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Combining the uncombinable: corporate memories, ethnobiological observations, oceanographic and ecological data to enhance climatic resilience in small-scale fisheries

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The global food production system is increasingly strained by abrupt and unpredictable weather events, which hinder communities' ability to adapt to climate variations. Despite advances in meteorological predictions, many communities lack the academic knowledge or infrastructure to interpret these complex models. This gap highlights the need for solutions that make climate forecasts more accessible and actionable, especially for communities reliant on natural resources. This study explores the potential of enhancing seasonal climate forecasts by integrating local ecological knowledge (LEK) with scientific data. Specifically, we combined ethnobiological information gathered between 2022 and 2024 with existing oceanographic and ecological data to create an ethnobiological calendar for four fishing cooperatives. An ethnographic approach was used to understand the population's ethnobiological knowledge and their perceptions of marine heatwaves and climate change impacts. Coastal monitoring data was collected using moorings that recorded temperature over a 14-year period (2010–2024). To characterize giant kelp dynamics, we used an existing dataset of multispectral Landsat images, which estimates the surface canopy biomass of giant kelp forests. Ecological monitoring was conducted annually every summer from 2006 to 2023 to record the in situ abundance of ecologically and economically important invertebrate and fish species. Combining oceanographic, ecological, and ethnographic data, allowed for alligning fishers' observations with recorded marine heatwave events and ecological shifts. Our findings revealed that these observations closely matched documented marine heatwave data and corresponding ecological changes. The integration of LEK with scientific oceanographic data can significantly improved our understanding of dynamic climate regimes, offering contextually relevant information that enhances the reliability and utility of seasonal climate forecasts. By incorporating yearly data into an ethnobiological calendar, we promote more inclusive, community-based approaches to environmental management, advocating for the integration of LEK in climate adaptation efforts, emphasizing its crucial role in strengthening resilience strategies against climatic shocks.

KEYWORDS

climate adaptation, environmental baselines, local ecological knowledge, ethnobiological calendars, marine ecosystems, corporate memories

1 Introduction

Weather and climate significantly influence environmental processes and ecological responses (Wax et al., 1977). Human survival has long depended on recognizing and interpreting these processes (Narchi et al., 2024). However, abrupt and unpredictable weather increasingly challenges global food production systems. Local communities are struggling to interpret and prepare for environmental changes, limiting the reliability of traditional weather knowledge for forecasting (Kolawole et al., 2014; Narchi, 2014; Ndlovu et al., 2024). In coastal and marine environments, sudden climatic shocks and gradual climate shifts disrupt marine ecosystems, affecting essential resources like food (Kidane and Brækkan, 2021), oxygen (Giomi et al., 2023), livelihoods (Price and Narchi, 2018), blue spaces (Britton et al., 2020), and medicines (Antunes et al., 2023), as well as other cultural services and material goods (Turner, Cuerrier, and Joseph, 2022).

Despite continuous advancements in meteorological predictions, with no apparent limits to improving predictability (Alley et al., 2019), computer-generated weather and climate models are cultural and temporal abstractions of weather rather than representations of nature itself (Helmreich, 2023). These models not only create and predispose people to simulated versions of nature, thus naturalizing the social world (Jasanoff and Wynne, 1998), but also rely on variables such as sea surface temperature, atmospheric pressure, and annual precipitation. This reliance reflects implicit choices about what is deemed important to measure, as well as how and where data are collected (Hepach and Lüder, 2023).

These choices reflect epistemic biases and challenge meteorological predictions. To serve all communities effectively, weather forecasts should be co-developed with local participants, creating culturally relevant, hybrid models. These models should emphasize place-based education and inquiry-driven approaches, focusing on key regions and correlating weather patterns with significant phenological events (Mugi-Ngenga et al., 2021). Despite being overlooked, phenological observations offer valuable insights into climatic patterns (Kugara et al., 2022; Bulian, 2020) and can improve the accuracy of seasonal forecasts and decision-making (Streefkerk et al., 2022). When properly interpreted, they serve as reliable indicators of climate change and weather variability (Alley et al., 2019). Integrating this locally developed knowledge with resource management is crucial for rural and remote communities lacking the resources, rights, and infrastructure to respond to external shocks (Micheli et al., 2024) and facing shifts in seasonal weather patterns (Narchi et al., 2014).

Incorporating historical knowledge into formal fisheries models (Pauly, 1995) has helped reconstruct records for marine species influenced by extractive human activities (Ferretti et al., 2014). In a similar sense, the concept of Shifting Baseline Syndrome (SBS) highlights the generational oversight of significant changes in marine ecosystems, such as on sea turtles in the Caribbean (Jackson, 1997) and marine fauna in the Gulf of California (Saenz-Arroyo et al., 2006). SBS has been instrumental in studying ecological responses to past climate conditions and events, assessing fisheries changes, promoting environmental policy, and has relevance to forestry and ethnobiology (Jackson, 1997; Saenz-Arroyo et al., 2005, 2006; Vera, 2009; Hanazaki et al., 2013).

Local ecological knowledge (LEK) produces baseline information (such as fisheries records, naturalist observations and local cookbooks) that can be used to understand ecological characteristics of the ecosystems that local communities depend on (Narchi et al., 2014). In the context of marine and coastal settings, local ecological knowledge refers to the understanding that coastal communities have developed regarding the ecological characteristics (both structure and function) of the coastal and marine ecosystems they rely on for resource exploitation (Early-Capistrán et al., 2022), as well as for aesthetic, cultural, and spiritual fulfillment (Narchi et al., 2014). This understanding includes ethnometeorogical knowledge, i.e., locally developed knowledge on climate variability and change based on vernacular observations and practices (Leonard et al., 2013).

In Baja California's fisheries, the term "local ecological knowledge" may not fully apply to cooperatives like those we've worked with, as they originated from international collaboration. Specifically, these cooperatives were established through a treaty between Japan and Mexico, with Japanese expertise in fishing and diving techniques forming the foundation (Estes, 1977). As the industry grew, Mexican fishers, ranchers, and hunter-gatherers from San Ignacio, Baja California, were trained by Japanese immigrants to dive for abalone, later applying this knowledge to other fisheries like lobster and sea cucumber (Álvarez et al., 2018). The similarity between the seascapes of Japan and Baja California facilitated the successful transfer of fishing technologies and knowledge, creating a collective repository of expertise within the industry—referred to here as corporate memory (Euzenat, 1996). We argue that these fishing cooperatives operate with a corporate purpose, focusing on the extraction, capture, and fishing of various shellfish, fish, and crustaceans for sales, transportation, and industrialization (Vargas-Hernández et al., 2016).

Enhancing and transferring knowledge within an organization is vital for improving its competitiveness (Vesperi and Ingrassia, 2021). This knowledge, often referred to as know-how, includes expertise in problem-solving across various functional disciplines, human resource management, process knowledge, technical design challenges, and lessons learned (Decker and Maurer, 1999). While corporate memory studies have been extensively explored in fields like public administration and the automotive industry, they have received little attention in the small-scale food-producing sector. This sector is characterized by small and micro-sized organizations with limited innovation potential, low investment in research and development, and managerial practices with low knowledge capacity (Vesperi and Ingrassia, 2021, and references therein).

Our dataset indicates that fishing cooperatives in Baja California, particularly those discussed in this study, have developed a noteworthy corporate memory within their organizations. This knowledge is predominantly documented in reports covering various aspects such as catch statistics, national and international trade, financial earnings, fishing and factory permits and regulations, profit sharing, and membership rights and responsibilities (see McCay et al., 2014) However, to improve the sustainability of fishing practices, fishing cooperatives must constantly adapt and adopt new organizational models and processes (cf. Vesperi and Ingrassia, 2021). Achieving this requires members to share both informal and formal knowledge in a structured manner, facilitating reciprocal referencing between the two types of knowledge: corporate memory and local ecological knowledge. This approach enables cooperative members to actively utilize, disseminate, and maintain knowledge through participatory activities, ensuring a coherent system of meanings and understanding is formed (Euzenat, 1996).

When informal knowledge integrates into corporate memory, it becomes dynamic and adaptable to new circumstances. This includes local ecological knowledge, which is deeply connected to specific places through a lifetime of interaction with the environment. Sense of place links communities to their natural surroundings and is both a physical and socially constructed space (Cresswell, 2015; Masterson et al., 2017). Such connection fosters environmental stewardship and pro-environmental behaviors (Dang and Weiss, 2021; Daryanto and Song, 2021) and reinforces conservation and restoration efforts (Ardoin et al., in press)[1]. This tacit knowledge, developed through lived experience, is essential for understanding local ecological dynamics in ways conventional Western science cannot. In the communities where this knowledge circulates, it enhances adaptability (Mason et al., 2022), survival (Hosen et al., 2020), and economic success (Albuquerque et al., 2021).

Our research stems from a project that aims to investigate the resilience and adaptive capacity of coastal socio-environmental systems to shock from both the environment (e.g., climate change) and human systems (e.g., social, political, and market change). In this study, we use local ecological knowledge (in the form of corporate memory) as a means of reconstructing environmental baselines for five distinct fishing cooperatives to understand climate change and adaptive capacity to this change. Considering their relatively young age and entrepreneurial origins, we view these cooperatives as corporate entities wherein members acquire, retain, and exchange local ecological knowledge through their daily interactions with marine resources and coastal environments. We use an innovative approach that extends beyond solely relying on local ecological knowledge, as we integrate local ecological knowledge with oceanographic and ecological times series data, matching the fishers' perception of conspicuous environmental shocks with oceanographic timelines for water temperature, as well as data from ecological monitoring and surface canopy of giant kelp.

We propose leveraging the corporate memory of these fishing cooperatives along with the local ecological knowledge of their members to reconstruct environmental baselines. Our goal is to highlight the importance of incorporating local ecological knowledge into seasonal climate forecasts, particularly in the context of climate change and shifting weather patterns. Recognizing the value of integrating local knowledge systems (Balick et al., 2022) into weather prediction, we advocate for the use of ethnobiological calendars as a simple yet powerful tool to develop relevant records and proactive responses to environmental changes. This approach can enhance natural resource management, generate data for future validation, and increase resilience to climatic shocks. By doing so, we support global efforts to promote relevant research and reciprocal collaboration with local science (Winter et al., 2020). The use of calendarized knowledge has already proven effective in helping Baja California fishers advocate for seasonal bans on species like *Octopus bimaculatus* and *O. hubbsorum* (Anonymous, 2023).

1 Ardoin, N., O'Connor, R., and Bowers, A. (in press) Exploring how place connections support sustainability solutions in marine socio-ecological systems. In L. B. Crowder (Ed.) Navigating Our Way to Solutions in Marine Conservation (Cambridge, United Kingdom: Open Book Publishers).

2 Data collection

To harness all the predictive power of combined oceanographic, ecological, and ethnobiological data, it is necessary to build a monitoring tool with much more resolution than that provided by corporate records and cooperative members' memories. One such tool is an ethnobiological calendar, which on local ecological knowledge and life histories aim to generate robust information supporting the development of adaptation plans in response to various stressors as well as regional climate regime change (Narchi et al., 2024).

2.1 Study area and system

The Baja California Peninsula, characterized by its xeric and insular environment, is home to numerous fishing cooperatives that play a significant role in the region's fishing industry, often focusing on high-value species. These cooperatives are scattered both through Baja California and Baja California Sur and have been granted exclusive fishing rights (i.e., fishing concessions) over local stocks, including abalone, lobster, sea urchin, and other benthic resources since the 1930s (McCay et al., 2014).

Participatory oceanographic and ecological research was conducted between 2006 and 2024 in five different fishing cooperatives located along the Baja California Peninsula: El Rosario, Isla Cedros (Cedros Island), and Islas Benitos (San Benito Islands) in Baja California; and Isla Natividad (Natividad Island) and Bahía Asunción (Asuncion Bay) in Baja California Sur, Mexico (Figure 1).

The northernmost community we collaborate with is Cooperativa Ensenada in San Quintín, with 2,423 residents across El Rosario de Arriba and El Rosario de Abajo (INEGI, 2020). Founded in 1940, Cooperativa Ensenada is one of several key cooperatives in the region. Isla Natividad, in the El Vizcaíno Biosphere Reserve, has 268 residents (INEGI, 2020) and hosts the "Buzos y Pescadores de la Baja California" cooperative, established in 1942. Isla Cedros and Islas San Benito, part of the Pacific Islands of the Baja California Peninsula Biosphere Reserve, have populations of 1,233 and 8, respectively (INEGI, 2020), and are home to the "Productores Nacionales de Abulón" cooperative, founded in 1936. Bahía Asunción, also in the El Vizcaíno Biosphere Reserve, has 1,453 residents (INEGI, 2020) and hosts two cooperatives: "Ribereña Leyes de Reforma," established in 1974, and "California de San Ignacio," the region's first cooperative, founded in 1943.

The study area and its fisheries have faced significant shocks in the past, such as severe El Niño Southern Oscillation (ENSO) effects, combined with overfishing and illegal fishing of key resources since the 1980s. These factors greatly reduced the productivity of fisheries like abalone and had a profound impact on the socio-ecological system (Micheli et al., 2024). Additionally, climate shocks have recently impacted kelp forest ecosystems that sustain these fisheries (Arafeh-Dalmau et al., 2019; Beas-Luna et al., 2020).

In response to the challenges faced by the fisheries—such as the decline in fish stocks due to overfishing, illegal fishing activities, and environmental changes—co-management measures were introduced after the fisheries struggled to survive after being impacted by severe ENSO and overfishing in the 1980s. New territory-based access rights for community-based cooperatives were established (McCay et al., 2014; Álvarez et al., 2018). These measures aimed to address declining productivity and ensure sustainable fishing practices. In exchange for exclusive fishing zones for benthic species (e.g., abalone, lobster, snails),

Research Area

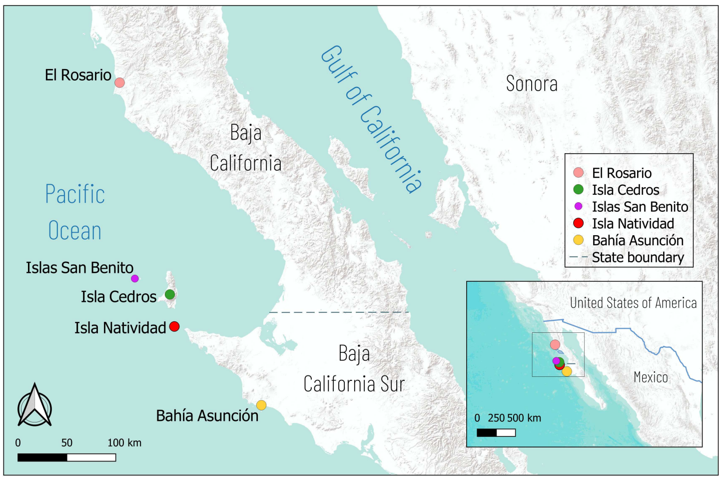

FIGURE 1
Map showing the research area in the central portion of the Baja California Peninsula. The circles represent the different localities where oceanographic and ecological participatory research was conducted, pink for El Rosario (fishing cooperative "Ensenada"), green for Isla Cedros and purple for Islas San Benito (fishing cooperative "Pescadores Nacionales de Abulón"), red for Isla Natividad (fishing cooperative "Buzos y Pescadores de Baja California"), yellow for Bahía Asunción (fishing cooperative "California San Ignacio" in the north and "Ribereña Leyes de Reforma" in the south).

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cooperative members are legally obligated to collaborate, pay dues, and assist governmental authorities in monitoring and enforcing their concessions (Young, 2001; McCay et al., 2014). Additionally, these cooperatives rely on other fisheries, including several finfish species for which they do not hold exclusive rights and have historically lacked developed and enforced management plans (Shester and Micheli, 2011; Micheli et al., 2014).

2.2 The California current system

Driven by economic and political motivations, interest in describing the oceanographic characteristics of the Eastern North Pacific dates back to 1535 AD (Pares-Sierra et al., 1997). One of its most prominent features, identified since 1565 by Andrés de Urdaneta, is the oceanic gyre of the North Pacific (Pares-Sierra et al., 1997), largely fueled by the California Current System and regarded as the largest ecosystem on the planet (Karl, 1999). The California Current System is characterized by abundant oceanic fronts, which are known to be associated with coastal upwelling (Mauzole et al., 2020), leading to moderate to high productivity and species diversity (Wilkinson et al., 2009).

The region is influenced by pronounced climatic cycles, including the El Niño Southern Oscillation (ENSO), the Pacific Decadal Oscillation, the North Pacific Gyre Oscillation, and warm water anomalies like the 2014-2015 event known as The "Blob" (Micheli et al., 2024; Arafeh-Dalmau et al., 2019; Villaseñor et al. (2024)). These phenomena, either synergistically or independently (Mancilla-Peraza et al., 1993), can lead to significant fluctuations in ocean temperature (Durazo and Baumgartner, 2002), upwelling intensity (Zaytsev et al., 2003), primary productivity (González-Silvera et al., 2020), and the composition of species assemblages (Pearcy and Schoener, 1987).

2.3 Steps for building ethnobiological calendars; a climate resilience tool

The process involved integrating ethnobiological information gathered between 2022-2024 with existing oceanographic and ecological data, resulting in the creation of an ethnobiological calendar for the study's five fishing communities. Before reaching this stage, we identified perceived changes and shocks, allocating these through time and space within timelines. Timelines are valuable for examining historical changes, impacts, and responses. However, to fully utilize the predictive capabilities of integrated oceanographic, ecological, and ethnobiological data, a more detailed monitoring tool is required than what corporate records and cooperative members' memories can offer. An ethnobiological calendar serves this purpose, leveraging local ecological knowledge and life histories to produce comprehensive information. This information is crucial for creating adaptation plans to address various stressors (Narchi et al., 2024). We detail the datasets and methodologies employed.

2.3.1 Ethnographic methods to understand the corporate memory and derived local ecological knowledge

To understand the population's perceptions of the impacts of marine heatwaves and climate change, we employed an ethnographic approach (Montes Vega, 2023). The core of our research team has extensively collaborated with these cooperatives for over 20 years. For this phase, we visited five fishing cooperatives sharing fisheries resources but contrasting in terms of organization, oceanographic patterns, and levels of production. The fieldtrips, from late 2022 through 2024 (October 2022; February, June and October 2023; and March 2024), allowed us to witness the development of local activities directly related to commercial fisheries as they occurred throughout the year.

During this period, we employed a range of anthropological methods and techniques, primarily based on direct observation. The ethnographic approach emphasizes direct observation and participation in the communities we collaborated with (Seim, 2024). Although extended stays were not possible, our research involved multiple short trips between 2022 and 2024 to various localities. As of this publication, the team has conducted five field trips, each lasting approximately 15 to 20 days.

This immersion allowed for engaging in numerous formal and informal conversations during everyday events and community activities, such as cooperative assemblies, preparing fishing expeditions, community tours, and formal conversations with structured questions administered in nine workshops and 38 individual interviews organized to investigate specific topics related to shocks and resilience in fishing. For this project, participants were invited by cooperative leaders, and those interested in participating attended the workshops. This meant that individuals participated regardless of their tenure, rank, or position, resulting in a heterogeneous mix. This approach allowed us to hold 185 interactions with 169 individuals (Table 1) residing in four localities in the central region of Baja California, who belong to five fishing cooperatives.

Direct observation provided insights into the dynamics between people and the species of interest by allowing us to witness firsthand the interactions and behaviors that define these relationships. We conducted workshops to gather cooperative members and followed up with personal interviews, asking relevant questions at opportune moments. During participant observation, we made initial notes in a field notebook, which were later meticulously transferred to a detailed field journal, enriched with additional observations and reflections. Our final goal aligns with the principles of Grounded Theory, where local theories about how the world works emerge through a systematic process of induction (Hurst, 2023). To minimize bias, we engaged in constant feedback by presenting results to the community, allowing these local theories to evolve and be refined based on their input (Urquhart, 2023). This approach nurtures and expands the community's self-created theories. By integrating diverse data collection methods, i.e., interviews, workshops, conversations and fieldnotes (Bernard, 2017), we quickly achieved data saturation through triangulation while building a more robust understanding of community dynamics through triangulation (Aldiabat and Le Navenec, 2018).

TABLE 1 Summary of participant interactions (185) during fieldwork (October 2022 – March 2024), including workshop attendees (117), interviewees (38), and informal interactions (30).

	Cooperative Members	Cooperative Employees	Unidentified cooperative members	Townye people not related to the cooperative
Formal interviews	21	12	5	
Workshop participants	29	53	35	
Informal meetings	-	-		30

Sixteen of the interviewees also participated as workshop participants and were selected for interview due to the depth of their knowledge.

Interactions were recorded through audio recordings (30 h, 51 min, 32 seconds) whenever feasible and supplemented with contextual information recorded in ethnographic field notes, producing a combined record of 1173 pages of notes and transcripts. The combined files were transcribed and categorized using Atlas.ti 8 software. To move beyond mere anecdotal description, we employed a thematic coding approach outlined by Urquhart (2023). This involved assigning codes to sentences or words referring to specific actions, attributes, or behaviors. Our coding process aimed to identify patterns in the data by initially organizing them into large thematic categories, which were then further refined with smaller codes. This methodical approach allowed us to analyze how these codes intersected spatially, providing more in-depth insights and ensuring the data accurately captured the complex dynamics between the people and the species of interest.

With the data collected, we began creating a timeline for each cooperative using their corporate memory. Since the data did not extend back far enough to cover the establishment and early years of the cooperatives, we decided to seek out retired fishers and elderly individuals for interviews about their active fishing years and the stories passed down from their parents. We interviewed 18 elders (from 54 to 71 years old) from various cooperatives. These timelines were then enriched with data from additional interviews and informal conversations, providing us with over 60 years of lived experience related to the abundance of natural resources, as well as economic, infrastructural, social, and political changes.

2.3.1.1 Timelines for constructing corporate memory

Over the span of one year, we conducted five visits to five fisheries along the Pacific coast of Baja California Peninsula crafting a methodology in the spirit of Grounded Theory. Our initial objective was to comprehend both present-day challenges and historical shifts encountered by the cooperatives. To facilitate this, during a workshop, we provided cards for participants to write down their experiences. We asked them to write down the shocks, risks and changes they were facing during the workshop and in the past. After collecting their input, we affixed the cards to a wall and categorized them based on common themes, thus forming overarching meta-categories representing the risks and changes they confronted (Figure 2).

FIGURE 2
Photograph taken in Bahía Asunción in 2023 with participating members of the California San Ignacio Fishing Cooperative during the initial workshop. In this session, shocks, risks and changes that the cooperative has experienced were written on colored cards, affixed to the wall, and grouped by categories. Photograph by Arturo Hernández-Velasco.

After collecting the cards, we read each aloud to put under public scrutiny the timing of the documented events. Then, the assembly reached consensus on when each of the events began, what was their timespan or if these remain ongoing processes. We then constructed a timeline, organizing these risks and changes chronologically to provide a comprehensive view of their evolution over time (Figure 3).

Once all the gathered information was systematized, we used subsequent field visits to interview key stakeholders. These interviews followed closely related topics to those touched throughout the workshop, ensuring we asked the same set of questions. This method ensured consistency in data collection processes across different groups, allowing us to delve deeper into the information and gather data from further back in time, especially when working with older individuals and retired fishers. The timelines contained extensive information on social, political, climate, resources, and infrastructure changes. For this article, we decided to primarily focus on the climate and resource shocks.

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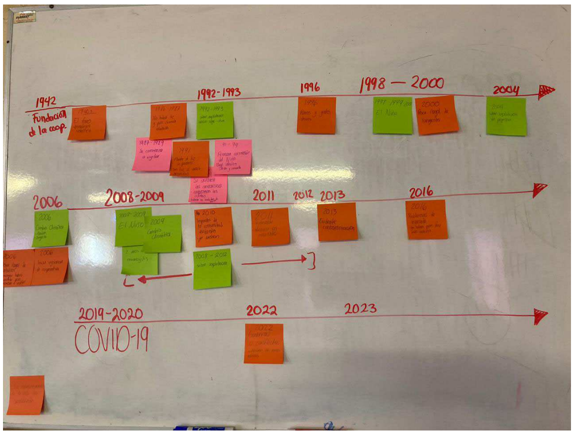

FIGURE 3
Timeline created during the workshop with the Cooperative "Buzos y Pescadores de Baja California" at Isla Natividad, February 2023.

2.3.2 Oceanographic data

2.3.2.1 Coastal monitoring

Mooring sites were established on each side of Isla Natividad (starting in 2010; Morro Prieto and Punta Prieta) and El Rosario (Isla San Gerónimo beginning in 2013; Sportfish and Chinatown) in approximately 15 meters of water in collaboration with each cooperative (Figure 4). These moorings recorded temperature, salinity, and dissolved oxygen every 10 minutes over a 14-year period from 2010 to 2024 (Comunidad y Biodiversidad, ND)[2]. Each mooring consists of a bottom-mounted conductivity-temperature-depth (CTD, Seabird SBE37-ODO) sensor with dissolved oxygen or a combined temperature-dissolved oxygen sensor (PME MiniDot). Other sensors have been included on the moorings over various periods including high-frequency temperature loggers (SBE56), acoustic doppler current profilers (Nortek ADP; Teledyne RDI Workhorse); however, the CTD and MiniDot records are consistent across the entire sampling period at each site and are reported here (Villaseñor-Derbez et al., 2017).

Sensors and moorings undergo maintenance every six months, performed by dive teams comprising of researchers and local fishers. Temperature records span more than 10 years in each cooperative (2008-2024 at Isla Natividad; 2012-2024 in El Rosario). All data are collected, quality-controlled, and shared with the local cooperatives. The sensors are recovered, and the information is downloaded periodically, generating annual databases. When necessary, the sensors are calibrated or reconfigured *in situ* or sent to the manufacturer for calibration and repair. Sensors are also cross calibrated opportunistically and serviced annually as needed. The aim here is to demonstrate how relatively inexpensive data can contribute to local management and conservation efforts, enhancing the sustainability of these vital ecosystems.

2 Comunidad y Biodiversidad, ND La red oceanográfica. Available online at: https://cobi.maps.arcgis.com/apps/Cascade/index.html?appid=6f837e0ef0c84d21a4ab87126dbdaebb (Accessed 6.30.24).

2.3.2.2 Ecological monitoring

To characterize giant kelp (*Macrocystis pyrifera*) dynamics we used an existing dataset that uses multispectral Landsat images and estimates the surface canopy biomass of giant kelp forests (henceforth "giant kelp biomass") (Bell et al., 2020). Giant kelp forests are one of the primary habitats in Baja California that sustain important fisheries in our study region (Piñeiro-Corbeira et al., 2022). This dataset provides quarterly estimates of giant kelp biomass at a 30 m grid resolution from 1984 to present (Cavanaugh et al., 2011) from central California (37°), USA, to Central Baja California (~27°) where giant kelp forest is the dominant canopy-forming kelp species (Bell et al., 2020).

The dataset can be visualized on kelpwatch.org (Bell et al., 2023). We extracted all 30 m grid pixels that overlay with the fishing concession polygons of our study area and estimated the mean pixel biomass for each quarter of the year and created a dataset from 1984 to 2023 (Figure 5) for each fishing concession. The methods developed to estimate kelp biomass were validated using 15 years of monthly kelp canopy surveys by the Santa Barbara Coastal Long Term Ecological Research project at two sites in Southern California.

2.3.2.3 Biological monitoring

Ecological monitoring was conducted annually, every summer from 2006 to 2023. The data collected varied per fishing cooperative: Buzos y Pescadores from Isla Natividad started in 2006, Ensenada from El Rosario started in 2013, while California San Ignacio from Bahia Asuncion and Pescadores Nacionales de Abulón from Isla Cedros and Islas San Benito only have data from 2022 and 2023. Using SCUBA, trained divers lay a 30 x 2 m (60m2) belt transect to record *in situ* abundance data of ecological and economically important invertebrate and fish species (Freiwald et al., 2021). Every year, between 16-30 transects per 5 sites in Isla Natividad, 13-21 transects per nine sites in El Rosario, six transects per two sites in Bahia Asuncion and six transects per seven sites in Isla Cedros and Islas San Benito were surveyed. Data was square root transformed for better species visualization.

2.3.2.4 Calendars as a tool for integrating local ecological knowledge

The construction of calendars was centered on the main fisheries for each cooperative. Abalone (Haliotis spp), sea cucumber (*Apostichopus parvimensis*), lobster (*Panilurus interruptus*) and sea urchin (*Strongylocentrotus franciscanus*) for Coop. Ensenada; lobster, abalone, common wavy snail (*Megastraea undosa*), and sea cucumber for California San Ignacio; abalone, common wavy snail, and lobster for Ribereña Leyes de Reforma and abalone, common wavy snail, Yellowtail amberjack (*Seriola lalandi*) and lobster, for Buzos y Pescadores in Isla Natividad. While these species remain popular throughout the area due to their market value, other fisheries and their opening seasons are also portrait in the calendars, as can be seen with octopus (Octopus sp), flounder (*Paralichthys californicus*), and the barred sand bass (*Paralabrax nebulifer*), in Bahía Asunción or ocean whitefish (*Caulolatilus princeps*) at Isla Natividad.

To create ethnobiological calendars for each cooperative, we followed the methodology described by Narchi et al. (2024),

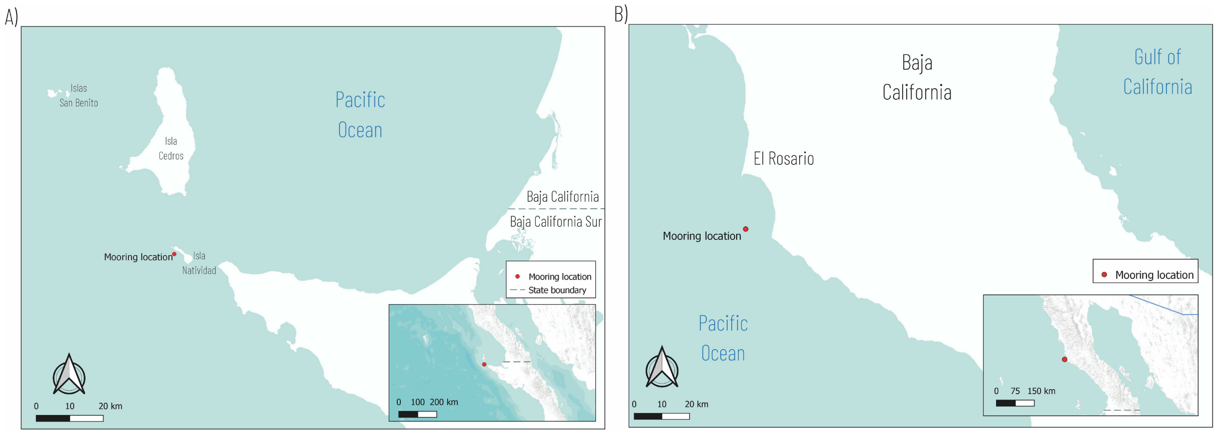

FIGURE 4
Maps showing the mooring locations at **(A)** Isla Natividad and **(B)** El Rosario, indicated by red dots.

focusing on seven key aspects. We conducted nine workshops with all cooperative members, regardless of seniority or position, using a structured script to guide discussions. We gathered information on: a) type of year (normal, hot, or other), b) the number and names of seasons as perceived by the fishers, c) local divisions of the year, d) oceanographic characteristics (currents, sand deposition, sea temperature), e) meteorology (mean temperature, humidity, winds, rainfall), f) phenology, capturing the interconnected observations related to climate, biology, and ecology, and g) the biology and management of target species, including behavior, diet, reproductive cycles, growth stages, morphological changes, and management considerations like closed seasons.

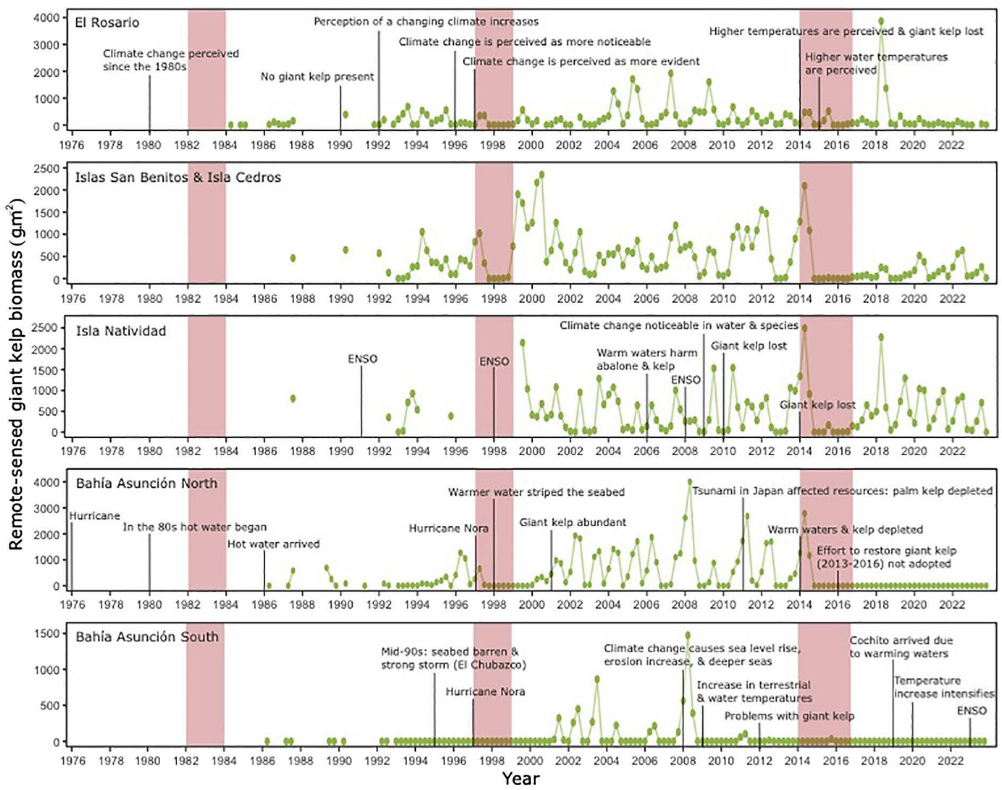

FIGURE 5
Time series of canopy kelp biomass (g/m^2) detected in each quarter of the year, along with information about events impacting kelp biomass for each of the five cooperatives in Baja California, Mexico. The pink shaded polygons represent years with the strongest warming events (1982-1983 ENSO, 1997-1998 ENSO, and 2014-2016 "Blob" + ENSO). The text includes ethnographic records related to environmental events and kelp dynamics for each community.

3 Results

Analyzing corporate memory and individual accounts of changes in fishery yields in response to environmental change and uncertainty provides a robust understanding of climatic alterations and responses to political, economic, and sanitary shocks, among others. This approach enriches the context and highlights human reactions to specific shocks (Figure 6).

During the workshops with members from each of the cooperatives (where active fishers were the most numerous attendants), we asked about shocks, changes and risks related to the oceans or fishing activities and requested that these were referenced over time. The results show that participants from the cooperatives had a similar sense of weather anomalies. They clearly remembered the warm anomaly known as “The Blob” that developed northern Pacific. They mentioned that since that event, there has been more kelp in some communities, and there has been a decrease in the abalone population and abnormally high water temperatures. In Bahía Asunción, Baja California Sur, people recalled a drastic drop in the abalone population (Figure 7D).

Additionally, for El Rosario, Baja California, participants noted that climate change was becoming more intense, meaning that the weather and water temperatures were drastically changing, which affected the abundance of marine resources (Figure 7A). On Isla Cedros and Islas San Benito, Baja California, participants reported that the recovery of abalone, sea snail, lobster, and floating sargassum had slowed down after initial recovery following the 2014-2016 marine heatwaves. They remembered that sea cucumber was “freely fished” until it was depleted. The fishers from Cedros and San Benito also knew that the decrease in abalone and sea snail in 2012 was due to low oxygen levels (Figure 7C).

3.1 Oceanographic and giant kelp biomass data

Coastal monitoring provided us with a time series for temperature from 2013-2024 in two localities: Isla Natividad and El Rosario (Figure 8). For Isla Natividad only one observation overlapped with ethnographic data mentioning overexploitation. Temperature data for El Rosario, with ethnographic counterparts occurred for the years of 2014-2016.

Landsat dataset on giant kelp biomass gains context when merged with ethnographic data. For El Rosario (Figure 5), it is inferred that the first reports of climate change by cooperative members around 1980 align with initial records of canopy biomass, which remained relatively low (-1000 g/m²) until the 2000s. For these 20 years (1980-2000), ethnographic highlights match the low canopy biomass.

From 1996 to 1997, fishers perceived more noticeable climatic alterations, such as warm waters entering their fishing grounds. This pattern coincides with major climatic shocks, whether from a high peak of the ENSO signal or other abnormal hot water currents, such as the 2014-2016 marine heatwaves. These signals and their effects on surface canopy biomass are evident and can be related without ethnographic mediation, as seen in the timelines for Isla Cedros and Islas San Benito (Figure 5). However, associating a decrease in canopy surface cover with specific perceptions provides a richer context, as observed in the northern part of Bahía Asunción. Here, the impacts of Hurricane Nora (1997), another ENSO positive peak (1997-1999), and the 2014-2016 “Blob” on surface canopy biomass are clearly noticeable.

It is worth mentioning that high variability in oceanographic conditions, occurring both across and within fishing concessions, can be inferred from the surface canopy biomass data. A clear example of this is clearly illustrated when comparing what occurs across Bahía Asunción, where yearly biomass in the northern location is significantly higher when compared with its southern, historically less canopy dense, more stressed, and patchy counterpart. This is true even for peak years (2008-2009) where, given its appropriate proportion, the highest peak is observed at both locations.

Ethnographic accounts, closely aligned with the strongest warming events across all locations, also show synchronicity with other events of lower intensity. This was evident for El Rosario in 1996, that people remember as more noticeable in terms of water temperature and surface canopy coverage dropped below 1000 g/m². Similar observations are noted in other locations, such as Isla Natividad in 2009, where fishers observed the impact of climate change on biological species.

In the northern portion of Bahía Asunción, fishers also reported positive outcomes, such as an increase in the abundance of giant kelp in 2001. This initial observation of kelp recovery marked a trend of more desirable kelp surface coverage compared to the previous lustrum, despite some downfalls. Kelp surface coverage in the region remained relatively constant until 2008, when there was a massive increase in canopy biomass. After 2008, the trend stabilized until the population was negatively affected by the “Blob”. Following this event, cooperatives struggled economically and were unable to implement kelp restoration programs, compounded by the market closures during the COVID-19 pandemic.

3.2 Fisheries abundance

Parallel to what has been observed for oceanographic and giant kelp coverage patterns, fisheries abundance, by itself as well as combined with oceanographic data, becomes more informative when combined with ethnographic accounts and vignettes (Figure 7).

For example, in El Rosario during the period from 2014 to 2016 the sea cucumber and abalone catches notably decreased, while lobster catches grew amid a “Blob” + ENSO event, allowing cooperative members to report increased profits. It is worth mentioning that, along with lobster, there is a marked overall positive trend for sheepshead (Figure 7A).

For the same period, 2014 to 2016, and extending slightly towards 2017, survey data for Isla Natividad shows a steady decline in abalone density and a more dramatic but similar trend for lobster and sea cucumber compared to El Rosario. However, in Isla Natividad, there is some recognition that abalone populations were overexploited during this period, which adds more context to the abrupt decline in abalone and sea cucumber populations prior to 2014-2016 marine heatwaves, which marks an abrupt negative trend for lobsters and sea cucumbers in this location (Figure 7B).

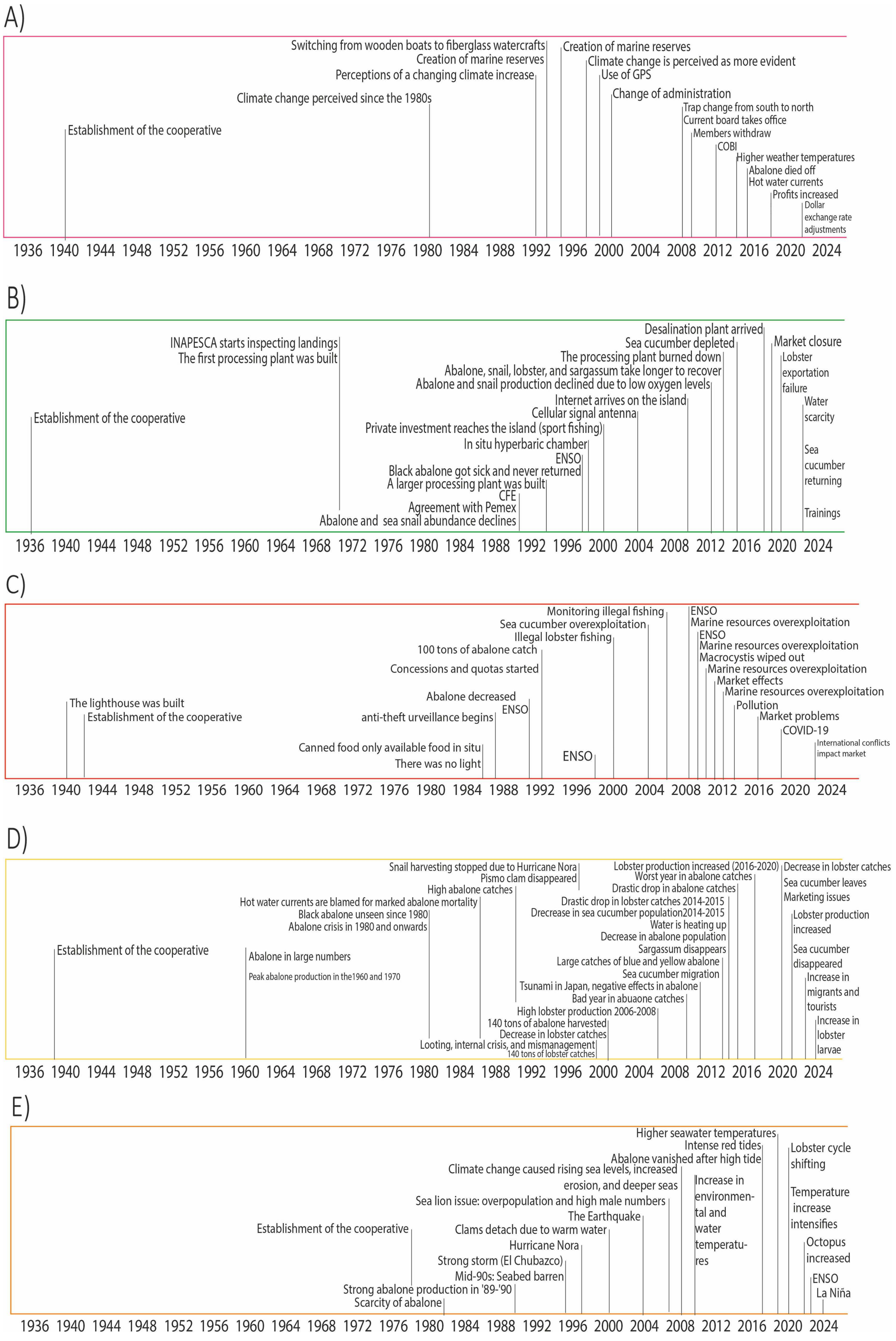

FIGURE 6
Timelines for five different cooperatives in the Baja California Peninsula constructed through ethnographic data. Condensed bullet points illustrate the events reported as changes or shocks by the five fishing cooperatives along the northern Pacific coast. These results are derived from ethnographic data collected during workshops and individual interviews with key stakeholders from each cooperative: **(A)** SCPP Ensenada from El Rosario, **(B)** SCPP Pescadores Nacionales de Abulón from Isla Cendros and Islas San Benito, **(C)** SCPP Buzos y Pescadores de la Baja California from Isla Natividad, **(D)** SCPP California San Ignacio from Bahía Asunción and **(E)** SCPP Ribereña Leyes de Reforma from Bahía Asunción. Acronyms in the figure: PEMEX (Petroleos Mexicanos, the government owned Mexican oil company), COBI (Comunidad y Biodiversidad, a Mexican NGO promoting resilient societies and healthy oceans), INAPESCA (Instituto Nacional de Pesca, Mexican Institute for Fisheries, now IMIPAS), CFE (Comisión Federal de Electricidad, government owned Mexican electricity company).

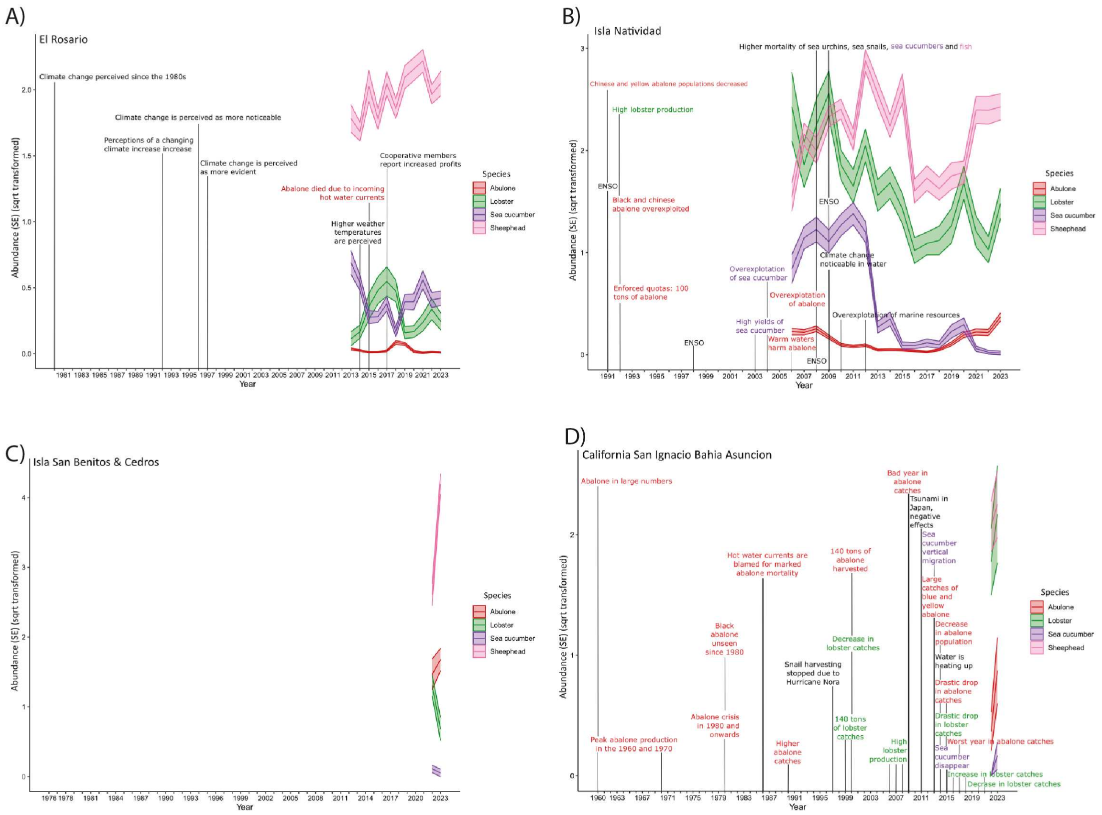

FIGURE 7
Time series of abundance (mean abundance (SE)) and major events detected by fishers for four cooperatives in Baja California and Baja California Sur, Mexico **(A)** El Rosario, **(B)** Isla Natividad, **(C)** Isla Cedros and Islas San Benito and **(D)** California San Ignacio Bahía Asunción. Lines represent species of economic interest to the cooperatives (red: abalone, green: lobster, purple: sea cucumber and pink: sheepshead). Note that the years differ between cooperatives.

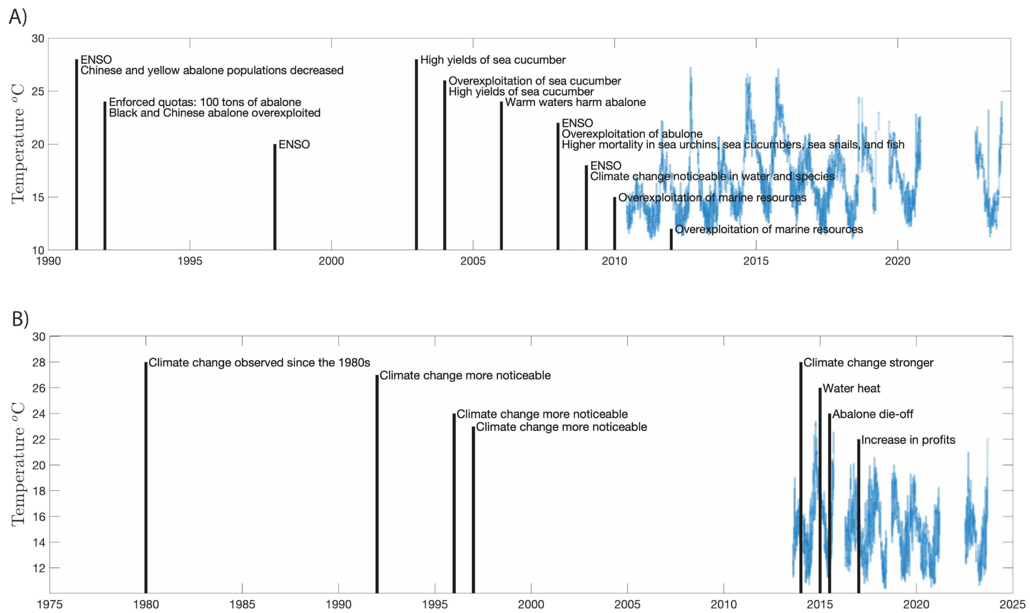

FIGURE 8
Time series of temperature at ~15 m depth from **(A)** Isla Natividad and **(B)** El Rosario. These time series combine oceanographic and ethnographic data collected for each location, resulting in a better and more accurate understanding of the oceanographic history of these places.

For the members of the Pescadores Nacionales de Abulón cooperative form Isla Cedros and Islas San Benito, as well as those pertaining to the California San Ignacio cooperative of Bahía Asunción, the information on the ethnographic timeline goes further back than the ecological monitoring (Figure 7C). Additionally, due to insecurity and the overall political situation of the area, and as our research has not yet finished processing ethnographic data on Isla Cedros and Islas de San Benito, we decided to present the graph as is to compare it with that of California San Ignacio, for which we have an ethnographic timeline and similarly species survey data.

3.3 Calendars

So far, our research has presented enough evidence to argue that timelines are useful in analyzing past alterations, affections, and responses. However, to harness all the predictive power of combined oceanographic, ecological, and ethnobiological data, it is necessary to build a monitoring tool, capable of registering daily records of human perception. These features will add far more resolution than that provided by corporate records and cooperative members' memories in a timeline. One such tool is an ethnobiological calendar, which constructed with local ecological knowledge and life histories data generates a robust database capable of supporting the development of adaptation plans in response to various stressors (Narchi et al., 2024) and changing climate regimes.

Corporate memories consist of individual accounts on cyclical variability, regardless of its nature (administrative, climatic, ecological, economic, managerial, or political, to name a few). These individual accounts, when put together create cultural consensus around specific topics. In the case of seasons and phenologies attached to seasonal change the cultural consensus forms calendars (Figure 9). These calendars allow for understanding the natural trends occurring around a period, typically a year.

Throughout our research, with the help of local participants, we created primal calendars, representing normal and abnormal (hot or cold) years for four of the cooperatives. The provision of cold and hot year calendars helps in trying to sort out natural variation from shock events, which, to the best of our knowledge, is still an unresolved theme in terms of perception. Each of these calendars displays the seasons as described by the local participants which, in the case of the two cooperatives, is marked in two easily distinguishable seasons: a) Summer and b) Winter. One cooperative California San Ignacio (Figure 10) divided distinguished a) Summer, b) Spring and c) Lobster season (winter). Making it clear that this is a corporate memory driven primarily by economic interests and aspirations.

Additionally, the distinctions include characterization such as summer being associated with hot weather and cold water, while winter is characterized by cold and rainy weather and the advent of warm waters. These two seasons also correspond with the opening of the season for catching two main key species within the region: lobster which is caught in winter, and abalone which is caught

FIGURE 9
Ethnobiological calendar of the four most relevant resources chosen by Cooperativa Ensenada from El Rosario, Baja California. This calendar indicates information based on what occurs during a "normal year." The calendar was divided into months and the year was subdivided into two seasons: winter and summer. Observations regarding winds, tides, rains, and other aspects deemed relevant by the community were recorded. Finally, the fishers selected the most significant species (abalone, lobster, sea cucumber, and sea urchin) and assigned a section of the calendar to each, indicating fishing seasons, reproduction periods, closures, and other significant events for their activities. Created by Gabriela Sandoval using project data and adapted from Narchi et al. (2024) under Cc by - NC 4.0. https://creativecommons.org/licenses/by-nc/4.0/.

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FIGURE 10
Ethnobiological Fishing Calendar for a Normal Year of the S.C.P.P. California San Ignacio S.C.L. of Bahía Asunción, Baja California Sur. The calendar was divided into lobster season, spring, and summer. Fishermen selected the most significant species (abalone, lobster, sea snail, and scale fish) and assigned a section of the calendar to each, indicating fishing seasons, reproduction periods, closures, and other significant events for their activities. They also identified warm years as abnormal years.

during summer. The most noticeable feature of these calendars is that the seasons for different fisheries can be related to phenological observations. In the case of Cooperativa Ensenada (Figure 9), for example, the sea urchin season ends while lobsters become less abundant. This is also the best time to clip sargassum (*Gelidium robustum*).

Similarly, people in the cooperative can also relate other phenomena to specific fisheries. A good example of this happens from June to August where a larger number of dolphins present in the area indicate the arrival of tuna, sardine and yellowtail at the same time that beaches become rocky due to sand transport outside of the bay. On Isla Natividad, the indicator for the seasonal arrival of fish stocks are Hermann's seagulls (*Larus heermanni*) that live in the Gulf of California throughout the mating season (Figure 11).

In parallel, in Bahía Asunción, fishers from the cooperative California San Ignacio, start their lobster season on early October (Figure 10), this should be interpreted as a social mediation tool that prevents their fisheries and market opportunities from overlapping with the capturing of lobsters by the Ribereña Leyes de Reforma cooperative. They start their lobster season after the presence of heavy rains (Figure 12). Many of the local participants emphasized that it is in those years that it rains the most that they have achieved the highest lobster catches. Some of the retired fishers we interviewed agreed to that by using an old saying "the more pitaya (prickly pear) there is, the larger the lobster catch you will get" arguing that copious rains make more abundant pitaya harvest and that seems to be a useful proxy for predicting a good lobster season.

4 Discussion

This research, representing a possible way in which to integrate qualitative and quantitative data from ecological, oceanographic, and ethnographic sources, show that constructing ecological and climatic timelines from corporate memories and individual experiences of cyclical weather patterns is a promising approach for developing new forecasting tools for informing natural resource management and climate adaptation. These tools rely not only on statistical abstraction and data processing but also on direct experience (cf. Haskell, 2017).

Our findings demonstrate that local fishers possess a vast body of knowledge specific to their fishing territories. By drawing on corporate memories and fishers' perceptions of marine heatwaves, hypoxia, storms, seasonal changes, kelp cover, record catches, overexploitation, and resource depletion, fishers construct a relational ontology (sensu Escobar, 2014). This enables both fishers and researchers to understand the dynamics of local fisheries in relation to climate and ecological variability throughout Baja California. These perceptions align with documented literature, oceanographic data, satellite imagery, and ecological monitoring.

Significant changes in the oceanography of Baja California during El Niño years, which dramatically affect the region's flora and fauna, can be accurately described through these collective memories and individual experiences. This suggests that using these memories to develop detailed ethnobiological calendars could lead to new local records. When supplemented with daily entries, these

FIGURE 11
Ethnobiological Fishing Calendar for a Normal Year by the S.C.P.P. Buzos y Pescadores de la Baja California, S.C.L. of Isla Natividad, Baja California Sur, Mexico. The calendar was divided into winter-fall and spring-summer seasons. Fishermen selected the most significant species (scale fish, abalone, lobster, and sea cucumber) and assigned a section of the calendar to each, indicating fishing seasons, reproduction periods, closures, and other significant events for their activities. They also identified warm years as abnormal years.

records could serve as predictive tools for forecasting local climate change.

It is evident that environmental extremes such as marine heatwaves, storms, and escalating hypoxia are being detected by people working on the waterfronts (sensu Doyle et al., 2018), who spend considerable time at sea—whether fishing from the surface or diving for abalone, sea urchins, and sea cucumbers. This extended exposure, including the shorter but regular time SCUBA and

FIGURE 12
Ethnobiological Fishing Calendar for a Normal Year by the S.C.P.P. "Ribereña Leyes de Reforma," S.C. de R.L. of Bahía Asunción, Baja California Sur. They decided not to divide the year into seasons but to use months instead. Fishermen selected the most significant species (scale fish, lobster, abalone, and sea snail) and assigned a section of the calendar to each, indicating fishing seasons, reproduction periods, closures, and other significant events for their activities. They also identified abnormal years, such as cold years and warm years.

hookah divers invest in gathering their products, allows for constant observation of marine resources. Thus, those working on the waterfront can witness firsthand the impacts of external shocks and changing climate regimes on these resources (Rudiak-Gould, 2013). This experience and the expertise it develops are deeply connected to place—both physically, socially, and culturally—honoring the local ecological knowledge that emerges from this connection.

Consequently, local participants corroborate, through their own empirical observations, what has been independently described in terms of oceanographic variability affecting ecological settings (Micheli et al., 2012; 2024, Arafeh-Dalmau et al., 2019; Cavanaugh et al., 2019). A good example of this is that in spite of knowing that ENSO events produce an overall northward displacement of fauna in the Mexican Pacific (Lluch-Belda et al., 2005) individual species, such as the Pacific spiny lobster, tend to display positive associations with warm ENSO events in terms of larval survival and subsequent recruitment (cf. Koslow et al., 2012), as can be seen in Figures 7A, B for lobster abundance both in El Rosario and Isla Natividad, for the years of 2017-2018 and 2005-2010 respectively. Previous attempts to evaluate the socio-ecological vulnerability of cooperatives in this area have already made use of social sciences approaches to understand the impacts and responses of Baja California fishing cooperatives when confronted with oceanographic, ecological and market change (e.g., Micheli et al., 2024). Such attempts allowed for building a coherent narrative on the history of events connected with environmental and market change, especially those directly related to the post-hoc analysis of management actions leading to successful adaptation after any given shock.

Despite these valuable efforts, the results have primarily served as a reflexive tool for fishing cooperatives and their members to analyze past scenarios rather than anticipate future challenges. When oceanographic data is presented to these cooperatives, only their technical advisors—those formally trained in oceanography, aquaculture, or marine biology—can interpret the data collected by moorings and analyzed by research teams. This situation echoes Rudiak-Gould's (2013) reflection on how statistical abstractions have contributed to the notion that climate change is visible only to specialists, thereby relegating the public to a passive role of merely supporting experts, while underestimating the value of everyday experiences.

However, individuals in these communities often possess an accurate understanding of cyclical weather patterns and maintain corporate memories of climatic and ecological aspects vital to their livelihoods. This calls for a re-evaluation of their role as essential actors who offer a unique and valuable perspective on the pressing problems posed by emerging climate patterns. Although previous attempts to leverage local ecological knowledge to predict the impact of climate variability on small-scale fisheries (e.g., Cavole et al., 2020) have not succeeded in generating predictive scenarios, and while other methods, such as detecting early weather conditions through encounters with potential climate sentinel species (Early-Capistrán et al., 2024), have proven useful, they remain limited. These approaches often fail to infer ecological conditions across entire ecosystems due to a lack of focus on system connectivity.

The approach we describe allows for constructing systematic connectivity among all elements of the ecosystem by recording and analyzing phenology and combining this with oceanographic and ecological data, such as temperature, fisheries catch, and habitat coverage. A larger set of data (e.g., dissolved oxygen, water density, non-commercial species abundance) can be integrated with the original data to strengthen these relationships. This approach enables systematic follow-up analyses to create new yearly calendars with the help of fishers and divers.

Data from corporate memories and local ecological knowledge can be recorded as daily observations of all phenological aspects already described here and elsewhere (Winter et al., 2020; Balick et al., 2022; Franco et al., 2022; Narchi et al., 2024). An example from our research results makes evident these connections. In Isla Natividad, oceanographic sensors have been collecting data for the past 11 years; some members of the fishing cooperative have learned to interpret the results and they used this information for decision making in about their fisheries. But before the last warming event that took place in 2023, the members from the Isla Natividad cooperative made decisions in advanced of their abalone fishing season (fishing quotas) based on: 1) their previous experience with other warming events, where massive abalone mortalities have taken place, and 2) the time series of the oceanographic parameters measured with the sensors. In an interview in Isla Natividad (June 14, 2023), one of the youngest members of the cooperative mentioned that after observing the effects of ENSO events on abalone in previous years, along with the oceanographic conditions recorded by sensors, they decided to take preventive measures for 2023. These measures implied they would set a lower quota and harvest the product within the fishing season but before it was impacted by ENSO. As far as the cooperative's and our records go, this level of foresight has no precedents and is a direct result of combining human perception with oceanographic information in ways that are intelligible and culturally relevant to local communities.

Given the substantial amount of data derived from corporate memories, this method also allows for the future reconstruction of previously unrecorded stock sizes for past fisheries seasons (c.f., Early-Capistrán et al., 2020) once methodologies are adapted for the species in the area. A fishing cooperative that can successfully manage its corporate memory over generations will be at an advantage in terms of adaptation and decision-making. Retaining knowledge about best practices, fishing techniques, seasonal patterns, and local ecological conditions is vital for sustainable fishing practices and maximizing yields, thereby maintaining operational efficiency and effectiveness (Argote, 2012). Historical data and past decisions serve as critical references for informed decision-making, helping organizations navigate current and future challenges (Caswell et al., 2020). Moreover, corporate memory preserves the cooperative's culture and community values, fostering a sense of identity and solidarity crucial for collaborative efforts and mutual support (Schein, 2010). In times of crisis, such as environmental disasters or market fluctuations, well-documented

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corporate memory allows for swift implementation of effective response strategies based on past experiences (Pearson and Clair, 1998; Stark, 2020; Fulton, 2023).

Organizational memory loss has been attributed to aspects such as rapid changes, poor data-management and the failure to value knowledge (Pollitt, 2000). By creating narratives around their information, collaborating with local and international research centers and organizations, the Baja California cooperatives have reduced the loss of information over time and successfully managed their corporate memory over generations, contributing to their operational efficiency, sustainability and resilience.

As fisheries science increasingly recognizes the need for collaboration with anthropologists to enhance fisheries management and conservation (Ingles, 2007; Jentoft, 2020), it is essential to understand that the long-standing human presence in the ocean provides valuable data, often shaped by culture and vital for sustaining societies and livelihoods. Longitudinal timelines are crucial for tracking changes in fishing cooperatives over time, enabling retrospective evaluations of responses to shocks. When combined with ecological, oceanographic, and ethnobiological data, these timelines improve scientific forecasts by providing a temporal matrix for tracking changes and establishing links between these changes and human experiences. This approach reveals how social or environmental factors influence cooperative operations and, in turn, how internal dynamics within cooperatives shape broader decision-making processes. While the costs of systematizing this approach are unclear, its initial benefits include empowering individuals and fishing cooperatives—who have unique socioeconomic, political, and cultural stakes in the matter—to influence public policy on resource management and conservation (Aswani, 2020) and develop effective climate change management programs based on their observations and past decisions (Micheli et al., 2024).

In the context of local ecological knowledge, calendars transcend mere timekeeping tools; they embody a wealth of knowledge rooted in the interactions between human communities and their natural environment. Ethnobiological calendars (Narchi et al., 2024) serve a variety of functions ranging from social organization (Moura, 2017) to decision-making in biological resource management (Campos et al., 2018). By integrating local observations of climate, water, phenology, animal behavior, they offer a holistic view of the world around us (Narchi et al., 2024).

While providing a snapshot of knowledge at a specific moment, local calendars are essential for understanding the temporal dynamics of human activities and their impacts on the environment. In the case of Baja California, for two hundred years the members of different fishing cooperatives have developed local ecological knowledge and corporate memories by understanding natural patterns that, in our opinion, have emerged not from understanding something, but from taking a close look at everything regardless of how hard it is to integrate numerous data derived from different epistemologies. While providing a snapshot of knowledge at a specific moment, the creation of timelines has led us to appreciate the existence of corporate memories as being much denser in cyclical ecological information; ethnobiological calendars, which transcend timekeeping to embody a wealth of knowledge rooted in the interactions between human communities and their natural environment.

Presently, we are actively working with cooperative members to conceive and create a calendar that can be fed with daily entries. The completion of this tool, we assume, will allow us to depart from observing correspondence between different events to quantitatively prove correlation between them. A challenge worth pursuing is to lobby for these calendars to become an instrument for consensual decision making between fishers, environmental authorities, and policy makers as reconstructing these calendars entails not only preserving traditional knowledge but also fostering equitable dialogue between different forms of knowledge, such as technical and local knowledge, in pursuit of sustainable and contextually and locally relevant solutions.

Following the logic involved in creating these patterns, this article offers an incipient methodology to create local weather forecasts. This methodology should be followed with attention and the tools should be crafted with careful observation to detail as they recreate the fisheries' transactional relationship, not with something else, but with everything else.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Panel on non-medical human subjects, Stanford University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

IG-T: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation. CO-J: Visualization, Formal analysis, Data curation, Writing – review & editing, Methodology, Investigation. CW: Writing – review & editing, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. NA-D: Writing – review & editing, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation. JT: Writing – review & editing, Project administration, Investigation, Funding acquisition. SF: Writing – review & editing. FM: Supervision, Resources, Project administration, Investigation, Funding acquisition, Writing – review & editing. RO'C: Writing – review & editing. MP-D:

Investigation, Writing – review & editing. AH-V: Writing – review & editing. NN: Data curation, Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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