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Local participation in citizen science: Lessons learned and challenges from a community sentinel monitoring program in Southern Chile

Participación local en ciencia ciudadana: aprendizajes y desafíos de un programa de monitoreo de centinelas comunitarios en el sur de Chile

Participação local na ciência cidadã: aprendizados e desafios de um programa de monitoramento de sentinelas comunitárias no sul do Chile

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Abstract: The participation of local communities in research processes can be facilitated through citizen science initiatives. To strengthen conservation actions in relevant ecosystems, different methodologies of this discipline support the collaboration with local inhabitants in data generation and systematization. The objective of this work was to systematize the community monitoring experience and assess participants' motivations and expectations. In the Humedales del Río Maullín Nature Sanctuary (SNHRM) – a relevant area for biocultural conservation – two participatory monitoring initiatives took place using the community sentinels methodology. This methodology is based on sharing information on biodiversity, memory, practices, uses, environmental changes, and cultural landscape relevant to communities, integrating local information and the recovery of traditional knowledge. The first monitoring node included the initial stretch of the Maullín river, between the communes of Llanquihue and Los Muermos (-41.26°S, -71.99°W), and the second the estuarine area of Amortajado-Maullín (-41.661°S, -73.684°W). The main results include the need to involve participants in actions that raise awareness and promote SNHRM conservation, with a total of 90 records, notably 27 on biodiversity and 33 on environmental threats. This information was shared through instant messaging groups and complemented by field activities: 11 in the Llanquihue – Los Muermos Node and nine in Amortajado.

Keywords: Community science; monitoring; local conservation.

Resumen: La participación de las comunidades locales en los procesos de investigación puede facilitarse a través de iniciativas de ciencia ciudadana. Las diferentes metodologías de esta disciplina permiten colaborar con los habitantes de los territorios en la generación y sistematización de antecedentes para fortalecer las acciones de conservación de ecosistemas relevantes. Así, el objetivo de este trabajo fue sistematizar la experiencia de monitoreo comunitario y evaluar las motivaciones y expectativas de sus participantes. En el Santuario de la Naturaleza Humedales del Río Maullín (SNHRM), un área relevante para la conservación biocultural, se desarrollaron dos iniciativas de monitoreo participativo utilizando la metodología de Centinelas Comunitarios. Esta metodología se basa en compartir antecedentes de biodiversidad, memoria, prácticas, usos, cambios ambientales y paisaje cultural relevantes para las comunidades, permitiendo la integración de antecedentes locales y el rescate de conocimientos tradicionales. El primer nodo de monitoreo incluyó el tramo inicial del Río Maullín, entre las comunas de Llanquihue y Los Muermos (-41,26°S, -71,99°O), y el segundo en la zona estuarina de Amortajado – Maullín (-41,661°S, -73,684°O). Entre los principales resultados se identificó que existe una necesidad de involucramiento de los participantes en acciones que visibilicen y promuevan la conservación del SNHRM, obteniéndose un total de 90 registros, destacando 27 sobre biodiversidad y 33 sobre amenazas ambientales. Esta información se compartió a través de grupos de mensajería

instantánea y se complementó con actividades de campo: 11 en el Nodo Llanquihue – Los Muermos y 9 en Amortajado.

Palabras claves: ciencia-comunitaria; monitoreo; conservación local.

Resumo: A participação das comunidades locais nos processos de investigação pode ser facilitada por meio de iniciativas de ciência cidadã. As diferentes metodologias dessa disciplina permitem colaborar com os habitantes dos territórios na geração e sistematização de antecedentes para fortalecer as ações de conservação de ecossistemas relevantes. Assim, o objetivo deste trabalho foi sistematizar a experiência de monitoramento comunitário e avaliar as motivações e expectativas dos participantes. No Santuário da Natureza Humedales del Río Maullín (SNHRM), uma área relevante para a conservação biocultural, foram desenvolvidas duas iniciativas de monitoramento participativo utilizando a metodologia de Centinelas Comunitários. Essa metodologia se baseia no compartilhamento de antecedentes de biodiversidade, memória, práticas, usos, mudanças ambientais e paisagem cultural relevantes para as comunidades, permitindo a integração de antecedentes locais e o resgate de conhecimentos tradicionais. O primeiro nó de monitoramento incluiu o trecho inicial do Rio Maullín, entre os municípios de Llanquihue e Los Muermos (-41,26°S, -71,99°W), e o segundo na zona estuarina de Amortajado – Maullín (-41,661°S, -73,684°W). Entre os principais resultados, identificou-se a necessidade de envolver os participantes em ações que visibilizem e promovam a conservação do SNHRM, obtendo-se um total de 90 registros, destacando-se 27 sobre biodiversidade e 33 sobre ameaças ambientais. Essas informações foram compartilhadas por meio de grupos de mensagens instantâneas e complementadas com atividades de campo: 11 no Nodo Llanquihue – Los Muermos e 9 em Amortajado.

Palavras-chave: ciência comunitária; monitoramento; conservação local.

1. Introduction

Citizen science (CS), also known as community science or public participation in scientific research, is a growing movement that involves the active engagement of citizens in the design and implementation of a broad range of scientific research (Theobald et al., 2015). While CS is sometimes considered a recent phenomenon, non-professional scientists have studied the world throughout history (Miller-Rushing et al., 2012); most of today's knowledge about our natural environment comes from data collected, transcribed, and processed by people without any formal training or scientific knowledge (Bonney et al., 2014).

CS has become a well-spread methodology and is based on building collaborative, cooperative, and information co-producing relationships among scientists and people (Jordan et al., 2016), tapping on social participation resources to address environmental issues and share experiences within the scientific process (López-Gómez et al., 2014). CS can broaden research capacities while simultaneously providing encouraging opportunities for those involved, directly engaging them in the solution of public issues (Ellwood et al., 2017). Hence, it can be considered a methodological approach that supports the comprehensive understanding of the relationship between territories and their inhabitants (Araos et al., 2022).

CS has proven to be a valuable tool for biodiversity conservation (Ellwood et al., 2017). The interest of human community members to protect the places they inhabit against a myriad of environmental threats places conservation and the sustainable use of nature as the main strategy

to envisage the future, introducing traditional practices and knowledge and promoting diverse means to connect with the environment (Brondízio et al., 2021). Thus, participatory citizen monitoring actions point to these goals, establishing diagnostics that promote awareness about the territories' socio-environmental conditions and a shared strategy-building process to face such threats (Araos et al., 2023).

The promotion of CS actions that address the compliance of conservation goals requires methodologies that can help achieve sustainable and strong environmental management outcomes. It this therefore important to identify the interests, expectations, and participation and learning barriers faced by those involved (Kapoor, 2001). Although the relationship between territories and their inhabitants can be understood through citizen science (Araos et al., 2022), the extent to which people take part in the research process and the quality of such engagement are closely related to the variety and types of outcomes achieved (Shirk et al., 2012). Since the success of citizen science projects depends on engaging and retaining participants, there is growing research on the drivers that move people to devote unpaid time, skills, and knowledge to science (Larson et al., 2020; Shinbrot et al., 2023).

Motivations and participation barriers to volunteering are still poorly studied in the Global South, compared to research on this topic coming from Northern Hemisphere countries (Shinbrot et al., 2023). Overall, the driving forces seem to be influenced by socioeconomic status and cultural contexts (Bonney et al., 2009; Rotman et al., 2014; Ellwood et al., 2017). As a general rule, volunteering in higher in higher-income countries/places, since low-income individuals devote more than one third of their time to income-generating activities (Salamon et al., 2011). Recent research has identified a variety of motivations to take part in citizen science and, in the case of environmental monitoring, five categories have been identified to explain what influences participation:

(1) help the environment;

(2) learn about one's own surroundings;

(3) connect socially with others;

(4) be part of a well-organized team that values one's work; and

(5) experience opportunities for personal reflection outside one's routine and in nature (Shinbrot et al., 2023).

Underpinned by this discussion, we present two CS experiences developed in the *Humedales del Río Maullín* Nature Sanctuary (SNHRM) in the Los Lagos Region, southern Chile. Based on the Community Sentinel methodology (Araos et al., 2022) –which promotes the observation and register of a territory's relevant aspects from the perspective of their inhabitants – a community monitoring program was developed to characterize a territory's socio-environmental aspects from the standpoint of those who live there.

The initiative considered the participation of locals who shared information voluntarily through an instant messaging group; attended training workshops on water watch and monitoring; and collective reconnaissance boating trips of the territory to further explore the socio-environmental characterization in different areas of the SNHRM.

Thus, the goal of this study was to systematize the community monitoring experience as well to as assess the participants' motivation and expectations. Through the description of their monitoring work and scientific research, and the use of surveys, we assessed the relative success of the participatory strategies implemented. Finally, we critically discussed their potential to support existing conservation strategies or the development of new experiences.

2. Methodology

2.1. Study area

In Southern Chile (-41.15° S), the wetland complex formed by the Maullín river is a relevant site for aquatic biodiversity conservation, particularly based on its role as one of the few wetland systems that forms a water biological corridor between lake Andean ecosystems and the Pacific Ocean (Cursach et al., 2022). On the basis of an important social coordination that resulted in a proposal to create the *Humedales del Río Maullín* Nature Sanctuary (SNHRM), legal protection was achieved for 8,152 ha (20,144 acres) of wetlands with the creation of the sanctuary in 2022 (Delgado et al., 2020). This hydrological system contains the Monteverde archaeological site – dating back to more than 14,000 years – and still provides ecosystem services that support the lifestyles of many riverside communities that interact with these wetlands (Delgado et al., 2020). Hence, this new protected area emerges as a safeguard mechanism for the life spaces that have supported diverse riverside communities (Almonacid & Araos, 2021), who have carried out traditional livelihood practices throughout generations (Skewes et al., 2012). During the past decades, however, the area's conservation has been threatened by the environmental degradation from industrial and intensive agricultural and livestock activities, as well as the lack of land-use planning (Almonacid & Araos, 2021).

The monitoring method used was Community Sentinel, which involves careful observation during a specific time frame (minutes, days, weeks, seasons, etc.) of different elements and/or conditions present in a specific site to collect data on its features and behavior. Members of the communities and organizations collect the data, which includes photographs or audiovisual recordings, a description of what is being shared and the geographic position (Araos et al., 2022). Between May 2023 and May 2024, two citizen monitoring took place at the SNHRM. The first one was developed at

the Llanquihue – Los Muermos Node, in the upper stretch of the Maullín River, between the communes of Llanquihue and Los Muermos. This area features residential and industrial urban areas, with dwellers mainly devoted to work in dairy farms, forestry, and potato fields, with the support of local industries and services. The second sector is located at the San Pedro Nolasco estuary, in the commune of Maullín, specifically the Amortajado Node, a rural area with mainly agriculture, livestock, and artisanal fishing activities (Figure 1).

2.2. Application of the Community Sentinel method and development of the initiative

This initiative arose from the concern of environmental organizations linked to Los Lagos University researchers, who took part in the Territorial Program for the Maullín Watershed, with funding from the Investigation Territorial Networks. In the case of this social and natural science project, these networks promote the work and engagement of multidisciplinary teams, and collaborate with different stakeholders in conservation actions from citizen science. An invitation was issued through social media and local organizations to citizens interested in learning about the ecosystem status, biocultural diversity, and the threats faced by this valuable heritage. People took part voluntarily and attended training sessions on the Community Sentinel methodology and the activities organized during the project's development. After introducing the project in Llanquihue and Nueva Braunau, the Llanquihue – Los Muermos Monitoring Node was

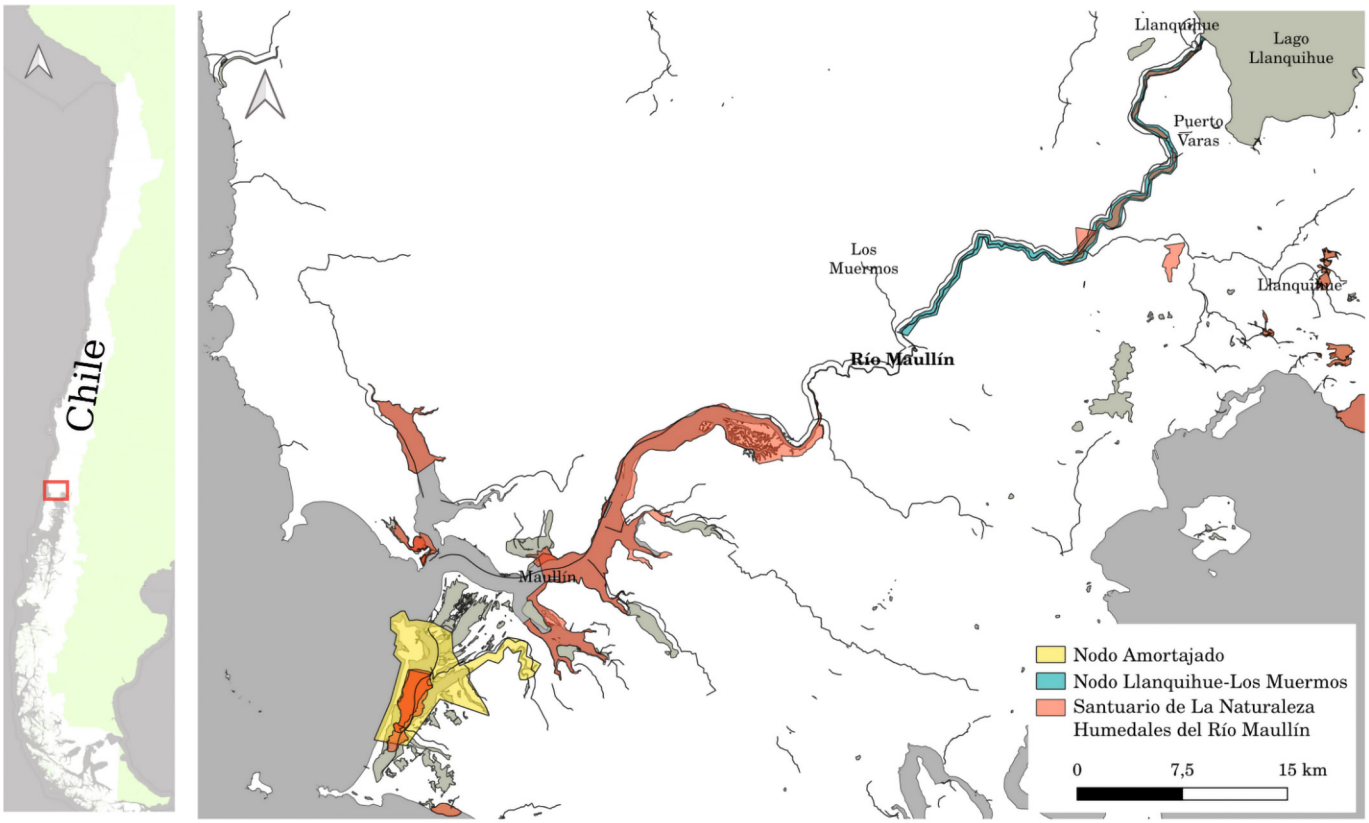

Figure 1

Study area of the Community Sentinel monitoring at the *Humedales del Río Maullín* Nature Sanctuary (in orange). The light blue polygon is the Llanquihue – Los Muermos Node of the Maullín river; and the yellow polygon, the Amortajado Node, located at the San Pedro Nolasco estuary area.

Source: Community Sentinel, own elaboration.

formed in the first stretch of the Maullín river, composed by 38 people from Llanquihue, Puerto Varas, Puerto Montt, and Los Muermos. An introduction meeting was held in the coastal zone of the SNHRM, coordinated by the project's technical team and Neighbors Association No.12 of Pasaje Amortajado, a local community organization that represents the area's residents; the Amortajado Node was formed with 11 sentinels. In both cases, all the sentinels were people of legal age (>18 years old) who shared information and took part in the activities voluntarily.

In both nodes, these meetings allowed participants to agree on shared monitoring interests and goals (first coordination stage). In the case of the Amortajado Node, this was complemented by a social mapping. Subsequently, messaging groups were formed (second organization stage). Sentinel monitoring and submission of records (third stage) was promoted by the project's technical team, who checked the data closely, particularly to make sure that the reports contained location, visual support (photographs, videos, or drawings), and descriptions. The shared records were classified in the following dimensions: biodiversity; climate change; cultural landscape; practices, stories, and memory; and environmental threats. To complement the information in hard-to-reach areas, boating trips through the SNHRM were conducted, identifying new aspects of the biocultural heritage and its threats on site (Figure 2).

Based on the goals defined, the reports shared by the sentinels, and field explorations, environmental monitoring was coordinated to become the socio-environmental baseline. In the Llanquihue Node, the monitoring assessed physical, chemical, and microbiological water quality parameters

Figure 2

Stages of the Community Sentinel methodology and activities performed during the community monitoring experiences at the SNHRM.

Source: Community Sentinel, own elaboration.

Stages 1 and 2: Coordination and creation of sentinel groups

- Meetings in each local community
- Definition of operation agreements
- Shared goals

Stage 3: Monitoring and sending records

- Interaction within messaging group
- Sending records
- Group boating trips

Stage 4: Dissemination of information

- Organization of the information
- Dissemination of maps
- Creation of action protocols

Stage 5: Application of protocols

- Continuation of socio-environmental monitoring
- Generation of new background information

in the initial stretch of the Maullín river, an area characterized by multiple wastewater discharges from industrial activities. Water quality and sediments were monitored in the Amortajado Node, assessing physical, chemical, and microbiological parameters from the San Pedro Nolasco estuary and tributary rivers. This is a relevant biodiversity conservation area and also a fish, mollusk, and algae extraction site.

Training workshops were also conducted on the socioecological aspects of the SNHRM, stressing the importance of learning about water quality from an ecological point of view, and the need to conduct socio-environmental monitoring and collect information. Training activities were carried out for the Llanquihue Node, while results were presented with the Amortajado Node.

The most common issues shared within the messaging groups and identified during the field outings encouraged the project's technical team to prepare socio-environmental action protocols that could lead potential monitoring-based actions –legal, dissemination, organizational – by sentinels. Thus, a field data collection and report preparation handbook was shared with the groups, to guide them in identifying impacts, threats, and damages to the natural and cultural heritage and local socioeconomic activities. The issues addressed in the protocols included illegal dumpsites; wastewater discharges; exotic species; and deforestation or riparian forests. In addition, information was shared on environmental reporting before relevant agencies and officials.

The fourth and last stage included the dissemination of the materials. The records shared by the sentinel – in addition to the information collected during community boating trips – allowed the characterization of the biocultural heritage and environmental threats in the Maullín river watershed. The information was organized, classified, and arranged to create an illustrated map of the SNHRM, which was also posted at www.centinelascomunitarios.cl, and shared during the results dissemination and discussion activities.

2.3. Perceptions of the monitoring experiences

To learn about the perceptions of those who took part in the community monitoring activities using the Community Sentinel method at the SNHRM, an online survey was shared through the instant messaging groups of the Llanquihue – Los Muermos and Amortajado nodes. The survey was answered voluntarily by 14 project participants, 12 from the Llanquihue – Los Muermos Node, and two from the Amortajado Node. The dimensions addressed in the survey included sentinels' motivations and expectations; participation barriers; lessons learned during project implementation; and general assessment of the initiative[1].

1 The survey shared and its results are available at: https://doi.org/10.34691/UCHILE/IUZEYL

3. Results

3.1. Creation of sentinel monitoring nodes and participation agreements

The Amortajado Node was created with 11 volunteers, mainly members of the local neighborhood association and dwellers of the commune of Maullín. The main goal agreed upon during the node creation workshop was to identify the source of environmental disturbances that impact the waters and sediments of the San Pedro Nolasco wetland and estuary, in Amortajado. The evidence shared by the sentinels that points to changes in the environmental conditions and in the distribution and abundance of benthonic organisms were complemented by environmental monitoring performed by the project's technical team (Figures 3a and 3b).

The establishment of the Llanquihue Node initially summoned 38 volunteers. The participants defined that the main goal of the community monitoring initiative was to collect data on the biodiversity of riparian areas in the initial stretch of the Maullín river and its threats. The participants also agreed to take part in theoretical and hands-on workshops on study and conservation methods of riparian ecosystems (Figures 3c and 3d). The nodes did not agree on a maximum or minimum number of reports per sentinel.

Figure 3

Dissemination, node creation, and definition of monitoring goals. a) Introduction of the initiative to the community at Amortajado, Maullín; b) Goal definition and participatory mapping workshop; c) Presentation of the initiative to participants at Llanquihue; and d) Nueva Braunau.

3.2. Records shared by community sentinels at the SNHRM

A total of 90 biocultural heritage and threat alert records were collected in the entire study area. These records were classified in predefined dimensions (Table 1), with particular emphasis on environmental threats (33) and biodiversity (27). Within the messaging group of the Llanquihue – Los Muermos Node sentinels, 18 records were shared, complemented by 52 records collected in three collective boating trips conducted jointly by the project's coordination team and sentinels living near different stretches of the Maullín river. The San Pedro Nolasco sentinels shared seven records through the messaging group, data that was complemented by 13 records collected during a community mapping workshop conducted at the headquarters of the local neighborhood association.

3.3. Activities conducted

Among the activities that complement the voluntary monitoring shared in the messaging groups are training sessions and meetings to share results and present the water quality participatory community monitoring (Table 2).

The Amortajado Node conducted several complementary activities, among them environmental monitoring over rivers and tributary streams. The goal of these activities was to identify the presence of fecal coliforms in water bodies onto which the wastewater treatment plants of Maullín and Carelmapu discharge their output. In addition, a sediment monitoring was carried out in the estuarine area and estuary's mouth, to determine

Table 1 Number of records shared by SNHRM community sentinels according to monitoring sectors.

Dimension	No. of records from the Llanquihue Node – Initial stretch of the Maullín river	No. of records from the Amortajado Node – San Pedro Nolasco estuary	Total No. of records shared
Biodiversity	24	3	27
Environmental threat	30	3	33
Climate change	2	2	4
Cultural landscape	1	2	3
Practices	5	7	12
Stories and memory	3	4	7

Table 2 Activities conducted at each SNHRM monitoring node.

Node	Total No. of activities	Type of activity
Llanquihue	11	• 2 information workshops on the Community Sentinel initiative • 4 theoretical training workshops • 2 community boating trips down the initial stretch of the SNHRM • 1 water quality technical monitoring • 2 water quality citizen monitoring activities
Amortajado	9	• 2 information workshops on the Community Sentinel initiative • 3 water quality monitoring • 1 sediment monitoring • 2 results sharing workshops • 1 community reconnaissance boating trip over the initial stretch of the SNHRM

the total share of organic matter (Figures 4a and 4b). This data was used to inform the environmental state of relevant ecosystems for the area's inhabitants, and became the first environmental baseline of the Amortajado estuary, in addition to identifying water disturbance sources (Cárcamo & Niklitschek, 2023).

The Llanquihue – Los Muermos Node sentinels took part in complementary activities to identify relevant aspects of the fresh water bodies' community monitoring. The activities performed feature workshops to identify the socioecological aspects of the Maullín river watershed and the importance of monitoring with technological devices. Four training workshops were conducted, addressing the following topics:

1) Introduction to the Maullín river ecosystem, focusing on its biodiversity and main threats;
2) Monitoring water bodies and key aspects of riparian ecosystem ecology;
3) Use of camera traps; and
4) Use and operation of water quality assessment sensors (Figures 4c and 4d).

Based on these initiatives, a group of sentinels developed a regular physical and chemical water parameter monitoring plan for lake Llanquihue (the main water body that flows into the Maullín river).

Figure 4

Participatory activities complementary to the community monitoring performed by the Amortajado Node sentinels: a) Water quality monitoring over the stream that flows into the San Pedro Nolasco estuary; b) Sediment quality monitoring at the San Pedro Nolasco estuary; and by the Llanquihue Node sentinels: c) Participatory and community water quality monitoring; d) Community boating trip down the initial stretch of the Maullín river.

3.4. Summary of the information collected during the community monitoring process

A socio-environmental characterization of the area was prepared with the data collected under the SNHRM community sentinel initiative. The illustrated map of the biocultural heritage and environmental threats to the SNHRM shows georeferenced and systematized data according to the monitoring dimensions (Figure 5).

The socio-environmental action protocols are a tool that guides citizen monitoring activities facing the most frequent threats to the SNHRM, as identified by the sentinels. With the four handbooks completed, participants can complement and reinforce in practice the community monitoring in the context of small-scale illegal dumpsites, riparian forest deforestation, presence of exotic fauna, and water pollution caused by wastewater (Figure 6).

The protocols are a guide that explains how to collect background information on the impact's location and extension; health risks; threats and harm to natural and cultural heritage; and the area's socioeconomic activities. These aspects are addressed through questions that provide the information collected on the field: What do we want to characterize? What

Figure 5

Illustrated map of the *Humedales del Río Maullín* Nature Sanctuary's biocultural heritage and its environmental threats.

Source: Community Sentinel, own elaboration.

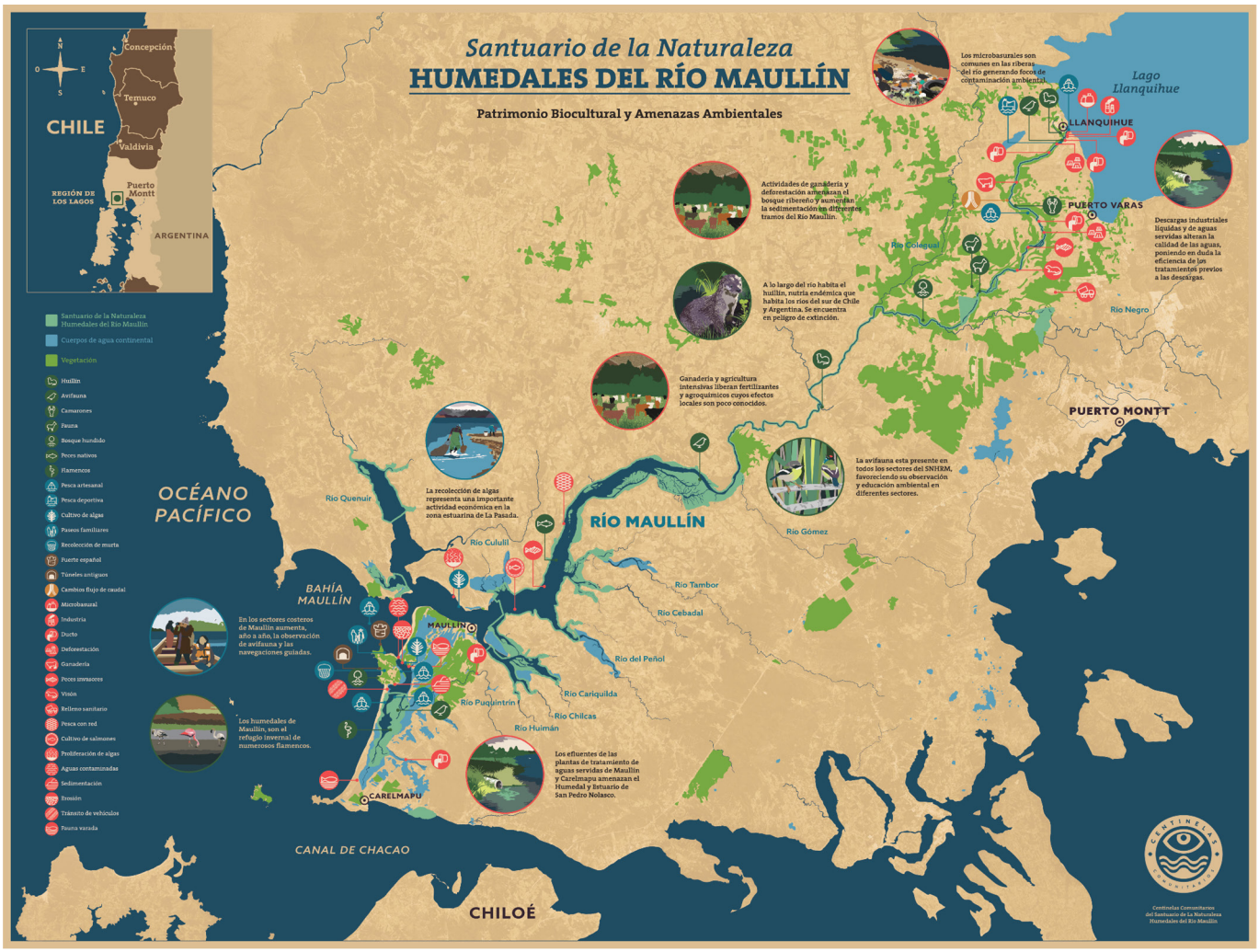

Figure 6

Socio-environmental action protocols of the main threats to the SNHRM identified by community sentinels.

Source: Community Sentinel, own elaboration.

data do we need? How can we collet that data?, as well as the synthesis of such data to create a report, namely: What should my report contain?, and How can I do it?

3.5. Characterizing the sentinels' experience

The community monitoring of the Llanquihue Node at Maullín river summoned 35 participants, of whom 14 responded to the questionnaire shared through the messaging groups. According to the answers, 60% of those who participated live in the rural areas of Llanquihue, Puerto Varas, Puerto Montt, and Los Muermos, and are part of the 12% rural share of these communes population. In Maullín, all the participants who engaged in the Amortajado Node's community monitoring live in a rural area, and are thus part of the 53% rural share of Maullín's population.

The participants of the Llanquihue – Los Muermos Node have high schooling levels, with more than 70% of them with university training, and 40% with postgraduate studies. This compares to the situation in the Amortajado Node, where the highest level of education attained by its residents is high school diploma.

Concerning *Motivations and expectations* (Figure 7.1), the main motivations expressed by those who answered the survey were to learn about the SNHRM's nature (7.1.a) and cultural heritage (7.1.b), and support specific environmental protection actions (7.1.c). There was also significant interest

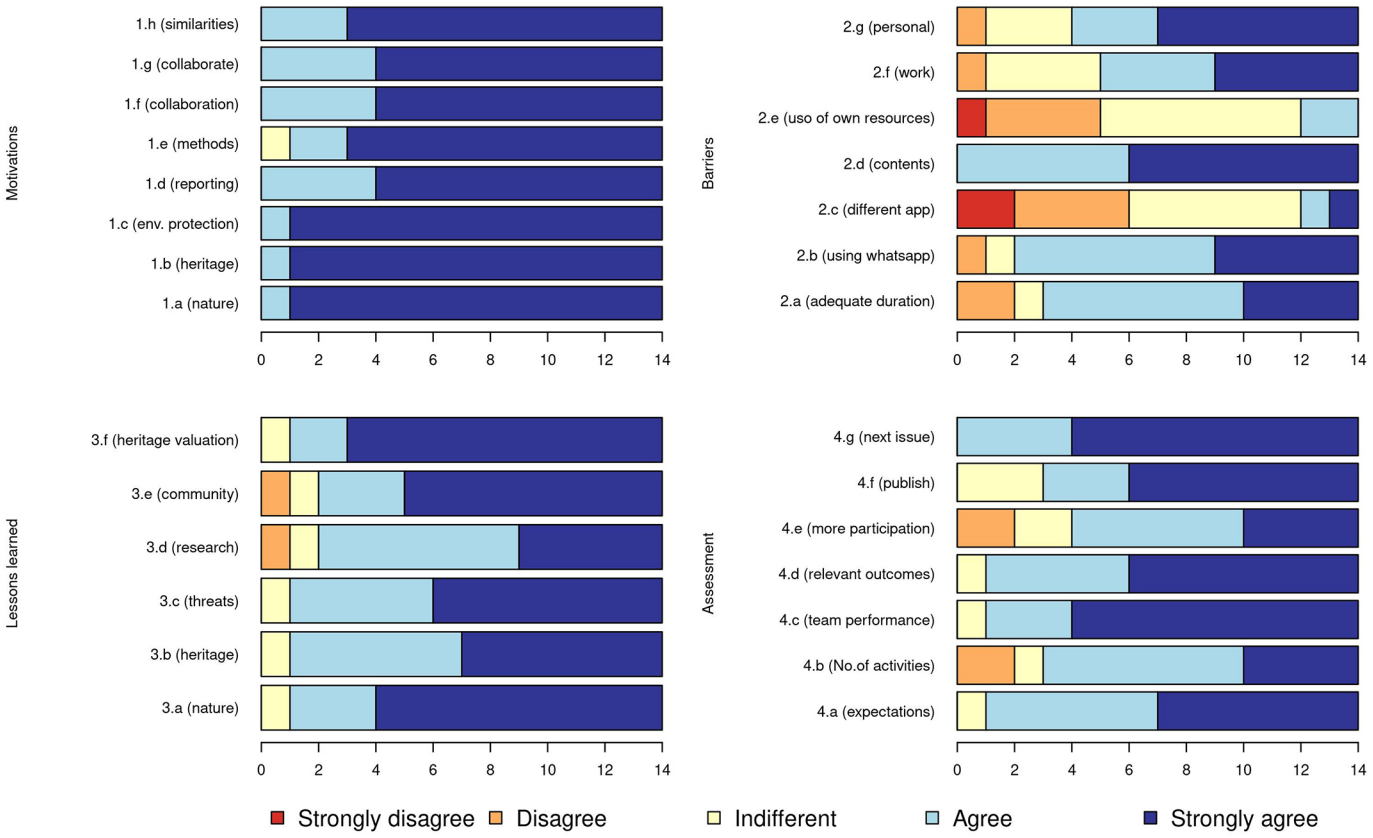

Figure 7

1) Interests and expectations;
2) Barriers to participation;
3) Lessons learned, and
4) Assessment of the experience by the SNHRM Community Sentinel Project volunteers.

in reporting actions that threaten heritage conservation (7.1.d); learning about the scientific method; being part of a research process (7.1.e); collaborating with research institutions (7.1.f); and being part of collective activities (7.1.g).

The analysis of *Barriers to participation* (Figure 7.2) reveals that most of the participants agreed that the project's duration was adequate to participate and prepare records (7.2.a). About the WhatsApp's group, while most of the participants agreed in general that it was an adequate media to register and send registers; others were indifferent or even disagreed on the use of this app (7.2.b). The latter matches some suggestions concerning the use of a specific app to register observations (replacing the WhatsApp group); some interviewees strongly agree with this option, but a large group did not express any opinion on the matter (7.2.c). Most people surveyed considered that the content of the documents, talks, and dissemination materials handed out during the project were clear and appropriate to the interests of those involved (7.2.d). Only a small portion of participants expressed that having to use their own financial resources had an effect on their involvement in the project's activities (7.2.e). The balance between time spent in the project with work/academic (7.2.f) and personal (7.2.g) responsibilities was considered adequate; only a small share of the group disagreed.

In terms of the *Lessons learned* (Figure 7.3), most of those who collaborated expressed to have acquired new knowledge about the territory's

natural and cultural heritage (7.3.a and 7.3.b), and also about the threats it faces (7.3.c). The hands-on activities developed helped them learn about new aspects of scientific research applied to socio-ecological conservation (7.3.d), which in turn relates to the spaces used, which were a chance to meet new places and people/organizations in the territory (7.3.e), boosting their valuation of the cultural and natural heritage (7.3.f).

The *Assessment of the initiative* (Figure 7.4) suggests that the project met the expectations of most participants (7.4.a, six agree and seven strongly agreed), acknowledging that the performance of the project's leading team was adequate to keep the groups motivated (7.4.c); adding that the project's outcomes could become relevant policy contributions in the territory (7.4.d). Part of the participants, however, expressed that the number and types of activities failed to keep them interested in the project (7.4.b), and that they would have benefitted from greater participation in data collection and analyses (7.4.e). Additionally, a growing interest in participating in the scientific publication of the data was observed (7.4.f), as well as in taking part in a new issue of the Community Sentinel project (7.4.g).

4. Discussion

The development of the SNHRM Community Sentinel initiative provided sentinels and scientists with a tool that can be easily adapted to the needs of the territory, enabling them to contribute to and share data on biodiversity, cultural landscapes, and environmental risks (Araos et al., 2023). This methodology prompted dialogues among the local population and scientists, and unlocked possibilities to develop individual and shared actions for environmental transformations in the SNHRM, the initial stretch of the Maullín river, and the San Pedro Nolasco estuary.

4.1. Community monitoring and shared information

The use of digital messaging group tools enabled people from different localities in the Maullín river watershed to share data gathered through community monitoring, and contributed to an ecosystem valuation based on their personal experiences and points of view (Araos et al., 2023). This interaction substantially facilitated the project's visibility, functionality, and accessibility (Bonney et al., 2014), as well as the interaction among participants. We think that the methodology proposed – based on widely spread technological devices used on an everyday basis by participants – facilitated record keeping and data sharing. However, apps designed with specific monitoring and registration purposes in mind have proven to be successful in other contexts (Johnston et al., 2021), and could favor the systematization by automating data processing while supporting the universal dissemination of data developed by community initiatives.

This issue is important as it concerns the alignment among the project's goals, the scale of the desired actions, and the people involved in data collection. The experience with Community Sentinels shows that – for the case of community-based, local level initiatives involving small amounts of data – messaging services or apps that directly connect scientists and volunteers is the most effective way to sustain the initiative over time and achieve its goals. Thus, as data volumes grow and local experiences expand, automation becomes essential for the success of initiatives seeking to scale up their impacts, such as programs that collect biological and physical datasets on a national or continental scale (Miller-Rushing et al., 2012).

4.2. Participation strategies

The integration of methodologies and the implementation of various initiatives to complement the community-based monitoring carried out by volunteers in each locality or node revealed varying levels of interest, distinct constraints, and degrees of participation (Lawrence, 2006). These initiatives help identify and acknowledge interests that are not apparent at the outset of a project, and to address new interests that may emerge as the project evolves (Shirk et al., 2012). We believe that this design – which included a variety of activities – fosters a deeper understanding of the topics (Shirk et al., 2012; Jordan et al., 2016), and helps participants develop new skills and confidence, making it an effective tool for raising awareness and promoting SNHRM conservation.

It has been reported that volunteers with environment- or science-related professions are more likely to get involved, driven by their personal interests and commitment to conservation (Larson et al., 2020). This aligns with the profile of many Llanquihue Node volunteers, where professionals with advanced academic training in topics related to the project's themes participated. In contrast, sociodemographic differences based on education and income could contribute to lower participation (Tiago et al., 2017; Larson et al., 2020), a phenomenon observed in the Amortajado Node, where the number of reports and sentinels was lower, with participants having lower educational levels and occupations directly dependent on the natural resources present in the study area. This situation can be interpreted as a consequence of environmental activism based on post-material values, where social mobilization takes place once the material conditions of existence (such as securing income and housing) have been met. That said, this interpretation may be incomplete and requires adaptation to specific contexts, since it has been demonstrated both globally – where environmental concerns cut across societies, beyond social stratification – and locally, with environmental degradation and conflicts commonly affecting marginalized and vulnerable groups (Dunlap & York, 2008). The proliferation of sacrifice zones and social mobilizations in highly vulnerable areas in Chile is a clear example of this (Anbleyth-Evans et al., 2022); therefore,

in the case presented in this article, we believe that participation rates are better explained by the type of environmental issue being monitored than by the participants' social conditions.

The Llanquihue Node volunteers expressed that their engagement was driven by environmental concerns, stressing early on the need to care for the environment, learn about their surroundings, and have the opportunity to reflect away from their daily routines and in nature (Shinbrot et al., 2023). The latter can be associated to the fact that most of those who were part of this node came from different communities, and the boating trip allowed them not only to access hard-to-reach and less-traveled areas along the upper stretches of the Maullín river, but also to identify threats such as water pollution from industrial activities and habitat destruction due to deforestation, intensive livestock farming, and land subdivision.

The daily routines and residence in the area of the Amortajado sentinels keeps them deeply connected to and immersed in the ecosystem of the San Pedro Nolasco estuary. Being familiarized with the environment meant that the community monitoring boat trip did not spark their enthusiasm. However, identifying practices, environmental threats, and ecosystem changes through discussions and participatory mapping proved very productive. In these activities, volunteers contributed valuable local knowledge about coastal biodiversity that supports economic activities relevant to fishermen and gatherers, addressing aspects such as traditional practices and their transformations over time, framed within an exercise in collective memory. Residents of this area have had to face constant environmental pollution issues, so learning about the results of an environmental monitoring that provides data on these issues is a greater motivation than simply participating in the monitoring activities themselves.

4.3. Moving forward

The challenge of developing conservation-focused citizen science projects demands having multiple goals in mind, including aspects related to conservation, individual participants, and socio-ecological systems involved. This requires the development of different strategies, actions, and indicators that can end up confusing participants and creating massive irregular and heterogeneous datasets, instead of few highly relevant and actually useful data. A way to reduce project redundancy is for scientist and project developers to establish a dialogue on potential collaborations (Bonney et al., 2009).

By using increasingly collaborative tools and resources, citizen science projects can advance conservation science, support public engagement in science, and enhance appreciation of and commitment to environmental management (Dickinson et al., 2012; McKinley et al., 2017; Phillips et al., 2018). In this regard, socio-environmental action protocols provide guidance on the methodologies and data systematization required to monitor

different issues identified. This – combined with community monitoring and collective participation opportunities – provides a tool for autonomous information management, using simple, low-cost methodologies to address a territory's environmental, cultural, and economic aspects.

Overall, sentinels in both SNHRM Nodes expressed their interest in continuing the community monitoring process, which poses the challenge of moving the initiative to a new co-creation phase that can introduce the diverse interests that motivated the participants and allows for the definition of clearly coordinated objectives (Shirk et al., 2012). The continuity agreements by Llanquihue Node participants aim at keeping long-term coordination to raise awareness among others and organize activities that promote specific conservation community actions, such as filing complaints. In the case of the Amortajado Node, where residents have had to face constant environmental pollution issues, they believe that the initiative's continuity should strengthen a co-created monitoring plan coordinated with other public stakeholders and promote greater commitment from monitors through financial contributions, tailoring the project to the specific needs of their context. We believe that the shared background is relevant because, to date, most publications addressing citizen science participation in Chile focus on school-based experiences (Burgos et al., 2017; Senabre et al., 2018; Tejeda & Medrano, 2018; Nuñez-Farias et al., 2019; Hiriart et al., 2022; Colina-Vargas et al., 2024). This experience was conducted by adults who engaged in community monitoring efforts aimed at addressing the common concerns of their local communities.

5. Conclusions

We believe that the results obtained through this initiative are of great value for SNHRM conservation and management efforts, as they provide skills and information to local communities in various regions where there is already a concern for the environment and biocultural heritage. The coordination of real-time community monitoring networks can alert communities to changes in the sanctuary area, their territories, or shared resources, and also facilitate collaboration with regulatory agencies or decision-makers to influence local public policies that can benefit their territories.

The sentinels' interest in the continuity and future of this effort can strengthen their connection with nature, help them appreciate and protect it, and invite new participants to join in care-giving efforts and the promotion of diverse ways to engage with the environment.

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