4			*Dryophytes plicatus*[1] (Brocchi, 1877)	*Cho´kwa*	X	X	X	X	A	LC
5	Ranidae	*Lithobates*	*Lithobates spectabilis*[*1] (Hillis and Frost, 1985)	*Cho´kwa, Mé´cruz*	X	X		X		LC
6	Ambystomatidae	*Ambystoma*	*Ambystoma rivulare*[1] (Dugés, 1895)	*Méntawi*	X	X	X	X	A	E
7	Plethodontidae	*Isthmura*	*Isthmura bellii*[1] (Gray, 1850)	*Mé´noni*	X	X	X	X	A	LC
8		*Aquiloeurycea*	*Aquiloeurycea cephalica*[1] (Cope, 1865)		X	X	X	X		LC
9		*Pseudoeurycea*	*Pseudoeurycea leprosa*[*,1] (Cope, 1869)			X		X	A	LC
10			*Pseudoeurycea robertsi*[*,1] (Taylor, 1939)					X	A	CR
11	Anguidae	*Barisia*	*Barisia imbricata*[1] (Wiegmann, 1828)	*Santenu*	X	X	X	X	Pr	LC

12		*Gerrhonotus*	*Gerrhonotus liocephalus*[**,1] (Wiegmann, 1828)		X				Pr	LC
13	Scincidae	*Plestiodon*	*Plestiodon copei*[1] (Taylor, 1933)		X	X	X	X	Pr	LC
14		*Phrynosoma*	*Phrynosoma orbiculare*[1] (Linnaeus, 1789)		X	X			A	LC
15			*Sceloporus palaciosi*[*,1] (Lara-Góngora, 1983)	*Chik´uni*	X	X	X	X		LC
16	Phrynosomatidae	*Sceloporus*	*Sceloporus scalaris*[*,1] (Wiegmann, 1828)	*Chik´uni*		X		X		LC
17			*Sceloporus subniger*[*,1] (Poglayen & Smith, 1958)	*Yëchik´uni*	X	X	X	X		
18			*Sceloporus torquatus*[*,1] (Wiegmann, 1828)	*T´ank´uxi*	X	X		X		LC
19	Colubridae	*Conopsis*	*Conopsis biserialis*[*,1] (Taylor & Smith, 1942)	*Ch´ini*				X	A	LC
20		*Storeria*	*Storeria storerioides*[1] (Cope, 1866)	*Tahoránch´ini Xarunta*	X		X	X		LC
21	Natricidae	*Thamnophis*	*Thamnophis pulchrilatus*[*,1] (Cope, 1885)	*Bathïnch´ini*	X	X		X		LC
22			*Thamnophis scalaris*[*,1] (Cope, 1861)	*Ch´ini*		X		X	A	LC
23	Viperidae	*Crotalus*	*Crotalus triseriatus*[1] (Wagler, 1830)	*Mé´chiwi*	X	X	X	X		LC
Total=					16	18	11	21		

* First records for the locality of San Francisco Oxtotilpan, Temascaltepec, State of Mexico. ** Species mentioned by the collaborators and not found during fieldwork. Conservation Status NOM-059-SEMARNAT-2010: A= Endangered, Pr= Under Special Protection. Conservation Status Red List (IUCN): CR= Critically Endangered, E= Endangered, LC= Least Concern. Endemic= 1.

Table 2. Uses (*praxis*) and beliefs (*cosmos*) associated with amphibians and reptiles in the community of San Francisco Oxtotilpan, Temascaltepec, State of Mexico, Mexico

No.	**Class**	**Family**	**Species**	**Local name**	**Name in Matlatzinca**	***Praxis* (Uses)**	***Cosmos* (Beliefs, myths, and legends)**
1			*Dryophytes eximius*	Rana de lluvia, ranita	*Chok*'wa	The tadpole or Capowi was used as food	They call the rain when they sing
2		Hylidae	*Dryophytes plicatus*	Rana, ranita	*Chok'wa*	The tadpole or Capowi was used as food	They call the rain when they sing
3		Ranidae	*Lithobates spectabilis*	Sapo, rana	*Chok'wa, Mé'cruz*	The tadpole or Capowi was used as food; the adult as well	N/A
4	Amphibia	Ambystomatidae	*Ambystoma rivulare*	Ajolote	*Méntawi*	Medicinal (to cure *etico* and diabetes), food, recreational	If you kill them, the water goes away; they protect the water.
5		Plethodontidae	*Isthmura bellii*	Salamandra	*Mé'noni*	N/A	They are poisonous; if you don't kill them, they will chase you
6		Anguidae	*Barisia imbricata*	Escorpión	*Santenu*	Medicinal (to remove envy)	If you put its blood on your fists, it gives you strength to fight
7	Reptilia	Scincidae	*Plestiodon copei*	Alicante, elegante, elecante		N/A	It is poisonous

8	Phrynosomatidae	*Phrynosoma orbiculare*	Camaleón		Medicinal (to *cure el aire*)	They are poisonous; they make you fall asleep
9		*Sceloporus palaciosi*	Lagartija	*Chik'uni*	N/A	When they rise up, they suck your blood
10	Colubridae	*Storeria storerioides*	Dormilona	*Tahoréch'ini Xarunta*	N/A	If you don't kill it, you'll find more; if you see one outside your home, it means witchcraft is being done to you
11	Natricidae	*Thamnophis pulchrilatus*	Correlona, culebra de agua, víbora rayada	*Bathïnch'ini*	N/A	If you don't kill it, you'll find more
12	Viperidae	*Crotalus triseriatus*	Víbora de cascabel	*Mé̗'chiwi*	Medicinal (to cure cancer and diabetes)	Its rattle represents its age; it brings good luck and makes guitars sound better; it fears the smell of cigarettes; if it is near the house it turns into money; they represent the devil

N/A= No reported uses or associated beliefs.

Translation and synthesis of knowledge

The multidirectional exchange of knowledge among the three knowledge systems is an effective tool for identifying local problems, generating solutions, and translating those solutions into tangible prototypes. The structured, step-by-step workshop methodology facilitated the flow of information across knowledge systems during joint activities, fostering mutual understanding and learning. Subsequently, prioritization and selection of problems and solutions became possible through a common understanding of the issues under discussion.

Workshop 1. The contributions of the different knowledge systems can be seen in the Sankey diagram (Fig. 3), which also shows the convergences and divergences between the responses of each system. In total, nine problems affecting the local herpetofauna were identified. The LKS focused on issues related to culture and species, while the AKS and GKS prioritized issues related to species ecology and conservation. The three knowledge systems converged on three of these problems: the introduction of exotic species, pollution, and habitat loss. Conversely, the LKS identified three problems that diverged from the responses of the other knowledge systems (negative myths, water loss, and loss of ecological and traditional knowledge; Fig. 4). When voting on prioritized items, lack of information was identified as the main problem for which solutions were proposed.

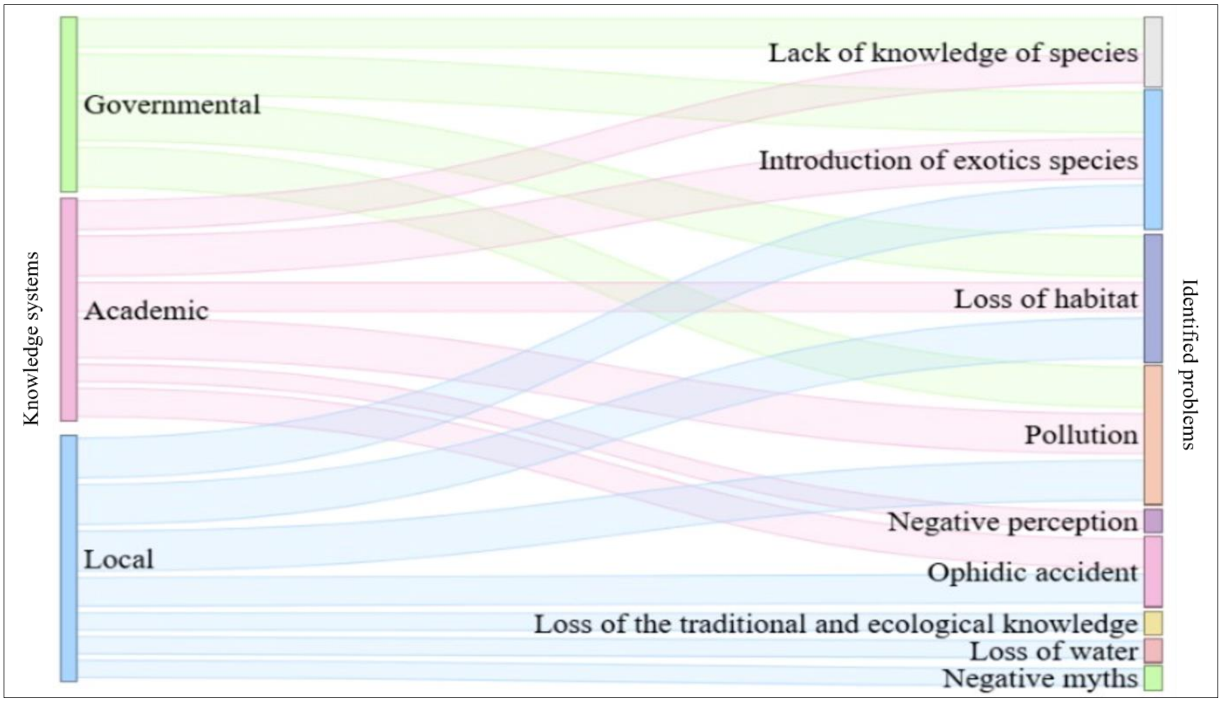


Fig. 3. This Sankey diagram shows the problems identified by the three knowledge systems. The introduction of exotic species, habitat loss and pollution are mentioned by the three knowledge systems. In San Francisco Oxtotilpan one of the main causes of pollution is excessive use of agrochemicals in farming. Agriculture and deforestation are the main pressures on habitat. Whilst rainbow trout (an introduced species), threatens native amphibians and reptiles in aquatic systems, and species such as rats and cats are important for terrestrial biodiversity. Lack of knowledge and ophidic accidents are recognized by two knowledge systems. LKS also identified three more problems that are not detected by the other knowledge systems.

Fig. 4. Development of a brainstorming session among the participants of the local knowledge system to identify the main problems of the herpetofauna in the Matlatzinca community of San Francisco Oxtotilpan, Temascaltepec, State of Mexico, Mexico.

Fourteen proposed solutions were identified in response to the lack of information (Fig. 5). The LKS provided the largest number of proposals, characterized by having an inclusive approach and being easily understood by the entire community. These proposals contrast with those of the AKS and GKS, which focused on more conventional and formal solutions. Despite these differences, all three knowledge systems agreed that giving talks in schools represents the best solution to address this problem. This convergence shows how divergent perspectives can align on solutions that complement traditional and formal approaches. The LKS further highlighted the importance of these talks as tools not only to inform but also to awaken the interest of children and youth in learning the names of animals in Matlatzinca.

Taken together, these differences in knowledge systems approaches show how, by being complementary, they can provide valuable perspectives that, when merged, can more effectively address information gaps.

Subsequently, the ideas from Figure 5 were grouped into four themes based on their similarity: knowledge transfer, audiovisual material development, trails, and celebration of an emblematic day for the species; it was also suggested that a garbage collection day to be added, resulting in a total of five solutions.

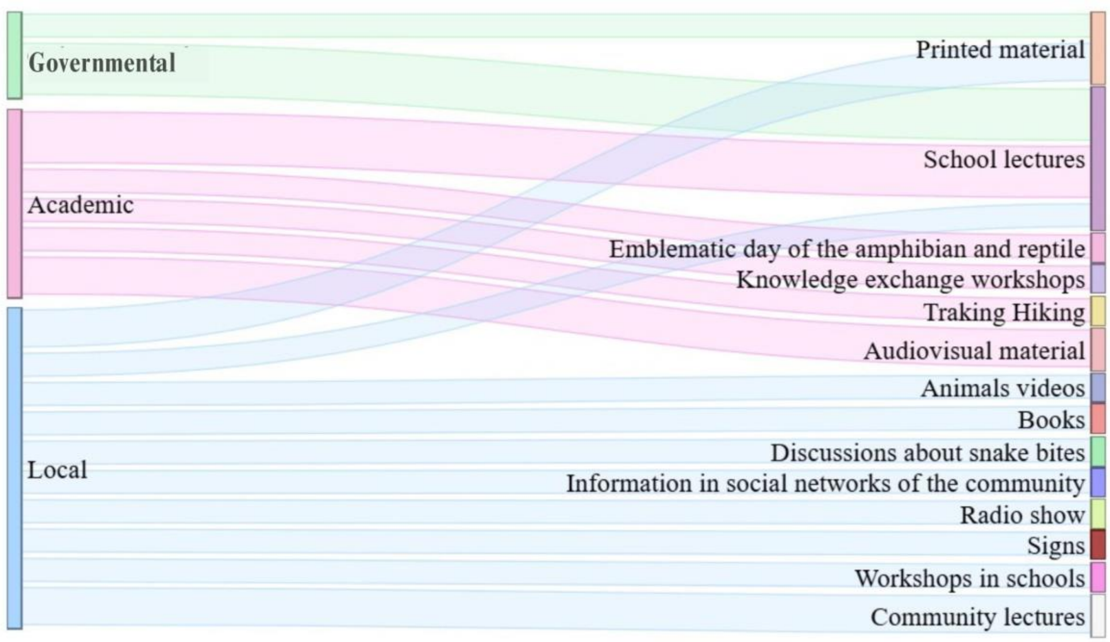


Fig. 5. The Sankey diagram shows the solutions proposed by the three knowledge systems. Note the important richness in solution options for the lack of information (just one problem), particularly from the LKS participants, which illustrate the great potential of collaborative work to generate diverse solutions to socio-ecological problems. The solution most mentioned by the participants was “school talks”, which was also the point where the three systems converged. For the LKS, both “printed materials” and “community talks” represented important solutions for addressing the “lack of information” in the community.

In the voting process, participants identified knowledge transmission as the most effective solution for addressing the community’s lack of information and fostering behavioral change.

In addition, the three knowledge systems converged on the choice of audiovisual materials. At the end of the vote, a group dialogue was held in which participants determined that the best way to transmit this knowledge was through an audiovisual product, specifically a video that could be disseminated in schools through workshops, in the community at large, or through community groups on social media. The decision to produce a video emerged from group discussions, in which participants agreed that it was the most effective way to communicate and raise awareness of conservation. This approach was chosen for its accessibility and effectiveness in reaching diverse community sectors, including children and elderly people with varying literacy levels. The script was developed collaboratively, incorporating ecological information from academic sources, cultural narratives shared by local participants and recommendations from government bodies. Cultural adaptations included using the Matlatzinca language for the names of amphibians and reptiles and including visual references to landscapes and practices that are meaningful to the community.

Application

Once the audiovisual product was developed, it was presented to the three knowledge systems for review and refinement. This exercise marked the entry into the iterative protocol of the co-design approach, which allows continuous improvement of the tangible solutions. For this study, material improvements were completed following the incorporation of feedback from the three knowledge systems. Nonetheless, product optimization may be adjusted to meet specific needs in different contexts; for example, at basic, intermediate or higher education levels, or for farmers or other social groups.

Workshop 2. The LKS focused its suggestions and improvements on the images shown in the prototype, recommending the inclusion of more representative locations from the locality. In contrast, the GKS and AKS suggestions focused on the presentation of information. Overall, collaborators responded enthusiastically to the video content, describing it as "clear, concise, and impressive." In addition to positive feedback, some recommendations significantly improved the product. The most frequently mentioned recommendations from the three knowledge systems included reducing the file size of the video, improving the narrator's tone and presentation, adding images of local landscapes, changing the background music, adding species descriptions, removing the white background, and adding short videos or photos showing the handling of organisms.

Final prototype. By implementing the suggestions received from the three knowledge systems, the content of the final prototype was significantly improved (Multimedia S2). Once editing of the video was completed, it was shared via WhatsApp to collaborators from the three knowledge systems. Several days later, the video was shared by community members who were not directly involved in the project, and it is now being used as an information resource about local herpetofauna.

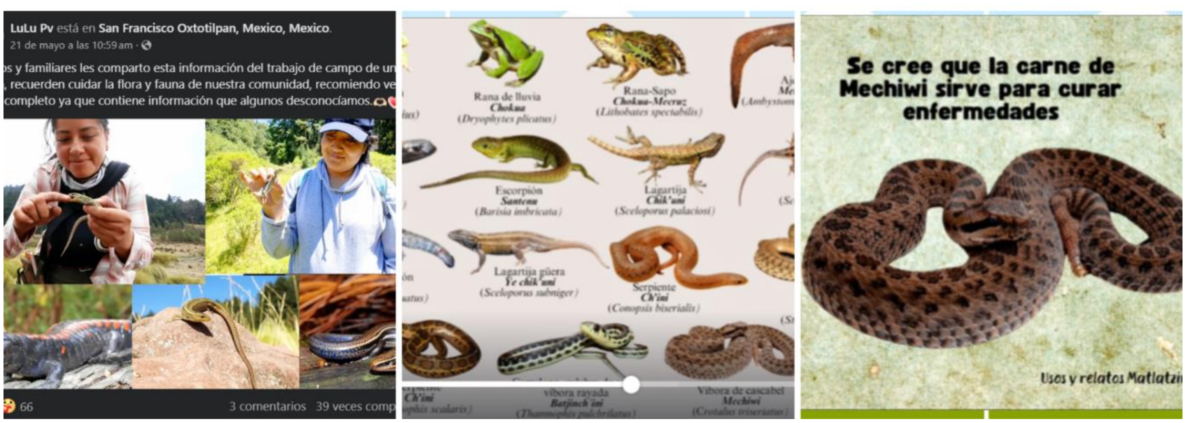


Fig. 6. The final prototype of the video was shared with the three knowledge systems, who in turn shared it through their social networks. This dissemination has generated diverse reactions and positive comments, so we believe that it is achieving the purpose of transmitting information on the biocultural diversity related to the Matlatzinca herpetofauna in an accessible way.

Discussion

By integrating the strengths of the MEB approach and co-design, we created a collaborative methodological framework that leverages the synergies between the different knowledge systems, producing tangible and implementable results in the short term. The framework presented in this study integrates the strengths of both approaches, such as building a more comprehensive knowledge base from different knowledge systems (Tengö et al. 2021) and applying a practical, human-centered design process to create tangible, desirable, feasible, and viable solutions (IDEO.org 2015). In our case, the co-designed solution was a video; however, in other studies, the final product may differ significantly according to each context's requirements. This integration resulted in the co-creation of a useful and tangible solution in the field of biocultural diversity conservation. This framework also allows the use of various methods for collecting information and sharing knowledge, as well as tools for practical analysis. In this way, knowledge related to herpetofauna and biocultural diversity was co-produced at the local level and used as the basis for co-designing a tangible solution.

The MEB approach aims to address complex problems related to ecosystem knowledge and management (Tengö et al. 2021). For example, this approach has proven useful in protected area planning (Austin et al. 2019) and improving inclusive strategies to enhance the coexistence of wildlife and local communities (Torrents-Ticó et al. 2021). Furthermore, the inclusion of co-design makes this method a more accessible framework capable of identifying and addressing the elements that make up the complexity of socioecological problems, thus contributing to the conservation of biocultural diversity. Therefore, it becomes possible to identify specific problems in their full complexity and address these issues even in situations with limited time and resources. In this study, the knowledge systems identified several local problems, such as a lack of information, and proposed possible solutions, such as the dissemination of knowledge through videos. Although in this study we propose the use of co-design to generate a tangible solution, its use may vary depending on the objectives of the research in question.

Our methodological framework recognizes not only the need to generate new knowledge but also the importance of understanding different meanings and opportunities in solution development that promotes knowledge exchange. The integration of these approaches also prevents a single knowledge system from benefiting exclusively from the results obtained, as is often the case with traditional approaches. Similarly, Hoyte (2021) showed that the inclusion of local knowledge systems guarantees a greater chance of success in biocultural diversity conservation projects. Indeed, a key indicator for evaluating the success of projects with collaborative approaches is the extent to which the results are used by the participants who contribute their knowledge (Malmer et al. 2020; Torrents-Ticó et al. 2021). Therefore, knowledge and co-generated solutions are more likely to be used and implemented if knowledge systems are deeply involved in their understanding, design, and development from the outset (Nel et al. 2016; Yadav et al. 2021).

We propose using this integrated methodological framework for biocultural diversity conservation. Although various authors have proposed their use individually as biocultural approaches (Tengö et al. 2014; McCarter et al. 2018; Hoyte 2021), their integration provides an opportunity to advance biocultural conservation in a more holistic and complementary way. Their use can be a useful and efficient tool in developing projects that address problems at local scales and with specific biological groups, as in this case. While this study focused on herpetofauna in the Matlatzinca region, the framework is transferable to other taxa and cultural contexts.

Co-design combines knowledge collaboratively to create solutions that have a significant impact on change (Moser 2016). Moreover, this approach is effective for empowering stakeholders in the process, ensuring ownership of co-created products, and promoting change at local and regional levels in different knowledge domains (Yadav et al. 2021; McKelvie-Sebileau et al. 2022). However, we identified a limitation in co-design for biocultural diversity conservation projects: the lack of processes for building a knowledge base to collect and share information from different knowledge systems. However, the knowledge mobilization step proposed in the MEB approach proved to be a crucial complement to overcome this limitation.

We also found that incorporating various knowledge systems related to the use, management, and conservation of biodiversity was essential to developing the co-design process. This was because they showed greater interest and commitment to the jointly created solutions due to their experience. Cultural and linguistic diversity presented opportunities and challenges alike. For instance, including the Matlatzinca language in the jointly designed video strengthened cultural identity and improved the community's sense of ownership over conservation outcomes. However, tensions sometimes arose among knowledge systems due to different perceptions of certain species. The local knowledge system (LKS) considered some amphibians and reptiles (such as snakes and salamanders) dangerous, whereas the government (GKS) and academic (AKS) knowledge systems denied this claim and emphasized their ecological importance. These findings align with previous studies emphasizing the necessity of integrating diverse knowledge systems to identify conservation opportunities and address conflicts stemming from differing perceptions and management approaches (Berkes, 2009; Tengö et al., 2017; Chengere et al., 2022). Through respectful dialogue and participatory methods, it was recognized that all forms of knowledge hold equal value, requiring open and respectful listening to the concerns and suggestions of others (Johanson et al., 2016).

A pending task is assessing the impact of this project. The perception of local people towards herpetofauna may be a key aspect to evaluate. Additionally, general knowledge related to herpetofauna should be assessed since knowledge gaps were identified as the main problem associated with herpetofauna conservation. Impact assessment is a key step for decision makers; this phase is currently considered a valuable way to strengthen the holistic perspective of collaborative projects (Dawson and Suich, 2024). There are many techniques aimed at social assessment of conservation, the selection of which may consider several aspects related to the characteristics of the study (Schreckenberg et al. 2010; Jones et al. 2017; Dawson and Suich, 2024).

We have found that the strengths and limitations of both approaches can complement each other, which makes collaborative work more efficient for achieving innovative, tangible, and feasible results in a short time. However, there are also logistical and cultural challenges that may threaten project execution. For example, the lack of face-to-face participation by knowledge systems, as time availability or other circumstances may limit the participation of the same people throughout the process. Other authors, such as Webb et al. (2018) and Bowie et al. (2020), also noted that the time availability of participants is often a challenge when using collaborative approaches. However, one of the advantages of using iterative processes such as the MEB approach and co-design is that the participation of the same stakeholders is not required throughout the project. This is because the methods that follow these approaches are not rigid protocols and can be adapted to the development of the tasks at hand (Tengö et al. 2021; Davies and Wilson 2023). The use of technologies such as video conferencing can be an alternative for helping collaborators; however, this approach largely depends on the sociocultural context in which the projects are developed. Cultural challenges may include communication issues (different languages) and power imbalances that may discourage participation in the different activities. We used two strategies to prevent these issues: first, integration activities (ice-breaking activities) to favor communication by establishing a common ground among participants, and second, allowing LKS representatives to present their opinions first in each activity to favor their empowerment and appropriation of the project.

With regard to the application of our co-designed product in amphibian and reptile conservation, we propose extensive socialization that may include, at local scale, its use in schools (kindergarten, elementary, and middle school), community meetings, and social media; LKS representatives may be the appropriate actors to increase the product application and the direct benefits for herpetofaunal conservation. On a regional scale, GKS and AKS may promote the use of this product as material for environmental education in other communities, but also as an example of community involvement in local governance and protection of its biocultural heritage, thus promoting its use among other academic and government agencies and extending its potential benefits for amphibian and reptile conservation in different contexts. We expect that the generated video will generate positive impacts on both local and regional scales, favoring conservation goals in the long term. At the local scale, we expect that our video improves the valuation and conservation of herpetofauna by increasing knowledge about local species. For example, we expect that the dissemination of species names in Matlatzinca promotes their valuation and contributes to the revitalization of this endangered language. Additionally, the video is expected to help correct local misconceptions associated with some species—particularly those perceived as extremely dangerous—which are often subject to retaliatory killing. At the regional scale, we expect this product to impact the protocols used by governmental agencies to promote conservation in protected areas, specifically by acknowledging the importance of collaborative approaches in biodiversity conservation. The participation of these agencies in our study may contribute to promoting its use in other areas under conservation as well as in projects where government and local communities work together to protect biodiversity. We think that, although our methodological framework may generate different kinds of products, the integration of different knowledge systems guarantees its appropriation and facilitates its dissemination at local and regional scales.

We generated some recommendations that might be helpful in continuing the development and implementation of this methodological framework. For example, in the mobilization phase, interview variables should be clearly operationalized. This approach enables clear definition of how each study characteristic will be observed and measured to obtain timely information from each knowledge system (Espinoza-Freire 2019). In the phases of mutual transmission of knowledge, identification of convergences, divergences, and contradictions, and synthesis, the application of tools used in co-design, such as brainstorming to identify problems and solutions, as well as interaction and feedback, made it possible to jointly propose desirable solutions that could transmit knowledge in an accessible and useful way to address the lack of information on biodiversity within the community. These activities not only highlight areas of improvement for the solution developed but also reaffirm its value as a tool for communicating information.

Conclusion

We were able to utilize the strengths of the Multiple Evidence Base (MEB) approach and co-design to create an integrated methodological framework that overcomes the limitations of both approaches. Therefore, we consider this to be a viable model for creating tangible and implementable solutions in the short term and with limited resources that also promote the valuation and conservation of biocultural diversity at the local level. While this study focused on herpetofauna in the Matlatzinca region, the framework is transferable to other taxa and cultural contexts. We recommend that future research adopt and adapt our framework to address biocultural diversity conservation challenges within other biological groups and cultural contexts. The insights gained from this project, along with the documented best practices, will be valuable to researchers aiming to design effective, culturally relevant, and socially inclusive conservation solutions. While our proposal is feasible, we have identified several limitations that may be considered in future projects. For example, in-person participation in workshops can be constrained by various social factors, such as bureaucratic constraints (for the governmental knowledge system) or potential income loss (for the local knowledge system). Additionally, participatory tools may be used to evaluate product impacts and effectiveness across knowledge systems, ensuring their long-term relevance and usefulness.

Finally, testing this framework across different cultural contexts and with various species represents a significant opportunity to advance the conservation of biocultural diversity. Evaluating how different knowledge systems collaborate to generate robust, contextsensitive solutions will strengthen both the theoretical basis of the approach and its practical relevance, enhancing its ability to be scaled up to address global conservation challenges.

References

Austin, B. J., C. J. Robinson, D. Mathews, D. Oades, A. Wiggin, R. J. Dobbs, G. Lincoln and S. T. Garnett. 2019. An Indigenous-Led Approach for Regional Knowledge Partnerships in the Kimberley Region of Australia. *Human Ecology* 47: 577-588. https://doi.org/10.1007/s10745-019-00085-9

Balderas-Valdivia, C. and A. González-Hernández. 2024. Inventario de la Herpetofauna de México. Retrieved 17 June, 2024, from ww.herpetologiamexicana.org/inventario-de-especies/

Berkes, F. 2009. Indigenous ways of knowing and the study of environmental change. *Journal of the Royal Society of New Zealand,* 39: 151-156. http://dx.doi.org/10.1080/03014220909510568

Böhm, M., B. Collen, B. Baillie, J. E. M. Bowles, P. Chanson, J. Cox, N. Hammerson, G. Hoffmann, et al. 2013. The conservation status of the world's reptiles. *Biological Conservation* 157: 372–385. https://doi.org/10.1016/j.biocon.2012.07.015

Bowie, M. J., T. Dietrich, P. Cassey and D. Veríssimo. 2020. Co-designing behavior change interventions to conserve biodiversity. *Conservation Science and Practice* 2: 1-14. https://doi.org/10.1111/csp2.278

Bridgewater, P., and I. D. Rotherham. 2019. A critical perspective on the concept of biocultural diversity and its emerging role in nature and heritage conservation. *People and Nature* 1: 291-304. https://doi.org/10.1002/pan3.10040

Burke, L., I. Díaz-Reviriego, D. P. Lam and J. Hanspach. 2023. Indigenous and local knowledge in biocultural approaches to sustainability: A review of the literature in Spanish. *Ecosystems and People* 19: 1-15. https://doi.org/10.1080/26395916.2022.2157490

Cantera, I., O. Coutant, C. Jézéquel, J. Baptiste Decotte, T. Dejean, A. Iribar, R. Vigouroux, A. Valentini, et al. 2022. Low level of anthropization linked to harsh vertebrate biodiversity declines in Amazonia. *Nature Communications* 13: 1-11. https://doi.org/10.1038/s41467-022-30842-2

Chengere, S. A, C. Steger, K. Gebrehiwot, S. Nemomissa and B. Warkineh-Dullo. 2022. Modeling cultural keystone species for the conservation of biocultural diversity in the Afroalpine. *Environments* 9: 1-16. https://doi.org/10.3390/environments9120156

Dalton, J. 2018. Dot voting. In: Great Big Agile. Berkeley, CA: Apress.

Davies, U. and K. Wilson. 2023. Design methods for developing services. Retrieved 17 October, 2023, from https://www.designcouncil.org.uk/fileadmin/uploads/dc/Documents/DesignCouncil_Design

Dawson, N. M., and H. Suich. 2025. Advancing social impact assessments for more effective and equitable conservation. Conservation Biology, 39(2), e14453.

Domínguez-Vega, H., Y. Gómez-Ortiz and L. Fernández-Badillo. 2019. Técnicas para Monitorear Anfibios y Reptiles en Ambientes Urbanos. In *Fauna nativa en ambientes urbanos*, eds. I. Zuria, A.M. Olvera-Ramírez and P. Ramírez-Bastida, 77-102.

Escalante, H. R. and M. Hernández. 1999. Matlatzinca de San Francisco Oxtotilpan, Estado de México. México: Archivo de lenguas indígenas de México.

Espinoza-Freire, E. E. 2019. Las variables y su operacionalización en la investigación educativa, segunda parte. *Revista Conrado* 15: 171-180.

Fernández-Badillo, L., I. Zuria, J. Sigala-Rodríguez, G. Sánchez-Rojas and G. Castañeda Gaytán. 2021. Revisión del conflicto entre los seres humanos y las serpientes en México: origen, mitigación y perspectivas. *Animal Biodiversity and Conservation* 44: 153-174. https://doi.org/10.32800/abc.2021.44.0153

Franks, P., y R. Small. 2016. Understanding the social impacts of protected areas: a community perspective. Retrieved 15 March, 2024, from: http://pubs.iied.org/14661IIED

Frías-Álvarez, P., J. Zuñiga-Vega and O. Flores-Villela. 2010. A general assessment of the conservation status and decline trends of Mexican amphibians. *Biodiversity Conservation* 19: 3699-3742. https://doi.org/10.1007/s10531-010-9923-9

García-Hernández, A. 2004. Matlatzincas: pueblos indígenas del México contemporáneo. Comisión Nacional para el Desarrollo de los Pueblos Indígenas. México.

Gavin, M. C., J. McCarter, A. Mead, F. Berkes, J. R. Stepp, D. Peterson and R. Tang. 2015. Defining biocultural approaches to conservation. *Trends in Ecology & Evolution* 30: 1-6. https://doi.org/10.1016/j.tree.2014.12.005

Grundmann, G. and J. Stahl. 2002. Como la sal en la sopa: conceptos, métodos y técnicas para profesionalizar el trabajo en las organizaciones de desarrollo, capacitación, asesoría, comunicación, manejo de proyectos y contexto organizacional. Ecuador: Ediciones ABYA-YALA.

Hasso-Plattner Institute of Design. 2010. An Introduction to Design Thinking. Process Guide. Retrieved 12 October, 2023, from: https://web.stanford.edu/~mshanks/MichaelShanks/files/509554.pdf

Hölting, L., M. Busse, S. Bülow, J. O. Engler, N. Hagemann, I. Joormann, M. Lee Kernecker, N. Larondelle, et al. 2022. Co-design: Working with farmers in Europe to halt the loss of biological diversity. E*cological Solutions and Evidence,* 3: 1-8. https://doi.org/10.1002/2688-8319.12169

Hoyte, S. 2021. Co-designing extreme citizen science projects in Cameroon: biodiversity conservation led by local values and Indigenous knowledge. In *Geographic Citizen Science Design: No one left behind*, eds, A. Skarlatidou and M. Haklay, 247-265. https://doi.org/10.2307/j.ctv15d8174

IDEO.org. 2015. The field Guide to Human-Centered Design. Retrieved 01 October, 2023, from: https://www.designkit.org/resources/1.html

Instituto Nacional de los Pueblos Indígenas (INPI). 2018. Etnografía del pueblo Matlatzinca. Retrieved 05 January, 2023, from: https://www.gob.mx/inpi/articulos/etnografia-del-pueblo-matlatzinca-del-estado-de-mexico?idiom=es

Instituto Nacional de Estadística y Geografía (INEGI). 2021. Uso del suelo y vegetación, escala 1:250000, serie VII (Continuo Nacional). Retrieved 08 August, 2022, from: http://www.conabio.gob.mx/informacion/gis/?vns=gis_root/usv/inegi/usv250s7gw

International Union for Conservation of Nature´s (IUCN). 2023. The IUCN Red List of Threatened Species. Retrieved 13 May, 2024, from https://www.iucnredlist.org.

Jones, N., McGinlay, J., and Dimitrakopoulos, P. G. 2017. Improving social impact assessment of protected areas: A review of the literature and directions for future research. Environmental Impact Assessment Review 64, 1-7.

Johnson, J.T., R. Howitt, G. Cajete, F. Berkes, R. Pualani Louis and A. Kliskey. 2016. Weaving Indigenous and sustainability sciences to diversify our methods. *Sustain Science* 11: 1-11. https://doi.org/10.1007/s11625-015-0349-x

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M. and C. J. Thomas. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science* 7: 25-43. https://doi.org/10.1007/s11625-011-0149-x

Levis, C., B.M. Flores, J.V. Campos-Silva, N. Peroni, A. Staal, M.C.G. Padgurschi, W. Dorshow, B. Moraes, et al. 2024. Contributions of human cultures to biodiversity and ecosystem conservation. *Nature Ecology & Evolution* 8: 866-879. https://doi.org/10.1038/s41559-024-02356-1

Lindholm, C. 2023. Short-Format Video Consumption: Evaluation of Key Quality and UX Aspects for Generation Z. Suecia: Uppsala University.

Lukawiecki, J., J. Wall, R. Young, J. Gonet, G. Azhdari and F. Moola. 2022. Operationalizing the biocultural perspective in conservation practice: A systematic review of the literature. *Environmental Science and Policy* 136: 369-376. https://doi.org/10.1016/j.envsci.2022.06.016

Maffi, L. 2001. On biocultural diversity: Linking language, knowledge, and the environment. *Chicago: Smithsonian Institution Press*.

Maffi, L. 2007. Biocultural Diversity and Sustainability. In Sage Handbook on Environment and Society, ed. J. Pretty, A. S. Ball, T. Benton, J. S. Guivant, D. R. Lee, D. Orr, M. J. Pfeffer, and H. Ward, 267–77. London: SAGE.

Maffi, L. 2018. Biocultural diversity. In *The International Encyclopedia of Anthropology*, ed. H. Callan, 1-14. https://doi.org/10.1002/9781118924396

Malmer, P., V. Masterson, B. Austin and M. Tengö. 2020. Mobilization of Indigenous and local knowledge as a source of useable evidence for conservation partnerships. In *Conservation Research, Policy, and Practice,* eds. W.J. Sutherland, P.N.M. Brotherton, Z.G. Davies, N. Ockendon, N. Pettorelli and J.A. Vickery, 82-113. United Kingdom, Cambridge University Press.

Man, M, T. Abrams and R. McLeod. 2019. Implementing and evaluating co-design. *London: New Philanthropy Capital.*

McCarter, J., E. J. Sterling, S. D. Jupiter, G. D. Cullman, S. Albert, M. Basi, E. Betley, D. Boceto, et al. 2018. Biocultural approaches to developing well-being indicators in Solomon Islands. *Ecology and Society* 23: 1-32. https://doi.org/10.5751/ES-09867-230132

McKelvie-Sebileau, P., D. Rees, D. Tipene-Leach, E. D. Souza, B. Swinburn and S. Gerritsen. 2022. Community Co-Design of Regional Actions for Children´s Nutritional Health Combining Indigenous Knowledge and Systems Thinking. *Environmental Research and Public Health* 19: 2-14. https://doi.org/10.3390/ijerph19094936

Moser, S. 2016. Can science on transformation transform science? Lessons from co-design. *Current Opinion in Environmental Sustainability* 20: 106-115. https://doi.org/10.1016/j.cosust.2016.10.007

Nel, J., D. Roux, A. drivers, L. Hill, A. Maherry, K. Snaddon, C. Petersen, L. Smith-Adao, et al. 2015. Knowledge co-production and boundary wok to promote implementation of conservation plans. *Conservation Biology,* 30: 176-188. https://doi.org/10.1111/cobi.12560

Pengüilly-Macías, M. A., A. Moreno-Fuentes, I. G. Mayer-Goyenechea and G. Espinoza-Pineda. 2010. Percepción acerca de las lagartijas consideradas nocivas por algunos otomíes, nahuas, tepehuas y mestizos en el estado de hidalgo, México. In *bases bioculturales para el aprovechamiento y conservación de los hongos silvestres comestibles en el municipio de Tenango de Doria, Hidalgo, México*, eds. Á. Moreno, R. Valadéz, M. T. Pulido, R. Mariaca, P. Mejía and T. V. Gutiérrez-Santillán, 99-105. México: Universidad Autónoma del Estado de Hidalgo. Asociación Etnobiológica Mexicana y Sociedad Latinoamericana de Etnobiología.

Pretty, J., B. Adams, F. Berkes, S. Ferreira de Athayde, N. Dudley, E. Hunn, L. Maffi, K. Milton, et al. 2009. The intersections of biological diversity and cultural diversity: towards integration. *Conservation and society* 7: 100-112. https://doi.org/10.4103/0972-4923.58642

Sánchez-Nuñez, E. 2006. Conocimiento tradicional Mazahua de la herpetofauna: un estudio etnozoológico en la Reserva de la Biosfera de la Mariposa Monarca, México. *Estudios Sociales* 15: 45-66.

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). 2019. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental– Especies nativas de México de flora y fauna silvestres– Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio– Lista de especies en riesgo. Diario Oficial de la Federación. Retrieved 14 March, 2023, from https://www.dof.gob.mx/notadetalle.php?codigo=5578808&fecha=14/11/2019

Schreckenberg, K., I., Camargo, K., Withnall, C., Corrigan, P., Franks, D., Roe, L. M., Scherl and V., Richardson. 2010. Social assessment of conservation initiatives. A review of rapid methodologies IIED.

Sterling, E. J., E. Betley, A. Sigouin, A. Gomez, A. Toomey, G. Cullman, C. Malone, A. Pekor, et al. 2017. Assesing the evidence for stakeholder engagement in biodiversity conservation. *Biological Conservation* 209: 159-171. https://doi.org/10.1016/j.biocon.2017.02.008

Suazo-Ortuño, I., A., Ramírez-Bautista, and J., Alvarado-Díaz. 2023. Amphibians and reptiles of Mexico: Diversity and conservation. In Mexican Fauna in the Anthropocene (pp. 105-127). Cham: Springer International Publishing.

Tengö, M., E. Brondizio, T. Elmqvist, P. Malmer and M. Spierenburg. 2014. Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach. *Ambio* 43: 579-591. https://doi.org/10.1007/s13280-014-0501-3

Tengö M., R. Hill, P. Malmer, C. M. Raymond, M. Spierenburg, F. Danielsen, T. Elmqvist and C. Folke. 2017. Weaving knowledge systems in IPBES, CBD and beyond-lessons learned for sustainability. *Current Opinion in Environmental and Sustainability* 26: 17-25

Tengö M., B. Austin, F. Danielsen & A. Fernández-Llamazares. 2021. Creating Synergies between Citizen Science and Indigenous and Local Knowledge. *BioScience*, 71: 503-518. https://doi.org/10.1093/biosci/biab023

Torrents-Ticó, M., A. Fernández-Llamazares, D. Bugas and M. Cabeza. 2021. Convergences and divergences between scientific and Indigenous and Local knowledge contribute to inform carnivore conservation. *Ambio* 50: 990-1002. https://doi.org/10.1007/s13280-020-01443-4

Valdez-Rentería, S.Y., H. Domínguez-Vega, V. Trujillo-Mendoza, C. E. Morón-García, Y. Ortiz-Gómez, L. Fernández-Badillo and D. Gómez-Sánchez. 2023. Importancia cultural de las serpientes: más allá de la visión ecológica. *Herpetología Mexicana*, 5: 1-16. https://doi.org/10.69905/xbqkar19

Webb, R., X. Bai, M. S. Smith, R. Costanza, D. Griggs, M. Moglia, M. Neuman, P. Newman, et al. 2018. Sustainable urban systems: Co-design and framing for transformation *Ambio* 47: 57-77. https://doi.org/10.1007/s13280-017-0934-6

Wilson, L. D., V., Mata-Silva, and J. D. Johnson. 2013. A conservation reassessment of the reptiles of Mexico based on the EVS measure. Amphibian & Reptile Conservation, 7(1), 1-47.

Wong, C. C., K. Kumpulainen and A. Kajamaa. 2021. Collaborative creativity among education professionals in a co-design workshop: A multidimensional analysis. *Thinking Skills and Creativity* 42: 1-17. https://doi.org/10.1016/j.tsc.2021.100971

Yadav, U. N., J. Lloyd, K. P. Baral, N. Bhatta, S. Mehta and M. F. Harris. 2021. Using a co-design process to develop an integrated model of care for delivering self-management intervention to multi-morbid COPD people in rural Nepal. *Health Research Policy and Systems* 19: 1-12. https://doi.org/10.1186/s12961-020-00664-z