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Human-wildlife coexistence through the lens of fishermen's knowledge and lived experience

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Climate change-related shifts in marine resource availability and species behavior are increasing rates of human-wildlife conflict (HWC). Although this trend poses significant risks to both human livelihoods and conservation efforts, strategies to resolve HWC focus largely on ecological outcomes, overlooking key impacts and contributions of human resource users. Here, we draw on the case study of whale entanglement in the Dungeness crab (*Metacarcinus magister*) fishery in California, U.S.A. to demonstrate the promise of integrating – and the consequences of neglecting – the voice and expertise of fishing communities. Semi-structured interviews with 27 commercial fishermen across nine towns in California revealed the diverse sociocultural impacts of HWC – often converging on livelihood and identity losses – as well as fishermen's potential role in addressing HWC as long-time experts in the marine ecosystem. Our findings highlight pathways for achieving human-wildlife coexistence, underscoring the need to engage the knowledge and lived experience of local communities affected by HWC.

The world's oceans harbor rich biodiversity and represent an important source of human nutrition, livelihood, and culture. Yet as climate change-related shifts in resource availability and species behavior increase rates of human-wildlife conflict[1] (HWC), tensions between ocean-based livelihoods and marine wildlife have escalated[2,3]. Numerous scholars recognize the complex social-ecological nature of HWC[4] and call for interdisciplinary strategies that balance conservation goals with the needs of local livelihoods. However, current efforts to resolve HWC predominantly focus on the ecological dimension, neglecting the experiences and contributions of human resource users[5–7]. To bridge this gap, we use a qualitative, phenomenological approach that draws on shared human experiences to explore intersubjective phenomena, bringing attention to the perspectives that are frequently overlooked.

High-profile examples of marine-related HWC feature tensions between fishing activity and recovering marine mammal populations – such as the entanglement of large whales in fishing gear[8,9]. Incidental fisheries bycatch of large marine mammals is an issue of global concern – from the North Atlantic[10] to the East Sea of South Korea[11] – that has been described as "the single greatest threat to cetaceans from human activities"[12]. In many cases of fishery-wildlife conflict, enduring efforts to protect charismatic marine megafauna outpace efforts to protect fishing livelihoods[13]. Some researchers have noted these asymmetric tradeoffs between fishery and conservation goals, advocating instead for scenarios that are both ecologically and socioeconomically tenable[14–17]. To this end, it would be beneficial to engage directly with fishing communities in order to understand the complete landscape of HWC-related impacts and solutions[15,18,19]. Yet systemic biases within fisheries management have historically impeded the contributions of this key stakeholder group[20–22]. Here, we focus on a case study of humpback whale entanglement in the Dungeness crab fishery in California, U.S.A. to demonstrate the promises of integrating – and the consequences of neglecting – the lived experience and expertise of fishermen (note: all participants, regardless of gender, preferred use of the term 'fishermen').

Dungeness crab (*Metacarcinus magister*) has long represented one of the most economically and culturally important fisheries along the U.S. West Coast. In California, the fishery generates more than $53 million in seasonal revenue[23], providing the primary basis of many fishermen's livelihoods[24,25] and supporting a robust value chain of sustainable seafood consumption[26,27]. However, the Dungeness crab fishery contributes, on average, less than 0.003% to California's total Gross Domestic Product (GDP)[23,28], giving it limited economic and political influence – especially when compared to the state's ocean-based tourism sector, which generates over $30 billion annually[29] (around 1% of GDP).

A prolonged marine heatwave event and associated harmful algal bloom between 2014 and 2016 drove a sharp spike in whale entanglements in fishing gear [9,30,31]. From 2014 to 2017, there was an annual average of 42

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confirmed whale entanglements in fishing gear along the U.S. West Coast, with commercial Dungeness crab fishing gear implicated in an average of 12 cases per year[32]. From 2018 to 2023, coastwide entanglement rates decreased to an average of 28, with commercial Dungeness crab gear implicated in 6 cases per year on average[32]. Despite these marked decreases in annual entanglement rates from historic 2014–2017 highs, growing whale populations[33] and future extreme weather events continue to pose elevated risk for fishery-whale overlap[34]. To reduce this risk, the California Department of Fish & Wildlife (CDFW) developed a Risk Assessment and Mitigation Program (RAMP) in 2017[35]. Based on environmental monitoring and ecological data, RAMP assesses whale entanglement risk, then outputs management measures – most often in the form of fishery delays and closures – when certain risk triggers are met[36]. In the 2024 fishing season, RAMP management actions included multiple delays and an early closure of the fishing season based on the anticipated arrival of humpback whales[37].

RAMP has been criticized by social scientists[15] and industry stakeholders[38] for focusing primarily on the ecological dimension (i.e., risk to whales) while overlooking impacts to fishermen – which are felt across a range of social, economic, and cultural scales[17,24,27,39,40]. Researchers have called for more holistic perspectives on whale entanglement that reflect the complex human dimensions of the issue, yet these integrated approaches are precluded by an absence of social science research that engages the fishermen[14,15,17]. Our study addresses this gap, illuminating both the sociocultural impacts of fishery perturbations and the critical role that fishermen can play in both understanding and resolving fishery-wildlife conflict as long-time experts in the marine ecosystem. As understandings of human-wildlife interaction evolve towards models of coexistence, this kind of social science research accounting for the needs, livelihoods, and expertise of local resource users will become increasingly essential[41–44]. While studies have shown the effectiveness of involving local communities in HWC management, most have focused on terrestrial systems in low- and middle-income countries – such as large predator conservation in sub-Saharan Africa[45] and elephant management in India[46,47]. This marine case study from the Global North helps bridge the data gap by providing transferable approaches that support balanced and sustainable human-environment interactions across diverse ecological and socio-political contexts.

Our work builds on a rich tradition of marine social science that champions interdisciplinary research and resource co-management by acknowledging the intrinsic coupling of humans and their environment[48–55]. By expanding on these frameworks, we emphasize the need to develop holistic conceptualizations of fisheries as social-ecological systems (SES).

Fisheries governance studies have often reduced these complex human factors to quantitative metrics and variables that can be easily modeled. By contrast, we purposefully prioritize voiced and lived experience, presenting an extensive corpus of qualitative data, narratives, and oral histories. By starting from an understanding of fishermen's lived experience, we aim to highlight the fundamental role that fishermen should play in developing equitable co-management and conservation strategies. We underscore that fishery-wildlife coexistence is just as much about understanding the social, economic, and cultural dynamics of fishing communities as it is about understanding species biology and ecology.

Results

Semi-structured interviews revealed both the impacts of human-wildlife conflict (HWC) that fishermen face as well as their potential role in addressing the issue. We present this dual narrative of impact and contribution in the following section, placing an emphasis on participants' voice and lived experience. Illustrative examples were chosen based on a consensus, which we defined as general agreement among participants and established through emerging themes that we identified through iterative coding[56].

Impacts

The central impact of HWC on commercial Dungeness crab fishermen is a loss of livelihood and identity. These overarching losses are fueled by a diverse set of intermediate impacts, as outlined in Fig. 1. Specifically, we identify negative public perception and reduced fishing opportunity as the most primary and direct human consequences of HWC – both of which in turn contribute to marginalization, erosion of trust, exacerbation of conflict and inequity, and income loss.

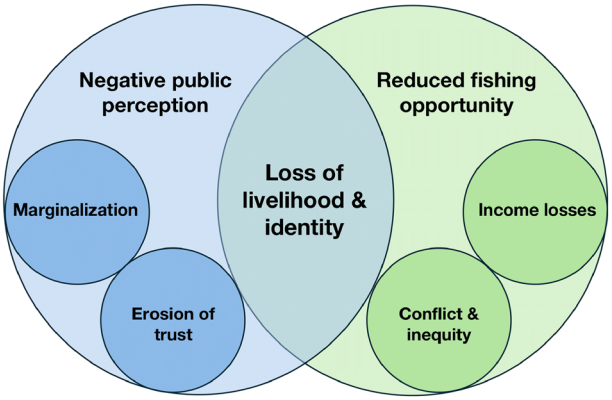

Fig. 1 | Key impacts of human-wildlife conflict on commercial dungeness crab fishermen identified by participants.

Declining Public Perception

> *"All they hear is crab fishermen are killing whales. It's on the news. It's everywhere. That's all they hear."* – Fisherman, Crescent City

Incidents of whale entanglement in fishing gear exacerbate negative public perception of the fishing industry and reinforce the narrative that fishermen are antagonists to the marine environment. "They think we're the ogres of the ocean," said one participant, who, alongside many others, described feeling "looked down upon" for his perceived role in HWC. Others frequently noted a "real divide between our industry and the world at large" that is fueled by California's 'green' political climate and its powerful sector of environmental NGOs (ENGOs). "They make it sound like we're out there just murdering the whales intentionally," said one fisherman, in reference to the actions of a particular ENGO. "And I'm not sure that the people who are sending them money are getting a true vision of what's really taking place or why it's taking place."

Marginalization

> *"I feel like we're the handicapped kid and we're getting pushed out of our wheelchair. It's a brutal way to say it, but it's true. It's like we can't fight back."* – Fisherman, Santa Cruz

Mounting bias against the fishing industry contributes to fishermen's perception of increasing marginalization from society. Feelings of powerlessness and exclusion were frequently voiced during interviews and rooted in the growing sense that fishermen are insignificant or unimportant to the state at large. "We're not essential. We're an easy target," said one participant. "If we're not allowed to catch crabs anymore, California will be just fine. Nobody's going to miss us." Similar sentiments of peripherality were mentioned in the context of fishermen's role in management and decision-making. "You can go up there and tell 'em till you're blue in the face the way you feel about it. But they just go right back to what they've already decided," described one participant on his communications with fisheries managers. "I think everybody should be able to give their information. I just feel like the fishermen get left out," noted another. Ultimately, the experience of marginalization was shared to such a universal degree among fishermen that it allowed for a sense of solidarity, as one participant poignantly described:

"We didn't agree as fishermen on a lot of things, but we felt the same pain on how we were treated."

Erosion of trust

> *"It all boils back to the trust side of it. When you have zero trust with the people you're working with, you just kind of throw up your hands and walk away. You don't wanna be involved with it."* – Fisherman, Fort Bragg

Declining public perception of the fishing industry erodes trust between fishermen and external actors comprising two main groups: fisheries managers and members of ENGOs. With regards to the former group, fishermen view the actions of various government agencies as largely "driven by public opinion," biased towards environmental protection, and negligent of the fleet's interests. "Their goal is entirely to protect the whales, not protect the industry," noted one participant. Said another, "It seems like they're more worried about having a bad newspaper article written about 'em than they are about actually managing in the best way." A similar lack of trust was reported between fishermen and ENGOs, with participants communicating suspicion about the agenda of such organizations and claiming they are "not driven necessarily by wanting to protect marine mammals." "It's in their business plan to show a crisis," said one participant, who later went on to describe whale entanglement as a "cash cow" for ENGOs. Many others echoed this view, describing that they have been "regulated out of business just because it fits the agenda of these ENGOs." Importantly, participants pointed out, a sense of mistrust goes both ways, with fishermen often discounted as "a bunch of liars" who are concerned only with their own personal interests. "It's just the fishermen trying to get more time. The fishermen just want more fish," said one participant as he described the perceived motives ascribed to the fishing fleet.

Reduced fishing opportunity

> *"Those opportunities are just getting slimmer and slimmer every year. I mean we're just getting chopped down to nothing."* – Fisherman, Eureka

In addition to fueling negative public perception of the fishing industry, HWC has also curtailed fishing opportunities. "I would say the biggest threat to the crab fishery right now is the diminishing time on the water; the days we're allowed to fish. And it's because of the whales," said one participant. Indeed, the Dungeness crab fishing season, which used to run for nearly eight months from late fall to mid-summer, has consistently been shortened in recent years to only a couple of months during the winter. "Now we're down to just a few of the worst months of weather," explained one fisherman. Although many participants recognized that restrictions on fishing activity are a necessary aspect of HWC risk mitigation, they also noted that there still need to be opportunities for fishermen to earn a living. "If you don't have an opportunity, you don't have anything," explained one participant. "Your whole business model is based on opportunity." Another similarly described, "In the past, if we didn't get 200, 225 days a year on the water, we'd go crazy. Now if I get 90, I'm lucky. What am I going to get this year?" He later went on to say, "You have to adapt. I get that. But you have to have the opportunity to adapt. The way this whale thing's working out, we're not given the opportunity to adapt. They're not going to let me survive."

Income losses

> *"I've taken a hit. I'm struggling. I haven't made a dime. And we gotta invest $20,000 just to get started."* – Fisherman, Bolinas

Income losses resulting from reduced fishing opportunities were another frequently cited impact of HWC. The Dungeness crab fishery, once a cornerstone of many fishermen's livelihoods and one of the most lucrative fisheries along the U.S. West Coast, now yields only a fraction of its historic profit due to HWC-related restrictions. One fisherman reported a nearly forty percent loss in total income, joining many others in expressing concern that he would no longer be able to earn a living: "They're making it so difficult that you can't make it pay. I mean, I've been doing it a long time and I never thought it would come to this." Another lifelong fisherman lamented, "It's hard. Not just for me but for my crew. You know? They're taking outside jobs…they got families to feed. We don't know when we're going." One participant newer to the fishing industry provided a vivid account of the economic impact that he suffered during the previous season's early closure: "It really, really hurt…You're waiting for that paycheck to come to keep moving. I didn't have a lot of money. I was a small boat, small person, trying to keep bills going. I was living out on my boat actually. I didn't have anything. I was down to nickels and I was screaming. I didn't understand. I was so frustrated. I wanted to go, let me go try to make a living. Let me try."

Conflict & inequity

> *"Small boats, big boats, large permits, small permits…everyone's battling each other for a right to have their own business model."* – Fisherman, San Francisco

Increasingly scarce fishing opportunities lead to rising tensions within the fleet as individuals compete to sustain their own livelihood. In the case of highly individualized industries such as fishing, business models and operations vary greatly, which leads to conflict over who should be able to fish and when. "Every boat here is their own business," explained one fisherman. "What works for me doesn't work for someone else. And it's his livelihood too. And he has a right to his opinion too…So then everyone just butts heads." Competition for viability in the face of reduced fishing opportunities not only undermines social cohesion but also exacerbates inequity within the fleet. "At some point, this isn't going to be viable for everybody," explained one fisherman. He joined many others in noting that smaller-scale fishing operations, which often rely heavily on crab, are disproportionately impacted by fishing restrictions. "It really hurts the smaller boats 'cause the big guys go shrimp fishing and dragging, the medium size boats take off and go salmon fishing or do something, and then the small guys just…they have nothing. Just devastating to a lot of 'em," described one participant. Finally, the recent authorization of testing for alternative gear designed to reduce whale entanglement risk has exacerbated conflict and inequity within the fleet, as select fishermen are granted exclusive access to the crab resource while others are excluded.

Loss of livelihood and identity

> *"I'm just Grandpa, trying to do right by my family, you know? And it breaks my heart. There's nobody following. There's nobody to give the boat to. Nobody's going to follow what this family has done for a lot of years."* – Fisherman, Fort Bragg

Individually and in aggregate, the impacts of HWC described in this section contribute to pervasive losses of livelihood and identity among fishermen. "It's just one, after the other, after the other…just eliminating us as a fishery," remarked one individual. "Death by a thousand cuts as they say." For nearly all participants, the crab fishery transcends mere economic value and embodies a profound sense of self and cultural significance. "Since I was a little kid, it's been in my blood," said one fisherman. "I'm a lifer, I'm a career guy. This is what I do. I don't have a pension. I got nowhere else to go," noted another. Identity-related ties to the crab fishery are experienced not

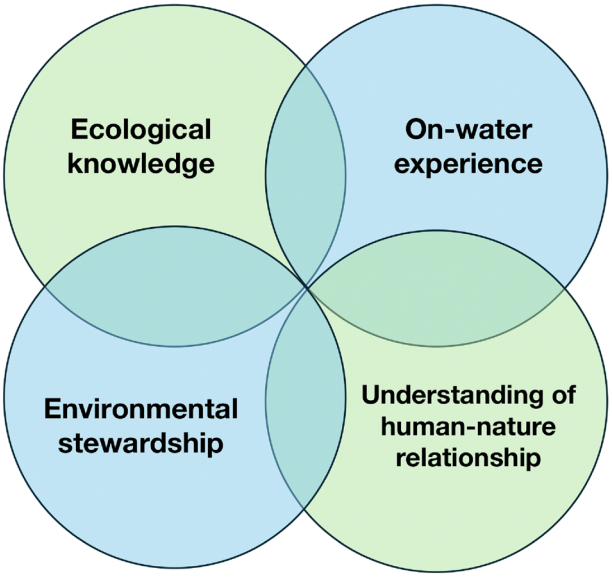

Fig. 2 | Fishermen's potential contributions towards understanding and addressing HWC, as identified through collaboration.

just individually but communally, creating an interconnected cultural system that spans the California coast. "It's our jobs, it's our families, it's our towns," said one participant. "Some of these coastal towns are based on their fisheries, Fort Bragg and a lot of Eureka." Familial ties to the fishery were present in 56% of the study population, and, even for those without, the crab fishery was viewed not just as a profession but as a way of life. "This is what I do. I didn't grow up in the business. I earned my way into the business. You know? I don't want to do anything else. But I'm losing that option. This isn't gonna work," said one fisherman. The relentless struggle to preserve the fishery has exacted a steep psychological toll on many participants, leaving them drained and disillusioned. "I'm getting tired. I mean, I'm getting tired of the fight. It's depressing," said one fisherman. Another described feeling "torn up mentally," and later went on to say, "How much more do you got? I mean, there's not a lot left in my heart and soul to continue this quest right now. Looking back here from today, I wish I maybe would've sold the boat. You only got so much. You only got so much."

Contributions

Fishermen's role in understanding and addressing HWC can be assessed through four lenses – ecological knowledge, resource stewardship, on-water experience, and understanding of the human-nature relationship. While distinct, each of these contributions does not exist in isolation and is instead part of a larger and interconnected network of involvement (Fig. 2).

Ecological knowledge.

> *"You've got a data-rich community here, and it's so sad that it's not tapped."* – Fisherman, Bodega Bay

Participants often pointed out that their expertise in the marine ecosystem could play a critically important role in understanding and mitigating HWC. "There's nobody here that knows more than the fishermen," said one participant, who argued that a lifetime of experience on the ocean affords himself and others "more knowledge than any biologist is ever going to have." Whereas current datasets used to manage the fishery and map HWC risk rely largely on the work of outside scientists and government agencies, participants envision an alternative approach that engages fishermen's own "wealth of knowledge." "Listen to what we have to say. We're pretty sharp guys," said one participant. Another added, "I think that we could have a lot of common ground with the science advisors because we see it empirically. We see what their models predict and we can corroborate each other's data." In addition to expressing interest in collaborating with scientists, participants also saw a potential role for themselves as the "eyes and ears" of the fisheries managers, explaining, "They're making decisions outside of the field and we're seeing it all in real-time. We could be their support, but our voices are not being heard."

On-water experience.

> *"Guys like Bill, Tom, they've been here forever, you know? I mean, I've been on the water since I was 18 years old, diving and fishing out here off the coast."* – Fisherman, Bodega Bay

Fishermen's extensive experience on the ocean represents another crucial contribution towards understanding and mitigating HWC. "We were some of the very first guys doing this, like literally the first guys vertical fishing for years and years," explained one participant, as he spoke on the longevity of the crab fishery and the firsthand practical knowledge that much of the fishing fleet boasts. "We've always fished around whales," noted another participant. "I mean, I've fished around whales my whole life." According to many participants, this extensive experience has allowed the fleet to make "great strides" in mitigating the chance and risk of HWC – including through a universally adopted 'Best Practices' guide that informs optimal rope and buoy. Several participants noted that their valuable contributions are largely discounted by fisheries managers who think "five years of education is worth more than fifty years of experience." "They don't ask the guys that are doing it. I've been doing this since I was 12 years old," lamented one participant. Another poignantly noted, "Fishermen have to be able, to some extent, have an influence on their own fate." "We're talking about radical changes in the way we fish. And I don't think that that should be left up to a couple [fisheries managers]."

Environmental stewardship.

> *"I think all commercial fishermen are environmentalists…It behooves us, benefits us, to protect our fishery."* – Fisherman, San Francisco

Fishermen's stewardship of the marine environment was recognized as another critical contribution made by the fishing fleet. This sense of stewardship is rooted in both moral imperative and self-preservation: participants noted that their livelihood depends on the health of the environment, so it is within their best interest to sustain and protect it. "Just by being a fisherman, you're an environmentalist," explained one participant. "Just by the nature of what we do. If we screw up the environment, it directly impacts us." Said another, "We always have been environmentally proactive, regardless of what some people in the state say. We're the ones that are trying to do it right." In many cases, participants' belief in environmental stewardship is what attracts them to the fishing industry. "I find so much romance in it," remarked one participant, who pivoted to a career in commercial fishing later in life. "Of harvesting your food and bringing it to the consumer and doing it as sustainably as you can. I love that. It's neat." Others similarly celebrated their role in supporting the public's access to a sustainable food source, with one lifelong fisherman describing environmental stewardship as the "essence of the fishery" and the basis of "what's in our heart, what's coming from our mind, what we believe in."

Understanding of human–nature relationship.

> *It's part of life and coexisting on this planet that these things sometimes happen."* – Fisherman, San Francisco

Participants frequently demonstrated a nuanced understanding of the human-nature relationship. The contribution of this understanding represents the final – and perhaps most abstract – missed opportunity to address HWC. During interviews, participants invoked principles of coexistence to

assert that human-wildlife interaction is not only inevitable but essential. "We have a flourishing population of humpbacks, which is awesome, and it should be celebrated more than anything," said one fisherman. "But therefore, inherently, unfortunately, we're going to have more interactions with the animals." Participants called for a re-imagined approach to HWC that balances outcomes for both the fishery and whale populations by permitting an "acceptable level of interaction." "The solution isn't to have an unlimited number of whales that we can tangle," said one fisherman. "But the solution is also not to have such a low threshold of interaction that we can't operate what once was the most valuable fishery in California. There needs to be a balanced approach that takes in all the factors and is realistic." Given their belief that current rates of entanglement pose little risk to whale population viability, many participants asserted that HWC mitigation efforts should not come at the expense of their livelihood. They expressed frustration with current approaches to HWC, which they feel fail to acknowledge the realities of coexistence by seeking to eliminate all instances of overlap. "We're trying on our end, but I feel like the environmentalists, all they're doing is saying 'There's a dead whale, it's your fault. That's it. Nobody should fish anymore. Everyone should eat plant-based.'" Another participant poignantly asked, "Is a whale's life more valuable than a fisherman's life?" then noted, "I definitely don't want to see any whales tangled. But I definitely need a job. I need to survive."

Discussion

This study reveals the many impacts of whale entanglement on commercial Dungeness crab fishermen, extending beyond the commonly recognized economic losses[24,39,40]. Participants recount how reduced fishing opportunities and declining public perception of the fishing industry resulting from human-wildlife conflict (HWC) exacerbate feelings of marginalization, fuel conflict and inequity within the fishing fleet, and erode trust between fishermen and external actors. Collectively, these impacts contribute to a loss of livelihood and identity on both the individual and community level. Current approaches for addressing whale entanglement largely overlook these sociocultural and economic risks to fishermen, instead focusing primarily on ecological impact (i.e., risk to whales).

Our qualitative, phenomenological approach centers fishermen's voices, perspectives, and insights to generate a holistic vision of HWC in this fishery, engaging with the complexity and nuance of lived experiences and generating rich, contextual data that allows readers to assess the applicability of findings to other settings. Thus, this qualitative research aims for transferability – a process of abstraction used to apply information from specific persons, settings, and eras to others not directly studied without aiming for universal generalization – an established, fundamental concept in qualitative research[57–59]. Importantly, our work demonstrates how sidelining the human dimensions of fisheries in this way not only undermines the needs and ways of life of fishing communities[14,17,27] but also limits strategies for HWC resolution[15]. Indeed, our study highlights the valuable contributions that fishermen stand to make in addressing whale entanglement as long-time experts in the marine ecosystem. Specifically, we find that engaging fishermen's ecological knowledge, on-water experience, and resource stewardship ethos could inform more effective, balanced HWC management strategies. This form of stakeholder engagement has proven effective in similar cases of HWC, such as the incidental bycatch of sea turtles in the U.S. shrimp trawl fishery and the bycatch of dolphin in the U.S. tuna purse seine fishery. In both cases, fishermen played a critical role in designing effective gear innovations to reduce HWC while maintaining viability for fishing livelihoods[60].

Our research challenges the historically dominant practices of conservation that position human and wildlife interests as fundamentally separate[61]. In cases of HWC, this dualistic perspective gives rise to imbalanced outcomes by implying a need to 'choose' between human livelihoods and conservation targets[7,43]. For example, in California, ongoing efforts to protect humpback whale populations have outpaced considerations for human livelihoods, resulting in steep economic and sociocultural costs to fishermen. Responding to these seemingly imbalanced tradeoffs, fishermen in this study call for an expanded understanding of the human-nature relationship. They invoke principles of coexistence and mutual dependence, explaining that their role as stewards of a marine resource depends on – and oftentimes contributes to – the health of the oceans. In these contexts, where human and environmental outcomes are inextricably linked, some level of HWC is both natural and inevitable[44]. Rather than seeking to eliminate all instances of conflict, there is a need to reframe HWC based on principles of tolerance and mutuality that recognize and promote sustainability for people and the planet[7,43,44]. By integrating – rather than dichotomizing – the needs of resource users and wildlife populations, this coexistence framing of HWC will expand opportunities for mutually beneficial outcomes[62] within complex social-ecological systems.

Transitioning from antagonistic to cooperative framings of the human-nature relationship will require engaging multiple disciplines[41,42,63] and multiple stakeholders[18,19]. While the biophysical and ecological aspects of HWC are well-researched, the underlying sociocultural and economic dimensions of the issue are less understood[5,6]. This study brings a qualitative, phenomenological approach to the topic, one that illuminates the human aspects of fisheries and is often overlooked. Far from simplifying the issues underlying HWC, this approach imbues the richness and complexity necessary for developing holistic management strategies that balance ecological conservation with the livelihoods of those who depend on marine resources.

Methods

This qualitative study used a phenomenological and grounded theory to build up from the data rather than beginning with existing theories or assumptions[64]. In the social sciences, phenomenology relies on shared human experiences and perspectives to explain intersubjective phenomena, calling for prolonged engagement with participants to discern patterns and relationships of meaning[65–67]. Importantly, phenomenology does not aim at empirical generalization but an understanding of lived experience[68]. In grounded theory, researchers engage in iterative coding processes of methodically gathered qualitative data to identify and categorize data, uncover relationships, and find emerging patterns that inform the development of a conceptual framework grounded in the empirical data itself[69]. Accordingly, this study employed semi-structured interviews as the foundational method for understanding fishermen's lived experiences and perceptions regarding human-wildlife conflict (HWC). To the extent that this research posits an integrated framework for HWC management, it can also be characterized as a case study elucidating the real-world example of whale entanglement in California's commercial Dungeness crab fishery.

Participant selection

All research methodologies were conducted in compliance with Stanford University's Institutional Review Board policies and procedures for human subjects research under Protocol no. 67793.

Semi-structured interviews were conducted with twenty-seven members (twenty-six men and one woman) of the California commercial Dungeness crab fleet ranging in age from approximately thirty to seventy-five years. Individuals of any gender and racial or ethnic background were invited to participate in this study, provided they spoke English and were over the age of eighteen. Interviews were conducted across nine fishing towns in California representing all of the major ports used by the Dungeness crab fleet, and participants were categorized on strata relating to production level, commercial fishing experience, and home fishing port (Table 1). While this qualitative study does not aim to be statistically representative, our participant selection process aimed to have the broadest coverage of geography, income strata, and experience levels to ensure diversity of perspectives.

To ensure adequate participation within each stratification, a non-probabilistic method of respondent-driven sampling was used[70]. Potential interviewees were identified from the Dungeness Crab Task Force charter and regional fishermen's associations in an effort to reach members of the fleet with strong cultural competency and specialized knowledge. A key

Table 1 | Characteristics of study participants

		Participants (n = 27)	
Home port	Crescent	8	(29.6%)
	City	7	(22.2%)
	San	4	(14.8%)
	Francisco	2	(7.4%)
	Bodega Bay	2	(7.4%)
	Eureka	1	(3.7%)
	Morro Bay	1	(3.7%)
	Bolinas	1	(3.7%)
	Fort Bragg	1	(3.7%)
	Half Moon		
	Bay		
	Santa Cruz		
Experience	<15 years	6	(22.2%)
	15-30 years	9	(33.3%)
	30+ years	12	(44.4%)
Production level	Lower	10	(37.0%)
	Upper	17	(63.0%)
Interview format	In-person	21	(77.8%)
	By phone	6	(22.2%)

collaborator provided contact information for prospective participants and helped to set up interviews. Snowball sampling – wherein existing participants identified potential interviewees based on their peer networks – was used to augment the study population until saturation was reached (i.e., additional interviews yielded redundancies rather than novel insight)[71].

We recognize that this approach has trade-offs. The combination of purposive sampling and grounded theory analysis allows for a deep dive into complex social processes and interactions, potentially uncovering new concepts or relationships. This methodological approach is particularly valuable in exploring understudied areas or in challenging existing assumptions about well-known topics. However, purposive sampling is inherently biased[72]. We address this in the following ways. First, as a qualitative study, this work does not aim to make broad or generalizable claims or establish statistical significance. Instead, it emphasizes the importance of context-specific insights and the value of an in-depth exploration of participants' experiences[68]. Thus, we refrain from making interpretations beyond the sampled population. Second, we carefully document and describe the selection process, ensuring a broad representation of age and industry strata, as detailed in Table 1. This careful documentation not only helps in identifying biases but also enhances the transparency of the research, allowing other researchers to evaluate the transferability of findings to similar contexts and populations.

Data collection

Building trust and rapport with participants was an integral element of the study design[73]. During the two months prior to the data collection period, the research objectives and design were frequently discussed with key collaborators and industry representatives, and purposeful efforts were made to integrate their feedback, insight, and knowledge while acknowledging potential power dynamics.

Data collection spanned three weeks during December of 2022. Throughout this period, a combination of single-day and overnight trips were made across California to conduct in-person interviews. Travel and lodging expenses were covered by funding from The Nature Conservancy. All interviews were conducted on a voluntary basis with informed consent according to IRB guidelines. In keeping with guidance from a key collaborator, participants chose the location of their interview to ensure comfort and foster candid conversation. Most participants elected for interviews to take place on their boat, though some chose to speak in cafés near the fishing dock. Six participants requested that their interview be conducted by phone.

Interviews ranged from thirty minutes to three hours in length, with most lasting about one and a half hours. Emerging themes, noteworthy quotes, and nonverbal cues were recorded in a notebook for the duration of each interview, and audio recordings were captured using a Zoom H1n portable audio recorder. Each recording was transcribed within 24 hours of the interview using Otter.ai Pro software. In accordance with IRB consent protocol, interview recordings and transcripts were stored securely and not made publicly available.

Standardized delivery of a semi-structured interview protocol limited researcher bias while still allowing for ease and flexibility of conversation[74]. The interview protocol, which contained a blend of fixed-response and open-ended questions, was pilot-tested with one key collaborator to strengthen validity and integrate knowledge of the local context (see Supplementary Information)[75]. Fixed-response questions mainly solicited demographic information – such as boat size, distribution model, and income diversification – while open-ended questions explored participants' beliefs and experiences surrounding whale entanglement and fisheries management. Unscripted follow-up questions were occasionally leveraged when the topic of conversation was deemed productive with regard to the research question[74], thereby allowing participants to elaborate and/or emphasize their personal experiences and topics they felt strongly about.

Finally, extended fieldwork was a cornerstone of the study design. In the months leading up to the data collection period, considerable time was spent with participants, and during the data collection period, in-person interviews were prioritized. Spending prolonged time with participants in their own settings not only bolsters an understanding of the nuances of the field but also lends credibility to the study's inductive hypotheses and resulting theoretical frameworks[76].

Data analysis

Data collection and analysis proceeded concurrently, with emerging themes and insights documented frequently throughout the interview process. Following the data collection period, a codebook (i.e., a set of words or short phrases that "symbolically assign a summative, salient, essence-capturing, and/or evocative attribute for a portion of data"[77]) was developed using coupled inductive and deductive analytic approaches[78] (see Supplementary Information). Whereas inductive codes were extrapolated from internal patterns within the data, deductive codes relied on external research objectives and literature-backed theories[78]. This approach enabled organic identification of themes[79] while also integrating predetermined codes derived from prior experience with and knowledge of the fishery. The resulting sixty-six codes were applied line by line to interview transcripts in two passes using NVivo 12 qualitative data analysis software.

First-pass codes were discrete and descriptive, serving as high-level organization for the data. By contrast, second-pass coding required more interpretation and consisted of focused subcodes that added specificity to the identified themes. In particular, second-pass coding prioritized the voices of study participants through the use of in vivo codes, which originate from frequently repeated phrases[78]. Examples of in vivo codes include "infighting," "real science," and "death by a thousand cuts."

Throughout the coding process, reflective analytic memos were written to identify themes and propose explanations for relationships within the data[78]. A clustering technique involving inductive categorization and iterative sorting of the data was also used to facilitate pattern recognition[78]. Matrices, network models, and other forms of data display were constructed to test research propositions and assertions and further extrapolate meaning from the data[78]. In the final step, data-driven themes and patterns were interpreted in the context of the research question and adjusted for clarity and coherence, ultimately allowing for analytical conclusions to be made.

To address the potential effects of researcher bias, frequent reflections on positionality were made, and preconceptions were purposefully bracketed throughout the data collection, analysis, and writing process[78,80].

For instance, the results of this study were intentionally framed as a distillation of participants' lived experiences and perspectives to bolster objectivity and minimize the influence of researcher assumptions and personal beliefs[76,80]. Negative case sampling – in which the researcher "actively seeks disconfirmation" of what they believe to be true[76,80] – was also used to minimize potential bias. In this study, the negative case sampling strategy involved applying codes in later passes to look for disconfirming evidence about emerging propositions. For example, when participants' desire for improved fisheries management emerged as a theme early on, a "satisfied [with management]" code was added to the codebook to isolate and examine all cases where this pattern did not hold.

Additional strategies to promote interpretive validity – which describes the "degree that the participants' viewpoints, thoughts, intentions, and experiences are accurately understood and reported"[76] – were integrated throughout the study design. For instance, participants were frequently invited to provide verification and insight into the interpretations and conclusions drawn from interviews[76,80]. The resulting feedback was incorporated into the research, and interpretations were adjusted when necessary. Additionally, throughout the results report, a purposeful emphasis was placed on the use of verbatims (i.e., direct quotations) to honor participants' voice and language[76].

Data availability

The datasets generated and analyzed during the current study are not publicly available due to the sensitive and confidential nature of interview data. To protect the privacy of participants, all interview data (including field notes, audio recordings, and transcriptions) are stored in secure archives and may only be accessed by the core research team (Molly Glickman, Michelle María Early Capistrán, Dick Ogg, and Larry Crowder), in compliance with the ethical guidelines of the Institutional Review Board (IRB).

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Author contributions

M.G. conceived and designed the study, conducted data collection (interviews), analyzed results, and drafted the manuscript, with input from all authors at each stage. D.O. served as an industry representative and provided relevant expertise; M.M.E.C. defined the study methodology, supported data analysis, and provided substantive feedback on all drafts of the manuscript alongside L.B.C.

Competing interests

The authors declare no competing interests.

Additional information

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