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Research

Mobile apps increase the visibility of women's work contributions in Mexican small-scale fisheries

Tamhida Ahmed[1], *Magdalena Précoma-de La Mora*[2], *Kara E. Pellowe*[1] and *Emilie A. L. Lindkvist*[1]

ABSTRACT. Small-scale fisheries in low and middle-income countries often lack information on data reporting processes and reliable data sources. Accurate data collection is crucial for accountability, as it helps track reporting sources and monitor fishing activities. Current empirical studies on the effectiveness of mobile apps in facilitating transparent data sharing, addressing gender disparities, and improving compliance with marine reserves remain limited. To address these challenges, the non-governmental organization Comunidad y Biodiversidad launched PescaData in 2020, a mobile app designed to help fishers record logbooks, share community solutions, and access a marketplace for trading, knowledge exchange, and communication. This study examines the potential of PescaData to enhance the visibility of women's contributions to small-scale fisheries, using marine reserves in Mexico as a case study. The research employs Q-methodology, a participatory mixed-methods approach that identifies shared perspectives within a group. Using generic purposive sampling, 10 fishery leaders participated, representing general opinions on PescaData's impact. Findings highlight two key perspectives. First, mobile apps like PescaData increase the visibility of women in fisheries, fostering trust and collaboration between male and female fishers and fish workers, strengthening collective action. Second, as trust grows, male fishers begin to delegate traditionally male-dominated tasks, such as reporting catch data, to women. This shift enables women to take on more active roles in reporting both community solutions and catch data, which leads to increased compliance with marine reserves in the fishing community. These findings emphasize the transformative potential of mobile technology to promote gender inclusivity and sustainability in small-scale fisheries. By integrating digital tools like PescaData, fisheries management can enhance data transparency, accountability, and conservation efforts while fostering equitable participation among fishery actors. The study underscores the need for further research and policy to maximize the benefits of mobile technology to achieve sustainable and inclusive fisheries.

Key Words: *collective action; data; gender equality; marine reserves; Q-methodology; trust*

INTRODUCTION

Small-scale fisheries (SSF) in low and middle-income countries lag significantly behind in access to trustworthy, consistent, and easily available data, which is needed to promote agency and sovereignty (Development Gateway 2023). Currently, there is a lack of available data on who is reporting and how data is being used (Pita et al. 2019). Communities have become testing grounds for technology, with little control over how the resulting data is used, maintained, and evaluated (Tilley and Roscher 2020), leading fishers to value transparent and fair data sharing (Fujita et al. 2018). Given that mobile apps are perceived as transparent and fair, there is the potential for increased adoption of apps in fisheries (Bradley et al. 2019). As mobile apps become more integrated into data collection and management in SSF, it is essential to ensure that digital tools like mobile apps capture and reflect the contributions of all fish workers, including women, for equitable and inclusive fisheries management.

Women's role in fisheries is often not recognized (Mills et al. 2011, Kleiber et al. 2017), and they have limited decision-making power and access to or control over resources (Tilley et al. 2021). The contribution of women fishers and fishworkers in SSF is substantial (Harper 2019), but is often omitted from statistics and decision making, which impacts the ability to manage resources effectively (Tilley et al. 2020). This research gap makes it pertinent to study whether mobile apps could assist in recognizing and accounting for women and their role in SSF. Based on recent reviews (Kleiber et al. 2015, Frangoudes et al. 2019, Tilley et al. 2021), there is a widespread trend in SSF toward differentiating space and resource use based on gender. Different environmental impacts are generated because men and women use coastal and marine resources differently (de la Torre-Castro et al. 2017). Gender issues have recently come to light in SSF within a diversity of areas such as empowerment and agency (Onyango and Jentoft 2011, Torre et al. 2019, Freeman and Svels 2022), well-being approaches (Weeratunge et al. 2014, Szaboova et al. 2022, Drury O'Neill et al. 2024*b*), women's contribution in fisheries (Harper et al. 2013, Fröcklin et al. 2014, Kleiber et al. 2015, Harper 2019, Harper et al. 2023), recognition of the gendered aspects of knowledge (Iniesta-Arandia et al. 2015, Salmi and Sonck-Rautio 2018), the need for policy inclusion and way of life considerations (Santos 2015, Koralagama et al. 2017, Mangubhai and Lawless 2021), women entering fish trade arenas (Fröcklin et al. 2013, Gopal et al. 2020), and gender integration in coastal management (Diamond et al. 2003, Szymkowiak and Rhodes-Reese 2020). Despite these initiatives, the management discourse continues to employ terms like "stakeholders" and "appropriators," or "fishermen" and "middlemen," which categorize resource users broadly. These phrases are typically linked to the actions and characteristics of males and conceal the contributions of women (de la Torre-Castro et al. 2017).

In the context of SSF, traditional gender roles often dictate women's roles as supportive rather than central to fishing activities (Lentisco and Lee 2015, Monfort 2015). Gender theory acknowledges the unequal distribution of power and resources between men and women in many societies (Carter 2014), which can influence trust and group identity dynamics (Danyliuk et al. 2022). Identities in fisheries are shaped by traditional ideas, such as the perception of women as housewives, whereas male identities

[1]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, [2]Comunidad y Biodiversidad (COBI), Guaymas, Sonora, Mexico

are strongly linked to reinforced concepts of masculinity (de la Torre-Castro et al. 2017). Trust and group identity may be constructed around masculine norms and values in male-dominated contexts, with men holding greater authority and influence within groups. This can create barriers for women to fully participate in and contribute to group identity formation, leading to feelings of exclusion or marginalization (Kleiber et al. 2017). Trust and reciprocity-based social norms have been recognized as key variables in overcoming principal-agent or collective action problems (Ostrom 1990). This also holds true in SSF, where it has been shown that the different levels of trust in a community and the heterogeneity of fishers (e.g., gender and fishing roles) matter for sustainable fisheries outcomes and collective action (Basurto et al. 2013, Lindkvist et al. 2017, Drury O'Neill et al. 2024*a,b*). The use of "inclusive management," which incorporates gender and women's participation, may offer a solution to coastal resource management (de la Torre-Castro 2019). Mobile apps can provide women with access to information, resources, and networks that enhance their visibility, voice, and agency within SSF (Organization for Economic Development and Cooperation (OECD) 2018).

Of particular interest in fisheries from a gender, equity, and conservation perspective are marine reserves (Ban et al. 2019). Marine reserves are one of the main conservation strategies in fisheries that provide a refuge for targeted species and create a positive spillover effect that benefits fisheries. Yet struggles with non-compliance, gender-related equity, and fairness issues are common (Bergseth et al. 2023, Drury O'Neill et al. 2024*a*).

This research aims to explore if and how mobile apps enhance women's visibility in SSF. The study will examine how apps shape social identities and power dynamics, and examine their impact on compliance with marine reserves, by answering the following research questions: (1) Can mobile apps be used as a digital tool to increase the visibility of women's contributions to Mexican SSF, and how? (2) Can apps build trust and lead to increased compliance with marine reserves, especially among the male fishers in the community, and how? and (3) Does the use of mobile apps lead to stronger collective action in Mexican SSF, and how? Using Q-methodology, we examine the impact of PescaData, an app developed by the NGO Comunidad y Biodiversidad (COBI) in Mexico (pescadata.org). We further discuss the implications of our findings for the future of apps as tools for increasing women's visibility, trust, and collective action in the pursuit of sustainable fisheries.

METHODS

Case study context

Comunidad y Biodiversidad (COBI) is a non-governmental organization founded in 1999 by young people interested in marine life and reducing poverty levels (cobi.org.mx). It promotes marine conservation and sustainable fisheries management through its work with Mexico's coastal communities (Sanchez 2015). With a strong participation strategy, COBI encourages future generations of fishers to co-design solutions for resilient communities and healthy oceans (COBI and PescaData 2025).

In 2020, COBI launched the PescaData mobile app as part of the Innovación Azul (Blue Innovation) digital ecosystem (pescadata.org). With over 2500 registered users across Mexico, PescaData is a free and interactive mobile app with three main functions. One part of the app helps fishers record logbooks to keep more accurate control of target species and access the resulting data. Most importantly, these data are owned by the fishers. Second, the app has a section where any user can share solutions that can reach other fishers across different coastal communities through anyone who is using the app. In addition, a third use is that fishers are able to access "The Market" interface in the app to buy and sell products, share knowledge, and create communication forums (Precoma de la Mora et al. 2020). This research focuses on the first two parts of the app.

The demographic composition of PescaData users reflects the diversity of the Mexican fishing community, encompassing fishers of different ages, genders, and ethnic backgrounds (see Append. 1). Users include fishers, but also those involved in post-processing activities and/or those who take on administrative roles. Approximately 75% of PescaData users are male, with the remaining 25% being female. In terms of age distribution, the majority of PescaData users fall within the 25–45 age range, reflecting the active participation of both younger and middle-aged fishers in adopting mobile technology for fisheries management (pescadata.org). Additionally, as shown in Fig. 1, PescaData users are geographically dispersed, with significant user populations located in coastal regions such as Baja California Sur, Sonora, Quintana Roo, Oaxaca, Nayarit, Colima, Guerrero, Sinaloa, and Yucatan, where SSF play a crucial role in local economies and livelihoods.

Q-methodology

Q-methodology is a way to articulate numerous individual viewpoints into a few "factors" that are believed to represent shared ways of thinking between people (Li 2022). Q is especially appropriate for uncovering points of view and emphasizing differences and similarities between and within groups (Damio 2016). The participants do a Q-sorting exercise that captures the concept that individuals think about ideas in connection to other ideas rather than in isolation. The set of statements, better known as the Q-set, is usually written as expressions of opinions or beliefs on a given topic (Watts and Stenner 2005). The Q-set is drawn from the "concourse," which is the sum of all things people say or think about the issue being investigated. Ranking the Q-set gives rise to the Q-sorts, which is a cluster of subjectivity representing a shared view (Watts and Stenner 2005).

Drawing on the suitability of Q-methodology according to Brown (1980, 2004), Q was suitable for this study because: (1) the research participants are end users themselves and have reported community solutions using PescaData, and Q is good for articulating their shared visions on how the app has changed their understanding of women's role in Mexican SSF; and (2) through a careful process of selection, the research participants can mirror the breadth of individuals who are using PescaData.

Q-factor analysis is an inversion of the conventional by-item factor analysis (Stephenson 1965). Q-factor analysis differs from traditional factor analysis by correlating individuals rather than test items, making it a form of by-person factor analysis. If each participant held entirely unique preferences—expressed through their Q-sorts—no meaningful correlations would emerge. However, when significant clusters of correlations are present, they can be factorized to identify shared viewpoints, with individuals aligning to specific factors. Thus, Q-methodology is designed to uncover and describe distinct perspectives within a

Fig. 1. Map showing the geographical distribution of the Q-method participants across eight communities located in four different states of Mexico. The eight communities marked on the map (1 - San Felipe, 2 - Bahía Asunción, 3 - Punta Abreojos, 4 - Bahía Kino, 5 - San Carlos Nuevo Guaymas, 6 - Cozumel, 7 - Punta Allen, 8 - Xcalak) also correspond to regions where fishers are actively using the PescaData mobile app.

population, rather than categorizing individuals as in conventional factor analysis (Brown 1980, van Exel and de Graaf 2005, ten Klooster et al. 2008). In studies employing Q-methodology, a small but strategically selected sample is sufficient, as participants are chosen to represent the diversity of opinions within the target population (Brown 1980, 1996). Therefore, Q-analysis as part of Q-methodology does not need large numbers of participants because it can reveal characteristics independent of the distribution of that characteristic relative to other characteristics (Smith 2001, van Exel and de Graaf 2005). It only requires a sufficient number of participants to establish the existence of a factor for purposes of comparing one factor with another (Militello and Benham 2010).

The Q-method steps are summarized in Fig. 2 below and are detailed in the following sub-section.

Discourse identification

The first step of Q-methodology is to gain a good understanding of the discourse and gather all possible information related to the research objective. In this study, the aim was to itemize the full range of subjective perceptions (attitudes and norms) of the fishers who are using the mobile app, PescaData, based on four themes, i.e., trust, collective action, closure areas, and women's work contributions to Mexican SSF that exists in the studied area. In order to understand the discourse, we used the following methods: analysis of the COBI database, which comprised a collection of community solutions provided by the users of the PescaData app; informal discussions with fishery experts from COBI; and a review of literature on Mexican SSF. This study concluded with 25 statements, where the saturation point was achieved, i.e., when the addition of more statements did not present more opinions (Eden et al. 2005).

Process of identifying statements

Step 1: A single researcher conducted the thematic coding, as the data were obtained from a pre-existing COBI database containing 172 statements on community solutions, collected during field workshops through PescaData, led by COBI. The data were color coded and analyzed using Quirkos qualitative software (Quirkos n.d.) to identify preliminary correlations between the themes. Thematic coding involves identifying predefined themes in the data (Bryman 2016). Of the 172 statements, 133 were extracted, each connected to one or more of the four themes. As codification was conducted by a single researcher, intercoder reliability was not applicable in this step.

Step 2: The Quirkos statement clusters revealed a group of 12 statements under the theme "Trust," a group of 17 statements under the theme "Closure areas," a group of 35 statements under the theme "Women's contribution to SSF," and a group of 111 statements under the theme "Collective action," along with overlap statements between and across the four themes. The statement clusters helped to map out the themes that were more or less represented. This approach also enabled the selection of representative statements from each theme, including those with overlaps, allowing for the identification of themes that clustered together and the formulation of relevant statements. Subsequently, this step guided the development of the concourse and unpacked the shared ways of thinking among the fishers to design the Q-set.

Q-set design

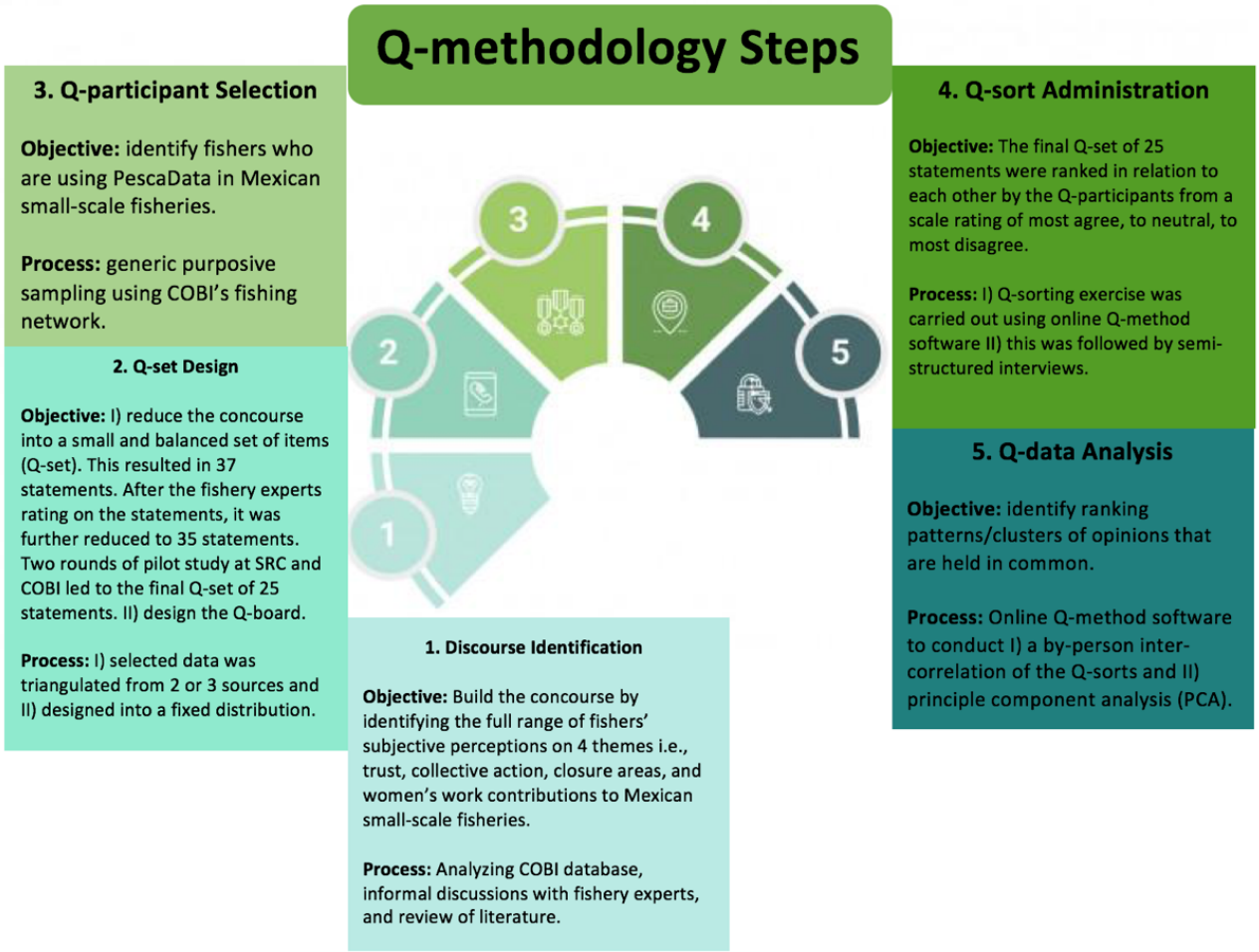
Q-set content

This step involved reducing the concourse into a manageable and comprehensive set of statements (Q-set) that the participants would rank during the Q-sorting exercise. A deductive coding technique was used to color code all the statements in the concourse and group them into the four main themes.

Triangulation was applied to determine which subjective perceptions (attitudes and norms) of the fishers under the four themes (trust, collective action, closure areas, and women's work contributions to Mexican SSF) would be included in the final list (Q-set). This required data to be identified from at least two independent data sources (Bryman 2016). Triangulation was used to strengthen the internal validity of the research design and ensure an inclusive and relevant inventory of fishers' subjective perceptions. As indicated in Fig. 3, only those statements validated through all three data sources were chosen. If that was not possible, then data from a minimum of two different sources were considered. This concourse development resulted in a total of 37 statements.

Three fishery experts from COBI initially refined the 37 statements to 35. Subsequently, two rounds of pilot studies were conducted with two academics from the Stockholm Resilience Centre and the three COBI fishery experts, resulting in the development of the final Q-set comprising 25 statements, as outlined in Append. 2. The pilots refined the clarity of statements and comprehensiveness of the Q-set and provided feedback on the shape and scale of the distribution, clarity of instructions, and overall experience.

Fig. 2. Q-methodology steps conducted for the current study. Adapted from Winkler and Nicholas (2016).



Q-board design

The Q-board in the Q-method software was designed as a quasi-normal, symmetrical distribution with 25 spots (one for each of the 25 statements), as shown in Fig. 4. Participants were asked to rank the statements in order of agreement.

Q-participant selection

Using COBI's network of fishery actors, a generic purposive sampling was used to identify individuals who are using PescaData in Mexican SSF and would be representative of general opinions of PescaData. The individuals selected to participate were fishery leaders in their communities, came from diverse backgrounds with varying ages, were geographically dispersed, and are representative of the larger group of fishers' main viewpoints. The study consisted of 10 participants (i.e., four males and six females). Two of the participants were PescaData users outside of COBI's network.

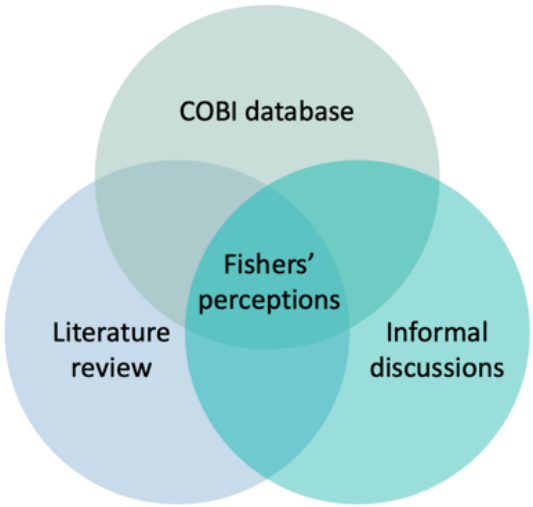
Q-sort administration

Q-sorting with the research participants was conducted online using Q-method software (Q Method Software n.d.) between 11–20 January 2024, and semi-structured interviews were conducted and recorded on Zoom on three separate interview days (23, 25 January and 1 February 2024). Studies have suggested no apparent difference in the validity or reliability between in-person and online Q-sorts (Reber et al. 2000).

After completing their Q-sorting exercise, the participants were assigned individual interview time slots. There were five rounds of interviews, each with two participants, spread over three interview days. The participants completed their Q-sorting exercise in around 15 min., and the semi-structured interviews took approximately 30 min. per person for each interview round.

The participants were sent a short message (53 words) via WhatsApp before the Q-sorting exercise, as well as a link to the exercise in the Q-method software. After signing the consent form integrated into the Q-method software, the participants completed their Q-sorting exercise. They were instructed to sort the 25 statements into three piles: Agree, Neutral, Disagree. During the interview, the researcher provided the plain language statement, which was translated by an interpreter who was present on Zoom for the interviews. The interpreter provided live translations from English to Spanish and vice versa for both the

Fig. 3. Triangulation from the data sources to design the Q-set.



researcher and the participants. Stockholm Resilience Centre's ethics committee approved the consent forms and ethical assessment.

After the Q-sorts were generated and analyzed, the semi-structured interviews were structured based on the Q-results, which prompted the participants to reflect on the ranking of their Q-set again. Corresponding questions were asked when they expressed thoughts that were relevant to the study objectives in order to address the research questions.

A semi-structured method was chosen to complement the constructivist epistemology. The semi-structured interview provides the researcher with a more exploratory and open-ended approach, using the Q-set (Watts and Stenner 2005). Furthermore, semi-structured interviews give a level of structuring and standardization across participants while leaving the session open enough to allow for reflective insights and the emergence of an untold narrative (Bryman 2016).

Q-data analysis

From Q-sorts to Q-factor analysis

The ten Q-sorts collected were used to examine whether or not the group had common viewpoints. If opinions generated from the Q-sorts are sufficiently similar, they form clusters, also known as factors. A factor requires the participation of at least two individuals (Watts and Stenner 2005). The analysis was carried out using the online Q-method software (n.d.).

A Spearman correlation was established because the data in Q-sorts is ordinal. According to Alberts and Ankenmann (2001), this provides a standardized measure of the linear relationship between two sets of ranked scores. Secondly, a principal component analysis (PCA) was used because the factors are orthogonal to each other; they are being statistically and linearly independent of one another. Thirdly, a varimax rotation method was used to identify the factors that contributed the most to the study variance.

Fig. 4. The Q-grid has 25 available slots (white) on which to place the statements. The number at the top shows a rating scale from -4 to +4, and the numbers below in brackets show how many statements fit in that rating. For example, 5 statements can be rated at 0 but only 1 at +4. There is no value relating to the vertical axis. All 25 slots must be filled, forcing the participants to rate the statements in relation to each other.

Most disagree				*Neutral*				*Most agree*
-4	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**
(1)								(1)
	(2)						(2)	
		(3)				(3)		
			(4)		(4)			
				(5)				

Accepting a factor

To find the appropriate number of factors, the following criteria were followed: (1) after varimax rotation, at least two Q-sorts should load significantly to that factor at the level of $P < 0.05$. This meant exceeding ± 0.396 based on the equation for standard error: $1.96*(1/\sqrt{N})$, where N = number items in Q-set. $1.96*(1/\sqrt{25}) = 0.396$ (Watts and Stenner 2005); (2) if the Eigenvalue of the factors were equal to or more than 1; and (3) if the cross-product of the two highest factor loadings for that factor exceeded twice the standard error, called Humphrey's rule (Brown 1993). If a Q-sort loaded significantly to two or more factors, it was not included in the analysis as it would lead to confounded factor loading.

Factor interpretations

Factor interpretation involves an analysis of the factors with the support of the qualitative data gathered during the post-sort interviews. The crib sheet writing exercise (Watts and Stenner 2005), which guides the researcher to interpret the data holistically, and the answers from the semi-structured interviews helped build the study's narrative.

Discourse analysis: building the narrative from the Q-sorts

Discourse analysis summarizes the opinions of the factor it represents and aims to make the results more comprehensible across factors. The narrative was created using the crib sheet technique, which helped to give an overview of the insights of the findings. This was a security measure to ensure that statements were not overlooked. With this technique, the highest and lowest rated statements from each factor, along with the most different rated statements from the other factor, were chosen for the narrative (Watts and Stenner 2005). Ten statements chosen for the narrative from Factor 1 and Factor 2 rated +4, -4, +3, and -3. Additionally, seven consensus statements rated across +2 to -3 were also selected to build the narrative.

In total, 17 statements were selected to represent the narrative of the Q-exercise. These statements will later be referred to by number; for example, statement number 23 with a ranking of +4, will be referred to as (23: +4), and statement number 12 with a ranking of +1 from factor 1 and +2 from factor 2 will be referred to as (12: +1, +2) in the narrative. The viewpoints that create the narrative were also complemented with quotes from the interviews.

The chosen statements for the narrative (marked in *Italics*) can be found in Append. 3.

RESULTS

For factor extraction, the Kaiser-Guttman criterion and Humprey's rule were applied. The online Q-method software suggested two factors for retention, accounting for approximately 42% of the study's explained variance. Of the 10 Q-sorts, four loaded significantly to Factor 1, and five loaded significantly to Factor 2 (Table 1). In other words, two clusters of shared viewpoints could significantly be derived from this exercise.

The composite Q-sorts for Factor 1 and Factor 2 are shown in Figs. 5 and 6 below. Subsequently, the Venn diagram in Fig. 7 was created using these composite Q-sorts and the factor arrays from the crib sheet (see Append. 4). The Venn diagram prompted the development of the narrative for this study.

The narrative from the Q

This section will explain the Venn diagram (Fig. 7) with supporting quotes (see Append. 4 for the extended version) from the participants of the interviews to answer the three research questions of this study. A summary of Factor 1, Factor 2, and Consensus statements are highlighted below.

Factor 1

Summary of opinion 1: Mobile apps promote the visibility of women and lead to increased collaboration between male and female fishers in the community, creating a sense of group identity that fosters trust and facilitates stronger collective action.

Factor 1 demonstrates a relative disagreement with the statement that mobile apps like PescaData allow fishers to have self-recognition, which in turn, increases collective action in the community *(25: -3)*. Rather, apps generate group identity in the fishing community, which increases trust and collective action *(3: +3)*.

> *...apps are also able to connect to fishing communities on the other side of the village. They're able to share what they are doing and what has been done and they also promote collaboration between communities. So it definitely has strengthened these types of connections and allowed for the visibility of different fishing groups to increase.* (P4, Female)

Also, as noted by Factor 1, NGOs cannot train fishers on gender equality or provide a safe space for women to join fishing networks *(20: -4)*. Rather, the use of mobile apps has the potential to bridge the gender gap and facilitate knowledge co-sharing among male and female fishers in the community, which in turn fosters increased trust and leads to more inclusive decision making and compliance with marine reserves. This, in turn, encourages more collective action within the fishing community *(1: +3)*. In the post-sort interviews, a task-sharing mechanism was mentioned where, if fishers were working under a patron (i.e., a permisionario, or holder of an individual fishing permit), then whenever a male fisher encountered a female fisher (i.e., a wife or daughter at home), the male fisher hands over the catch data reporting to the woman. Similarly, in a fishing cooperative, the members come to a consensus on a woman qualified to report catch on behalf of the cooperative. This way, using the mobile app, the women start reporting not only community solutions but also the daily catch data on behalf of the male fishers in the community, leading to increased group identity and trust.

> *Once women actively use apps, it gives us a lot of trust and confidence to engage with each other as a community.* (P7, Male)

Additionally, Factor 1 demonstrated that fishers respect the ban placed on scarce species because they have trust in their community *(7: +4)*. Fishers' strong agreement with this statement demonstrates how apps help to build trust and increase compliance with marine reserves.

> *...in my community, marine reserves are respected using the app. We duly share information in the app, and then more people are able to respect the reserves and the norms that are established for our fishing community.* (P9, Male)

Factor 2

Summary of opinion 2: Mobile apps facilitate stronger collective action and promote gender equality, which has led to increased compliance with marine reserves among the male fishers in the community.

Relative disagreement is seen in the statement that mobile apps have allowed women to understand their fishing contributions across the value chain, making them more aware of their rights *(17: -4)*. The interviews later revealed that it is more from the support of the cooperatives that the visibility of women's contributions in small-scale fisheries increases (for example, by accelerating the process to obtain their fishing permits when

Table 1. This table illustrates the factor retention and participant grouping in Q-methodology. The Kaiser-Guttman Criterion retains factors with eigenvalue greater than 1.00, whereas Humprey's rule retains factors if the cross-product of their two highest factor loadings exceeds twice the standard error. The table shows two factors satisfy these criteria. Under "Factor 1" and "Factor 2," with the dagger symbols are the respective four and five participants' Q-sorts, that loaded significantly on each of the factors to create the shared viewpoints. Q-sort 6 loaded more strongly to Factor 1 than Factor 2 but significantly to both; therefore, it was excluded from further analysis as its dual association made it unsuitable for defining a single, clearly interpretable factor.

Participant	Q-factor 1	Q-factor 2
P01	-0.69678†	0.04676
P02	-0.21055	-0.53342†
P03	-0.46601	-0.6611†
P04	-0.36007	0.59837†
P05	-0.51311†	-0.26067
P06	0.36345	-0.20037
P07	-0.79665†	-0.06136
P08	-0.17045	0.52465†
P09	-0.00164	-0.50141†
P10	-0.74542†	0.04088
Eigenvalue	2.524533	1.68888
% of Explained Variance	25.24533	16.8888
Cumulative Variance	25.24533	42.13413
Humphrey's Rule	0.57276	0.36527
Standard Error	0.31623	0.31623

Fig. 5. Composite Q-sort for Factor 1. A composite of the four participants that loaded to Factor 1. A cluster of their viewpoints.

Most disagree -4	-3	-2	-1	Neutral 0	+1	+2	+3	Most agree +4
20. NGO training on gender equality can create a safe space for women to join fishing networks.	**18.** Mobile apps aid fishers in connecting with NGOs, enhancing their training and promoting the inclusion of women and youth in the fishing network.	**15.** Female fishers can actively participate in environmental promoter groups, raising awareness for fishermen to respect marine reserves.	**19.** A cooperative led by young female fishers encourages the creation of more such cooperatives in other communities.	**24.** Using social media to communicate social campaigns, festivals, or events raises awareness for issues in our community leading to stronger collective action.	**12.** The rise in gender-specific fisheries data highlights women's involvement in decision-making processes enhancing their visibility in our community.	**22.** Cooperatives offer scholarships and support to their members' children, in the hope that they contribute to the fishing community when they are older.	**1.** Mobile apps facilitate increased collaboration between male and female fishers in the community, resulting in stronger collective action.	**7.** We respect the ban placed on scarce species because we have trust in our community.
	25. PescaData allows fishers to have self-recognition which increases collective action in the community.	**13.** Traditional gender roles in fishing communities have led to the perception that women don't participate in fisheries.	**21.** Mobile apps like PescaData increase visibility of women's involvement in beach clean-ups, monitoring activities, and awareness campaigns.	**4.** Mobile apps facilitate registration of fishing areas, resulting in greater trust in my community.	**9.** Respecting the marine reserves has brought the fishing community together.	**11.** Cheating is reduced and compliance with marine reserves is increased when seasonal cultural taboos are recognized.	**3.** Group identity within the community increases our trust and collective action.	
		16. Female-led cooperatives that own fishing permits offer equal opportunities for female fishers to earn fair compensation.	**14.** Support from cooperatives enables women to have more capacity for action and opportunities to be involved in decision making.	**2.** Focus groups among the fishers are safe spaces to improve trust and collective action in my community.	**5.** Illegal fishing is minimized by enhancing compliance with marine reserves, leading to increased trust among fishers in my community.	**10.** A longer period of marine reserves is required to maintain fish abundance and catch if there is low compliance among the community.		
			6. Fishing communities with a lot of trust in each other will be willing to have compliance even for larger marine reserves.	**17.** Mobile apps allow women to understand their fishing contributions across the value chain, increasing awareness of rights.	**23.** Collective action and gender equality starts when men increasingly support and collaborate with their wives.			
				8. The use of mobile apps for reporting community solutions fosters trust among community members, increasing respect for marine reserves.				

women are involved), which enables them to have more capacity for action and provides opportunities to be involved in decision making *(14: +3)*. Factor 2 further illustrates that gender equality and collective action begin when men increasingly support and collaborate with their wives *(23: +4)*, or female fishers in their cooperatives. This collaboration unites the fishing community with greater respect and compliance with marine reserves *(9: +3)*. The participants' high support for this statement demonstrates how mobile apps lead to stronger collective action in the community.

> *...in their community, they work closely with CONANP [National Commission of Natural Protected Areas], and for CONANP projects and the projects that are realized within the community, they're obligated to include about 60–70% women on these projects.* (P2, Female)

> *The ability to communicate between fishers or community members that this action or this reserve is precisely for conserving so we can have these species in the future as well, leads to better fishing in general. Well, I believe that this would promote trust and collective action.* (P3, Male)

Consensus statements—shared opinions by all research participants

Summary of consensus statements: The rise in gender-specific fisheries data through mobile apps indicates a growing trend of women's active participation in decision-making processes, thus increasing their visibility within Mexican fishing communities.

The participants of the study showed a relative disagreement with the statements that female-led cooperatives that own fishing permits offer equal opportunities for female fishers to earn fair compensation *(16: -2, -1)*, and mobile apps aid fishers in connecting with NGOs, enhancing their training, and promoting the inclusion of women and young people in the fishing network *(18: -3, -3)*. It was later revealed from the interviews that fishing cooperatives and NGOs like COBI need to play a significant role in increasing the use of mobile apps among fishers in the community by explaining to both male and female fishers how mobile apps like PescaData can benefit them in their day-to-day fishing activities.

> *Explain how Pescadata helps fishers to improve their market or the agility of the river warnings; so more people want to use mobile apps. Such training not only gives us [women] visibility but also empowerment without having us require independent permits...* (P5, Female)

Fig. 6. Composite Q-sort for Factor 2. A composite of the five participants that loaded to Factor 2. A cluster of their viewpoints.

Most disagree -4	-3	-2	-1	Neutral 0	+1	+2	+3	Most agree +4
17. Mobile apps allow women to understand their fishing contributions across the value chain, increasing awareness of their rights.	**18.** Mobile apps aid fishers in connecting with NGOs, enhancing their training and promoting the inclusion of women and young people in the fishing network.	**4.** Mobile apps facilitate registration of fishing areas, resulting in greater trust in my community.	**24.** Using social media to communicate social campaigns, festivals, or events raises awareness for issues in our community leading to stronger collective action.	**20.** NGO training fishers on gender equality can create a safe space for women to join fishing networks.	**8.** The use of mobile apps to report community solutions fosters trust among community members, thereby promoting respect for marine reserves.	**12.** The rise in gender-specific fisheries data highlights women's involvement in decision-making processes enhancing their visibility in our community.	**14.** Support from cooperative s enables women to have more capacity for action and provides opportunities to be involved in decision making.	**23.** Collective action and gender equality starts when men increasingly support and collaborate with their wives.
	15. Female fishers can actively participate in environmental promoter groups, raising awareness for fishermen to respect marine reserves.	**19.** A cooperative led by young female fishers encourages the creation of more such cooperatives in other communities.	**5.** Illegal fishing is minimized by enhancing compliance with marine reserves, which leads to increased trust among fishers in my community.	**2.** Focus groups among the fishers are safe spaces to improve trust and collective action in my community.	**6.** Fishing communities with a lot of trust in each other will be willing to have compliance even for larger marine reserves.	**22.** Cooperatives offer scholarships and support to their members' children, in the hope that they contribute to the fishing community when they are older.	**9.** Respecting the marine reserves has brought the fishing community together.	
		3. Group identity within the community increases our trust and collective action.	**10.** A longer period of marine reserves is required to maintain fish abundance and catch if there is low compliance among the community.	**11.** Cheating is reduced and compliance with marine reserves is increased when seasonal cultural taboos are recognized in the community.	**1.** Mobile apps are facilitating increased collaboration between male and female fishers in the community, resulting in stronger collective action.	**13.** The traditional gender roles in fishing communities have led to the perception that women don't participate in fisheries.		
			16. Female-led cooperatives that own fishing permits offer equal opportunities for female fishers to earn fair compensation.	**21.** Mobile apps like PescaData are being used to increase visibility of women's involvement in beach clean-ups, monitoring activities, and awareness campaigns.	**25.** PescaData allows fishers to have self-recognition which increases collective action in the community.			
				7. We respect the ban placed on scarce species because we have trust in our community.				

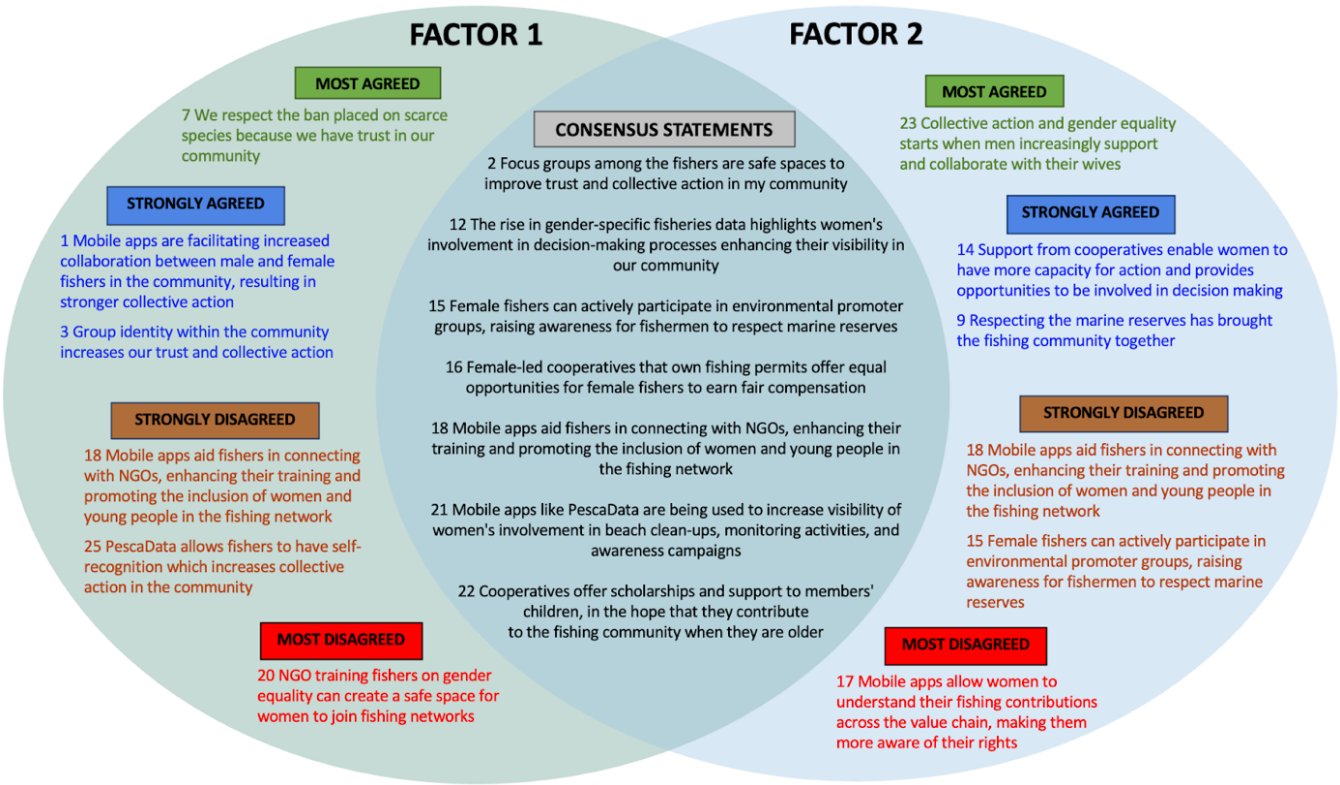
All respondents were in disagreement with the statement that female fishers' active participation in environmental promoter groups will raise awareness for fishermen to respect marine reserves *(15: -2, -3)*. Post-sort interviews later revealed that female fishers' active participation in reporting community solutions and catch data using mobile apps like PescaData has increased trust and collaboration between male and female fishers, leading to stronger collective action and compliance with marine reserves.

> *Well, I'm going to tell you from my experience of the time I have in fishing, which is 11 years that I have already been in the fishing sector, working as such, and I have realized that not only here in San Felipe but in the majority of coastal communities, women are the ones who promote conservation and environmental care. Although there are men in conservation, but we mostly see women, at least in the fishing communities of community groups or associations, we are more the women who promote conservation through reporting community solutions in the apps. I include myself in it.* (P10, Female)

The statement that focus groups are safe spaces to improve trust and collective action in the community *(2: 0, 0)* received a neutral opinion from both factors. However, in the post-sort interviews, all participants expressed strong support for the role of cooperatives or NGOs in setting up focus groups for discussing privacy policies of mobile apps. The reason was, first, to increase knowledge of apps among the fishers and, second, to discuss offering scholarships and other support to members' children, where the cooperatives can expect the next generation of children to keep contributing to the fishing community when they are older *(22: +2, +2)*. Another neutral opinion was expressed for the statement that apps are being used to increase the visibility of women's involvement in various communal activities *(21: -1, 0)*, a high positive consensus from all ten participants in the Q-sorting exercise and post-sort interviews revealed that the rise in gender-specific fisheries data significantly highlighted women's involvement in decision-making processes, enhancing their visibility in the community *(12: +1, +2)*. Thus, their contributions are acknowledged and taken into account because the reporting source can be observed and monitored. This demonstrates how mobile apps provide a platform for women's fishing roles to be recognized in Mexican fishing communities.

> *Of course, as my colleague said, women have always participated in fishing activities, but to a certain extent, they are not seen, because, in a certain way, they are hidden. So when using the apps, they appear, as they have always been there.* (P3, Male)

Fig. 7. Summary of factors. A Venn diagram illustrating key statements associated within each factor. Distinguishing statements (with scale ratings of most agreed, strongly agreed, strongly disagreed, and most disagreed) are positioned in the outer sections, and consensus statements are placed in the center. Distinguishing statements are statistically significant at $P < 0.05$. Consensus statements represent areas where both factors exhibit similar perspectives, either through shared agreement (score ≥1) or shared disagreement (score ≤−3), with only minor differences in the strength of opinion (score difference ≤1). These statements encompass both agreed and disagreed responses, emphasizing points of convergence between the two factors. For a more detailed breakdown of statistical scores and interpretations, refer to Append. 4. By analyzing the varying scale ratings of Factor 1, Factor 2, and consensus statements, a synthesized summary of opinions is derived. Factor 1 emphasizes how mobile apps increase women's visibility and collaboration with male fishers, strengthening trust and collective action. Factor 2 highlights their role in promoting gender equality and collective action, leading to greater compliance with marine reserves. The consensus statements reflect a shared recognition that gender-specific fisheries data from mobile apps indicates growing female participation in decision making.



Overall, the consensus statements in this study highlight the significant role that mobile apps, like PescaData, play in increasing women's visibility and participation in decision-making processes within Mexican fishing communities. Although mobile apps have empowered women by providing a platform to report fishing data and promote conservation efforts, challenges remain in achieving gender equality, particularly regarding fair compensation in female-led cooperatives. The study revealed that, although there was initial disagreement about women's equal opportunities in cooperatives, post-sort interviews showed that women's involvement in reporting data has fostered trust and collaboration among fishers. Additionally, focus groups, facilitated by cooperatives and NGOs, play a crucial role in enhancing understanding of mobile apps and fostering support for the next generation of fishers. In summary, mobile apps were found to be a valuable tool for amplifying women's voices and promoting their roles in the fishing community, although structural barriers to achieving full equality persist.

DISCUSSION

This study finds that mobile apps like PescaData can play a transformative role in fostering collaboration, trust, and gender inclusivity within small-scale fisheries (SSF). By analyzing fishers' perspectives through Q-methodology, it reveals how increased visibility of women's contributions reshapes social and collective dynamics in Mexican fishing communities. These findings offer valuable local insights and contribute to global conversations on gender equity and fisheries management, addressing challenges such as gender invisibility, data transparency, and compliance with marine reserves that affect SSF worldwide. Although Tilley and Roscher (2020) caution that digital technologies can exacerbate social inequalities, digital exclusion, and elite capture if not carefully governed and locally engaged, our study provides empirical evidence that co-developed tools like PescaData—designed to promote transparency and data ownership—can enhance gender inclusivity, trust, and collective action. However, Ferguson (2006) critiques that development technologies are rarely neutral, often reinforcing existing bureaucratic and political

power structures rather than dismantling them. He asserts that development efforts may function "not as a machine for eliminating poverty [...] but a machine for reinforcing the power of those who dominate the poor" (ibid.). Our study responds to Ferguson's critique by showing that when digital tools are developed collaboratively with local communities and integrated into inclusive management frameworks, they can help redistribute power—for example, by increasing women's visibility in resource management. This highlights that the potential of information and communication technology depends heavily on their embeddedness within supportive social and institutional contexts that address power dynamics and ensure meaningful participation (Cuevas Gómez et al. 2022). Ultimately, the transformative impact of digitalization arises not from technology alone, but from its inclusive, context-sensitive integration into fisheries management.

In the following paragraphs, we explore the key themes that emerged from the Q-factor analysis, emphasizing how mobile apps enhance women's involvement across the fisheries value chain and how this, in turn, strengthens group identity and compliance with marine reserves. Additionally, we discuss the study's methodological contributions, broader implications, and limitations, offering a clearer understanding of the relationship between digital tools, gender inclusivity, and sustainable fisheries management.

Factor 1, which includes all Q-sorts from the female participants across the value chain (fisherwoman, community monitors, technical, post-harvest processing), reveals an important finding of this study: PescaData has increased the visibility of women's work contributions; this, in turn, has fostered collaboration between male and female fishers to operate as a social unit in the community. This leads to increased trust and a sense of group identity, which strengthens collective action within and across communities. Importantly, these findings contribute to global conversations on gender equity in SSF, where women's roles remain largely invisible despite their substantial contributions across the fisheries value chain (Food and Agriculture Organisation (FAO) 2016, Franz et al. 2023).

On a global scale, women constitute half of the small-scale fisheries workforce and are extensively engaged in processing and commercial activities (FAO 2016). According to Monfort (2015), "women are perceived to be trustworthy, dedicated, meticulous, flexible, compliant, quality minded, and cheaper than men." Given that, with PescaData, women are now involved in reporting both catch data and community solutions, it can be concluded that women's activities are more visible across the fishing sector. This higher visibility of women together with their perceived trustworthiness may contribute to increased trust within the community, and thus, better management of illegal fishing. The findings of this study contribute to the global discourse on gender equity by demonstrating how digital tools like PescaData can increase the visibility of women's contributions, foster gender-inclusive fisheries governance, and promote collective action in traditionally male-dominated sectors.

Furthermore, to counteract the invisibility of women in the fishing sector, COBI collaborated with various institutions to jointly develop key actions and programs that contribute to achieving gender equality. One such program is called "Gender Equality at Sea," through which women recognize themselves as part of the fishing sector and strengthen their capacities to actively participate in the implementation of fisheries sustainability solutions (Igualdad de Género en el Mar 2025).

Additionally, initiatives promoting gender equity in Mexico have included a forum on this topic held by the Fisheries Commission and chaired by a deputy of the National Chamber of Deputies (a legislative arm of the Mexican government), which highlighted the critical yet often overlooked role of women in the fishing sector and the inequalities they face (Cámara de Diputados 2022). Women contribute significantly across the entire fisheries value chain—as fishers, processors, and sellers—yet their work remains undervalued, and they are underrepresented in decision making. Speakers at the forum emphasized key challenges, including limited access to credit, economic and infrastructure constraints, unfair wages, and even workplace harassment. Despite these barriers, women continue to be a fundamental pillar of the industry, particularly in indigenous communities where they often lead fishing activities. Calls were made for stronger public policies, increased institutional support, and greater recognition of women's contributions to ensure gender equity and empower women within the fisheries sector (ibid.). Initiatives like these are part of a growing global effort to address gender disparities in SSF, as similar challenges of underrepresentation and limited decision-making power persist worldwide. By showcasing the positive impacts of digital tools on gender dynamics, this study offers valuable insights for other regions facing comparable socio-economic contexts, reinforcing the global relevance of promoting women's agency in fisheries management.

Our results show that PescaData is reshaping gender dynamics in fisheries by increasing the visibility of women's contributions and influencing power structures within fishing communities. Although the sector remains highly gender-stratified, digital tools could facilitate shifts in traditional roles by fostering greater recognition of women's economic and decision-making power (Castillo and Vosloo 2018). According to Pedroza-Gutiérrez et al. (2024), economic power plays a crucial role in enabling the formal participation of women in the fishing sector. Access to fish resources, economic activities, and social institutions (e.g., family networks, cooperatives, and government programs) significantly influence gender equity (ibid). Regional differences in gender roles further highlight how variations in fisheries productivity, resource availability, and external economic opportunities shape power dynamics within households and communities (Frangoudes and Gerrard 2018). Frangoudes and Gerrard (2018) argue that achieving gender equity in fisheries requires increased visibility of women's work, better access to training, and supportive policies that enhance their economic, positional, and definitional power. Our results support this conclusion with respect to increased visibility of women's work.

Building on this, our findings (drawing on Factor 2 results) indicate that the increased visibility of women through PescaData has led to a shift in attitudes and norms among male fishers in the community, resulting in greater recognition and appreciation of women's contributions to small-scale fisheries. Furthermore, the app has fostered trust and collective action, promoting gender equality through the delegation and co-production of fishing knowledge by both male and female fishers. Higher levels of trust

have, in turn, led to increased compliance with marine reserves, demonstrating the broader social and environmental benefits of integrating women more fully into fisheries management and decision making. Thus, our study supports earlier findings that trust and reciprocity-based norms are crucial for addressing collective action challenges in general (Ostrom 1990) and in small-scale fisheries in particular (Basurto et al. 2013, Lindkvist et al. 2017).

Based on the subjective perceptions of the 10 fishery leaders, this study adds new knowledge to the current literature by showing how the growing trend of women's active participation in decision-making processes through the use of mobile apps has increased their visibility in Mexican fishing communities. Correspondingly, the study also shows that this increased visibility has strengthened collaboration between the male and female fishers in the fishing communities, leading to increased trust and group identity. The participatory approach that is facilitated by apps leads to fairer and more sustainable fisheries management outcomes like gender equality and increased compliance with marine reserves among the male fishers in the community. As previously identified by Ban et al. (2019), marine reserves are a key component of fisheries conservation strategies because of their positive spillover effect on target species. However, the challenge of compliance with marine reserves remains. The results of this study suggest that women's active reporting of fishing activities on a daily basis increases compliance with marine reserves, which can help to address non-compliance by reducing illegal fishing.

Furthermore, the results show that apps like PescaData can serve as tools for providing accessible and transparent data on who is reporting. Our results also show that this can lead to capacity building and knowledge exchange, whereby fishers retain rights over their data they generate, learn from each other, and share best fishing practices within and across different communities without third-party involvement. Such collective action can prevent the exploitation of common-pool resources and mitigate the tragedy of the commons in SSF (Basurto et al. 2020, Thanh et al. 2021, van Klingeren and de Graaf 2021). This has global implications for small-scale fisheries, where the adoption of digital tools may enhance transparency, empower local communities, and promote more equitable and sustainable fisheries management worldwide.

Methodological contributions

This is the first study in the context of Mexican SSF that used Q-methodology to investigate the relationship between mobile app usage and women's visibility in SSF. The study further explored the implications of this relationship on communal trust, collective action, and compliance with marine reserves. Q-methodology was used to conduct an exploratory analysis to uncover underlying patterns in fishers' perspectives and opinions. This allowed for the identification of shared and differing viewpoints and emergent themes within SSF, shedding light on key issues and dynamics in the Mexican fishing community that may not have been apparent through the traditional combination of quantitative and/or qualitative methods employed in previous studies (see, e.g., Solano et al. 2021). Although some unexplained variance in participant's Q-sorts is expected in Q-methodology, it does not undermine the validity of the study's conclusions. The key aim of Q-methodology is to identify and describe distinct shared viewpoints rather than account for all individual variations. The factors extracted represent the most salient and commonly held perspectives within the participant group, ensuring that the study's findings remain meaningful and reliable (Millar et al. 2022). Furthermore, according to Gao and Soranzo (2020), the unexplained variance likely reflects individual nuances rather than systematic gaps in the data, and its impact is minimized by the rigorous factor extraction process used in the analysis.

Moreover, in Q-methodology, a confounded Q-sort—where a participant's responses load onto multiple factors—does not compromise the robustness of the results (Sneegas et al. 2021). Instead, it indicates that the individual's perspective shares similarities with multiple viewpoints rather than aligning strongly with a single factor. This is a natural occurrence in Q-methodology, as perspectives often exist on a continuum rather than as rigid categories (Hugé et al. 2016). The study's conclusions remain valid because the identified factors represent the most distinct and commonly shared viewpoints within the data set. Furthermore, the presence of confounded Q-sorts reinforces the complexity of subjective viewpoints without undermining the integrity of the findings (Sorola 2022).

Implications of the findings

The study demonstrates that promoting the inclusivity of women and granting them agency significantly enhances their visibility within the fisheries sector. According to Bergseth et al. (2023), broadening our perspective and focus to govern for compliance, rather than for simple rule enforcement, represents a cost-effective approach to addressing compliance issues in marine reserves. Involving fishers, including women, in data collection and analysis can lead to more accurate and relevant information for better management decisions and marine governance (Tilley and Roscher 2020). This study shows how the involvement of women is central to tackling the issue of non-compliance with marine reserves.

As Fujita et al. (2018) noted, fishers value transparent and fair data sharing, a fundamental design principle of PescaData and a crucial consideration for this study. Tilley and Roscher (2020) find that the spread of mobile apps in SSF requires transparency in how data are used and evaluated. Although PescaData's community solutions are public, the fact that fishers own the reported catch data and have exclusive rights to them may accelerate the adoption and impact of the proposed solutions. Through this diffusion mechanism, the visibility of women's contributions to SSF can be significantly increased, particularly when apps ensure transparency in how data are used and evaluated. This model of participatory, transparent data has the potential to inspire similar approaches in other regions. The scaling of inclusive digital tools globally can help meet the broader goal of equity in fisheries management and policy.

Our findings suggest that mobile apps can amplify women's voices and increase their participation in communal activities. To be fully effective for increasing gender equity in fisheries, mobile apps must be embedded within broader institutional frameworks. As highlighted by both the fishery leaders in our study and the findings of Espinosa-Romero et al. (2017), community trust and app adoption are strengthened when cooperatives and NGOs actively participate in training and outreach activities. This underscores the need for collaborative management models as suggested in Ocean Risk and Resilience Action Alliance

(ORRAA) (2023), where mobile apps are integrated with institutional support mechanisms that safeguard livelihoods and ensure inclusive participation. Finally, based on our findings and prior studies, we suggest that app-based interventions should actively involve local communities in both the design and implementation process, in line with the work of Torre and Fernández Rivera-Melo (2018) and Villaseñor-Derbez et al. (2022).

Limitations of the study

The selected participants were carefully chosen to represent the broader group of small-scale fishers in different communities around Mexico, and the results were cross-validated with COBI, however, the findings may not be generalizable to a larger population of fishers, as the sample may not be representative enough to draw broader conclusions. Although the small sample size of 10 fishery leaders is sufficient for identifying and comparing factors within Q-methodology, this limitation could be addressed in future research by expanding the participant pool. Ensuring more diverse representation across key demographic variables would also enhance the robustness of findings and improve the transferability of results to a broader population.

Additionally, the sample consisted of six female fishers and four male fishers, which could skew the results to a potential gender bias, and the exclusion of a confounding Q-sort could have given rise to a higher percentage of explained variance for Factor 2. We attempted to address this limitation by conducting post-sort interviews alongside the Q-sorting exercise, which provided more nuanced insights into gender dynamics and a clearer picture of the clustered opinions of the sampled fishers in Mexico. Additionally, the concourse statements may not cover the full range of perspectives or dimensions relevant to the research, potentially overlooking important aspects of the phenomenon under study. To mitigate this limitation, we conducted two rounds of pilot tests of the concourse statements with fishery actors to validate the relevance and comprehensiveness of the concourse statements before administering the full study (see Append. 5 for details). Moreover, the Q-sorting exercise's effectiveness depends on the participants' ability to understand and accurately rank the statements, which may vary. We addressed this limitation by integrating the Q-method with semi-structured interviews with the participants, thereby facilitating more reliable findings. Furthermore, the Q-method software is better suited to computer-based platforms with enhanced internet connectivity, compared with mobile devices. Due to interface limitations, including the precision required to make inputs on mobile touchscreens, and the restricted zooming capacity of the online Q-method software on mobile phones, we encouraged participants to use a computer whenever possible. For those who used mobile devices, a demo of the Q-sorting exercise was given prior to engaging in the exercise. Furthermore, limited internet connectivity in certain cases prevented some participants from completing the online Q-sorting exercise, and consequently, they were not included in the final sample. Lastly, due to time constraints, it was beyond the scope of the study to include individuals who were not actively using PescaData. This provides an opportunity for future research to include those who are not using PescaData or who have stopped using PescaData, as their inclusion in a future study would enhance the generalizability of the findings.

CONCLUSION

The study concludes that the use of technology like mobile apps can contribute to women's visibility and, in turn, may lead to sustainable fisheries management while promoting gender equality and inclusivity. Our results show that apps can empower women by giving them a platform to actively participate and be recognized in the fisheries sector. Women in small-scale fisheries in Mexico are key to building trust and reinforcing group identity within their communities. The solutions shared through PescaData facilitate immediate improvements within fishing communities and serve as catalysts for informing other fishing communities, thereby enhancing overall resilience across communities. As women take on the responsibility of reporting catch data and community solutions using mobile apps, they demonstrate reliability and commitment to sustainable fishing practices. This shift in roles encourages more men to entrust women with these tasks, and consequently, the increased participation of women enhances compliance with marine reserves among male fishers, as they respect and value the contributions of their female counterparts. This collaborative approach leads to stronger collective action within the community toward marine conservation. This study shows the potential for women's knowledge and contributions to bring fishers and fish workers across communities to work together toward equitable and sustainable small-scale fisheries, and therefore, highlights this theme as an important avenue for further research.

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Data Availability:

The data and code that support the findings of the Q-analysis (i.e., anonymized study analysis report exported from the online Q-method software in csv file) is available on request from the corresponding author, T. Ahmed. None of the data and code are publicly available because the survey information in the online Q-method software and transcription of the semi-structured interviews contain information that could compromise the privacy of research participants. Ethical approval for this research study was granted by the Stockholm Resilience Centre's ethics committee.

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Appendix 1: Demographic background of the participants

SL	Gender	Age range	State	Community	Role in PescaData
P1	Female	30-39	Baja California Sur	Bahia Asuncion	Technical
P2	Female	30-39	Baja California Sur	Punta Abreojos	Administration
P3	Male	18-29	Quintana Roo	Cozumel	Fisherman
P4	Male	30-39	Quintana Roo	Xcalak	Community Monitor
P5	Male	40-49	Baja California Sur	Bahia Asuncion	Fisherman
P6	Female	40-49	Sonora	San carlos nuevo guaymas	Value chain (post-sort harvesting of fished species)
P7	Female	30-39	Quintana Roo	Punta Allen	Community Monitor
P8	Male	50-59	Sonora	Bahia de kino	Community Monitor
P9	Female	30-39	Baja California	San Felipe	Fisherwoman and Technical
P10	Female	30-39	Quintana Roo	Punta Allen	Community Monitor

Appendix 2: Final Q-set

SL	Q-statements (in English)	Q-statements (in Spanish)
Trust		
1	Mobile apps are facilitating increased collaboration between male and female fishers in the community, resulting in stronger collective action.	Las aplicaciones móviles están facilitando una mayor colaboración entre pescadoras y pescadores de la comunidad, lo que da como resultado una acción colectiva más sólida.
2	Focus groups among the fishers are safe spaces to improve trust and collective action in my community.	Los grupos focales entre pescadoras y pescadores son espacios seguros para mejorar la confianza y la acción colectiva en mi comunidad.
3	Group identity within the community increases our trust and collective action.	La identidad grupal dentro de la comunidad aumenta nuestra confianza y acción colectiva.
4	Mobile apps facilitate registration of fishing areas, resulting in greater trust in my community.	Las aplicaciones móviles son una herramienta que facilita el registro de zonas de pesca , lo que genera una mayor confianza en mi comunidad.
5	Illegal fishing is minimized by enhancing compliance with marine reserves, which leads to increased trust among fishers in my community.	La pesca ilegal se minimiza mejorando el cumplimiento de las reservas marinas, lo que genera una mayor confianza entre los pescadores de mi comunidad.
6	Fishing communities with a lot of trust in each other will be willing to have compliance even for larger marine reserves.	Las comunidades pesqueras con mucha confianza entre sus integrantes, estarían dispuestos a comprometerse incluso con reservas marinas grandes.
Closure Areas		
7	We respect the ban placed on scarce species because we have trust in our community.	Respetamos las reservas marinas establecidas para recuperar especies objetivo porque confiamos en nuestra comunidad.
8	The use of mobile apps for reporting community solutions fosters trust among community members, thereby promoting respect for marine reserves.	El uso de aplicaciones móviles donde se documentan soluciones comunitarias fomenta la confianza entre los miembros de la comunidad, promoviendo el cumplimiento de proyectos en conjunto, como por ejemplo reservas marinas.

9	Respecting the marine reserves has brought the fishing community together.	Suponiendo que existe una reserva marina en tu comunidad, el respeto por estas zonas une a la comunidad pesquera.
10	A longer period of marine reserves is required to maintain fish abundance and catch if there is low compliance among the community.	Es necesario un período más largo de establecimiento de una reserva marina para mantener la abundancia y la captura de peces cuando el compromiso de la comunidad es bajo.
11	Cheating is reduced and compliance with marine reserves is increased when seasonal cultural taboos are recognized in the community.	Los engaños se reducen y el cumplimiento de las reservas marinas aumenta cuando los tabúes culturales se reconocen en la comunidad.
Women's Contribution to SSF		
12	The rise in gender-specific fisheries data highlights women's involvement in decision-making processes enhancing their visibility in our community.	El incremento de datos pesqueros específicos de género destaca la participación de las mujeres en los procesos de toma de decisiones, lo que mejora su visibilidad en nuestra comunidad.
13	The traditional gender roles in fishing communities have led to the perception that women don't participate in fisheries.	Los roles tradicionales de género en las comunidades pesqueras han llevado a la percepción de que las mujeres no participan en la pesca.
14	Support from cooperatives enables women to have more capacity for action and provides opportunities to be involved in decision making.	El apoyo de las cooperativas permite que las mujeres tengan más capacidad de acción y brinda oportunidades para que se involucren en la toma de decisiones.
15	Female fishers can actively participate in environmental promoter groups, raising awareness for fishermen to respect marine reserves.	Las pescadoras pueden participar activamente en grupos promotores ambientales, sensibilizando a los pescadores sobre el respeto por las reservas marinas.
16	Female-led cooperatives that own fishing permits offer equal opportunities for female fishers to earn fair compensation.	Las cooperativas dirigidas por mujeres y que poseen permisos de pesca, ofrecen igualdad de oportunidades para que las pescadoras obtengan una compensación justa.
17	Mobile apps allow women to understand their fishing contributions	Las aplicaciones móviles permiten a las mujeres comprender sus contribuciones pesqueras a lo

	across the value chain, making them more aware of their rights.	largo de la cadena de valor, haciéndolas más conscientes de sus derechos.
18	Mobile apps aid fishers in connecting with NGOs, enhancing their training and promoting the inclusion of women and young people in the fishing network.	Las aplicaciones móviles ayudan a las pescadoras y pescadores a conectarse con Organizaciones No Gubernamentales (ONG), incrementando sus capacidades y promoviendo la inclusión de mujeres y jóvenes en la red pesquera.
19	A cooperative led by young female fishers encourages the creation of more such cooperatives in other communities.	Una cooperativa dirigida por jóvenes pescadoras fomenta la creación de más cooperativas de este tipo en otras comunidades.
20	NGO training fishers on gender equality can create a safe space for women to join fishing networks.	Las Organizaciones No Gubernamentales (ONG) que capacitan a pescadoras y pescadores sobre la igualdad de género pueden crear un espacio seguro para que las mujeres se unan a las redes pesqueras.
21	Mobile apps like PescaData are being used to increase visibility of women's involvement in beach clean-ups, monitoring activities, and awareness campaigns.	Se están utilizando aplicaciones móviles como PescaData para aumentar la visibilidad de la participación de las mujeres en actividades como: limpieza de playas, monitoreo y campañas de concientización.
Collective Action		
22	Cooperatives offer scholarships and support to their members' children, in the hope that they contribute to the fishing community when they are older.	Las cooperativas ofrecen becas y apoyo a los hijos de sus miembros, con la esperanza de que contribuyan a la comunidad pesquera cuando sean mayores.
23	Collective action and gender equality starts when men increasingly support and collaborate with their wives.	La acción colectiva y la igualdad de género comienzan cuando los hombres apoyan y colaboran cada vez más con sus esposas.
24	Using social media to communicate social campaigns, festivals, or events raises awareness for issues in our community leading to stronger collective action.	El uso de las redes sociales para comunicar campañas sociales, festivales o eventos genera conciencia sobre los problemas de nuestra comunidad, lo que lleva a una acción colectiva más sólida.
25	PescaData allows fishers to have self-recognition which increases collective action in the community.	Las aplicaciones móviles como PescaData permiten a las pescadoras y pescadores tener un autorreconocimiento que incrementa la acción colectiva en la comunidad.

Appendix 3: Crib sheet

The crib sheet below is a schema that helps to interpret the results of the Q-sort. It serves as a reference guide and outlines the key statements and their placements across different factors, which are derived from the factor analysis of the Q-sort data. The crib sheet helped to easily compare and contrast how different statements are ranked by various participants and how these rankings contribute to the formation of distinct factors.

The components of a Crib Sheet in Q-methodology is outlined below:

1. **Statements and factor arrays (represented in the table below):** A list of all the statements (numbered from 1 to 25) used in the Q-set. Factor arrays show the position of each statement within each factor. This helps in understanding how each factor views the statements across a scale rating of most agree (+4), to neutral (0), to most disagree (-4).
2. **Distinguishing statements:** Statements that are ranked differently between Factor 1 and Factor 2 (items ranked higher by Factor 1 than Factor 2, items ranked lower by Factor 1 than Factor 2 and vice versa). These are crucial for interpreting the unique perspectives of each factor.
3. **Consensus statements:** Statements that are ranked similarly between Factor 1 and Factor 2, indicating areas of agreement among participants.

	Factor arrays	
Item number and wording	**Factor 1**	**Factor 2**
1.Mobile apps are facilitating increased collaboration between male and female fishers in the community, resulting in stronger collective action.	+3	+1
2. Focus groups among the fishers are safe spaces to improve trust and collective action in my community.	0	0
3. Group identity within the community increases our trust and collective action.	+3	-2
4. Mobile apps facilitate registration of fishing areas, resulting in greater trust in my community.	0	-2
5. Illegal fishing is minimized by enhancing compliance with marine	+1	-1

reserves, which leads to increased trust among fishers in my community.		
6. Fishing communities with a lot of trust in each other will be willing to have compliance even for larger marine reserves.	-1	+1
7. We respect the ban placed on scarce species because we have trust in our community.	+4	0
8. The use of mobile apps for reporting community solutions fosters trust among community members, thereby promoting respect for marine reserves.	0	+1
9. Respecting the marine reserves has brought the fishing community together.	+1	+3
10. A longer period of marine reserves is required to maintain fish abundance and catch if there is low compliance among the community.	+2	-1
11. Cheating is reduced and compliance with marine reserves is increased when seasonal cultural taboos are recognized in the community.	+2	0
12. The rise in gender-specific fisheries data highlights women's involvement in decision-making processes enhancing their visibility in our community.	+1	+2
13. The traditional gender roles in fishing communities have led to the perception	-2	+2

that women don't participate in fisheries.		
14. Support from cooperatives enable women to have more capacity for action and provides opportunities to be involved in decision making.	-1	+3
15. Female fishers can actively participate in environmental promoter groups, raising awareness for fishermen to respect marine reserves.	-2	-3
16. Female-led cooperatives that own fishing permits offer equal opportunities for female fishers to earn fair compensation.	-2	-1
17. Mobile apps allow women to understand their fishing contributions across the value chain, making them more aware of their rights.	0	-4
18. Mobile apps aid fishers in connecting with NGOs, enhancing their training and promoting the inclusion of women and young people in the fishing network.	-3	-3
19. A cooperative led by young female fishers encourages the creation of more such cooperatives in other communities.	-1	-2
20. NGO training fishers on gender equality can create a safe space for women to join fishing networks.	-4	0
21. Mobile apps like PescaData are being used to increase visibility of women's involvement in	-1	0

beach clean-ups, monitoring activities, and awareness campaigns.		
22. Cooperatives offer scholarships and support to their members' children, in the hope that they contribute to the fishing community when they are older.	+2	+2
23. Collective action and gender equality starts when men increasingly support and collaborate with their wives.	+1	+4
24. Using social media to communicate social campaigns, festivals, or events raises awareness for issues in our community leading to stronger collective action.	0	-1
25. PescaData allows fishers to have self-recognition which increases collective action in the community.	-3	+1

The chosen statements that the study used to build the narrative from the Q-sorts are in *(Italics).*

Factor 1

Factor 1 has an eigenvalue of 2.52453 and explains approximately 25% of the study variance. Four participants are significantly associated with this factor. They are all females with an average age between 30-50 years old.

Item Ranked at +4

- *7 We respect the ban placed on scarce species because we have trust in our community*

Item Ranked at +3

- ***1*** *Mobile apps are facilitating increased collaboration between male and female fishers in the community, resulting in stronger collective action*

- ***3*** *Group identity within the community increases our trust and collective action*

Items ranked higher by Factor 1 than Factor 2

- 1 Mobile apps are facilitating increased collaboration between male and female fishers in the community, resulting in stronger collective action
- 3 Group identity within the community increases our trust and collective action
- 4 Mobile apps facilitate registration of fishing areas, resulting in greater trust in my community
- 5 Illegal fishing is minimized by enhancing compliance with marine reserves, which leads to increased trust among fishers in my community
- 7 We respect the ban placed on scarce species because we have trust in our community
- 10 A longer period of marine reserves is required to maintain fish abundance and catch if there is low compliance among the community.
- 11 Cheating is reduced and compliance with marine reserves is increased when seasonal cultural taboos are recognized in the community
- 15 Female fishers can actively participate in environmental promoter groups, raising awareness for fishermen to respect marine reserves
- 17 Mobile apps allow women to understand their fishing contributions across the value chain, making them more aware of their rights
- 19 A cooperative led by young female fishers encourages the creation of more such cooperatives in other communities
- 24 Using social media to communicate social campaigns, festivals, or events raises awareness for issues in our community leading to stronger collective action

Items ranked lower by Factor 1 than Factor 2

- 6 Fishing communities with a lot of trust in each other will be willing to have compliance even for larger marine reserves
- 8 The use of mobile apps for reporting community solutions fosters trust among community members, thereby promoting respect for marine reserves
- 9 Respecting the marine reserves has brought the fishing community together
- 12 The rise in gender-specific fisheries data highlights women's involvement in decision-making processes enhancing their visibility in our community
- 13 The traditional gender roles in fishing communities have led to the perception that women don't participate in fisheries

- 14 Support from cooperatives enable women to have more capacity for action and provides opportunities to be involved in decision making
- 16 Female-led cooperatives that own fishing permits offer equal opportunities for female fishers to earn fair compensation
- 20 NGO training fishers on gender equality can create a safe space for women to join fishing networks
- 21 Mobile apps like PescaData are being used to increase visibility of women's involvement in beach clean-ups, monitoring activities, and awareness campaigns
- 23 Collective action and gender equality starts when men increasingly support and collaborate with their wives
- 25 PescaData allows fishers to have self-recognition which increases collective action in the community

Item Ranked at -4

- ***20*** *NGO training fishers on gender equality can create a safe space for women to join fishing networks*

Items Ranked at -3

- ***18*** *Mobile apps aid fishers in connecting with NGOs, enhancing their training and promoting the inclusion of women and young people in the fishing network*

- ***25*** *PescaData allows fishers to have self-recognition which increases collective action in the community*

Factor 2

Factor 2 has an eigenvalue of 1.08563 and explains approximately 18% of the study variance. Five participants are significantly associated with this factor. They are two females and three males with an average age between 18-60 years old.

Item Ranked at +4

- ***23*** *Collective action and gender equality starts when men increasingly support and collaborate with their wives*

Item Ranked at +3

- ***14*** *Support from cooperatives enable women to have more capacity for action and provides opportunities to be involved in decision making*

- ***9*** *Respecting the marine reserves has brought the fishing community together*

Items ranked higher by Factor 2 than Factor 1

- 6 Fishing communities with a lot of trust in each other will be willing to have compliance even for larger marine reserves
- 8 The use of mobile apps for reporting community solutions fosters trust among community members, thereby promoting respect for marine reserves
- 12 The rise in gender-specific fisheries data highlights women's involvement in decision-making processes enhancing their visibility in our community
- 13 The traditional gender roles in fishing communities have led to the perception that women don't participate in fisheries
- 14 Support from cooperatives enable women to have more capacity for action and provides opportunities to be involved in decision making
- 23 Collective action and gender equality starts when men increasingly support and collaborate with their wives
- 25 PescaData allows fishers to have self-recognition which increases collective action in the community

Items ranked lower by Factor 2 than Factor 1

- 1 Mobile apps are facilitating increased collaboration between male and female fishers in the community, resulting in stronger collective action
- 3 Group identity within the community increases our trust and collective action
- 5 Illegal fishing is minimized by enhancing compliance with marine reserves, which leads to increased trust among fishers in my community
- 10 A longer period of marine reserves is required to maintain fish abundance and catch if there is low compliance among the community
- 19 A cooperative led by young female fishers encourages the creation of more such cooperatives in other communities

Item Ranked at -4

- ***17*** *Mobile apps allow women to understand their fishing contributions across the value chain, making them more aware of their rights*

Items Ranked at -3

- ***18*** *Mobile apps aid fishers in connecting with NGOs, enhancing their training and promoting the inclusion of women and young people in the fishing network*

- ***15*** *Female fishers can actively participate in environmental promoter groups, raising awareness for fishermen to respect marine reserves*

Consensus statements

- ***2*** *Focus groups among the fishers are safe spaces to improve trust and collective action in my community*

- ***12*** *The rise in gender-specific fisheries data highlights women's involvement in decision-making processes enhancing their visibility in our community*

- ***15*** *Female fishers can actively participate in environmental promoter groups, raising awareness for fishermen to respect marine reserves*

- ***16*** *Female-led cooperatives that own fishing permits offer equal opportunities for female fishers to earn fair compensation*

- ***18*** *Mobile apps aid fishers in connecting with NGOs, enhancing their training and promoting the inclusion of women and young people in the fishing network*

- ***21*** *Mobile apps like PescaData are being used to increase visibility of women's involvement in beach clean-ups, monitoring activities, and awareness campaigns*

- ***22*** *Cooperatives offer scholarships and support to their members' children, in the hope that they contribute to the fishing community when they are older*

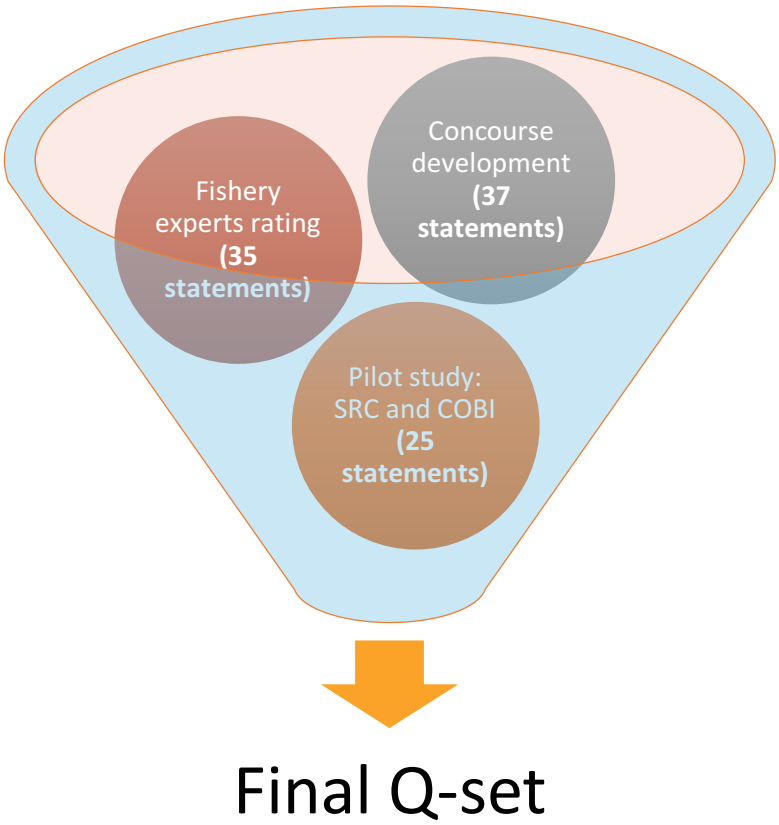
Appendix 4: Extended quotations from the interviews

Factor 1
"...and so this large network is subdivided into smaller subgroups. Every single subgroup also follows the same ideology..." (P2, Female) *"...apps like Pescadata helps to visualize their responses and it does lead to more adherence to the norms of reserves and fishing." (P7, Male)* *"Apps helps to see the results that worked in one community and might help in another community, depending on how you're carrying your things. For example, in Punta Ale, which has the same part of a reserve for the Meros, perhaps in another community in which they are not taking care of the Meros, they receive information through Pescadata and they can realize that there is a benefit. In the same way, if I'm not mistaken, I think that now there was the sargassum problem and through Pescadata we were able to inform ourselves as a group what we could do in a community that was working for another community. So I think that little by little it will be possible to have that trust among all the fishermen." (P5, Female)* *"...In years past, they didn't even think that women could be connected to or belong to or participate in these types of groups and they absolutely believe that technology like mobile apps provided a platform to know what other women in the same community or different communities are doing in groups." (P8, Female)* *"After using this app, Pescadata, there are positive actions. A person who uses the app has a good experience and shares the information with another person. And they do this excessively, so this is expanding and leads to good actions." (P9, Male)* *"I am a traditional cook and I had a business that worked well so people comment that I should continue doing that because that leaves money and it works well; however, my interior was like I needed to be in the sea. As mothers we can be workers, but we can also have important roles in the conservation of our community and not just take care of the home. We also have roles in surveillance, we have roles in monitoring, and we also have roles in cleaning beaches." (P10, Female)*

Factor 2
"I mean everything starts at home right? … If the wives support their husbands or daughters with the support of their parents or grandparents, that contributes a lot, right?" (P8, Female) *"Yes, it does start at home, but it also has to do with how our parents raise us, and their example that we follow, so the example of parents that there is that equality, that is what contributes to there being that gender equality." (P7, Male)* *"Specifically, I know two marriages of fishermen, husband and wife, who are going to fish together and that seems like a clear example of gender equality within fishing. It influenced a lot the example that his father included his mother in the fishing and now he includes his wife. So he follows the example of his parents." (P3, Male)*
Consensus statements
"So, I think they help a lot to make known, either at the local level, at the state level, at the country level, or worldwide, that women also carry out activities, not only of extraction, but an infinite number of activities within the fishing value chain." (P1, Male) *"…as a woman now through apps, we can monitor these refuge zones that we have in the community and we directly participate in the fishing cooperative and we are present in decision-making to maintain these refuge zones in our community." (P2, Female)* *"We have made community groups of women and we have formed some women's cooperatives dedicated to oyster culture, for example, or to other types of activities. In the Gulf of Santa Clara, for example, there is a group of women who are engaged in crafts with fish skins, edible collagen, with fish scales; who diversify the economy of communities, by conserving and not just extracting." (P6, Female)* *"…Despite the fact that my job is in the kitchen, I also need to have that role in the sea because my father is a fisherman, and also the most important thing for me is to leave an example to my children, especially to my daughter who is going to the university now with scholarship. I want her to carry on our family tradition and contribute to our fishing community with her modern knowledge and cooperatives should play a role in updating our knowledge too…" (P2, Female)* *"Well, starting from scratch, explain to us what is going on with Pescadata… with more knowledge on mobile app privacy policies, fishers will start using apps much more, especially women …" (P4, Female)* *"…in terms of collective action, apps helped to create links or networks between groups of individuals." (P1, Male)*

Appendix 5: Administering the pilot study with the final Q-set of 25 statements

Statements for the concourse development were selected if they were validated by two or more data sources within the COBI database, a literature review on Mexican small-scale fisheries, or informal discussions with fishery experts. This process resulted in 37 statements. These statements underwent another round of filtering by three fishery experts at COBI, whose consensus reduced the number to 35 statements for the pilot study. Two rounds of pilot studies were then conducted: the first with three academics from the Stockholm Resilience Centre (SRC), and the second with two fishery experts and one fisher from COBI. This iterative process resulted in a final Q-set of 25 statements for the full study which the 10 fishers had to rank in relation to each other from a scale rating of most agree to neutral to most disagree in the Q-sorting exercise using online Q-method software.



Legend 1: The initial step yielded 37 statements derived from the concourse development. Subsequently, the second step, involving a comprehensive evaluation of these 37 statements by three fishery experts from COBI, resulted in a refined set of 35 statements. In the third step, two rounds of pilot studies with academics from SRC and fishery experts from COBI further reduced the number of statements to 25. These 25 statements constituted the final Q-set, which the fishers ranked relative to one another from most agree to neutral to most disagree.