Using Local Ecological Knowledge to Identify Adaptation Strategies Used in Western Nayarit's Fisher Communities

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Abstract

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As climate change continues, it becomes increasingly crucial to understand its profound impacts on small-scale fishers. The coast of Nayarit, Mexico, recognized as a climate change hotspot, is home to vulnerable small-scale fishing communities. Utilizing local ecological knowledge documented from Nayarit fishers, this study aims to identify their adaptive capacities from the 1960s to the 2020s. We analyze the adaptation strategies employed by fishers to sustain their livelihoods. These strategies include diversifying their target species, switching their primary target species, and changing the gear they utilize. Fishers are progressively broadening their range of target species and switching their primary targets, acknowledging the diminishing abundance of previously prevalent species. They exhibit more frequent changes in target species than in the gear type used to catch them. By conducting a comprehensive analysis of these adaptive measures and their impact, our study provides insights into the resilience of small-scale fishers in facing environmental stressors.

Introduction

Small-scale fishers' livelihoods are deeply intertwined with the ebb and flow of our ever changing oceans, which directly impacts the well-being of their families and local communities (Macusi et al., 2021). In Mexico, approximately 260,000 small-scale fishers engage in fishing operations characterized by individual, familial, and or small-group endeavors, employing traditional and or artisanal methods (CONAPESCA, 2018). Despite the absence of a universal definition, these fisheries typically involve small boats and gear that require relatively low capital investment to target nearshore and or coastal stocks mainly sold in local markets (Smith & Basurto, 2019). Small-scale fisheries are distinguished by their reliance on local knowledge and skills, playing a crucial role in local food security, livelihoods, and cultural heritage (Macusi et al., 2021; Smith & Basurto, 2019).

The ongoing impacts of anthropogenic climate change continue to reshape ocean and coastal ecosystems (Perry et al., 2010). Those who depend on these systems, including small-scale fishers, must adapt to these changes (Macusi et al., 2021). However, previous literature suggests that small-scale fisheries with limited capital flexibility confront challenges in adapting, heightening their vulnerability to disruptions induced by climate change (Allison & Ellis, 2001). Adaptive capacity is defined as the ability to absorb stresses and maintain function in the face of change to minimize impacts, recover, and seize new opportunities through adaptation and transformation strategies (Adger, 2006; Grothmann & Patt, 2005). Fishers may use specific adaptation strategies, or tactics, to accommodate shifts in species distribution and preserve their financial stability while modifying social-ecological systems to enhance their resilience (Ojea et al., 2020). Such strategies may involve targeting new species, diversifying fishing gear, and finding new markets. Conversely, transformative strategies require systemic

changes, altering the structure of the social-ecological system. Examples include shifting jobs within the fisheries, exiting fisheries, and closing unsustainable operations (Ojea et al., 2020).

Analyses of small-scale fisheries development have tended to focus on the resources small-scale fishers lack, such as decision-making infrastructure, finance, and technology, rather than what they do have (Allison & Ellis, 2001; Green et al., 2021). Furthermore, recent studies, particularly those in Mexico have focused on exploring transformative strategies involving fishers exiting the industry (Ilosvay et al., 2022; Nomura et al., 2022). Nevertheless, there remains a scarcity of information on adaptive responses when individuals remain within the fisheries, exacerbated by the data-poor nature of many small-scale fisheries (Badjeck et al., 2010). Investigating alternative strategies that fishers can employ beyond exiting the fisheries is crucial for food security, cultural continuance, and sustainable fisheries management (Phelan et al., 2023). Since every community has different access to assets, it is important to understand the community-level responses to climate and overfishing stressors. Adaptive mechanisms can include shifting target species, diversifying species portfolios, acquiring new assets, and changing fishing grounds (Cinner et al., 2018; Kluger et al., 2019; Vargas et al., 2022). Fishers may shift target species in response to overexploitation or population declines due to climate stressors (Kluger et al., 2019). Diversification strategies entail expanding the range of targeted species to mitigate risks associated with fluctuations in the abundance of any single species, changes in market demand, or regulatory shifts (Beaudreau et al., 2018; Vargas et al., 2022). Fishers observing shifts in species ranges may acquire different assets, such as larger boats and different gear (Cinner et al., 2018). It is important to note that while these changes can increase the fishers' adaptive capacity, they may entail ecological consequences (Cinner et al., 2009).

The coastal region of Nayarit, Mexico, renowned as the national producer of Pacific red snapper (*Lutjanus peru*), is a climate change hotspot, where local communities have felt and perceived the climate change impacts (Ilosvay et al., 2022). Coastal climate change hotspots, like Nayarit, are subject to extreme exposure to cumulative climate-related hazards, including increases in sea-surface temperature, tropical storms, and marine heatwaves, compared to other coastal regions worldwide (Giorgi, 2006; Ilosvay et al., 2022; Turco et al., 2015).

In this study, we aimed to uncover the adaptive strategies employed by fishers, guided by their rich local ecological knowledge, to address environmental challenges in Western Nayarit's fisher communities. While fishers can use various adaptive and transformative strategies to reduce environmental impacts, the objective of this paper was to perform an in-depth analysis of adaptive strategies. We asked whether small-scale fishers in Western Nayarit employ adaptation strategies to reinforce the social-ecological system and maintain their livelihoods and, if so, how. We hypothesized that small-scale fishers in Western Nayarit can employ adaptation strategies to reinforce the social-ecological system they are part of and maintain their livelihoods by 1) shifting their target species 2) diversifying their target species portfolios and/or 3) introducing new gear. To answer these questions, members of our team and community partners conducted fieldwork in 2021, engaging in semi-structured interviews with fishers across six coastal communities. Using the interview data, we analyzed historical changes in target species and gear used since the 1960s, and reasons behind these changes. Our research highlights the adaptive capacities of small-scale fishers in Western Nayarit, providing insights into social-ecological resilience dynamics and informing strategies for community livelihoods and sustainable small-scale fisheries management.

Methods

From August to September 2021, members of our team and community partners conducted face-to-face semi-structured interviews with 102 fishers representing multiple generations at six coastal fishing communities in Nayarit state, Mexico. These communities are: Boca de Asadero, Boca de Camichín, Chacala, La Cruz de Huanacaxtle, La Peñita de Jaltemba, and San Blas. Fishers interviewed were selected based on their current or previous involvement in fishing activities, identified by researchers at the National Fisheries and Aquaculture Institute (INAPESCA) of Mexico. Initially, key interviewees were identified, and additional participants were recruited through snowball sampling. Prior to commencing interviews, participants were given a non-technical overview of the research objectives and assured of the confidentiality of their responses. They were also informed that they could choose to skip any questions and or end the interview at any time. These interviews were conducted in compliance with the University of Washington Human Subjects Division (protocol no. 13209).

The interviews, lasting between 30-60 minutes, began with inquiries into the fishers' backgrounds to gather demographic and activity-related information. Demographic questions such as "What is your age, and at what age did you start fishing?" were asked to link observations to their age rather than specific time periods in which they fished, which is much more difficult to recall. Questions like "Are you currently actively engaged in fishing?", and "How frequently do you fish?" ensures participants were actively involved in the fishery and not just occasional recreational fishers. Individuals who responded as never or only fishing once were removed from the analysis. To understand the fishers' target species and the gear they utilized for these species, questions included "What are your top three most important target species for each decade in which you fished?" and "What type of equipment did you use for your

top three targeted species for each decade in which you fished?" Fishers were also prompted to explain any observed changes in their target species and gear used over time. The interview questions are listed in Appendix A.

To prepare the data for analysis, we initially verified the year of fishing activity based on the interviewees' ages, ensuring alignment with the specified decades from the 1960s to 2020s. Subsequently, we reviewed responses to identify and correct any typographical errors in listed fish species and gear and removed any missing data. Since interviews were conducted in Spanish and fishers referred to species by their common names, we cross-referenced these names with scientific nomenclature using sources such as FishBase (Froese & Pauly, 2024), MexFish archives (MexFish, 2024), and peer-reviewed articles. These sources provide comprehensive information on fish taxonomy, geographic distribution, habitats, behavior, and morphology. These species were identified to their lowest possible taxonomic level. Gear terminology was translated using Google Translate. To ensure these translations were accurate, we verified them with a local fisheries research collaborator (Javier Tovar, INAPESCA, pers. comm.). The gear "virola" could possibly refer to lure used by recreational fishers, but we were unable to confirm this information with our local collaborators. Since it could not be identified, "virola" was omitted from the study. We believe that this did not greatly alter our results since "virola" was mentioned by only 10 fishers as their main fishing gear and by 20 fishers in total. For comparison "hook and line" was mentioned by 149 fishers as their main fishing gear and by 251 fishers in total.

After organizing the data, we tallied the number of fishers reporting each species in each decade to compute frequencies. These frequencies were then divided by the total number of responses in each decade to derive relative frequencies for each target species. Similarly, we

calculated relative frequencies for the gear type used across all decades by expressing the proportions of fishers mentioning each gear type relative to the total number of respondents in each decade. These relative frequencies were represented in a matrix (Figures 1 and 4) using Microsoft Excel, providing a visual representation of species and gear diversification trends in the studied communities. Additionally, we tabulated the number of unique species and gear types mentioned as primary, secondary and tertiary targeted species by fishers in each decade. We divided these tallies by the total number of fishers that responded in each decade to compute relative species and gear mention frequencies per decade. A subsample of these relative frequencies, which included only the primary targeted species, was then used to create Sankey plots using the ggsankey package by David Sjoberg (davidsjoberg), publicly available on GitHub (Figures 2 and 5). These diagrams visualize the proportions of fishers who changed their primary target species and primary gear between decades, aiding in illustrating the flow and transitions across the species and gear used from the 1960s to 2020s.

Lastly, we reviewed the reasons for fishers changing their primary target species and conducted a thematic analysis and grouped similar responses into the following categories: biological factors, climate change, competition, enforcement/policy, market-driven factors, new equipment/skills, pollution, and warming waters (Lester et al., 2020). We then visualized these data in a stacked histogram (Figure 3). Biological reasons include changes in spawning patterns, declines in fish abundance, and reductions in species diversity. Climate change was defined by interviewees as anthropogenic climate change altering environmental conditions affecting marine ecosystems. Competition encompassed the increased presence of fishers and boats or perceived growth of the industrial fishing fleet. Enforcement/policy factors involved closures and regulatory actions such as shark bans. Market driven reasons included buyers accepting new

species. New equipment/skills referred to advancement in fishing gear and techniques. Pollution was considered as a factor affecting fish populations such as runoff from shrimp farms. Lastly, warming waters denoted rising sea temperatures. Additionally, we examined the reasons for fishers changing their gear type, which were described as there were only six responses from the 1990s to 2020s.

Results

Fieldwork Observations

Fieldwork observations revealed that Boca de Asadero described their community as a small town with 15 local fishers and 85 fishers from surrounding areas, typically fishing within a four-mile radius. Their pier is located at the mouth of the Río Grande de Santiago, and they noted that their fishing production is highly dependent on water supply and quality, as nearby shrimp farms divert water from the estuary they fish in and pollute the water. In Boca de Camichín, oyster farming is the primary activity, with approximately 200 members in the Ostricamichin cooperative. In contrast, many fishers from Chacala have shifted their focus to tourism. During the 1980s, Chacala served as a hub for young fishermen venturing into shark fishing, primarily due to the PIDER-PESCA initiative. This government scheme involved shark fishing in various regions. Eventually, the value of sharks declined, leading the government to provide fishing cooperatives with loans for shrimp boats, enabling the same fishermen to sustain their livelihoods, extending into the early 2000s. La Cruz de Huanacaxtle is home to approximately 200 fishers, who primarily described Pacific red snapper as their main target species. However, over the years, they shifted their focus to yellowfin tuna (*Thunnus albacares*) due to high market prices. La Peñita de Jaltemba consists of about 150 fishers in four or five cooperatives who take

daily trips, often using gillnets. Older fishers expressed dissatisfaction with younger generations' practices, such as capturing juvenile Pacific red snapper for ceviche. Other commonly caught species include various snapper (*Lutjanus* spp.), jacks (*Caranx* spp.), mahi mahi (*Coryphaena hippurus*), and yellowfin snook (*Centropomus robalito*). San Blas is the largest fishing community interviewed, with over 2,000 fishers. Fishers stay near shore and fish in the estuary; however, shrimp farms have altered the hydrology and contaminated the water with copper sulfate. Thus, fishers have ventured further with a diverse array of vessels and gear to target various species and cover the high trip costs.

Fishing Portfolios

Small-scale fishers harvested a diverse range of target species over the decades, leading to shifts in the composition of fishing portfolios in Western Nayarit, including diversification to new species (Figure 1). Certain species, such as yellowfin snook, prawns (*Litopenaeus* spp.), Mojarra (*Eucinostomus* spp.), snappers, cartilaginous fishes (Elasmobranchii), Pacific sierras (*Scomberomorus sierra*), and Gulf weakfish (*Cynoscion* spp.), were consistently targeted, while other species showed fluctuating trends. Over the years, new species emerged as targets for fishers, while the proportions of others declined. For instance, the proportions of mullets (*Mugil* spp.), finescale triggerfish (*Balistes polylepis*), jacks (*Caranx* spp.), and mahi mahi (*Coryphaena hippurus*) increased from the 1970s onwards. Conversely, the proportions of some species, such as groupers (*Epinephelus* spp.), seabass (*Serranidae* spp.), narrow-headed puffers (*Sphoeroides angusticeps*), Gulf coneys (*Hyporthodus acanthistius*), cod (*Gadus* spp.), bonito (*Sarda* spp.), loggerhead sea turtles (*Caretta caretta*), and grunts (*Rhencus* spp.), experienced declines or even disappeared from the dataset entirely. Relative frequencies of certain species showed

habitat-specific patterns. Species primarily associated with estuarine environments maintained relatively stable proportions over time, reflecting the consistent importance of estuarine habitats to fishers. From the 1990s, all estuarine species were targeted consistently, with the exception of Cortez oysters. In contrast, species inhabiting rocky reefs, pelagic waters, and demersal zones exhibited more varied trends, possibly influenced by the use of non-selective fishing gear.

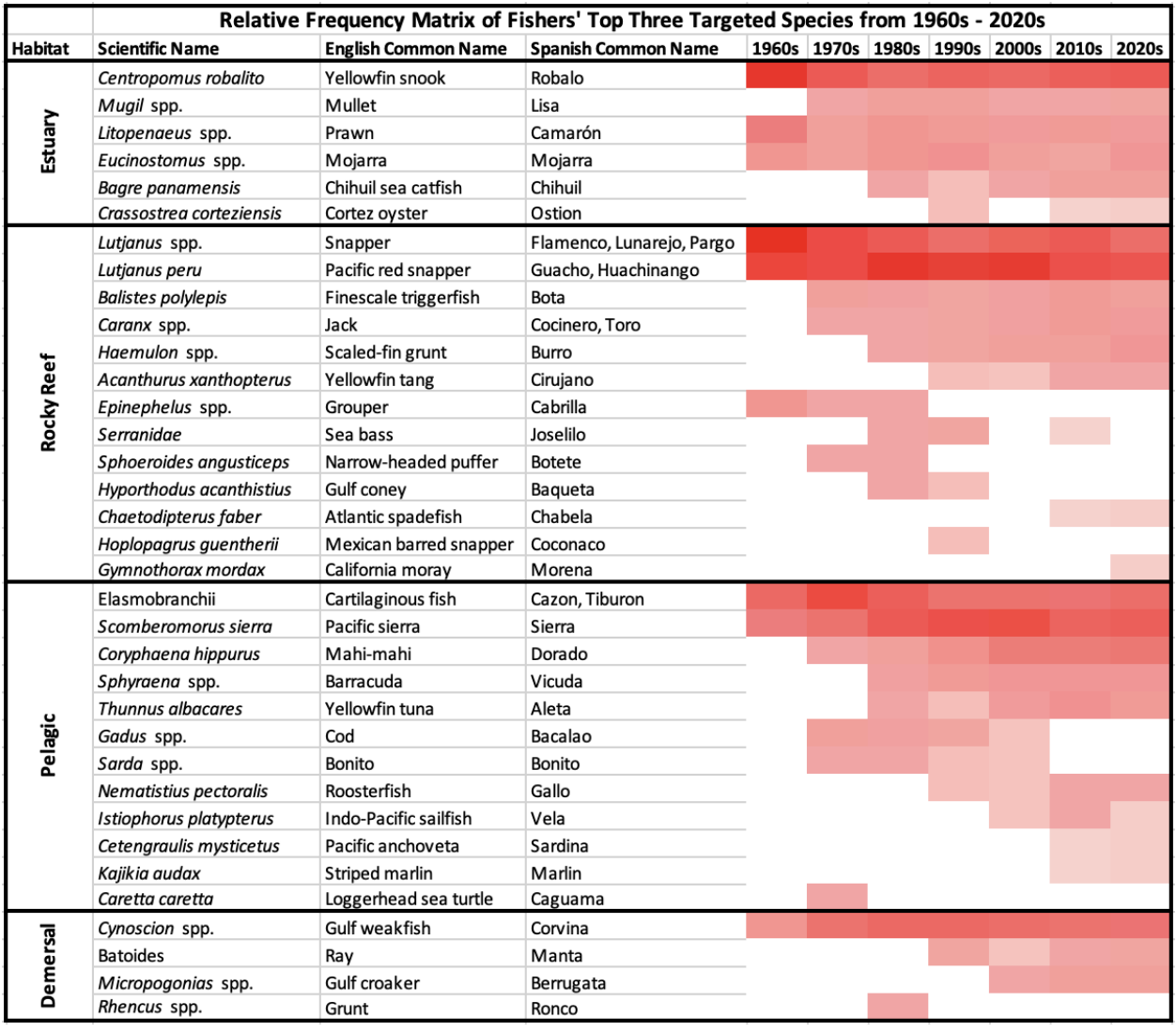

Fig. 1. Relative frequency matrix depicting the top three target species by fishers from the 1960s to the 2020s, arranged according to the habitat they inhabit as adults. The species' scientific

name, English common name, and Spanish common name are listed in the columns. Each cell in the matrix represents the relative frequency of a target species in the corresponding decade. The matrix is color-coded on a gradient scale, with red indicating the highest frequencies (0.36-0.70), light red representing intermediate frequencies (0.01-0.35), and white indicating the lowest frequencies (0).

We were interested in understanding the individual fisher's adaptive strategies, so we constructed a Sankey diagram of the fishers' top target species (Figure 2). Between the 1960s and 2020s, 18 primary species were targeted, exhibiting dynamic shifts in fishers' target preferences. Throughout the decades under scrutiny, a consistent set of five species remained targeted from the 1960s onwards: yellowfin snook, cartilaginous fishes, prawns, Pacific red snapper, and other snappers.

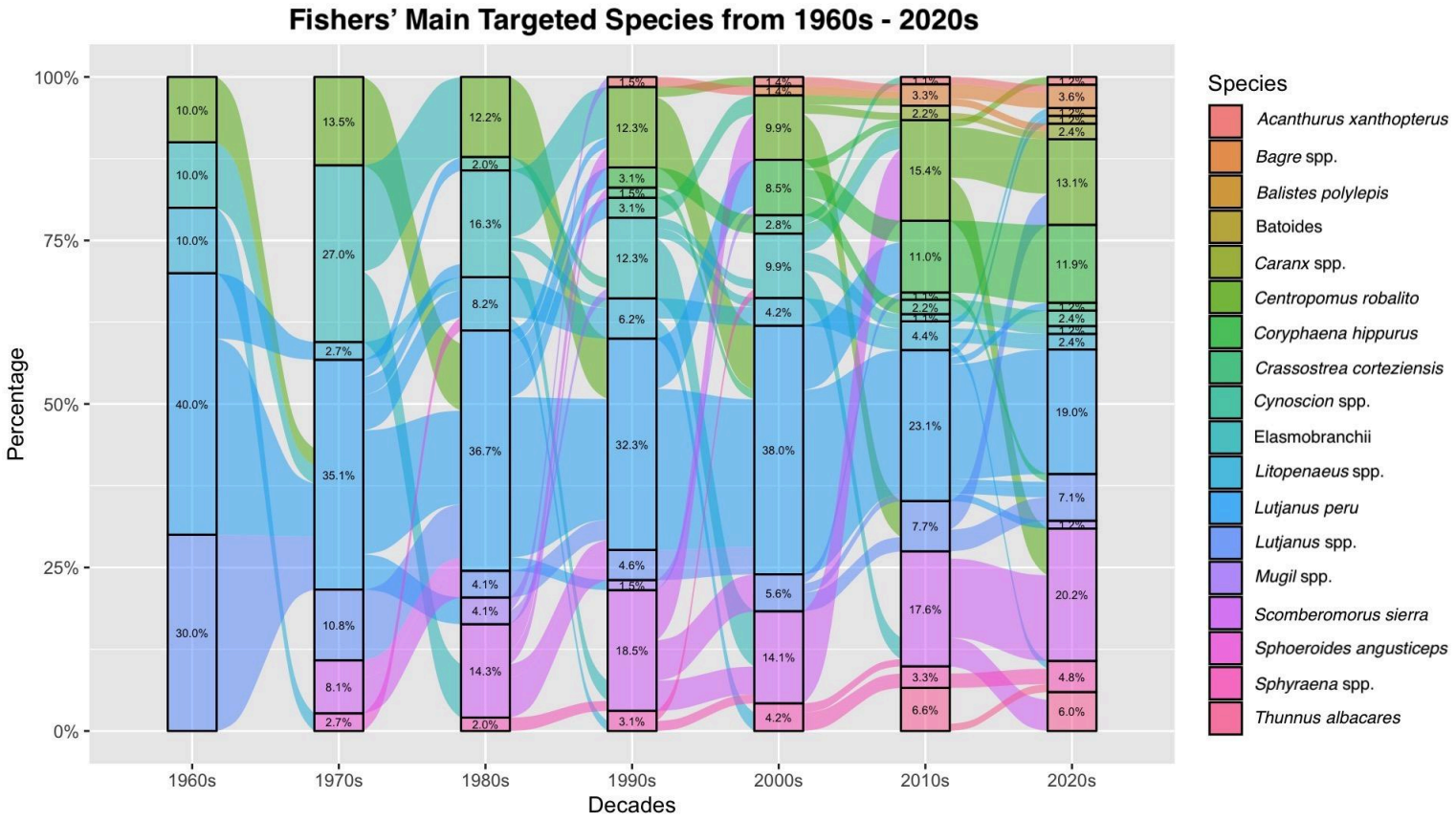

Fig. 2. Sankey diagram illustrating the primary species targeted by fishers from the 1960s to the 2020s. The x-axis denotes the decades, while the y-axis represents the percentage of species targeted. Nodes within the diagram represent individual species, classified to the lowest identifiable level, each assigned a unique color. The ribbons connecting columns show shifts (or consistency) in targeting practices from one decade to the next. The percentage in each node represents the proportion of fishers targeting that species in that decade.

The targeting of yellowfin snook (robalo) remained relatively stable, with approximately 10 to 15% of interviewees per decade referring to it as their main target species (Figure 2). Most fishers who switched from yellowfin snook targeted Pacific red snappers from the 1970s to 2000s, other snappers in the 2010s, and Pacific sierras in the 2020s.

Cartilaginous fishes (cazon or tiburon) were targeted in every decade from the 1960s to the 2020s. Between the 1960s and the 2000s, approximately 10 to 16% of interviewees per decade referred to cartilaginous fishes as their primary target species. However, these proportions dropped to just 1% in the 2010s and 2020s. Fishers previously targeting elasmobranchs shifted their focus to a range of other species, primarily Pacific red snappers, yellowfin snook, and Pacific sierras.

Prawns (camarón) were targeted by 10% of interviewees in the 1960s, but this dropped to approximately 2 to 8% per decade between the 1970s and the 2020s. All fishers targeting prawns in the 1960s switched to targeting the narrow-headed puffer. In recent years, most fishers targeting prawns continued to do so, while some fishers switched to targeting barracuda (*Sphyraena* spp.) and finescale triggerfish.

Pacific red snapper (guacho or huachinango) consistently remained a highly targeted species. From the 1960s to the 2010s, it accounted for the highest proportion of all targeted species, with 23 to 40% of fishers per decade mentioning it as their primary species. In the 2020s, it became the second most targeted species with 19% of fishers identifying it as their primary species.

Other snappers (flanco, lunarejo, or pargo) were being targeted by 30% of fishers in the 1960s, but this fell to approximately 4 to 11% of fishers per decade from the 1970s to the 2020s. All fishers targeting other snappers in the 1960s switched to targeting Pacific red snappers in the following decade. However, from the 2000s onwards, in addition to targeting Pacific red snappers, fishers continued to target other snappers as well as oysters (*Crassostrea corteziensis*) and yellowfin snook.

As fishers diversified their target species, there was a noticeable shift towards targeting more pelagic species. This includes Pacific sierras (sierras), which were being targeted from the 1970s onwards by approximately 8 to 20% of fishers per decade. Another pelagic species that appeared as a primary target was mahi mahi (dorado) from the 1990s onwards. Mahi mahi made up 3.1% of the target species in the 1990s, increasing to 9 to 12% per decade between the 2000s and 2020s. Lastly, yellowfin tuna (aleta) emerged as a target species in the 2010s and 2020s, making up 6 to 7% of the target species per decade. Although yellowfin tuna only emerged as a primary target species in later decades, the relatively consistent and high proportion indicates that it may be gaining importance as a target species in pelagic environments, reflecting the broader trend of fishers switching to pelagic species as observed in Figure 2.

Fishers changed their target species due to a variety of factors, including biological changes, climate change, competition, enforcement/policies, market demands, technological advancements, pollution, and warming waters (Figure 3). These shifts were sometimes driven by biological factors beyond their control, such as changes in fish abundance and or distribution. Responses related to warming waters and climate change started appearing in the 1980s and 2000s, respectively. Additionally, the number of fishers reporting shifts due to competition increased from the 1970s to the 2000s. Occasional responses were related to enforcement/policy, particularly in the 1980s and the 2010s. The number of fishers switching due to market-driven reasons fluctuated over the years but generally remained small. There was an increase in the number of fishers switching due to acquiring new equipment or skills, particularly noticeable in the 2000s. Responses related to pollution appeared in every decade from the 1970s to the 2010s, suggesting pollution may be a small but relevant factor driving fishers to leave polluted areas and switch their target species as a result.

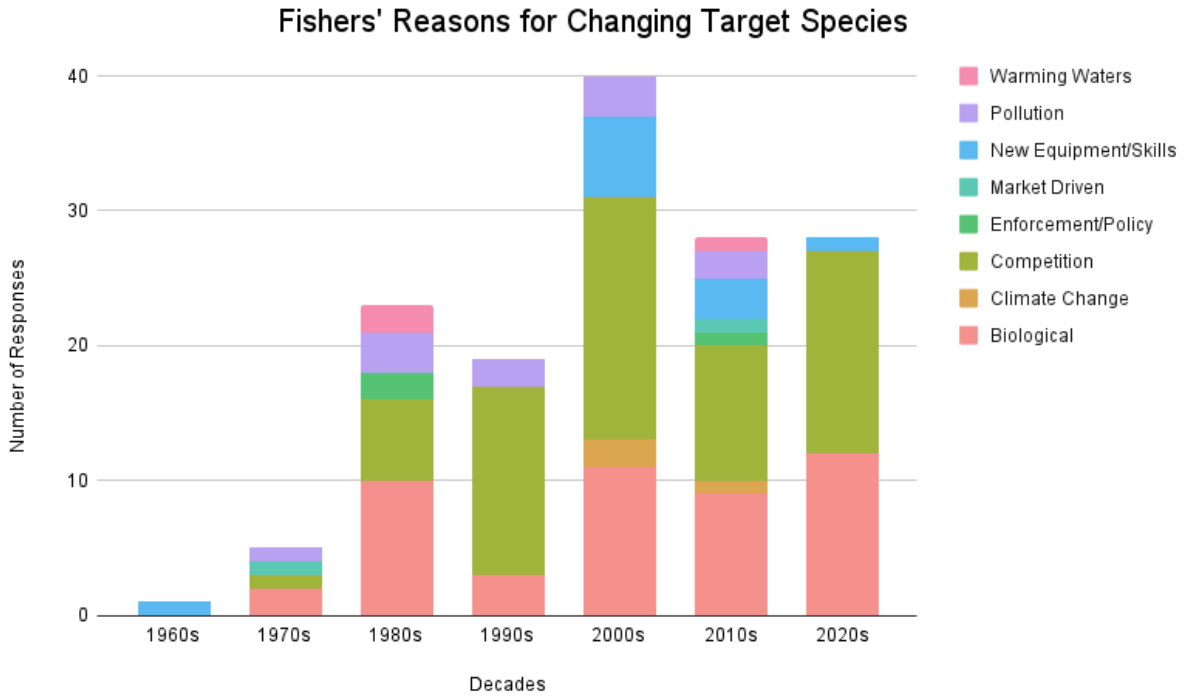

Fig. 3. Stacked histogram showing the reasons why fishers' changed their target species from the 1960s to 2020s. Each reason is assigned a unique color as shown in the legend to the right. The x-axis denotes the decades while the y-axis represents the number of responses.

The two primary gear types used across all decades were hook and line and gillnets with mesh sizes less than 8 inches (Figure 4). Hook and line emerged as the dominant gear type in the 1960s, constituting approximately 67% of gear usage. Starting from the 1970s, there was a notable increase in the use of gillnets with small mesh sizes (< 8 inches), reaching approximately 51% of gear usage by the 1970s. Gillnets with small mesh sizes continued to be heavily used across all decades. Over the decades, there was a steady decline in the proportion of fishers using hook and line, dropping to around 25% by the 2020s. We observed an increase in longline usage over the years, becoming more prominent by the 2000s and maintaining relatively stable usage

through the 2020s. Gillnets with larger mesh sizes (> 8 inches) and trawling methods were utilized by a smaller proportion of fishers when targeting their primary, secondary, and tertiary species. However, their usage remained relatively stable over the decades, with slight fluctuations. Cast nets and harpoons constituted a small proportion of gear usage throughout the decades. While cast nets saw a slight increase in usage in the 2020s, harpoons remained negligible or nonexistent in terms of gear utilization. New gear types also emerged, such as trolling lures and trammel nets, albeit with relatively low utilization compared to other methods. These gear types may represent specialized techniques targeting specific species or habitats.

Relative Frequency Matrix of Fishers' Top Three Gear Types Used from 1960s - 2020s

English Gear Type	Spanish Gear Type	1960s	1970s	1980s	1990s	2000s	2010s	2020s
Hook and line	Cuerda							
Gillnet w/mesh size of < 8	Chinchorro							
Cast net	Atarraya							
Longline	Cimbra							
Gillnet w/mesh size of > 8	Enmalle							
Trawling net	Chango							
Trammel net	Trasmallo							
Trap	Trampas							
Harpoon	Arpon							

Fig. 4. Relative frequency matrix depicting the gear types used to target fishers' top three target species by fishers from the 1960s to 2020s. The gear type is listed in English and Spanish in the columns. Each cell in the matrix represents the relative frequency of a gear being used in the corresponding decade. The matrix is color-coded on a gradient scale, with red indicating the highest frequencies (0.35-0.67), light red representing intermediate frequencies (0.01-0.34), and white indicating the lowest frequencies (0).

The changes in fishers' gear usage from the 1960s to the 2020s reflected a shift from traditional cast net and hook and line methods to the increased use of gillnets and longlines. The utilization of hook and line among fishers for catching their main target species showed a steady decline from 71.4% in the 1960s to 30.9% in the 2020s. Fishers predominantly using hook and line shifted their gear towards gillnets and longlines. Gillnets emerged as the dominant gear type from the 1970s onwards. The use of gillnets increased from being used by 14.3% of fishers in the 1960s to 52% of fishers by the 1970s, after which it was relatively consistent at 35-40% of fishers in the 2000s-2020s. While the majority of fishers using gillnets continued to do so, some transitioned to hook and line or longline gear. Initially representing 7.1% of gear used in the 1960s, cast nets fell out of use until their reappearance in the 2020s, comprising only 1% of fishers who used this gear. Those using cast nets in the 1960s transitioned entirely to gillnets the following decade. Throughout the decades, cast nets consistently constituted the smallest proportion of primary gear used compared to other methods. Longline usage increased, particularly after the 1980s, from 7.1% in the 1960s to 30-32% in the 2000s-2020s. While most fishers utilizing longlines continued to do so, some shifted towards hook and line or gillnets. Lastly, just 2% of fishers used trawl gear in the 1970s. The use of trawling remained relatively stable over the decades, fluctuating between 1% and 4.5% of fishers using this gear in each decade. The majority of fishers engaged in trawling persisted with this method, with only a negligible proportion transitioning to hook and line.

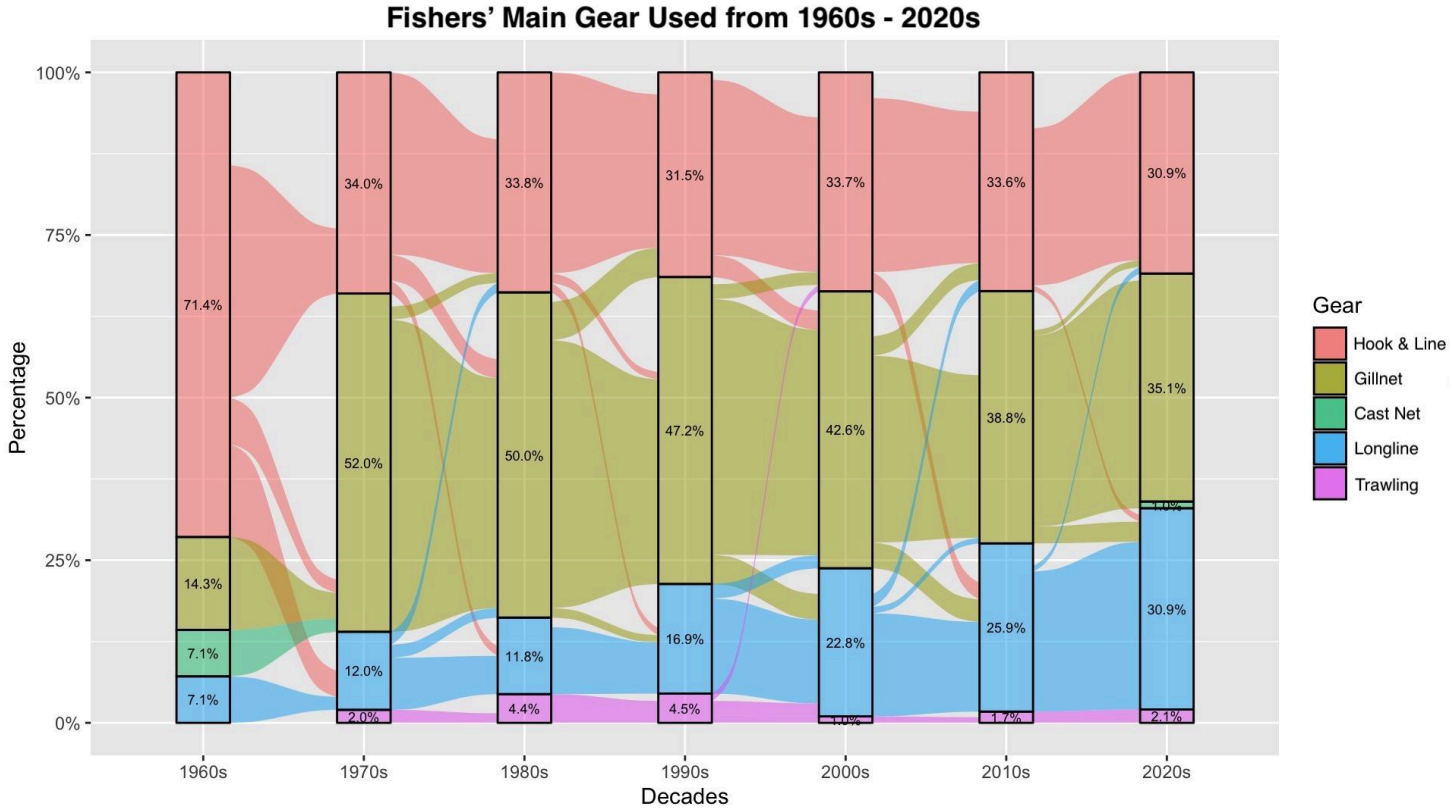

Fig. 5. Sankey diagram illustrating the primary gear used by fishers to catch their main target species from the 1960s to the 2020s. The x-axis denotes the decades, while the y-axis represents the percentage of gear utilized. Nodes within the diagram represent individual gear types, each assigned a unique color. The ribbons connecting columns show shifts (or consistency) in gear types from one decade to the next. The percentage in each node represents the proportion of fishers utilizing that particular gear type in that decade.

Only six fishers spanning from the 1990s through the 2020s, shared reasons for their switch in gear types. These reasons were: obtaining permission to use new gear types, gillnets becoming ineffective for catching profitable fish, transitioning due to the difficulty of hook and line, changing target species, resorting to gillnets for deeper fishing, and gear damage caused by mahi mahi.

Discussion

The findings of this study reveal that small-scale fishers in Western Nayarit primarily responded to social and environmental changes by adapting their target species to maintain their livelihoods. We hypothesized that fishers would respond to declining fish abundance and distributional shifts by switching their target species, diversifying their target species portfolios, and introducing new gear (potentially to less ecologically sustainable options that may increase bycatch). We observed evidence of fishers shifting their target species and diversifying their portfolios, but we did not find evidence of significant changes in gear types. This stability in gear use is likely due to the versatility of small-scale fishers' existing gear, allowing them to catch multiple species without needing to switch equipment. Over seven decades of data, the adaptability of small-scale fisheries is evident through shifts in target species and diversification while consistently utilizing the gear they have, highlighting the resilience and adaptability of fisher communities in response to environmental, market, and regulatory changes.

Western Nayarit fishers often target species that live in estuaries, which make up half of the landings in northwestern Mexico (Rubio-Cisneros et al., 2016). In this study, most of the species targeted from the 1990s onward were estuary residents, with the exception of the Cortez oyster. Furthermore, five out of the six estuarine species that are among the fishers' primary, secondary, and tertiary target species are actually primary species, indicating that fishers heavily target estuarine species. Fishers' reliance on estuaries may be due to the high productivity of these ecosystems, which result from a mix of freshwater and saltwater (Aké-Castillo & Vázquez, 2008). The nutrient-rich estuaries support a diverse range of aquatic organisms, including fish, crustaceans, and bivalve mollusks, making them prime fishing grounds (James et al., 2019). The seasonal movements of many fish attract predatory fish, enhancing their appeal to fishers as they

can target species during their peak abundance (Salas & Gaertner, 2004). Additionally, estuaries, often easily accessible from coastal communities, provide convenient fishing grounds for small-scale fishers, as the relatively calm and shallow waters are suitable for small boats and traditional fishing gear, enabling fishers to operate close to shore without the need for large vessels and nets (Sievanen, 2014). Furthermore, estuaries serve as critical nursery grounds for many species as they seek refuge in the sheltered waters, where they can find ample food and protection from predators (James et al., 2019). Thus, it is important that regulations and enforcement ensure fish are given the time to mature and spawn prior to harvest (Dzul-Caamal et al., 2012). Despite fishers' historical reliance on estuary species, our data shows a notable shift in recent decades, with fishers increasingly targeting rocky reef and pelagic species, which are typically found further offshore in the waters of Nayarit. This shift is partly driven by declines in important estuary species like the yellowfin snook, which has historically been a primary target but experienced overexploitation due to factors such as bycatch in the shrimp fishery starting in the 1990s (Moreno-Sánchez, 2015). Despite the valuable insights gained from this study, it is important to acknowledge its limitations. Challenges in identifying target species to the species level when only provided with common names highlights the complexity of small-scale fisheries research. Similar problems have been faced in previous studies (Nomura et al., 2022) leading to potential bias in catch size estimations. Additionally, we did not look into any gear modifications that fishers might be making, which could be happening but would not be captured as a new gear type.

Competition with other fishers and fishery sectors emerged as a key driver of shifts in target species. This suggests growing pressures on certain species due to increased fishing activity. Encroachment of commercial fishers into primary fishing locations poses challenges for

small-scale fishers, potentially limiting their ability to access the catch (Pomeroy et al., 2007). Addressing issues of competition through effective fisheries management and community-based initiatives is essential for promoting equitable access to resources and supporting the sustainability of small-scale fisheries (BenDor et al., 2009). The role of policy and enforcement measures, particularly in the regulation of elasmobranchs, underscores the importance of governance structures in conservation (Shiffman & Hammerschlag, 2016). Biological reasons are another main reason for fishers switching their target species, including decreases in biomass of aggregating reef fish such as groupers, which were no longer highly targeted after the 1980s (Erisman et al., 2010), and species that occupy shallow coastal areas (Sala et al., 2004). Additionally, fishers mentioned changes in water temperature and explicitly stated “climate change” as reasons for switching their target species. This is valuable to note as fishers perceiving the change and attributing a shift in their actions due to “climate change” is crucial for their adaptation to future environmental changes due to climate change (Gianelli et al., 2021). This study examines responses to impacts that might be unrelated to climate change, such as overfishing and competition. However, the negative impacts of these activities have on species abundance are similar to those of climate change. Therefore the adaptations that fishers have made to these impacts from human activities, such as overfishing, increase their exposure to shocks and enhance their adaptive responses (Ilosvay et al., 2022).

In response to these challenges, fishers have adopted adaptive strategies, including diversifying their target species portfolios. By diversifying their portfolio, fishers can more flexibly switch their target species based on availability and overall ecological changes, as well as changing market dynamics. This results in risk mitigation associated with overfishing and fluctuations in individual stocks and market demand, potentially enhancing fishers' adaptive

capacity and the overall resilience of the fishery (Allison & Ellis, 2001; Finkbeiner, 2015; Nomura et al., 2022). Furthermore, the diversification of fishers' portfolios may allow for greater focus on species that are abundant while reducing pressure on declining stocks, leading to added ecological benefits (Cline et al., 2017).

While fishers demonstrated significant diversification in their target species portfolios, their adjustments to fishing gear occurred less frequently, suggesting a more conservative approach to technological adaptations. This may be attributed to the versatility of fishers' existing gear, which enables them to target multiple species without necessitating frequent gear changes. Many fishers relied on hook and line fishing in earlier decades, likely due to its simplicity and effectiveness. However, we observed a decrease in hook and line usage over the decades, possibly because it is primarily suited for targeting specific species rather than catching a wide array of species simultaneously (He et al., 2021). We saw an increase in longline fishing from the 2000s onward. This method is commonly used for targeting pelagic species (He et al., 2021), suggesting that fishers may be venturing further offshore to catch fish like yellowfin tuna, which has become a more frequently targeted species starting from the 2000s. The longline tuna fishery in Nayarit was recently established and is currently unregulated (Jurado-Molina et al., 2022). Cast nets and harpoons were not widely used to catch the target species by fishers. This is likely due to the fact that cast nets are primarily used recreationally, thrown from shore to catch bait (Rubio-Cisneros et al., 2016). Those using cast nets transitioned entirely to gillnets in the 1970s, which is more efficient to catch a wide array of species. Additionally, fishers began trawling in the 1970s. This coincides with the Mexican President's authorization to build pangas, small motorized vessels, across the country and other monetary incentives for technological advancement between the 1970s and 1980s (Fernandez et al., 2011). Despite fluctuations in

target species, our data shows that gear utilization has remained relatively stable across decades and did not support our hypothesis regarding the introduction of new gear to less ecologically sustainable options that may increase bycatch. The stability in gear usage may be attributed to the versatility of fishers' current gear, allowing them to shift their target species and diversify their portfolio. Additionally, financial investments, learning curves, and permit restrictions may contribute to this stability, as only fish caught by approved gear are permitted to be landed (Basurto et al., 2012). This result highlights the importance of considering socio-economic factors, the availability of educational resources, and cultural values when designing adaptive strategies for small-scale fisheries.

In short, our results show that fishers in Western Nayarit have adapted to a wide array of stressors by employing available strategies such as switching their primary target species and diversifying their portfolio. Although fishers in Nayarit seem to have access to adaptive strategies, institutional and governance structures must also evolve to support these fishers through upcoming changes. Increasing fishers' participation in management is crucial for building trust and fostering collaboration. This approach facilitates the gathering of expert fishers' perspectives to understanding long-term ecological changes (e.g., Beaudreau & Levin, 2014; Hind, 2015), which is currently unavailable through CONAPESCA and the literature. Moreover, integrating local ecological knowledge into the fisheries research and management process is essential because local communities have a deep understanding of their environments and have developed adaptive strategies over time, ensuring more informed management decisions (Hind, 2015). This invaluable knowledge system, rooted in the experiences and observations of the natural environment, is passed down through generations, fostering a strong connection to fisheries and intertwining the act of fishing with personal identity and family

heritage (Gilchrist et al., 2005; Haggan et al., 2007). By involving community members in decision-making processes, fisheries management can benefit from the insights that fill data gaps, thereby enhancing the sustainability and inclusivity of decision-making processes (Haggan et al., 2007). However, it is crucial to approach the integration of local ecological knowledge into fisheries research and management with respect and caution, avoiding practices that exploit knowledge holders. Instead, by fostering collaborative partnerships and acknowledging the expertise of community members, fisheries research and management can effectively incorporate this knowledge to ensure decisions align with conservation needs and reflect the long-term perspectives on ecological changes provided by local fishers (Beaudreau & Levin, 2014; Brook & McLachlan, 2008).

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Appendix A. Interview Questions

1. Birth Year: Year fisher was born
2. Age: Fisher's age
3. Background Information Questions
    a. What year did you begin fishing?
    b. Are you still actively fishing?
    c. What year did you begin fishing near Islas Marías?
    d. How often do you fish near Islas Marías in the present day?
    e. Are you still actively fishing near Islas Marías?
4. Current General Fishing Questions
    a. How frequently do you fish (#days/week)?
    b. How many months do you fish at sea each year?
5. Target Species Questions (fishers were asked to recall target species for only decades in which they fished)
    a. Your #1 most important target species for each decade
    b. Your #2 most important target species for each decade
    c. Your #3 most important target species for each decade
    d. If your answers changed over time, why?
6. Gear Questions (fishers were asked to recall gear types for only decades in which they fished)
    a. What type of gear did you use to fish for your #1 most important target species for each decade?

b. What type of gear did you use to fish for your #2 most important target species for each decade?
c. What type of gear did you use to fish for your #3 most important target species for each decade?
d. If your answers changed over time, why?