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ORIGINAL ARTICLE

Selection of indicators as a tool for negotiating objectives and evaluating targets within participatory monitoring

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Abstract

Information that is generated through the inclusion of different knowledge sources as a process of intensive negotiation, and mutual learning, is essential for adaptive co-management. To determine if participatory monitoring is fostering social learning and contributing to adaptive co-management, we propose a process of selection and assessment of environmental learning objectives and indicators. We draw from a case study regarding natural resources participatory monitoring in Calakmul, Campeche, Mexico. To guide the selection of indicators of advances in learning, we used the environmental citizenship framework. This framework considers the ecological knowledge and scientific tools acquired through the process, as well as the social, cultural and ethical capacities achieved that are useful for environmental management. The use of this framework helped orient the process towards attributes sought as important for community researchers, as well as to pay attention to the interactions between external actors and community researchers within the collaborative research effort. Most indicators selected corresponded to those related to natural resources management, yet indicators were also selected to measure progress regarding communication abilities among community members, their organization and critical attitudes. Differences in expectations between external actors and community researchers, have to do with distinct needs and realities, as well as with the recent history of the community. The adaptive process resulted in an important tool for helping all participants, manage different visions during the process, as well as obtain consensus on concepts and constantly redefining activities as need in the process.

Keywords Indicators · Social learning · Adaptive management · Negotiation · Decision-making · Participatory monitoring

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Introduction

The adaptive management of natural resources seeks to cope with the inherent complexity of socioecological systems (Holling and Meffe 1996). It implies learning cycles for stakeholders to increase their understanding regarding the dynamics of the social and environmental components of a system they are involved with, thereby expanding their knowledge and skills for addressing continuous challenges brought about by changing conditions (Armitage et al. 2009; Rist et al. 2013). For this to occur, a socioecological learning process must take place, in which groups of actors undergo relevant experiences of experimentation and reflection (Folke et al. 2005). In turn, these experiences generate ideas, questions and evidence, that lead to changes in the ways these actors perceive and act upon the system that will later scale up to a greater number of actors (Folke et al. 2005; Reed et al. 2008; Plummer and Armitage 2007). An important aspect of adaptive management is that learning is strengthened as greater sources of knowledge and experiences are considered (Holling and Meffe 1996; Rist et al. 2013).

Given the need to generate processes and experiences for socioecological learning, participatory monitoring can be an important learning source, not only facilitating the understanding of socioecological systems but also fostering social arrangements that influence decision-making (Cundill and Fabricius 2009; Armitage et al. 2009). Citizen participation and enrollment in monitoring processes have a long tradition of involving individuals or groups with no scientific training in the design and implementation of scientific research or environmental monitoring (Fernández-Giménez et al. 2008). In 2008, Evans and Guariguata used the term participatory monitoring as an approach in which monitoring activities are conducted with the participation of local representatives that may not hold any professional training but have different levels of knowledge, experiences, interests or social roles. Participatory monitoring schemes within the environmental arena, therefore, are generally conducted with the participation of scientists or technicians with scholarly training in collaboration with local actors that can include indigenous peoples, rural communities, natural resource users or any other stakeholder interested in biodiversity, natural resources, or the environment (Danielsen et al. 2009; Reed et al. 2008). The main assumption is that in order for the information generated through monitoring to translate into management actions, the people that make local everyday decisions must have an active role in all stages; from the process of formulation of objectives, to the monitoring actions and finally, the critical discussion of the results (Guijt 2008; Evans and Guariguata 2008; Danielsen et al. 2009; 2010; Villaseñor et al. 2016). This approach relies on the fact that local actors are keepers of important knowledge regarding the dynamics and distribution inherent in natural resources (Evans and Guariguata 2008; 2016). They can be the repositories of indigenous knowledge (Odora-Hoppers 2002). Furthermore, they possess invaluable experiences regarding the management of local resources, they perform different social roles within communities and have specific interests regarding information, all this with implications in the management of natural resources (Reed et al. 2008; Evans and Guariguata 2008).

Participatory monitoring, therefore, can be considered a novel way of conducting research and development towards sustainability through the co-production of knowledge with extra-scientific actors (van der Hel, 2016). It can be a means to conduct boundary work between knowledge systems aiming at capacity development for coping with pressing current environmental issues in a way in which salience, credibility, and legitimacy are enhanced (Cash et al. 2003). Nonetheless, participatory monitoring the way we present it here, is not new as a practice, having its roots in Participatory Action Research (PAR), that originated back in the 1940 and proliferated in 1970 in countries within South America, Asia and Africa (McTaggart 1994; Kindon et al. 2007). Lewin (1952), described PAR as a learning and action process conducted in iterative steps: planification, action, observation, and evaluation of outcomes generated through action (Lewin 1952). Later on, in 1981, Hall (1981) described the practice as a collaborative process aimed at conducting research, education, and action explicitly oriented for social transformation (Hall 1981). Collaborative research such as participatory monitoring seeks to engage long term processes for capacity development conducted in a critical and transformative sense, considering that a plurality of knowledge systems and a variety of institutions influence the way reality is understood and transformed (Kindon et al. 2007). Drawing from citizen science (Irwin 2002), it shares the consideration that sustainability requires that citizens take control of their own reality, which for research and development requires a shift in the power relations between technical expertise and citizen needs.

Information generated through the inclusion of different knowledge sources, such as through participatory monitoring, can, therefore, be implemented for fostering co-management processes (Borrini-Feyerabend et al. 2007; Folke et al. 2005; Armitage et al. 2009). Intensive deliberation, negotiation and mutual learning are needed for the integration of differing understandings that comprise adaptive co-management, contributing to building capacities needed to respond to changing conditions and uncertainty inherent in socioecological systems (Borrini-Feyerabend et al. 2007; Armitage et al. 2009; Carlsson and Berkes 2004).

A form of operationalizing the adaptive management learning process can be achieved through the selection of indicators as a process that aids in defining the needs and expectations of all participants regarding the information that is generated through monitoring (Danielsen et al. 2013). The process encourages negotiation among actors since it derives from reflection, aids in concept clarification, and helps define common objectives (Abbot and Guijt 1998; Van der Werf and Petit 2002). Selecting indicators as a negotiating means is essential since decision-makers as stakeholders have specific needs, compromises and expectations that may differ, which in turn determines to a great extent the time and effort they are willing to invest in the planning and execution of monitoring efforts (Guijt 1999; Cundill and Fabricius 2009). Therefore, the participatory selection of indicators as part of the co-learning process can aid in the clarification of concepts and for achieving consensual objectives. As adapted by Ballard and Belsky (2010), we used the "environmental citizenship" framework (Berkowitz et al. 2005) to propose a methodology for selecting indicators in a particular experience that was concerted through a monitoring endeavor. As part of the participatory monitoring process, the indicator selection was directed to deliver learning results in terms of ecological knowledge and scientific tools, as well as in terms of social, cultural and ethical aspects, all aiding in the clarification of concepts and determining consensual objectives of natural resources management.

Methodology

During 2012 to 2015 a participatory monitoring effort was conducted in the community Once de Mayo, located in the Calakmul municipality in Campeche, Mexico. The effort was part of the COMBIOSERVE research consortium "Assessing the effectiveness of community-based management strategies for biocultural diversity conservation" (Vogl et al. 2015; International Innovation Magazine 2015). The consortium aimed at working in collaboration between academic researchers and local stakeholders (Hart et al. 2016), in this case, a local Civil Society Organization (CSO) and community members, to: (1) develop, through participatory research, new scientific and technological knowledge for understanding and characterizing locally developed forms of community conservation; and (2) collaborate with local stakeholders in different contexts (Southern Bahia in Brazil; Pilón Lajas in Bolivia; and Chinantla, Oaxaca, and Calakmul, Campeche, both in Mexico) to engage in participatory research and mutual learning so that research methods and outcomes could be shared among communities facing similar challenges (Vogl et al. 2015). In this work, we report only partial results of the work performed in Calakmul.

Once de Mayo as the case study was appointed by the local CSO named Consejo Regional Indígena y Popular de Xpujil, S.C. (CRIPX) that was part of the COMBIOSERVE consortium. CRIPX engaged Once de Mayo as part of the monitoring experience based on two criteria: 1) the community had active members in the association, and 2) the organization had not yet worked directly in that Ejido (the CSO wanted to influence all the communities that had associated members).

Study site

The municipality of Calakmul was decreed in 1996. It is located Southeast of the state of Campeche, limiting to the south with Guatemala and to the east with the state of Quintana Roo. Calakmul is the municipality with the highest marginalization rate in the state of Campeche, with 46.1% of the total population considered in extreme poverty (Coneval 2012). In 2015, Calakmul had a total population of 28,824 inhabitants, living in 158 localities. The population growth of the municipality between 2005 and 2015 was up to 19%, having a high immigration rate. Actually, almost half (44.1%) of the municipality´s population has come from other states of the country (INEGI 2010). Calakmul Biosphere Reserve (CBR) occupies a large area of the municipality. It can be regarded as an institution that has an important influence on the natural resource management decisions of the municipality (Villaseñor et al. 2018). This reserve is an essential part of a biological corridor that unifies tropical forest from Mexico, Belize and Guatemala. The climate is warm sub-humid, with rains in summer and an annual precipitation mean ranging from 1000 to 1500 mm per year. The mean annual temperature is 24.6 degrees (INEGI 2010). The vegetation types include medium semi-deciduous forests that cover the largest area of the municipality, dry forests, and tall semi-deciduous forests. There are also scrub swamps and other aquatic types of vegetation (Arriaga et al. 2000; Martínez Galindo-Leal 2002). The morphology of the land and the karst nature of the subsoil means that during the dry season, the surface waters are reduced to small depressions of karst dissolution (dolins), locally known as "aguadas". These "aguadas" are a very important source of water for wildlife and for some communities it is their only source of water other than rain. There is no river system and the soil favor the infiltration of rainwater (García-Gil and Fernández 2002). The region has been subject to different waves of human occupation and colonization since before the Spanish conquest. The last colonization began in the 70 s with people from 23 different states of Mexico that arrived searching for agrarian lands (Haenn 2003).

Once de Mayo (18° 5′28.11″ N, 89°27′40.82″ O; Fig. 1) is a small community within the Calakmul municipality, and it is located along the influence area of the Calakmul Biosphere Reserve (CBR; INE 2000). The community is comprised of about 350 inhabitants (INEGI 2010). It has a

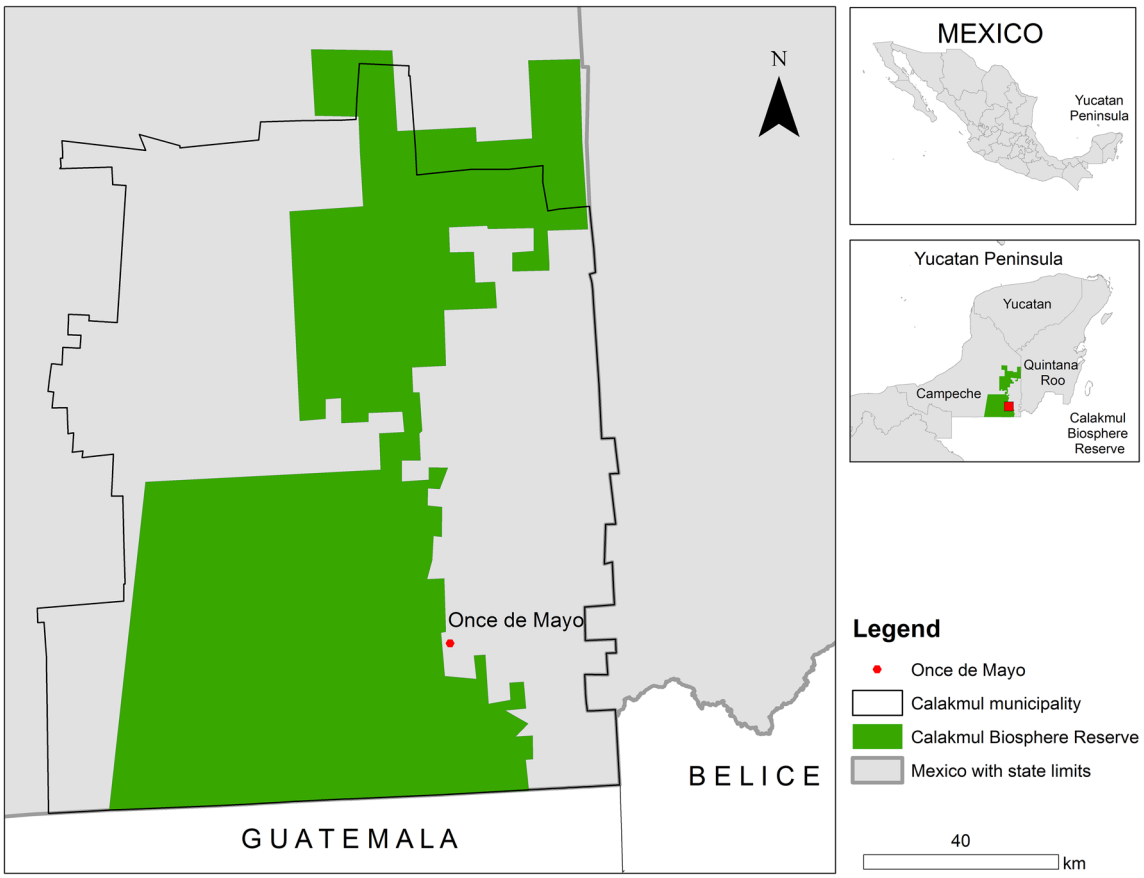

Fig. 1 Location of Once de Mayo, municipality of Calakmul, Mexico

tenure regime of Ejido (agrarian land) and a population characterized by families from different ethnic and geographic backgrounds: Chol and Tzetzal indigenous people that arrived from Chiapas and mestizo families from different states across the country, yet mostly from Veracruz, Michoacán and Chiapas. Agriculture is the main economic activity, particularly maize production for subsistence and *chihua* (*Cucurbita* sp.) and *jalapeño* chili (*Capsicum* sp.) as commercial crops. In Once de Mayo, there is a tendency towards mechanized monoculture, and traditional agroecosystems in which corn, beans and squash, among other products that are planted, are becoming less common (Desmartis 2012).

Determining monitoring themes and research questions

Table 1 summarizes the steps taken for the selection of indicators. The first step in the COMBIOSERVE project was to establish alliances between academic researchers and local stakeholders, both CSO and interested members of communities. An open call made in a community assembly of Once de Mayo to participate in COMBIOSERVE activities was made for the whole community. We explained objectives, goals and discussed possible implications regarding the process. With the interested members of the community (that included people from all ages, men and women), a participatory mapping workshop was conducted to select priorities for engaging in a monitoring endeavor (Porter-Bolland et al. 2019).

For COMBIOSERVE, community members participating in the research process were termed "community researchers". They were local inhabitants of Once de Mayo interested in participating in the resolution of some of the problems they identified as key for their wellbeing. Research questions and themes of study for the COMBIOSERVE monitoring experience were generated through the conceptualization and analysis of the local territory and its management. To accomplish this, a participatory mapping process was performed to generate discussion among participants regarding issues of relevance in relation to management practices within their territory. Through drawing mental maps, that is, sketches made by community researchers of their territory using blank papers with only the outline of the polygon representing their territory as a baseline, community researchers defined landscape units and within them, management issues, helping prioritize current concerns for choosing

Table 1 Steps taken for the selection of monitoring indicators at Once de Mayo as part of COMBIOSERVE monitoring endeavor at Calakmul, Campeche, Mexico

Steps	Process
Selection of community researchers	An open call was made to all members of Once de Mayo. The call was delivered through a community assembly
Selection of themes of study by community researchers	Through participatory mapping, an analysis of the territory derived in the identification of themes of interest regarding natural resources management and biodiversity, which were later ranked
Teams of community researchers, members of the CSO, and academic researchers were formed according to the selected themes of study	Through several workshops all participating members selected the themes of their interest and each group planned their activities
Discussion of research objectives and corresponding indicators	Focal groups with academic researchers, CSO and community researchers separately where held to choose indicators per each theme of research using the environmental citizen framework. The indicators where later prioritized by community researchers
Determination of a baseline was conducted for each selected indicator	Through interviews and focal groups, a baseline for each indicator selected by each research team using the environmental citizen framework was established
Activities for the measurement of each indicator selected by each research team were conducted	Depending on each selected indicator, group activities differed. Examples are monitoring though transect walks (for biodiversity inventories), insect traps sampling, field journal note taking, field log note taking, etc.), workshops, etc.

questions and themes of study (Rös et al. 2018; Porter-Bolland et al. 2019).

The selected monitoring themes addressed the following issues: (1) knowledge related to insects threatening agricultural crops; (2) disease of poultry raised in home gardens; (3) flora and fauna inventory of El Desierto (a landscape unit in which calcareous soil predominates, limiting the regular growth of plants, and where intermittent water flows encourage frequent visitation by different animals and birds); and (4) orchid diversity (Table 2). Regarding the themes related to the diversity of orchids and of flora and fauna of El Desierto, the interest of community researchers was to learn about biodiversity and its natural history, as well as evaluate their potential for conducting legal use of these resources (Porter-Bolland et al. 2019). For monitoring processes and selecting indicators, the themes were grouped in two categories: (1) local production, for the case of poultry production and agricultural systems and, (2) potential wildlife management, for the case of orchid diversity and El Desierto research.

Learning objectives for each monitoring team were defined during several discussion sessions with each community research group (which in turn led to a consensus regarding a research question) that drove work through the inquiry cycle proposed by Feinsinger et al. (2010). The inquiry cycle is a research process based on locally answerable questions

Table 2 Themes and research questions selected for participatory monitoring experiences in Calakmul as part of the COMBIOSERVE project

Local production modes	Monitoring themes	Research questions
Agriculture	Understanding and management of animals that threat agricultural crops	Which insects affect crops, negatively? Or, on the contrary, which benefit maize and chihua squash (*Cucurbita* sp.) crops? What is the proportion of damaged chihua squash per year? Can insect traps be a form of collecting information and controlling insects in chihua squash plantations?
Home garden poultry	Disease that threatens poultry	What are the main illnesses that affect poultry in home gardens at Once de Mayo? What plants can be used to treat these illnesses? What practices help prevent illnesses in hen houses?
Potential use of wildlife	Orchid diversity	What orchid species can be found at Once de Mayo? How does the phenology of orchid species change through time and in different types of vegetation? What legal use can be made regarding the orchids found at Once de Mayo?
Potential use of an ecosystem	Plants and animals of El Desierto	Which plant and animal species are present in El Desierto? Do the species of plants and animals found in El Desierto differ throughout the year? What legal use can be made using the plants and animals of El Desierto?

that can be comparative, simple and direct, situated within a specific spatiotemporal context (Porter-Bolland et al. 2019).

Selection of indicators using the environmental citizen framework

The participatory monitoring process had as a main objective to generate information to help facilitate the understanding of management systems leading to increased skills for coping with management problems in continually changing conditions. For selecting indicators in the process, we used the "environmental citizenship" framework (Berkowitz et al. 2005). In this framework, learning focuses in the development of critical aptitudes for environmental problem solving through four main attributes: (1) ecological literacy; (2) civics literacy; (3) values awareness; and (4) self-efficiency (Berkowitz et al. 2005). The attribute of ecological literacy implies an understanding of the socioecological system and its key ecological processes, as well as an understanding of the scientific method or the process of generating questions and being able to answer them (Berkowitz et al. 2005). The civics literacy attribute seeks for a critical comprehension of the social, cultural, economic and political realms; this literacy increases the capacity of individuals to participate in public life without separating environmental issues from their social context. The attribute of values awareness seeks the clarification of personal values in relation to the environment, as well as the appreciation of others' values and the ability to connect these values with understanding and actual behavior. This attribute emphasizes the need to understand that human well-being depends on the state of the environment and on different scales and forms that are not necessarily linear. The attribute of self-efficacy refers to the capacity of being able to learn and to take action with respect to personal values and environmental understanding. The framework of the environmental citizenship integrates these attributes through the development of practical capacities: communication skills, problem solving and clarification of situations, which leads to reinforcing the learning of the different attributes (Berkowitz et al. 2005).

For formulating and selecting indicators, group sessions were held with each of the three actors that participated in the COMBIOSERVE project: (1) community research groups; (2) CRIPX staff; and (3) INECOL staff (academics of COMBIOSERVE). Discussion groups were held separately among these actors to favor an environment of trust among participants. Discussions were held at two moments. First, monitoring objectives where selected for each theme of study, considering the four attributes of the environmental citizen. In a second discussion, indicators for evaluating the process of environmental citizenship by the theme of study were considered, as well as indicators regarding management systems involved (Fig. 2).

To have a broader opinion and feedback on the different issues at hand, information from each discussion group was synthetized and discussed with other research groups. Indicators were later prioritized within each group according to learning objectives previously selected in relation to

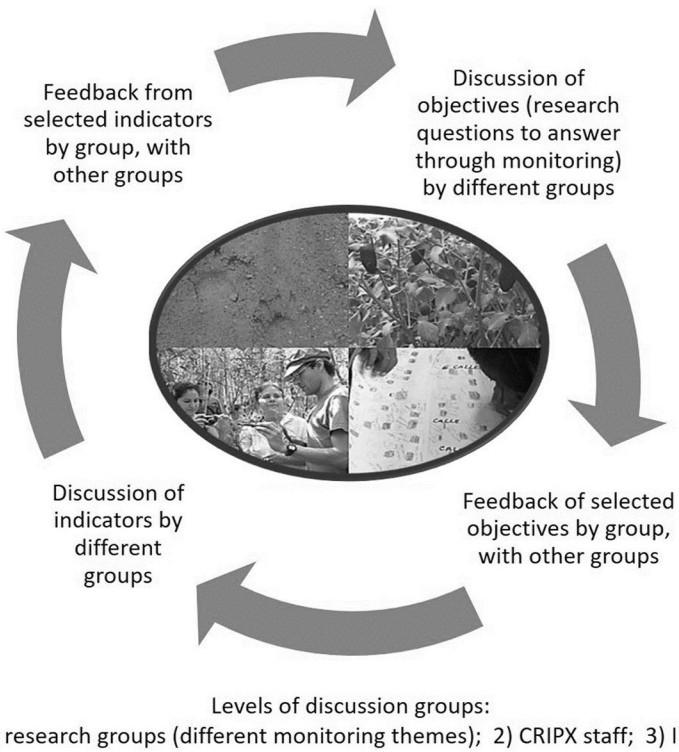

Fig. 2 Process for selecting indicators through group discussion sessions

each theme. Each indicator was selected according to its measurement viability and the likelihood that information could be reached to comply with objectives (for example, the feasibility to obtain the needed equipment, such as a weighing scale, insect traps, binoculars, trap cameras, etc., as well considerations regarding the time and abilities required to be able to conduct the monitoring activity). Discussion groups were recorded to register comments and questions of all participants, and talks began with the following generative questions: Do we know what goals we want to reach with our investigation? How will we know if we have reached our goals and what are the activities that will lead us to reach them? Responses were then synthesized into different indicators to evaluate the process and the results of the different participatory monitoring themes, that were later prioritized during the same workshops, considering their measurement feasibility and the likelihood that information could be gathered.

Baseline knowledge regarding monitoring themes

After discussing and taking agreement on the common themes of interest and objectives, participants of the different community research groups were interviewed to evaluate their knowledge and perceptions about the natural resources systems that related to their monitoring selected themes. The interview had 20 open questions divided into three sections. The first part related to personal information (place of birth, age, formal education, etc.). The second part dealt with their interest and disposition to participate in community processes such as communal work (tequios), assemblies and workshops, and with their knowledge about the practiced rules regarding natural resources in their community and the CBR. The third part of the interview sought to understand their interest or motivations to participate in the COMBIOSERVE project and the selected monitoring theme, as well as their view and importance regarding the resource(s) involved in that theme. In this last section, the order in which the interviewee indicated their motivations were taken into consideration. These interviews were complemented with informal talks that took place during the activities of the COMBIOSERVE project. The information derived from formal and informal interviews was systematized in a database to analyze the characteristics of each monitoring group and to draw a baseline regarding the knowledge and perceptions of community researchers (Villaseñor 2017).

Results

Baseline information regarding natural resource systems and monitoring themes addressed by community research teams.

A total of 16 community researchers from Once de Mayo were interviewed for the following groups: three for Agriculture, three for Orchid, six for Poultry, and four for El Desierto. Participants varied in terms of gender, age, schooling, ethnic origin and agrarian status. Of the 16 interviewed persons, 69% ($n=11$) were women and 31% ($n=5$) men. Their mean age was 46, 24 years old being the youngest and 64 the oldest. Nineteen percent had no schooling and did not know how to read or write, 31% did not finish primary school but knew how to read and write, another 19% did finish primary school and 31% finished junior high school or had a technical career. All participants were born outside Once de Mayo; 39% in Chiapas, 25% in Veracruz, 12% in Campeche, 12% in Michoacán and 12.5% in other Mexican states. Regarding land tenure, 56% had the status of poblador, which means they held no land tenure rights, and 44% were ejidatario, which signifies they had tenure rights over communal lands of the Ejido, as well as for their parcel. Ejidatarios are the people that have the right of making decisions in the assemblies from the Ejido and are, therefore, the only ones with influence in decisions taken regarding natural resources management rules.

Interviews showed that given the inhabitants have little time living at Once de Mayo, local knowledge (understood as the knowledge that a specific group of people have about the ecology of the local systems and its management; Raymond et al. 2010), was very recent and still in the process of being constructed. This is reflected in the poor recognition that people have about wild flora and fauna species; their knowledge was limited to species that hold a direct use, either as food, medicine or for construction. Species mentioned during interviews were mainly forestry species used for wood or in few occasions those that are edible such as chicozapote (*Manilkara zapota*), whose fruit is tasty and well known, and *hierbamora* (*Solanum nigrum*), an edible herbaceous plant. Most of these species have a wide distribution in different tropical areas of Mexico. Forestry species were recognized mostly by interviewees in association to their commercial use. Orchid species, on the other hand, were mostly unknown. Participants mentioned that orchids usually don't have a local name or if they did, they would not know it. During the monitoring process, participants named most of the species they surveyed according to their particular characteristics that included color, size and form. The fact that community researchers at Once de Mayo had only lived a short time in the area at the time of the interview and, therefore, were still in the process of learning about resources within their communities, is reflected in there being no references to cultural valuation, which for example would have included their use in rituals, or as medicinal or handicraft components.

Regarding participation in community processes, interviewees showed a lack of interest mostly because they

perceived inequalities regarding their ability to make decisions, which was clearly linked to land tenure rights and because of previous experiences regarding the continuity of external projects; take for example, the following quote: "I only go when Vicente [her husband, that is an ejidatario] is not here, and I have to represent him. I don't like to go because they start talking about things without providing a solution. They commonly go to another matter without a resolution. I become restless. I go to meetings when they require to sign out for projects" (woman pobladora at Once de Mayo, pers. com.).

Rules of resource use such as hunting, agrochemical applications, or flora or fauna extraction within the community are mostly unknown, and in cases that they are known, rules are perceived as ambiguous: "Regarding orchids they [ejidatarios] have not said anything [about rules for use], but I consider they have the right to say something. That I know, there are no rules about them. Regarding wood, each person [can extract if] in its own parcel" (woman pobladora at Once de Mayo, pers. com.).

Regarding the use of resources within the CBR, there is also confusion about what can or cannot be done, even though in general there remains the perception that it is prohibited to do anything within the reserves limits: "People do not go hunting. That about hunting is in the territory [territorial official zoning]. Someone came from an organization and said that hunting was prohibited within the reserve, the biosphere. A man said to them –if someone is caught, that person will go directly to prison. If it is in their parcel they can hunt, but only one animal, if someone wants. But it cannot be for selling or business. Only for consumption. He was from the government, but I do not remember very well, I thought he was from the reserve" (woman pobladora at Once de Mayo, pers. com.).

Motivations for participating in the monitoring endeavor were related mainly to curiosity and their will to learn: "I am interested in seeing what animals are there, learn more about nature" (man poblador at Once de Mayo, pers com); another motivation included the possibility of solving particular problems such as pests and poultry illnesses: "To begin with, to know why they are dying and when they have the illness, how to cure it" (woman pobladora at Once de Mayo, pers com). "We want to see if we can control or get rid of it (the pest) because if not, all the time we will be like that, with the pests that are not finished, we want to see if it can be controlled" (men poblador at Once de Mayo, pers. com.). The third most important motivation was the possibility of having a project being funded from which they could obtain economic benefits: "My hope is to see El Desierto converted into an ecotourist center" (woman ejidataria at Once de Mayo, pers. com.); "I would like to have an orchid nursery to be able to give another life to the children" (woman pobladora at Once de Mayo, pers. com.). Another motivation mentioned was the pure enjoyment of participation: "I like to participate. I always participate when we are invited to workshops" (woman pobladora, pers. com.).

Definition of objectives

A general objective was selected for each attribute of environmental citizenship and one or several specific objectives for each monitoring theme. Table 3 displays the objectives that were concerted among the three participating actors (community research groups, CRIPX and INECOL). These objectives reflect a summary of the discussed ideas and were adapted for the comprehension of all involved actors. Research priorities (objectives) and the perceived time needed for reaching results and using the obtained information, evolved significantly throughout the process. Institutional researchers (CRIPX and INECOL) prioritized an increase in the knowledge base of community researches and a reinforcement of their valuation of biodiversity, as well as processes that led to improvements in a community organization that ultimately contributed to conservation and sustainable management of natural resources. For community researchers, the priority was to implement practices that could solve problems (in the short term) affecting their crops and poultry ailments, as well as to generate information useful for the elaboration of projects that could lead to economic returns for families (Table 2). There were also differences regarding perspectives on timing. While institutional researchers aimed to generate a process that would produce long-term benefits, community researchers sought to obtain results in the short run, a solution to problems that affected their everyday wellbeing.

Selected indicators

A total of 24 indicators were finally selected to evaluate the process of learning and the results of the different participatory monitoring themes (Table 4). During the discussions held with community researchers, various indicators were eliminated as they were difficult to measure. Some others were not considered fit for the present monitoring scheme because they involved long-term changes and other decision-making scales (for example, indicators depending on the proportion of people able to demand their rights or make claims against unfulfilled agreements). Most indicators corresponded to those that refer to management, yet indicators were also selected to measure progress regarding socioenvironmental learning in terms of increasing communication abilities among community members, their organization and critical attitudes.

Table 3 Consented objectives of environmental citizenship for each participatory monitoring theme in the COMBIOSERVE project in Calakmul

Monitoring theme	Objectives
Attribute: ecological literacy	
General objective: community researchers develop abilities for deriving pertinent questions as well as designing the methodologies to be able to answer them	
Knowledge and management of animals that threaten agricultural crops (Agricultural group)	Learn about insect diversity and their eating habits Distinguish among beneficial, prejudicial and neutral insects Learn about aspects related to the integrity of agroecological systems
Diseases that threaten poultry in home gardens (Poultry group)	Learn aspects related to the biology of home garden raised poultry diseases
Orchid diversity (Orchid group)	Learn about the ecology of local orchids: their diversity, distribution, ecological requirements, phenology and reproduction
Plants and animals of El Desierto (El Desierto group)	Learn about the ecology of plants and animals found in El Desierto: diversity, distribution, ecological requirements, seasonality, reproduction
Attribute: civic literacy	
General objective: community researchers develop critical abilities to be able to question the social, political and economic systems that contextualize the management system of their interest	
Knowledge and management of animals that threaten agricultural crops (Agricultural group)	Reflect on the need to diversify agriculture and on agrochemical and market reliance Improve collaboration between agricultural producers Reflect on the advantages and disadvantages that agricultural subsidies have had in their modes of production
Diseases threatening home garden raised poultry (Poultry group)	Analyze how management practices regarding the care of home garden raised poultry influence the incidence of different ailments Improve collaboration among poultry producers Reflect on advantages and disadvantages that subsidies have had in their production modes regarding poultry in their home gardens
Orchid diversity (Orchid group)	Analyze the feasibility of taking legal commercial advantages of orchids Learn about the legal forms of making use of plant and animal wildlife in Mexico and the CBR Improve communication and agreements regarding communal lands in the ejido
Plants and animals of El Desierto (El Desierto group)	Learn about the feasibility of developing an ecotourism project at El Desierto, considering its natural attraction and its potential as an economically rewarding activity Learn about the legal forms of making use of plant and animal wildlife in Mexico and the CBR Improve communication and agreements regarding communal lands in the ejido
Attribute: value awareness	
General objective: community researchers reflect on the functions and services that ecosystems and particular species provide, including their non-utilitarian values	
Knowledge and management of animals that threaten agricultural crops (Agricultural group)	Recognize agricultural systems as agroecosystems and learn about the different functions of the elements that compose the system
Orchid diversity (Orchid group)	Reflect on the role that orchids have on the ecosystem and the services they provide to humanity
Plants and animals of El Desierto (El Desierto group)	Reflect on the role that flora and fauna species have on the ecosystem and the services they provide to humanity
Attribute: self-efficiency	
General objective: community researchers reflect on the need to take informed decisions and reduce their dependency on external agents including subsidies and technical knowledge	
Knowledge and management of animals that threaten agricultural crops (Agricultural group)	Develop abilities to take decisions based on acquired knowledge and reduce dependencies regarding external agents (including agrochemicals and technical assistance) Reduce the effects of animals that harm their crops using insect traps Reduce the effects of animals that harm their crops by implementing cultural practices (using a cropping almanac, for example) Increase efficiency in the use of pesticides

Table 3 (continued)

Monitoring theme	Objectives
Diseases threatening home garden raised poultry (Poultry group)	Increase abilities to make decisions based on acquired knowledge and reduce dependencies on external agents (medicines, technical assistance, and equipment) for production Reduce the incidence of ailments and deaths of home garden raised poultry
Orchid diversity (Orchid group)	Increase abilities to make decisions based on acquired knowledge and supported by communal agreements Analyze the social and environmental feasibility of building a community greenhouse for growing orchids
Plants and animals of El Desierto (El Desierto group)	Increase abilities to make decisions based on acquired knowledge and supported by communal agreements Analyze the social and environmental feasibility of making an ecotourism project at El Desierto

The parenthesis in the column Monitoring Theme refers to the name given to the group for further reference

Discussion

People that make natural resources management decisions on a daily basis are usually from communities that live close to the resource base for which they have legal or de facto rights. Access to these resources in the long run will greatly depend on the knowledge involved in management decisions and on institutional arrangements, both formal and informal, that frame that management (Schlager and Ostrom 1992). In this project, discussions regarding objectives and the selection of indicators showed to be useful in increasing local knowledge, as well as increasing the way resources are locally valued, a critical component for conservation (Boissiere et al. 2009).

Over the course of a year, the activities regarding the systematization of ecological information within the COMBIOSERVE process resulted in the gathering of information to a basic level of each considered system. We were able to formulate biological inventories in the case of agricultural-related insects, plants and animals of El Desierto, and in relation to orchid richness and phenological patterns. A monitoring process understood as the systematic and periodic collection of information for the means of comparing situations between differing moments or ecological/management conditions (Evans and Guariguata 2008) was not achieved, as it would have required more time. However, with the information obtained and the selection of indicators, we acquired the baseline information for designing a monitoring process, which itself implied a great amount of social learning for the research teams (including the involved community members and outsiders).

The discussion of objectives encouraged a collective reflection on productive systems as socioecological systems with various components and interactions between them and on the need to integrate activities that would provide greater contextual information that the monitoring itself. For example, achieving the objective of reducing the damage of insects in the production of squash, led to the need to identify which insects were effectively harmful to fruits, to be able to fight them successfully. That in turn, led to the reflection that not all insects are harmful, some produce a neutral effect, and others may even be beneficial, helping control harmful insects, or providing with other services such as pollination. With regards to the orchids theme, although the final purpose for the group was to implement a nursery for orchids, it was considered relevant for them to first gather information regarding the diversity and reproduction of orchids in the wild. Complementary information was, therefore, necessary to make decisions about what to monitor and how to do it. These information needs then became complementary activities for monitoring. For example, informative talks about insect diversity and their eating habits, predation dynamics, etc. were required. These ecological components and processes were later observed and discussed during the monitoring activities. Nonetheless, because the questions were raised during the definition of objectives, it was considered relevant to carry out informative talks and make collective discussions before or simultaneously to the process of data collection. These discussions necessarily led to reflection on the complexity and vastness of ecological processes. In the same way, they led to make the relationship between environmental components and socioeconomic ones, and on the role of humans in the modification of these dynamics, including each individual´s decisions, which sooner or later, will make an impact on the benefits obtained from the system and, therefore, on wellbeing.

These reflections that led to decisions on the research scheme itself coincide with the attributes of ecological literacy and civics literacy. However, we considered that the process fell short in terms of the development of attitudes related to the use of this knowledge with the attributes of values awareness and self-efficacy. As Berkowitz and

Table 4 Selected indicators for each objective generated in the different groups of participatory monitoring in Once de Mayo as part of COMBIOSERVE activities

Objective	Indicator
Monitoring theme: knowledge and management of animals that threaten agricultural crops	
Learn about insect diversity and their food habits Distinguish between beneficial, damaging and neutral insects Learn about the system´s integrity	(1) Proportion of damaged fruits with respect to chihua squash production (2) Number of different types of insects and their food preferences mentioned in interviews and during field activities (3) Number of persons able to mention or identify insects that are beneficial, damaging or neutral (or % of hits per person) (4) Number of persons able to recognize the cultivars as agroecosystems and the relations among components
Reduce the effect of animals that affect crops using insect traps Reduce the effect of production damage by implementing cultural practices	(5) Percentage of damaged fruits in relation to fruit production in the chihua crop planted at sites where insect traps were placed vs. sites that had no traps (6) Number of cultural practices learned (7) Number of cultural practices implemented during a planting cycle
Increase the efficiency of pesticide use	(8) Proportion of savings (in monetary terms) in respect to expenses of the previous year in pesticides (9) Number of applications performed during the cycle
Increase the capacity of decision-making using information on agricultural systems	(10) Usage of logbook
Monitoring theme: diseases threatening homegarden raised poultry	
Reduce the incidence of chicken illnesses and deaths	(11) Number of healthy chickens per month (12) Number of eggs produced per month (13) Number of mentioned practices learned (14) Number of practices implemented
Exchange knowledge regarding practices and plants that can be used to prevent and cure illnesses of home garden raised poultry	(15) Number of times that more than two members met to discuss these issues (16) Elaboration of recipe book
Monitoring theme: orchid diversity	
Learn about orchid diversity	(17) Number of species registered per transect walked (18) Increase of the vocabulary regarding orchid biology (19) Continuation of monitoring activities in 2016
Analyze the feasibility of implementing an orchid nursery	(20) Elaboration of a community document with the feasibility of an orchid nursery
Monitoring theme: plants and animals of El Desierto	
Learn about the plant and animal diversity of El Desierto	(21) Number of bird species registered per transect walked (22) Number of mammal species registered per transect walked (23) Number of plant species registered per transect walked
Analyze the feasibility of implementing an ecotourism project at El Desierto	(24) Elaboration of a community document regarding the feasibility of an ecotourism project

collaborators explain, the intersection of the attributes of ecological literacy and values awareness, promote attitudes that reflect the care for others (be it a person or another living being), as well as the ability to think about possible consequences and consider them when taking decisions and implementing action (Berkowitz et al. 2005). On the other hand, the intersection between the attributes of civic literacy and self-efficacy reflects the ability to perceive one's own power to make a difference.

As Irwin (2002) defines civic scientists, one of the objectives of COMBIOSERVE was that community researchers participating in the process of collaborative research engaged in capacity development to change the power dynamics of decision making that usually in that context is highly reliant in external actors such as agricultural technicians, environmental authorities or others, for bringing solutions. Changes in the decision-making dynamics within the communities were assumed to occur through capacity development, specifically through the strengthening of the self-efficacy attribute. We believe that to achieve this, more time and continuity were required in the process.

The differences in perspectives between stakeholders have been cited in other co-management and monitoring projects. For example, in the experience of Belcher et al. (2012), local actors prioritized objectives related to financial and physical capital (i.e., home electricity obtained per

capita) over social capital ones (i.e., proportion of women involved in community committees). In a similar vein, Sayer et al. (2007) mentions that aims regarding natural capital (in the context of sustainability frameworks) tend to differ for local members versus outsiders. Sayer et al. (2007) recommend including indicators that fulfill both perspectives so that ties between conservation objectives and those related to life quality can be made more explicit. This balancing of stakeholders' objectives is also relevant for the values awareness attribute. This negotiation phase of objectives that reflect the interests and priorities of both parties, show very well the intercultural differences in interests and priorities between the institutional and community researchers. The reflection about these differences was an important learning regarding transdisciplinary (Alatorre-Frenk 2018). We consider that both parties were enriched with this process. As Alatorre-Frenk (2018) reflects when discussing a series of transdisciplinary experiences, collaboration between professionals and those who manage the territories, have the potential to strengthen communities in organizational, technical, administrative, and political issues. Conversely, the academic community enriches its theoretical frameworks. The strengthening of communities can lead, in the case of one of the experiences analyzed by Alatorre-Frenk (2018) to processes of change as concrete as the acquisition of political autonomy for a community.

Within this research, differences in objectives resulted in certain frustration and lack of continued participation of some community researchers. For institutional researchers, it resulted in an important learning that influenced them to carry out activities that were more problem-oriented and less focused on information generation. However, constant follow-ups were similarly challenging given their own agendas and a failure to provide appropriate coaching. Nonetheless, the iterative and adaptive process regarding the definition of objectives was an important tool for both community and institutional researchers that helped them manage different visions during the process, as well as to obtain consensus on concepts and constantly redefine activities as necessary.

Other studies have identified the importance of communication for collaboration between inter and transdisciplinary teams. In the work of Izurieta et al. (2011) regarding the selection of indicators, there was a greater proportion of indicators related to the process of collaboration between park rangers and members of the indigenous communities for the management of a protected area. The authors stress that the process was useful to understand the "need to work on communication skills and decision making to make the transcultural collaboration more equitable".

Differences in expectations or perspectives were also related to the recent history, as immigrants, of the communities involved in this study, as there was little bonding or connection to the natural environment they were living in. Additionally, the relationship between community members and external agents has usually developed within a context of assistance-based approach that has not aided in the capacity building of self-organization and the development of critical attitudes towards community issues (Sosa-Montes et al. 2012). Problems of miscommunication between the CBR staff and forestry technicians that have implemented conservation projects within communities influence the vision and perception that community researchers have regarding biodiversity conservation. Other studies regarding community participation in conservation projects within Calakmul have concurred that community members view the forest as the basis for their subsistence and believe that top-down conservation efforts limit their livelihood (Haenn 1999; Sosa-Montes et al. 2012; Porter-Bolland et al. 2013). Armitage et al. (2009) consider these issues as obstacles to adaptive co-management. The authors argue that if there is no bonding on the part of resource management with the natural resource base, social and trust ties will be diminished.

Another important result from the process of reaching objectives was that CRIPX, as the regional grassroots organization, was obliged to start discussing their own organizational mission regarding the work they conduct, particularly in the area of agriculture and community organization. If dissimilar postures are found within the organization, it is unlikely that they can continue the monitoring process in the long run. Making explicit that the principles that constitute an organization are important for transcending the particular objectives of specific projects.

The process for deriving indicators within COMBIOSERVE began after the work started in the communities as part of the learning within the project. However, we found that it would have been very beneficial to have had this process before data collection began in the field and before the negotiations with community researchers initiated, which would, therefore, have clarified the final objectives regarding the use of the information gathered. In our case study, making explicit that objectives needed to be negotiated in a collaborative research process from the beginning would have helped for conducting activities in a more fluid and assertive manner. However, reaching consensual objectives is not possible without knowing the socio-environmental context of the communities involved and if there is no previous diagnosis such as the one the COMBIOSERVE project generated with participative mapping (Rös et al. 2018; Porter-Bolland et al. 2019). An important lesson from this is that conducting participative monitoring processes often requires a significant amount of time for generating the adequate working conditions: time for generating trusts among parties and getting to know the context, and time for conducting the prioritization of consensual objectives and the selection of indicators.

In general, once the process started and a mutual understanding began in terms of deriving and measuring indicators, it was easy to reach consensus. The greatest difficulty was the coordination between parties, particularly because the different groups were involved in multiple activities and responsibilities all the time (both institutional and community researchers as well as the members of the local organization). If we could have had discussion sessions with all members, the process would have been more assertive. In general, the evaluation of indicators became challenging because of the dynamics related to a limited continuity within the process, particularly on the part of external members both of INECOL and CRIPX. Nonetheless, lessons learned within the process are considered very valuable in many ways. One of these is the understanding that the process of selecting indicators in a participatory manner can be considered a form of engaging in collaborative research. These are lessons for the scientific community on ways that can lead to an effective co-production of knowledge such as the ones aspired by initiatives such as Future Earth (van der Hel 2016). And are tools that can be proven viable for realizing capacity development geared to achieving the Sustainable Development Goals in a way that delivers inclusive development (Gupta and Vegelin 2016).

Conclusion

We considered the generation of indicators as an adaptive process in which they are continually revised after discussions and reflections influenced by lessons learned from the collaborative experiences as well as by changes brought about by external and internal factors. In the case of COMBIOSERVE, the process was adapted to not only the group dynamics of each team but also the dynamics of the communities. In participatory monitoring, the generation of indicators and its continual evaluation can be considered part of the negotiation processes that make collaborative work possible. It requires a close coaching on the part of external members as well as the conduction of activities aimed specifically at generating critical attitudes. With the building of participants' capacities to imagine and engage in specific problem-solving processes, critical attitudes can help change bearings. The latter can broaden the agency of local actors in decision making within conservation contexts as well as reduce the dependency on outside aid for improving livelihoods.

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