

Socioeconomic context for fisher-shark interactions in the Marianas

Mia A. Iwane^{1,2}, Kirsten M. Leong²

¹ Joint Institute for Marine and Atmospheric Research
University of Hawai'i
1000 Pope Road
Honolulu, HI 96822

² Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, HI 96818



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Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
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Executive Summary

This project was designed in response to Guam and the Commonwealth of the Northern Mariana Islands (CNMI) fishers' reports of high or increasing shark impacts to their fisheries through time. Given that limited scientific documentation of fisher-shark interactions is available for the region, this work serves to document fishers' on-the-water observations through time. We also compare stakeholders' (fishers, researchers, and managers) perceptions of sharks and mitigation strategies, and contextualize these within the broader socioeconomic environment. Data was collected through semi-structured interviews, group discussions, and public meetings with fishers, researchers, and managers in Guam and Saipan, Rota, and Tinian of the CNMI.

Participants framed the “shark problem” through on-the-water impacts like loss of gear and catch, damaged equipment, safety risks, and fishers shifting fishing locations and investing more time while fishing (Figure 3). These translated to secondary impacts related to cost and effort, as well as on catch per unit effort (CPUE), which are key inputs into stock assessments. Contextual dimensions of the “shark problem” included confusion around shark regulations, a lack of shark research in the Marianas, and concerns about sharks being underutilized and wasted as a food resource. A breakdown of these problem framings by stakeholder group revealed their shared recognition of all facets of the problem, which provides a helpful foundation for collective problem-solving.

Fishers, in particular, described changes in their shark interactions through time. They noted increasing shark interaction frequency, numbers, aggression, prey diversity, broadening shark distribution, and responsiveness to fishing cues. The latter included descriptions of sharks arriving more quickly to fishing activity and biting unbaited artificial lures. Participants talked about decreasing fish abundance and size, shark finning bans, increases in fishing participation (and thus fishing effort), and changes to fish aggregating devices (FADs) being potentially related to these changes. Narratives relating these factors to shark populations varied, in some cases indicating shifting baseline syndrome.

Fishers also described pelagic sharks more often using negative, problematic descriptors. Coupled with a lack of pelagic shark research in the Marianas, this highlights an important research priority from both scientific and fishery impact perspectives. Ongoing and future research may help us to understand Marianas' shark populations and changes to shark abundance, especially for understudied pelagic sharks.

At present, however, fishers' experiential knowledge and observations serve as a valuable resource. Including fisher knowledge among other stakeholder perspectives may help to identify points of agreement and disagreement, and highlight stepping stones toward collaborative problem-solving. For example, the potential for shark habituation and conditioning around fishing activity may account for fishers' and researchers' divergent perspectives around shark abundance. Structuring discussions around these specific observed changes to shark behavior and their tangible impacts to fisheries may be productive and unifying as a short-term strategy, while actively addressing research gaps and establishing baselines for things like shark abundance will have critical value in the long-term.

This research also highlighted several issues not explicitly related to sharks that provide important context for the fisher-shark interaction problem. These included socioeconomic threats to fishery participation, fishers' role in the community, data validity and access, denying fishers' experiences, stakeholder disconnect, feelings of marginalization, and influence in management and research. We combine these contextual issues and with those explicitly related to sharks in Table 3 and situate them within the following categories: on-the-water, economic context, regulatory context, data and research, and political context. Fishers noted challenging socioeconomic conditions—like costly supplies, flooded markets, low fish prices, and the role of fishers in the wider community—that threaten fishers' sustained participation and are exacerbated by fisher-shark interactions.

Participants also highlighted various contextual issues related to political context, data, and research. Many of these connected back to fishers' feeling their experiences were dismissed by researchers and managers, who often had greater influence over the allocation of resources to research and management foci or regions, and access to management decisions. For example, fishers perceived certain shark research endeavors to produce invalid results because its design and execution failed to consider key differences between researchers' and fishers' experiences (e.g., traditional fishing stimuli). As a result, fishers may refuse to participate in cooperative research or withhold data from the scientific community.

The solutions and mitigative strategies discussed by participants included on-the-water tools and maneuvers, some means of shark population control or harvest, cooperative research, outreach to clarify shark legislation, and economic fisheries support. Each of these has unique potential to address fisher-shark interaction problem framings and stakeholder conflicts (Table 5). Barriers to employing a shark population control strategy emerge as we consider the feasibility of shark fishing, consumer demand, and historically oppositional voices from local and non-local NGOs and lobbyists. Confusion between and within stakeholder groups around territorial and federal shark legislation also complicates shark harvest and use, but may benefit from outreach efforts that build upon our summary of relevant legislation (Table 4). We found that the commercialization of shark meat is allowed for sharks landed legally (e.g., with fins naturally attached) within federal waters and Guam's territorial waters, but prohibited for sharks landed within the CNMI's territorial waters. For the CNMI, this complicates enforcement.

While this study highlights significant research gaps in Marianas shark research, it also documents opportunities to address them collaboratively. Fishers shared enthusiasm, took initiative to aid data collection for this project, and expressed interest in aiding other cooperative research endeavors. A cooperative approach can add value to research by accessing a broader range of knowledge and by establishing grounds for collective recognition of data validity. Executed properly, fisher-collaborative processes have potential to bridge stakeholder disconnect and mistrust, and address power differentials by acknowledging the experiences of fishers. This type of cooperative research could then feed into other solution-relevant outcomes like novel on-the-water strategies for fishers, or sustainable, species-specific guidance around shark harvest. Finally, economic fisheries support provides direct relief to socioeconomic challenges, and represents opportunities to reconcile power differentials and feelings of marginalization through the allocation of financial resources and managerial attention to the fishing community's socioeconomic challenges.

We suggest that efforts to address these multiple fisher-shark interaction problems employ a holistic approach, utilizing multiple solutions. The solutions documented in this study represent a foundation for this problem-solving effort, rather than an exhaustive list of solutions.

I. Introduction

This project was designed in response to concerns from Guam and the Commonwealth of the Northern Mariana Islands (CNMI) about sharks' impacts to local fisheries. Former CNMI Department of Land and Natural Resources (DLNR) secretary Arnold Palacios described "shark problems... plaguing the industry," resulting in the CNMI government and fishing community's consistent pleas for assistance from the Western Pacific Regional Fisheries Management Council (WPRFMC) dating back to 1979 (Palacios 2013). A 2012 proposal by the Pacific Islands Fisheries Group (PIFG) described sharks depredating¹ Guam's pelagic, bottomfish, and reef fish catches for at least two decades (Markrich 2013). In recent years, the WPRFMC has repeatedly recommended shark abundance and depredation studies in the Mariana Archipelago (WPRFMC 2016; WPRFMC 2017; WPRFMC 2018; WPRFMC 2019b; WPRFMC 2020), referencing its fisheries' high shark interaction and depredation rates. These, in turn, have negative impacts to fisher income and could deflate catch per unit effort (CPUE) estimates if not properly accounted for. WPRFMC discussions have also noted potentially conflicting local and federal shark legislation that obscures shark-handling guidance (WPRFMC 2019a).

In apparent contrast to fishers' frustrations, research in the Marianas indicates depleted reef shark populations. Guam DAWR coastal aerial surveys from 1963 to 2012 comprise the best available time series data for Marianas' sharks, and indicate an 84% decrease in reef shark density through time (Martin et al. 2016). A model analysis by Nadon et al. (2012) also suggests up to a 94% decline in reef shark densities from a simulated human-absent baseline. NOAA cruise reports describe reef shark sightings as "rare" and in low abundance compared to other remote Pacific islands (PIFSC 2006; PIFSC 2007). Beyond these reef shark population studies, scientific information on Marianas' sharks, especially pelagic species, are very limited.

Limited resources exist for the Marianas on shark species present (Bryan 1972) and the historical and contemporary use of sharks. Archaeological evidence indicates sharks, including pelagic species, were collected by the native Chamorro people in Guam, Saipan, Tinian, and Rota (Amesbury and Hunter-Anderson 2003), perhaps opportunistically instead of through targeted harvest (Amesbury and Hunter-Anderson 2008). One account from the early 1600s describes Chamorros residing on Guam as, "enemies of the sharks and they do not eat them. The Indian chiefs do not eat any fish with leathery skins" (Lévesque 1993, p. 176). In contemporary fisheries, the commercial harvest of shark in the waters surrounding Guam and the CNMI has primarily fed demand in Asia. In 1977, for example, CNMI commercial fishers landed nearly 60 tons of shark for export to Korea (U.S. Government 1977, p. 58). Recent decades saw a marked decline in the targeting of sharks and transshipment of their fins through Guam and the CNMI—primarily by foreign fishing vessels—following 2002 implementation of a federal shark finning ban (Dalzell et al. 2008; Shark Finning Prohibition Act of 2000).

The only available data on incidental interactions between fishers and sharks on the water—hereafter referred to as "fisher-shark interactions"—comes from the Guam Department of Agriculture's (DoAg) Division of Aquatic and Wildlife Resources (DAWR). In 2014, the Guam

¹ Depredation refers to predator removal of hooked fish or bait from fishing gear (Gilman et al. 2008).

DAWR implemented a yes/no field in their boat-based creel surveys for the catch or gear lost to sharks. This project therefore addresses a critical research gap by documenting the only available historical information on pelagic sharks and fisher-shark interactions in the Mariana Archipelago: stakeholder observations. We use the term “stakeholders” to refer to fishers, researchers, and managers involved in the fisheries of Guam and CNMI.

This study draws on stakeholder experiences and knowledge to characterize the frequency and nature of Marianas’ fisher-shark interactions. In an effort to reconcile potentially conflicting narratives around shark abundance, this work also compares fishers’, researchers’, and managers’ perceptions of sharks and potential mitigation strategies. Observations and stakeholder perceptions are contextualized within the Marianas’ broader socioeconomic environment to inform place-based solutions that may mitigate fisher-shark interactions. In its exploration of opportunities to mitigate fisher-shark interactions, this work may also inform the development of future shark management plans or handling guidelines. Thus, the ultimate goal of this work is to document stakeholder observations and perceptions around sharks in the Marianas, to inform potential solutions.

Differences in how stakeholders perceive or define a problem is important because it has implications for how that problem might be resolved, and whether or not solutions can be pursued collaboratively. Problem definition is an analytical tool and a first step toward problem-solving (Dery 2000; Nie 2001). Defining the problem is also a political process, as the perspectives of those involved are elevated and gain traction in solution finding (Weiss 1989). The power that different stakeholders wield in defining a problem also requires attention because stakeholders’ perceptions of a problem are partial and variable (Adams et al. 2003). Negotiating stakeholders’ diverse perceptions of a problem is critical for the pursuit of innovative, robust solutions (Adams et al. 2003; Bond and Morrison-Saunders 2011; Watkin et al. 2012).

This research is guided by three primary questions:

1. How do stakeholders define the “shark problem?”
2. What socioeconomic, cultural, and political contexts frame this issue?
3. What are some options to address these problems?

II. Methods

We collected data primarily during two trips to Guam and the CNMI in September and November of 2019. Initial points of contact were identified through conversations with WPRFMC staff, and Guam and CNMI agencies and fishers with representation at WPRFMC meetings. The latter included the Guam DoAg, CNMI Department of Fish and Wildlife, Micronesian Environmental Services, and fishers participating in the WPRFMC Advisory Panels (AP). These conversations also aided the development of our interview guide (see Appendix). Initial points of contact served as our first participants and provided referrals to additional participants. This referral process is typical of the snowball sampling method.

More than 100 individuals across Guam and the CNMI's Saipan, Tinian, and Rota were engaged through semi-structured interviews, fisher-organized meetings, and unstructured discussions in the field (Table 1). Engaged individuals represented experiences from the fishing, research, and management communities in Guam and the CNMI (Figure 1). Some participants provided experiences from fishing and research, or fishing and management communities. But, among stakeholders, Marianas' fishing community had the great representation, and included a few individuals with experience as fish vendors. This stakeholder group, inclusive of fishers and members of fishing industry, will hereafter be referred to as "fishers" or "the fishing community." In Guam, data were collected through group discussion at a public meeting hosted by the Guam Fishermen's Cooperative Association, and conversations with boat fishers returning from or departing for fishing trips at Hagåtña Boat Basin. In the CNMI, data were collected through group discussions at three fisher-organized meetings, one on each island, and through conversations with Saipan commercial fishers and their vendors in the field.

We also conducted participant observations at multi-stakeholder meetings in Honolulu, Guam, and Saipan hosted by the WPRFMC and its AP whenever possible. These included 2 AP and 1 Regional Ecosystem Advisory Committee (REAC) meeting in Guam, and 1 AP and 1 REAC meeting in the CNMI. Participant observation provided valuable context for understanding how Guam and CNMI stakeholders relate to one another and navigate other fisheries issues.

Detailed field notes were written up as soon as possible following the conclusion of each data collection endeavor, whether it consisted of a semi-structured interview, participant observation at public meetings, informal conversations in the field, or facilitated group discussions. Semi-structured interviews were audio recorded and transcribed, and interviewees were given a copy of their transcripts for review and revision. Field notes and interview transcripts were imported into NVivo (version 12, QSR International, Inc.) for coding. Data were coded to capture themes relevant to research questions as well as those that emerged from participant discussions. The coding scheme closely followed that of human dimensions research on fisher-shark interactions in the West Hawai'i region (Iwane 2019). This resulted in umbrella themes that housed participant commentary on dimensions of the fisher-shark interaction problem and its potential solutions. To answer research questions in this report, we also draw heavily on participants' descriptions of sharks and shark interactions, perceptions of fisheries management and stakeholder engagement, and descriptions of power dynamics and knowledge types in fisheries. Finally, coding captured important contextual information about Marianas' fishing practices, cultures, economies, and participants' identities and fishing motives, which cannot be separated from participants' experiences in the Guam and CNMI communities.

In May 2020 we shared preliminary results with participants via YouTube. Participants could review the videos at their leisure and provide feedback for integration into this report. The video series' introduction received 113 total views as of August 2020, with subsequent results videos 1–3 receiving about half the total views. More than 50 participants responded to our correspondence. Most of these simply acknowledged the receipt of our correspondence. 11 respondents confirmed viewership and 8 provided additional information or feedback, which contributed to the results we present in this report.

Table 1. Stakeholders engaged between September and November 2019 across various data collection methods.

	Guam	CNMI			Total
		Saipan	Tinian	Rota	
Interviews	19	16	-	*	35
Fisher-organized mtgs	14	11	11	11	47
Misc. fieldwork	~10	9	-	-	19
Total	43	36	11	11	101

*0 < n < 3

Stakeholders engaged:

Total = 103

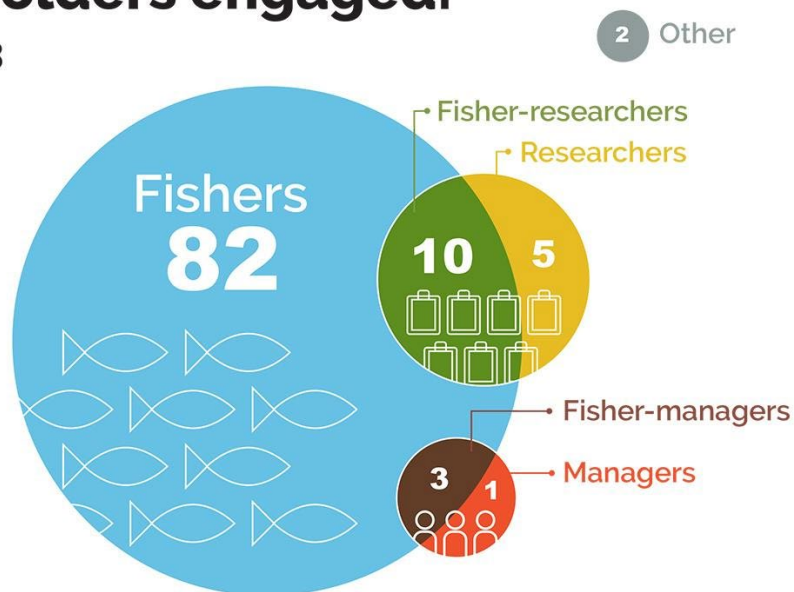


Figure 1. Breakdown of stakeholder groups represented by study participants.

III. Results

In this section, we present themes that emerged from interviews, fieldwork, and public meetings relevant to our research questions. Where applicable, quotes are provided to illustrate these themes. As much as possible, quotes are reported verbatim to capture interviewee perspective and voice. Author edits have been made as needed to make quotes accessible to broader audiences, and in some cases, to protect research participant identities.

How do stakeholders define the “shark problem?”

People have different ways of talking about sharks. These include, but are not necessarily dominated by negative descriptors, which made up 44% of all shark traits referenced by participants. In addition to describing negative characteristics or negative impacts from sharks, participants also described positive impacts or benefits derived from sharks, and neutral descriptors which were neither inherently negative nor positive. Positive and neutral descriptors comprised 17% and 39% of all shark traits referenced, respectively.

The frequency at which positive, neutral, and negative shark descriptors were used differed by stakeholder group. Fishers and fisher-researchers used negative descriptions of sharks the most and least, respectively. Negative references to sharks comprised 48% of all references for fishers, and 30% for fisher-researchers (Figure 2). Fisher-researchers also used positive shark descriptors most frequently (29% of all references). Researchers used neutral descriptors more than any other group, and positive descriptors less than any other group. The frequency at which fisher-managers used negative (41%), neutral (25%), and positive (24%) shark descriptors, respectively, were moderate relative to other stakeholder groups.

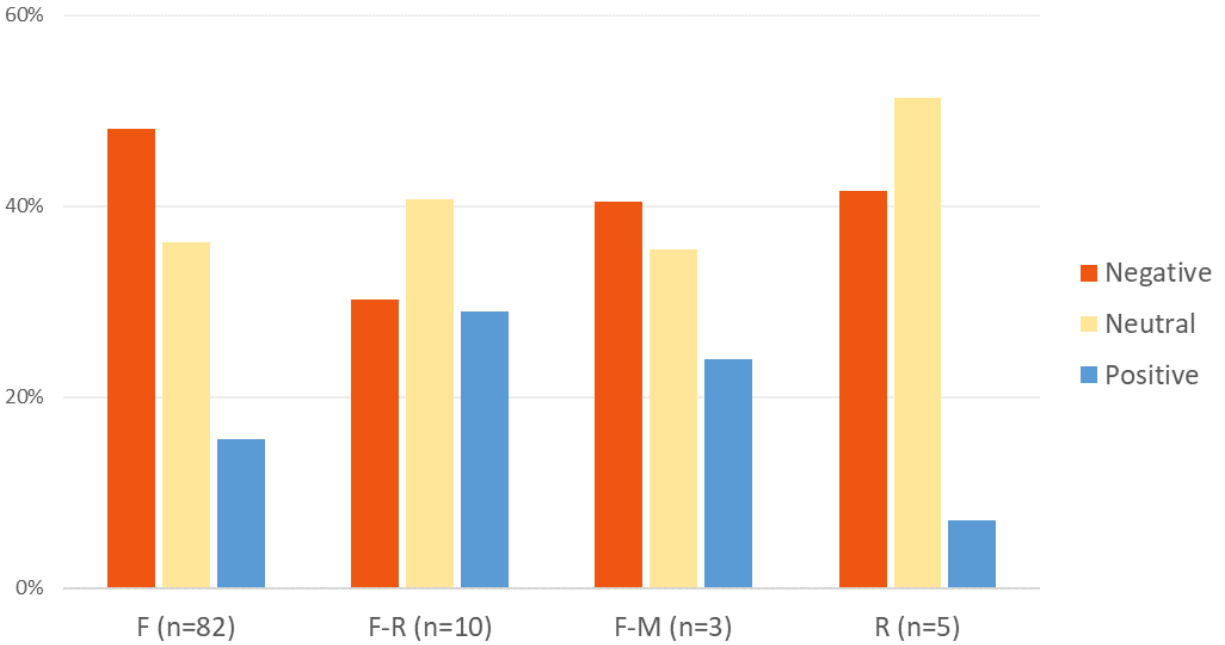


Figure 2. Breakdown of negative, neutral, and positive references made to sharks by stakeholder group, including fishers (F), fisher-researchers (F-R), fisher-managers (F-M), and researchers (R).

Table 2 provides a more detailed breakdown of individual positive, neutral, and negative shark descriptors used by different stakeholder groups, excluding descriptors that did not account for at least 5% of any stakeholder group’s references to sharks. It highlights perspectives and language of sharks that are both shared and unshared across stakeholder groups. More than their peers, fishers described sharks as competitors and too abundant, fisher-researchers described sharks as a hassle and not that problematic, fisher-managers described sharks as unpredictable, and researchers described sharks as non-target species and economically valuable. The framing of sharks as aggressive depredators, however, was shared across stakeholder groups.

Table 2. Breakdown of individual negative, neutral, and positive shark descriptors referenced by stakeholder group including fishers (F, n = 82), fisher-researchers (F-R, n = 10), fisher-managers (F-M, n = 3), and researchers (R, n = 5); cells highlighted where reference frequency $\geq 5\%$.

Descriptor		Includes descriptions of sharks...	F (%)	F-R (%)	F-M (%)	R (%)	All Participants (%)
Negative	Aggressive	Displaying aggressive behavior, typically related to feeding.	8	8	6	8	8
	Competitors	As competitors for fishers' fish or livelihood.	6	1	1	3	4
	Dangerous	Posing a physical threat to fishers and other ocean users.	7	5	9	1	6
	Hassle	As a pest or nuisance, costing fishers time, gear, physical effort, etc.	2	5	3	1	3
	Too abundant	As overly abundant, whether generally or in specific locations or fisheries.	7	1	4	0	5
	Depredators	Taking catch from fishers' gear.	11	15	10	7	11
Neutral	Fish-associated	In association with target fish species.	9	10	5	4	8
	Non-aggressive	Displaying non-aggressive, even docile behaviors.	1	6	1	5	3
	Non-target species	As incidental to the focal fishing activity, as opposed to desired catch.	3	2	1	7	3
	Not that problematic	Not posing a significant problem to fishers.	2	9	4	0	3
	Opportunistic	Taking advantage of feeding opportunities (e.g., presented by fishing activity).	2	4	6	7	3
	Part of fishing	As an inevitable part of the fishing experience.	4	5	0	7	4
	Unpredictable	Exhibiting variable behavior or interaction patterns over time and space.	0	0	5	0	1
Positive	Ecologically valuable	Playing important roles in the marine ecosystem.	3	0	9	5	3
	Economically valuable	Having economic value, typically through sale on the market.	3	3	4	5	4
	Food	As a food resource, both in practice and as a potential.	6	3	5	7	5
	Requiring protections	In need of regulatory frameworks to ensure their healthy populations.	2	1	5	7	3

Participants described reef sharks as problematic. For example, some spearfishers reported increasing aggression and signs of conditioning in reef species. However, participants described pelagic sharks more frequently using negative terms (55% of all references) than they did for

reef sharks (30% of all references). And, when pelagic and reef sharks were talked about relative to one another, pelagics were usually identified as more problematic by fishers. One fisher noted, “Reef sharks you don’t see that much, they’re not a big problem. When you go out pelagic fishing by the buoys, and the banks, it’s crazy. They’re aggressive.” Another said, “Ultimately, in the end, reef sharks we can deal with. Pelagic sharks, silkies and all that- different. Totally. When we first got the boat, I had no problem jumping out in the blue ocean when it was hot. Nowadays...”.

Sharks’ on-the-water impacts to fisheries made up a majority of participants’ descriptions of the “shark problem” (Figure 3). These included loss of gear and catch, damaged equipment, risks to fisher safety, and fishers shifting fishing locations and investing more time while fishing. Participants also described secondary and contextual problems related to sharks. Secondary impacts derived directly from on-the-water impacts, and included financial costs to fishers and decreased CPUE. Contextual dimensions of the “shark problem” included confusion around shark legislation, a need to better understand sharks in the Marianas, and concerns about sharks going to waste as a food resource. Together, these on-the-water, secondary, and contextual problems related to sharks comprise the shark-centric problem framings around fisher-shark interactions. They are noted with a single asterisk (*) in Table 3. Additional contextual problems not directly related to sharks are noted in Table 3 with a double asterisk (**) and will be described further in the next section.

Table 3. Summary of shark-centric (*) and contextual problems () relevant to fisher-shark interactions.**

Category	Issue	Description
On-the-water	*Gear + catch loss	Shark interactions result in fishers' loss of catch and gear.
	*Safety	Shark interactions and handling poses safety risks to fishers.
	*Shifting fishing locations + time investment	Dealing with sharks imposes a burden to fishers' time and has, in some cases, resulted in a shift of fishing locations.
Socio-economic context	*Cost	Many on-the-water impacts of shark interactions translate to financial costs to fishers (e.g., loss of catch, gear, time, fuel).
	*CPUE	Shark encounters may reduce CPUE, for a key data input for stock assessments.
	**Threats to participation	Costs and impacts of shark interactions to fishers makes it more challenging (and less desirable) to sustain fishing activity, given the economic challenges fishers face from various angles (e.g., costly supplies, flooded markets, low fish prices).
	**Fisher's role in community	Social dynamics encourage fishers to provide fish at prices accessible to community members, and to support local tackle shops, each at expense to fishers.
Regulatory context	*Regulatory confusion	Between local and federal legislation, there is disagreement among stakeholders about what can be legally done with a shark.
	*Waste	Concerns about sharks going to waste or being underutilized as a food resource.
Data + research	*Need to understand sharks	Little research has been done on sharks (particularly pelagic sharks) in the region, leaving unanswered questions about how and why shark interactions are changing (e.g., abundance v. behavior).
	**Data validity/access	Fishers expressed poor perceptions of data collection methods or the application of data in fisheries management. Enabling or hindering access to fisheries data represents one type of power that can be wielded by stakeholders.

Category	Issue	Description
Political context	**Denying fishers' experiences	Fishers felt their experiences were denied by other stakeholders, either through lack of recognition of fishers' challenges or explicit dismissal of the perspectives and knowledge shared by fishers.
	**Stakeholder disconnect	Mistrust, contradictory perspectives, and differences in power (e.g., livelihood security, influence in fisheries management/research) contribute to disconnect between stakeholders.
	** (Territorial) marginalization	Feelings of marginalization arose in discussions with participants regarding their status as fishers, territories, or outer-islanders.
	**Influence in management + research	Different stakeholders, depending on their stakeholder group or access to fisheries management and research discussions, have different levels of influence in said discussions.

By stakeholder group (Figure 4), on-the-water impacts were emphasized most by fisher-researchers (comprising more than 70% of their problem descriptions) and least by researchers (~30%). This difference could be accounted for by the groups' references to contextual issues, which were emphasized least by fisher-researchers (comprising ~14% of their problem descriptions) and most by researchers (>50%). Of the 6 different on-the-water impacts identified by participants, fishers and fisher-researchers referenced all 6, fisher-managers referenced 4 of the 6, and researchers referenced only 2 of the 6: gear and catch loss.

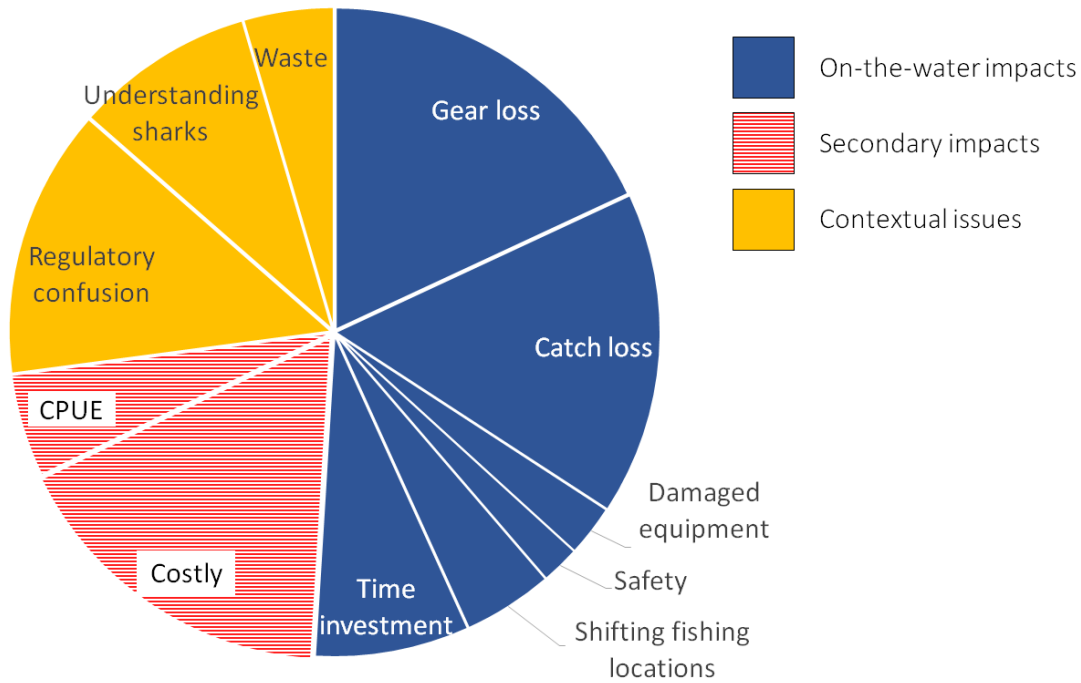


Figure 3. Dimensions of the “shark problem” cited by all participants. Wedge size represents the number of meetings (e.g., interviews, group discussions) in which a particular problem dimension was cited.

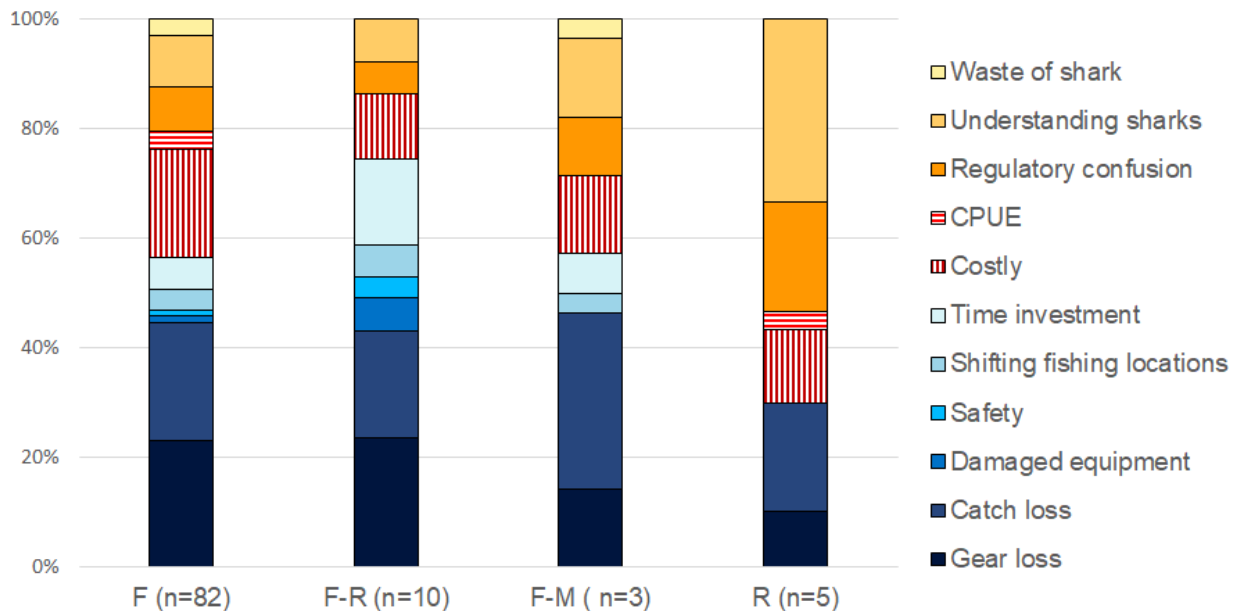


Figure 4. References to various on-the-water, secondary, and contextual problem dimensions cited by stakeholder groups, including fishers and members of fishing industry (F), fisher-researchers (F-R), fisher-managers (F-M), and researchers (R).

Fishers described shifting their fishing locations and investing their time on the water differently as shark distribution and behavior changed through time. A recreational fisher described avoiding fishing spots he once used to frequent given increasing shark presence. One commercial fisher described his fishing activity's northward succession up the CNMI over a 4-year period, propelled by sharks' changing behavior:

As a commercial fisherman, we're trying to leave the southern bank to the weekend warriors... So, probably 5 years ago, we could still fish near the Farallon de Mendinilla. We can still fish there with mafuti, or anything, onaga on the edges. But now, you cannot anymore... Now we have to go farther. And then, a couple years ago, same thing happened. We had to go far again.

Many on-the-water losses in gear, catch, and time incur financial costs to fishers. It's notable that these impacts may be felt differently depending on financial investments made to fish, which vary according to fishery. For example, one fisher noted:

I also do in lagoon fishing. Snappers. And when I lose a rig or a fish to shark, I accept it. Because you're talking only a dollar or two dollars. We have a lot of the shark attack but it's ok. But when you invest into your lures and your fishing equipment and you go out and you get destroyed by a shark, it hurts.

Across stakeholder groups, there was agreement around the region's lack of shark research and data, and a need to understand sharks better in the region. Topics of interest cited by participants included shark movement, interaction rates, why things have changed through time, and identification of both pelagic and reef species.

Fisher participants demonstrated interest and a willingness to participate in data collection efforts. They shared stories and submitted photo and video documentation of their shark interactions or depredation events. Upon drafting an electronic shark interaction data form, participants provided feedback, submitted data, and one participant offered to survey older fishers who may not be inclined to fill out electronic forms for their shark interaction data. Given that collecting quantitative shark interaction data was not a focus of this project, however, continued pursuit of fishers' data was not prioritized. Future efforts to collect fishers' data may benefit from dedicated staff and resources to continually engage with the fishing community, and encourage fishers to submit data for all activity, regardless of whether or not shark interactions occurred. The latter will help to eliminate bias from evaluations of shark interaction rates and impact:

I think most would say, "Yeah, there's a lot of sharks." 'Cause they went out like 3 weeks ago and got an interaction with a shark, but they were forgetting that the 2 other weeks you've been out fishing every week, they didn't catch any... You'd have to remind them constantly. Just a reminder. But yeah, that will be I think kind of a solution for this... These other guys say, 'Oh, there's a lot [of] sharks!' Shit, I didn't see it. I went out fishing — you know. We could probably go out fishing five days in a row and we would probably not get any shark interactions.

A prominent reason why sharks are recognized as a problem is because observations indicate a departure through time from some baseline, "normal" experience:

And then the frequency of [shark] interactions has increased even next to the island, versus, like, in the old days, it was just the banks... On a really good day once in, oh, back in I think it was '98 or '99, I got 8 big yellowfin and only got 2 that were bitten by sharks. Now, it would be the opposite. Lucky if you get 2 and have 8 bitten by sharks. Or, completely eaten in frenzied attacks.

However, participant discussions suggested the role of different factors in explaining how and why shark interactions are changing through time. Looking at co-occurrence between discussions of sharks changing through time and other shifts in the fishery, the four themes referenced most were fish abundance and size, shark finning bans, fishery participation, and FADs. Participants talked about fish abundance and size decreasing through time, which could affect sharks' behavior given dwindling food sources:

From my experience, back in the days, there was a lot more fish in our water. So, we had less interactions with [sharks]. I mean, they'd come around, but they wouldn't usually hang out, hang around us too long. But, nowadays, the fish population is going down. So when the sharks see us, you know, you spear fish and it gets away, that's their meal.

This decline in fish abundance and size was referenced primarily with regard to reef fish, but there were some cases in which fishers with more years of consistent fishing experience described similar trends for pelagic and deep bottomfish. Some participants associated shark finning bans and other shark protections with an increase in shark abundance:

Before we had, to me, a balance in Mother Nature. Where we had tunas removed and the sharks finned. But now we have the tunas removed, but the sharks released... Now there's no balance. These sharks are picking up residence.

Participants' narratives of fishery participation differed depending on the territory and fishing sector. In Guam, participants described increases in spearfish and pelagic fishery participation through time, attributed primarily to an influx from the migrant commercial fishing community in the last decade. One participant also described growing participation in the spearfish fishery from younger generations. In the CNMI, participants described decreases in commercial bottomfishing and local or indigenous fishers' participation. The latter was attributed by one interviewee to the regulation of traditional fishing practices like netting in the CNMI. In both Guam and the CNMI, participants described individual fishers' decisions to transition away from commercial fishing, but continue fishing recreationally or to supplement other sources of income. However, stakeholders in both territories described an overall increase in fishing boats through time. It is, therefore, difficult to determine from participants' accounts how fishing participation and effort overall has changed through time.

With regard to sharks, however, participants associated increasing fishery participation—and thus increasing fishing stimuli—with increasing shark interactions and impacts to fisheries:

In the beginning [sharks were] not really a big factor of the damages. But throughout the years I think because more fishermen [started] coming around, new fishermen [started] going out more often, and I guess the fishermen try just all over the place, then that's when you start seeing more sharks and... encounter more shark problems.

Participants described sharks' movement and distribution changing according to FADs' distribution changing through time:

Ten years ago, the sharks started attaching to the #2 FAD. Now that that FAD is gone, they're attaching themselves to the #1 FAD. But then now they're attaching themselves to all the FADs.

[Sharks were] never that way before, fishing with my dad and them. We never had that problem. There wasn't this many buoys back then either. Probably not as many fishermen.

Thus, participants attributed changing shark interactions to different contextual factors. Whether changes in their observations were due to changes in shark abundance or behavior, however, was a point of contention. Participants that perceived an increase in shark abundance referenced sighting more sharks at a time, seeing sharks more frequently, and in more areas. Disagreement around this issue highlighted tensions between stakeholders:

I don't care what any scientist says. They're saying, "Oh, it's not more shark, it's few shark that are just getting smarter." Can't be. Because everywhere you go, there's shark. It's not the same shark following you around to the Northern Banks, to the Southern Banks, to the FADs. It's not the few smart sharks following you, it's smart sharks, and more of them.

Disagreement between these narratives also arose within stakeholder groups; for example, within the fishing community: "The people that generally say there aren't any sharks, or the shark populations are declining, are generally not the people that are fishing consistently." However, some fishers commented that social media and a growing regulatory and political focus on sharks could also be contributing to perceptions of increasing shark abundance.

There seemed to be more agreement among fishers and across stakeholder groups that shark behavior is changing through time and may indicate conditioning. Participants described sharks growing more responsive to fishing activity. Although some fishers described interacting with sharks only after landing or spearing fish, others noted changes in shark behavior suggestive of conditioning. For example, fishers talked about sharks attacking unbaited artificial lures, which before was unusual: "Nowadays they bite your lure, your trolling lure. They actually bite it. Before [the] fish hits it, the shark is attacking your lure. Back in the day they will bite the fish that's on your line." One CNMI bottomfisher noted that in the '80s he would rarely see sharks and land almost everything he hooked, whereas today, sharks sometimes bite their gear as soon as they throw it in the water. Other fishers similarly noted examples of sharks arriving to their vessel even before they threw gear into the water. Most often, though, participants described sharks' responses to the smells, sounds, and sights of fishing activity:

And they kind of know already where the fishing spots are. They're just always there. And, once they hear the boat? Oh, gosh (chuckles). And they smell your chum, 'cause sometimes we chum? Once they come, you better move to another area. They won't leave you alone.

Several participants in both Guam and the CNMI raised the practice of chumming as they theorized, explained, or expressed concerns about sharks' changing behavior. Two participants,

one from each territory, offered similar timelines for the onset of widespread chumming in their fisheries: the last 10–15 years. The CNMI fisher described it as a “quick fishing” technique used to target pelagic and bottomfish². Guam participants described its use in pelagic FAD fisheries, noting the addition of chum to other fishing cues provides positive feedback for sharks’ conditioning.

Participants also discussed the potential for different fishing vessels and engines to affect shark interaction rates. One interviewee talked about a bottomfish sampling project in which shark interaction rates were unusually low. He hypothesized that this could be related to the researchers’ vessel and engine type, not typically used for fishing:

In two weeks of fishing we had one shark interaction. In two weeks. And we fished the areas that a lot of other fishers usually complain about shark interactions. And I think part of it is that we were not using boat engines that the sharks are familiar with... We were using little Zodiac type boats, or else fishing from the main vessel. And I don’t think those are engines that the sharks recognize as a dinner bell.

Kayaks, propelled manually, provide another alternative to traditional fishing vessel engines. Some kayak fishers described sharks tracking them throughout the day or depredating their catch. One such depredation event involved a kayak fisher fighting a hooked tuna for 4.5 hours before it was taken by a shark—a fight time that seemed unusually long compared to those cited by boat-based fishers. Another participant described the relative success of her kayak fishing friend’s pelagic and deep bottomfishing ventures compared to boat-based fishers:

He barely, rarely, rarely has shark interactions. [A boat-based fisher is] losing more onagas than catching them, because he swears that all his spots recognize his engines. But my friend has a kayak, and he's been catching onagas on a regular basis. He's caught mahis, wahoos, marlins, sailfish, like on a kayak... There's no engines.

In addition to signs of shark conditioning, fishers also talked about new fish species being depredated, as sharks diversified from their usual bloody tuna:

Now they’re attacking mahi, wahoo, barracuda, rainbow runner, I mean, they’re hitting everything now. Where, before, if you were reeling in a fish and you got nailed by a shark, you knew you had a yellowfin on there, because the shark’s only going to go after your yellowfin. But now it’s like, jeez. Anything you hook up is open game for sharks. Marlin now, too.

In our presentation of participants’ definition of the “shark problem,” we presented on-the-water, secondary, and contextual problem framings. These were shark-centric as they derived from fisher-shark interactions or were explicitly related to sharks in the Marianas. However, these secondary and contextual “shark problem” framings blend into the broader socioeconomic and

² Chumming occurs at different depths according to the target species: at the surface for pelagics and at depth (~450–800 ft) for deep bottomfish.

political contexts of this issue. In the next section, we elaborate on contextual issues that have a more ambiguous connection to fisher-shark interactions.

What socioeconomic, cultural, and political contexts frame this issue?

In contrast to the shark-centric problems introduced thus far, these contextual issues are related to the broader socioeconomic, cultural, and political contexts for fisheries and their management in the Marianas. Contextual issues noted by participants included threats to fishery participation, fishers' role in the community, data validity and access, denying fishers' experiences, stakeholder disconnect, feelings of marginalization, and influence in management and research. We present these in Table 3, alongside the shark-centric problem framings introduced in the previous section. All of the problems we documented relevant to fisher-shark interactions are grouped into the following problem categories: on-the-water, economic context, regulatory context, data and research, and political context (Table 3).

Socioeconomic context

In the previous section, we introduced the secondary impacts related to cost that shark interactions produce for fishers. Participants talked about various financial investments required to fish. Boat-based fisheries, for example, require investment in a vessel, motor, equipment maintenance, ice, bait and tackle, fuel, and safety gear. If fishers land catch, it may be sold on the market, consumed at home, or shared with friends, family, and community members. From this exchange some gain may be returned to the fisher, whether it be sustenance through direct consumption, monetary returns, strengthened social ties in the community, or the acquisition of some traded good. For example, participants described trading fish for meat, laundry detergent, and farmed produce. However, participants described both the quantity used and price of fishing materials increasing through time, as fishers adapt their strategies to changes in fish distribution and shark interactions:

He doesn't fish commercially anymore. 'Cause there's no more fish, so he stopped fishing... For him to get an adequate amount of money, to add up to all his costs and all that, he would have to boat out, motor out like twice as far. Just to get his quota for fish... And they're looking for different style boats now. That way you can go farther and catch those fish.

This interviewee described fishers giving up on commercial fishing for more stable occupations. Others talked about spending more on fuel or investing in different gear to adapt to changes in shark populations or behavior.

Fishers who take their catch to market described instances where flooded markets make offloading their catch impossible. Participants also described competition from imported seafood for products that may not be available year-round (e.g., mahimahi) or locally (e.g., imported salmon). The inability of local fisheries to supply products like these creates a barrier for their entry into the tourism industry. Participants also described a low price for their fish, which has not changed through time despite increasing fishing costs. One CNMI fisher noted that in the early '90s, fuel cost \$2/gallon, and fish sold at \$3/lb, where today, fuel costs \$5.15/gallon, and fish still sells at \$3/lb. Fishers also described fish prices as unresponsive to changes in product

supply or the quality of fish delivered. This complicates monetary returns to fishers, whether the goal is to recover fishing expenses or make a profit for livelihood.

Layered upon economic context are the social dynamics of fishing communities. A CNMI fisher noted, “If we charge more money [for fish] it’s like highway robbery.” This fisher likened asking more for your fish to “cheating your neighbors.” If the market prices rise, he said, people come to fishers’ doors to ask for fish directly. Thus, the social responsibility that fishers have to their community as providers of fish puts them in a difficult financial position:

You have to give to your family because you’re the fisherman. You’re required because of your status in the community to provide for the fiestas, and the wedding, and the christening. That’s your job, whether you fish or not anymore.

The community dynamic also affects fishers’ expenses. Various fishers from the CNMI, in particular, talked about the cost of fishing supplies being relatively high given the limited number of local tackle stores, but expressed empathy for store owners’ revenue needs and a desire to support local business. One participant noted:

Sometimes I just place an [online] order of different stuff. But yeah, I kind of support the local fishing tackle here, too. I mean, knowing that it's pretty expensive, but it's right there in front of you. Rather than wait another week or two for it to come.

Within these socioeconomic contexts, shark interactions represent not an introduction of challenges to fishers, but a lever for exacerbating existing challenges. Participants characterized these cumulative socioeconomic and shark interaction challenges as threats to fishery participation. Some fishers described being less willing to gamble with their finances on a fishing trip, deciding against fishing, and relying instead on what their fishing friends might bring in. One participant noted that shark research needed to be prioritized immediately, to provide support to fisheries and prevent further declines in participation:

All this stuff needs to be captured now. Because we’re talking 10 years from now, the fishing community is gone already. At the rate [sharks are] becoming a detrimental problem... People are going to quit faster than you can speak.

This quote also illustrates differences in impact and urgency of shark research to different stakeholder groups.

Political context, data, and research

Fishers feeling their experiences were dismissed by other stakeholders provided important overarching context for fisher-shark interactions. Fishers talked about lacking opportunity to share their perspectives, or feeling like other stakeholders dismissed their knowledge. They also talked about feeling like they weren’t being prioritized as fishers, residents of territories, or residents of smaller outer islands. This issue was also connected to several other concerns related to political context and data and research. We therefore present the issues that comprise fisher-shark interactions’ political, data, and research contexts together, providing examples that illuminate their interconnectedness.

Referencing unpublished efforts to evaluate shark interaction rates in the Marianas, participants described involved researchers concluding that sharks were unproblematic given low shark interaction rates during their studies. Fishers (including fisher-researchers) expressed concerns around such conclusions, citing data collection methods that lacked fishing stimuli completely, or utilized non-traditional fishing methods: “If you’re just doing a snorkel transect and you’re not doing anything to attract the shark, then of course you think that they’re not there.” This disconnect in stakeholder perception was attributed to differences in fisher and researcher observations, along with a lack of effort to reconcile these differences:

From a few prominent folks, there is a prevailing distrust of science. So you can say, “Oh, the science says that this is the number of sharks that are in our waters, and why there’s a lot more sharks now than before, blah, blah, blah,” versus, “Hell no! Last time I went out fishing it took my bait. There’s sharks out there!”

These quotes also highlight barriers to bridging fisher-scientist disconnect: data collection methods, or data validity, and mistrust.

One fisher highlighted an example of fishers’ mistrust of researchers specifically in discussing this project. He noted that:

One of my colleagues, another fisherman, he said, “Hey, these people are just here to try and safeguard their position, forget about that. And that’s on our watch.” I go, “Brother, listen, we’ve been crying about this problem for so many years... So why don’t we just bow down and let’s humble ourselves, and let’s try and help out to see.”

The interviewee noted that this mistrust originated from fishers’ previous experiences with researchers. The quote illustrates the important power differential between fishers and researchers, in which researchers conduct their work with relatively stable livelihoods, while fishers may be made vulnerable through research participation. Fishers, however, wielded power in their decisions about whether or not to participate, and therefore facilitate researchers’ access to new data.

The government’s decisions about allocating funds toward management or research represent another assertion of power. One fisher described feelings of marginalization as a result of Guam’s territorial status and physical distance from the mainland United States, which leaves issues of economic hardship unaddressed:

We’re just a territory... so far removed from everything. Spending money out here, from a government standpoint, it’s like, “Ah, we can use better money than that.” They won’t come and study where there’s actually people living and where it affects people’s lives... We’re always getting, being way out here, the short end of the stick.

Ultimately, different stakeholders wield different kinds of power in defining and resolving the “shark problem.” And, mistrust and past experiences between stakeholders may create barriers to collaboration.

What are some options to address these problems?

On-the-water strategies

Participants described a number of on-the-water strategies that fishers use to mitigate sharks' impacts to their fishing activity. From most to least commonly discussed, these included moving away from sharks, handling the sharks directly, modifying gear, avoiding sharks, bringing fish in as quickly as possible, breaking the line to release hooked sharks, deploying some distraction to occupy the shark while landing fish, limiting fishing stimuli to avoid conditioning or attracting sharks, limiting or rotating fishing effort, various boat maneuvers, or simply keep trying with little change to fishing strategy.

The handling of sharks either directly or through the use of fishing gear often required hooking up to the animal to occupy it while fish were landed. For example, fishers described jugging sharks, in which a free floating buoy or plastic jug is baited for the shark to hook up to. One fisher described hooking a shark with a rod and reel, which similarly occupies the animal while target species are landed:

It's just a spinning rod and reel, and he's fighting it and having fun and once I bring up the sets, just break the line, and we move... And it's successful, yeah. Most of the time, it's successful. Unless there's two sharks.

Participants also described a variety of gear modification strategies to adapt to shark interactions. These included the use of cheaper or more gear, deploying less gear at a time to manage interactions safely, reducing line test or reel drag to reduce gear loss, using an M-boat³ instead of stringers for spearfishing, or bringing multiple gear types. The latter allows for flexibility around fishing activity, for example, if depredation rates are higher in one fishery than another: "Now our option is, if we cannot bring up [bottomfish], we just troll, just for gas recovery."

Some fishers described avoiding fishing areas because of shark interactions. In some cases, information about shark-prevalent areas was acquired from friends or social media. Fishers also described avoiding conditions or areas that are reliably associated with sharks, including areas of high fish biomass (e.g., tuna schools), certain buoys, or shallow reefs and banks. One fisher noted some fishers' preference for fishing on the east side of Guam for its relatively low shark interaction rates:

I'm not saying there's not sharks. But it's not as bad as [the west] side. The north. The north side is bad... Like my friend won't even fish this side anymore, 'cause it's too sharky. He only fishes east side... I think less people fish there.

Some participants, however, described avoidance strategies losing their effectiveness through time given sharks' change in behavior:

³M-boats are floating devices used to store catch out of the water.

When you're trolling in the shallow part of the bank and you hook a fish... we're already turning out to deep water... You can get away from the shark by fighting the fish slowly or out to the deep water to avoid that interaction. But now, the sharks hone in on the boat. So, it doesn't matter if you've fought that fish out to deeper water. It's going to meet you there... The tactics of before on how to avoid them are changing. They're evolving. And, we can't change the tactic fast enough to avoid them.

Fishers noted various strategies to distract sharks from your fish, including feeding them fish scraps, taking advantage of other boats in the area, or throwing rocks or gravel into the water while a fish is landed. One fisher overheard positive reviews of the gravel strategy from Chuukese commercial fishers: "They swear by it," he said.

In an effort to limit fishing stimuli and therefore shark conditioning, some fishers described strategies to reduce fishing sounds and smells. For example, waiting to clean fish and blood from the boat until further from a fishing spot, subduing fish quickly while spearfishing, turning off depth sounders or engines after arriving at a fishing spot, or using quieter gear or fishing methods (e.g., kayaking).

In some cases, fishers talked about the need to keep moving and diversify fishing spots to avoid attracting or conditioning sharks:

Typically when I'm dropping my deep bottom... Eventually sharks will come, so I don't keep still, one spot. And if you see my GPS, it's all these coordinates for deep bottom, all these spots, everywhere. So, I never go back to the same place. You know, rotate. Depending on the water conditions too.

Finally, fishers described boat maneuvers to mitigate shark interaction impacts. They talked about dragging catch away from sharks, or skipping fish, like small bonito (*Katsuwonus pelamis*), on the water to avoid sharks. One person described handliners sending bottlenoses down the line to bring in fish faster and avoid shark bites:

You know their trick? A bottle. The nose of it. Cut it off and they slide it down the line and you can haul it in faster. Puts a cone over the fish, then it can't fight with an open mouth and can just drag it in faster.

In addition to diverse on-the-water strategies that fishers have developed on their own to mitigate shark interactions, participants discussed a number of solutions that may be implemented by researchers and managers. These included strategies such as shark population control, regulatory outreach, research, and economic fisheries support.

Shark population control

Shark population control was largely associated with interviewees' perception that overabundant shark populations are a disadvantage to fishers: "There's more sharks than fish. So yeah, I definitely think it needs something. Otherwise we're not going to have any fish to eat." Shark population control was talked about in a number of ways: developing a market and demand for shark meat, organizing shark derbies, legalizing shark take, or organizing a shark culling program. Sharks were discussed as a food fish across 27 different meetings or interviews. These

included examples of local consumption of reef and pelagic sharks. Some participants noted a general preference for small reef sharks, whereas pelagic shark consumption was referenced less and usually in cases of opportunistic landing and use. Participants described various preparation techniques to make shark meat more palatable, including soaking meat in coconut milk and yellow ginger or rinsing with lemon and vinegar. Other preparation techniques included using raw meat in kelaguen, grilling, fried “shark bites,” and shark “tuna salad.”

Despite local consumption of shark meat, recurrent across shark harvest and population control themes was the need for change in the broader community’s mindset around sharks as a food fish:

If they can develop some kind of palatable menu so people cannot just interact with sharks, lose the gear, and let it go, but land the shark and bring it in for consumption. Or for sale. Then I think that’ll ease the concern a little bit more. Maybe even have a shark category on the derbies, you know? ... Convert it to be a positive thing. ‘Cause sharks are good... It’s a sign of a healthy ecosystem. So, I think we can develop a change in the mindset of the community to say, “Hey, it’s ok to eat sharks. It’s on the menu in the restaurants, and it’s legal. Why not?”

Challenges in developing a market for shark meat, however, are threaded throughout the processes of landing, processing, and marketing shark:

If you’re not used [to it], it’s going to be hard for you to start dealing with sharks.... They’re tough in any which way, marketing, catching, everything... I mean, maybe if the federal government, the local government would allow that, then it’s probably not bad to try. But who are the consumers? Because I’m not sure if the locals will be consuming sharks a lot or — maybe for tourists or for the restaurants, and stuff like that?

Fishers’ small vessel sizes, which pose safety risks and limit storage capacity, were noted as one challenge to developing a shark market. Another was the need to provide consistent supply for “new” market products to build consumer familiarity and demand.

Outside of market development possibilities, shark harvest provides the opportunity to collect data and monitor trends through time:

If we can have a shark fishing derby, that would be a very good help. Why? Because everybody takes part in it. It’s not just to favor certain people, it’s to entice everyone to take part in it... And if somebody can come up with what we can do with the sharks, it’s not going to go to waste like that... And then we’ll see in the next year or so whether it’s the same or it got less, you know. It would be one way of studying also whether it helped.

Some participants suggested shark culling programs, which could enlist community members’ help through incentive programs:

Years ago, they had a program where I guess for any shark over 4 feet long that you kill, you get a hundred bucks. I’m not sure who sponsored that program, but I remember that. And I actually sent my boats out fishing for sharks. You catch 5 sharks, you get five hundred bucks, right? It was some kind of federal program I believe... They had

basically an attempt to reduce the sharks in our region. And, you know, to me, it almost seems like I wonder if that's necessary now.

Culling programs were also discussed in terms of NOAA or local agencies dedicating management resources to such a program. These discussions highlighted perceptions that sharks are currently not being actively managed by such institutions:

When there's overpopulation of one species, they hire somebody to reduce the population, or the Fish & Wildlife, like that. They can give funds to the Fish & Wildlife to do some eradications. And probably do more studies on how to lessen the population.

Participants also recognized that any shark population control measures or shark harvest may receive opposition from environmental groups and interests. One fisher expressed concerns that any shark population control efforts would result in, "a media frenzy saying we are killing for no reason," in contrast to what he perceived to be a more carefully weighted decision, "I personally since the year 2000 do not kill sharks. I believe [they're] part of our ecosystem, but lately it's difficult competing against them for fish." Participants referenced both local and non-local groups, including NGOs and educators, which have mobilized in the past to affect local fisheries and shark legislation:

That's just going to be a lot of bad publicity. There's a lot of conservationists that would hate to see that. I mean, we had a Council meeting a couple years ago, and the marine biology teachers here on Guam brought all their students and school buses and they were all protesting for a shark sanctuary, when that wasn't even part of the agenda.

Regulatory outreach

Across stakeholder groups, participants shared diverse and conflicting interpretations of territorial and federal guidance around shark handling and use. One researcher perceived that the sale of any shark product in Guam was prohibited. In contrast, other Guam researchers asserted that the sale of shark meat is legal:

I think sometimes [fishers] hide it, like they're afraid it's illegal or something and it's not. It's perfectly legal, as long as they bring in the whole shark... And you can't sell shark fin also... You can sell the whole shark. I think generally if there's fin on the shark, you have to sell the piece with the fin, like if you were selling a steak where the dorsal fin is, the fin has to be attached. You can't have that cut off.

Despite their efforts to assure the community of its legality, these researchers noted fishers' hesitation to land sharks for fear of legal repercussions. They highlighted, particularly for fishers who are left without options in the face of changing shark behavior, the importance of consistently communicating legal shark practices:

And about [shark conditioning], they don't really know what to do. And that's a good time that we tell them, you know, it's legal to catch them and keep them if you want. You can catch them and bring them in, just don't fin them. And I don't know too many people who've taken that up to bring in a shark, but we have to remind them that it is ok to do.

In an effort to begin to address regulatory confusion, we synthesize the relevant federal and territorial legislation guiding shark handling and use in the Marianas (Table 4). The U.S. Shark Conservation Act (SCA) requires that fins be naturally attached to landed sharks (81 FR 42285). CNMI Public Law 17-27 (2 CMC § 5651) and Guam Public Law 31-10 (5 GCA § 63114.1) prohibit shark finning, with exceptions for permitted research activities and subsistence uses. Correspondence between NOAA Assistant Administrator for Fisheries Eileen Sobeck and representatives from Guam (Barrett-Anderson 2015) and the CNMI (Sobeck 2014) establishes that territorial laws do not interfere with federally managed fisheries. That is, Guam and CNMI public laws do not prohibit the commercialization of shark carcasses landed in federal waters (3-200nm), with fins attached. Guam also allows the commercialization of sharks harvested in territorial waters (Barrett-Anderson 2015). In the CNMI, however, sharks landed in territorial waters may not be commercialized. Assistant Attorney General of the CNMI asserts that although “a person can fish for shark in CNMI waters and consume the meat from the shark without running afoul of CNMI law... a person cannot sell or trade the shark meat, pursuant to 2 CMC § 5651(c)” (P. Boone, personal communication, July 15, 2020). For the CNMI, then, the legal commercialization of shark meat landed in federal waters, but not territorial waters, poses challenges for enforcement.

Table 4. Summary of federal and territorial legislation relevant to shark use in the Marianas.

	Legislation/ Document	Details	Definitions
FEDERAL	U.S. Shark Conservation Act (81 FR 42285)	“Prohibits any person from removing any of the fins of a shark at sea, possessing shark fins on board a fishing vessel unless they are naturally attached to the corresponding carcass, transferring or receiving fins from one vessel to another at sea unless the fins are naturally attached to the corresponding carcass, landing shark fins unless they are naturally attached to the corresponding carcass, or landing shark carcasses without their fins naturally attached.”	Shark fin: “Any of the fins of a shark (including the tail) or a portion thereof.”
CNMI	Public Law 17-27 (Shark Fin Prohibition 2 CMC § 5651)	Prohibits possession, sale, trade, or distribution of shark fins in the CNMI, with exceptions for DLNR-licensed research, “person[s] in possession of a shark for subsistence purposes (non-commercial),” and “incidental catching of sharks” which Legislature recognizes as “unavoidable.”	Shark fin: “The raw or dried fin or tail of a shark.”
	Letter from Eileen Sobeck, NOAA Asst. Administrator for Fisheries, to Manny Pangelinan, Acting Secretary of the CNMI DLNR (Sobeck 2014)	“We also understand that CNMI Law 17-27 would not prohibit the possession, import, and/or landing of sharks with fins that are naturally attached to the shark carcass that are harvested in federally managed commercial fisheries. The prohibitions under CNMI Law 17-27 are with respect to the possession, sale, trade, or distribution of shark fins that have been removed from the shark carcass for commercial purposes on shore. Based on this, we understand that fishermen would be able to sell, trade, and distribute shark carcasses.”	
GUAM	Public Law 31-10 (5 GCA § 63114.1)	Prohibits possession, sale, take, purchase, barter, transport, export, import, trade or distribution of shark fins in Guam, with exceptions for Department of Agriculture Director-licensed research and “person[s] in possession of a shark for subsistence and traditional and cultural sharing purposes.”	Shark fin: “The fin or tail of a shark that has been removed from the body.”
	Letter from Elizabeth Barrett-Anderson, Guam Attorney General, to Eileen Sobeck, NOAA Asst. Administrator for Fisheries (Barrett-Anderson 2015)	“The statute’s reference to ‘shark fins’... statutorily excludes the possibility of prosecution in Guam for the possession, sale, import, export, or landing of intact shark carcasses, wherever landed... It is therefore confirmed that Guam’s Shark Fin Law does not prohibit the possession, sale, import, and/or landing of sharks with fins that are naturally attached to the shark carcass and are harvested by federally managed commercial fisheries outside of Guam’s waters; nor does it prohibit the possession, sale, import, export, and/or landing of intact shark carcasses and shark carcasses from which the fins are later removed, so long as the body is not disposed in the sea without fins at or around the time of capture.”	Shark finning: “The taking of a shark, removing the fin or fins (whether or not including the tail) of a shark, and returning the remainder of the shark to the sea.”

Research

In addition to regulatory challenges and opposition from environmental groups, participants identified a lack of shark research as a barrier to shark harvest. For many participants, the first step toward addressing the “shark problem”—especially through a strategy like shark harvest—is an investment in research:

Before anyone does anything, then there better be some really good, hard data because you can really mess up the food web. And so you might think that’s your answer, when ultimately that’s going to be your downfall. Even now... ‘Cause it could just really have the opposite effect. When really everyone wants the same thing. To a point.

Participants expressed interest in many facets of research, including evaluating shark abundance, determining why shark interactions are changing through time, collecting shark interaction data from fishers, tagging sharks to monitor their movement, and working to find novel tools or techniques that fishers can use on the water to reduce shark impacts to fishing. Participants also discussed the importance of identifying shark species, identifying it as a research gap in the Marianas. Several of this study’s participants were also enlisted in the Hawai’i Institute of Marine Biology’s ongoing shark species identification project to DNA-swab depredated fish.

Participants noted that an important component of research is that it is considered useful and valid across stakeholder groups:

And that’s my fear is, ok, now... we’re going to fund shark studies in Guam. We’re going to deploy BRUVs, BotCams, all over Guam and we’re going to record the amount of sharks. But that’s not a shark study. That has nothing to do with what we were talking about. You know? It has nothing to do with a struggling fish at the end of the line. It has nothing to do with the interactions that we’re talking about. And then they’re going to use that data and say, “Oh, you fishermen are bullshit, you guys have been lying. We did the studies, we spent millions of dollars on these studies and you fishermen are wrong.”

Cooperative research was identified as one way to achieve collective recognition of research validity. This research documented willingness and interest from the fishing community to participate in such research efforts. As evidenced by the fishing community’s involvement in this project, fishers were eager to contribute their on-the-water experience and knowledge to research endeavors:

I just hope they put effort into it, and they invest some time, and money, and science to let us know what they’ve done.... You know, listen to the fishermen, right? And ask for help. And, you know, we’re saying what we know, what we experienced, and let’s go from there. That’s a good start.

It can’t be one sided. There’s a lot of people that are against the scientists, because they’re like, “Oh, all the information is wrong.” Well, let’s help them make the information right, you know?

Many participants went out of their way to contribute data to this project, rally their peers, and show appreciation that this work represents an effort to respond to their concerns:

The fishermen I feel are very grateful that you came. Your agency made time for you to come, and listen to the fishermen, take their story, and probably compile after you listen to all the fishermen in Guam, CNMI.

Economic fisheries support

Participants also discussed economic fisheries support as a solution component. Often discussions of economic support were in reference to food stamp programs and government subsidies that support local agriculture and fisheries:

Are there any programs available within the government itself, with the feds, helping out fishermen with destruction [to] their gear or their equipment? ... If these farmers can be given subsistence allowance for the pests that have been eating up their crops or the typhoons, how about fishermen, too? Can they be given some sort of a gift certificate, or something? ... So it doesn't have to be money going into our pockets, but money that we can use for the fishing tackle to purchase our supplies, to replenish what we've lost.

One CNMI fisher noted that a local food stamp program can be applied to the purchase of fishing supplies. Economic fisheries support would directly address the financial burden placed on fishers, and may also have potential to change fishers' shark-related attitudes:

If there's some federal program [to] indirectly subsidize the fishermen that are affected by sharks.... That's an idea.... It's just that it'll probably make fishermen more, I don't know, may change their mind about sharks.

Metrics of solution success

Discussions of solutions to the fisher-shark interaction “problem” sometimes touched on success metrics. In some cases, participants described a decrease in shark interactions or a return to some baseline:

An equal balance of sharks and fish.... It would be nice to fish a spot for a couple hours before a shark comes, and then go and move onto another spot, which was normal before.

Well, when the interaction is reduced down to 25 percent. I mean, that would be a sustainable yield, I mean sustainable level.... [Now] the chances of interaction I say would be 75 percent versus where it used to be 25 percent. Because 25 percent interaction is not so bad. Down to 10 percent would be perfect.

These metrics of success depend on reducing on-the-water impacts to fishers. Other participants focused on processes preceding the mitigation of on-the-water problems. They noted that success metrics might instead focus on researchers and managers validating fishers' experiences through dedicated funding or research efforts:

You have to put in the time, you have to put in the effort. What are they going to drop in this to tell us, “Yeah, you've got a shark problem.” We know, we're saying there's a problem.

The number one measurement is how much money is put into the study. That's the

number we got to look at. How many man hours and dollars spent... that is guaranteed, tangible.... Because you can never use an outcome as a measure.... We can say we learned a lot more, but shoot, we tried everything and they're still doing it.... The result you never know. We just don't want, "Oh, we came here for 2 days and we figured it out, that's it, we're done."

Although these metrics of success don't guarantee improved fishing experiences, they play an important role in addressing the socioeconomic and political contexts that frame the fisher-shark interaction problem. Multiple fishing participants expressed gratitude for this work in specific reference to its efforts to amplify fishers' voices and experiences. One fisher shared after viewing preliminary results videos, "I am extremely pleased that the fishermen are being able to be heard." Another fisher commented:

Thank you, for your services to the Island. Your clear expressed interest [in] what we value here on this side of the Globe is a way of life. We need all the help we can get and you have gone beyond the call of duty. We look forward to more assistance and guidance in the future.

IV. Discussion

Participants talked about sharks and shark-centric issues in diverse ways that varied by stakeholder group. Participants described sharks in negative, positive, and neutral ways depending on the impacts and benefits they yield to fishing communities and marine ecosystems (Table 2). Each stakeholder group, however, used negative, positive, and neutral descriptors in slightly different proportions (Figure 2; Table 2). Participants framed the “shark problem” through on-the-water impacts like loss of gear and catch, damaged equipment, safety risks, and fishers shifting fishing locations and investing more time while fishing (Figure 3). These translated to secondary impacts related to cost, effort, and CPUE, key inputs into stock assessments. Contextual dimensions of the “shark problem” included confusion around shark legislation, a lack of shark research in the Marianas, and concerns about sharks going to waste as a food resource. A breakdown of these problem framings by stakeholder group reveal that those with fishing experience emphasized on-the-water impacts more than those who do not. In contrast, researchers focused more on contextual issues and referenced the least number of different on-the-water impacts compared to all other groups (Figure 4). These perspectives surrounding sharks, both shared and unique across stakeholder groups, provide important insights for collective problem-solving. Shared perspectives provide a foundation upon which to build collaborative efforts, while unique perspectives may indicate points of disagreement that may need to be addressed for successful collaboration.

Participants described changes in shark abundance and behavior through time, referencing increasing shark numbers, aggression, responsiveness to fishing cues, prey diversity, and broadening shark distribution. Participants talked about decreasing fish abundance and size, shark finning bans, increases in fishing participation, and changes to FADs being potentially related to these changes. However, narratives of how these factors changed through time—particularly fish abundance and fishing participation—and how they affected shark populations were variable. Declines in fish abundance and size, for example, appeared to be associated with participants who fished consistently in a particular fishery (e.g., pelagic fish) for decades, or who were mentored by fishers with long-term experience. This suggests a shifting baseline and affirms the importance of including fishers with long-term experience, especially when quantitative baselines are lacking (Katikiro 2014; Bender et al. 2014).

Participants described reef and pelagic sharks to exhibit increasing aggression and signs of conditioning, which produce negative impacts to fishers. However, pelagic sharks were discussed more often using negative, problematic descriptors than were reef sharks. Coupled with a lack of pelagic shark research in the Marianas, this highlights an important research priority from both scientific and fishery impacts perspectives. Ongoing and future research may help us to understand Marianas’ shark populations and changes to shark abundance, especially for understudied pelagic sharks.

At present, however, one of the best available resources for historical shark-related trends comes from the fishing community and its observations of shark behavior. Including fisher knowledge and considering diverse stakeholder perspectives may help to identify points of agreement that serve as stepping stones in collaborative problem-solving. For example, the potential for shark habituation and conditioning around fishing activity may account for fishers’ and researchers’ divergent perspectives around shark abundance. Much of the research that documents shark

learning in response to various sensory stimuli is based on experimental research and observations conducted around tour operations (Guttridge et al. 2009; Mitchell et al. 2018a). Interestingly, experimental studies suggest that learned shark behavior can persist for several months, although conclusions were drawn from small sample sizes with low shark diversity (Guttridge et al. 2009). Uniquely, field studies in and around Australia's Ningaloo Marine Park documented sharks' faster arrival times to baited cameras in areas subject to regular fishing pressure as compared to no-take sanctuary zones (Schifiliti et al. 2014), and higher shark depredation rates in areas with greater fishing pressure Mitchell et al. (2018b). These observations align with participants' descriptions of faster arrival times and increased shark aggression, as well as some fishers' hypotheses that changing shark interactions are related to increases in fishing pressure. Structuring discussions around these specific observed changes to shark behavior and their tangible impacts to fisheries may be more productive and unifying as a short-term strategy, while actively addressing research gaps and establishing baselines for things like shark abundance will have critical value in the long-term.

This research also highlighted a number of issues not explicitly related to sharks that provide important context for the fisher-shark interaction problem. These included threats to fishery participation, fishers' role in the community, data validity and access, denying fishers' experiences, stakeholder disconnect, feelings of marginalization, and influence in management and research. Table 3 summarizes both the shark-centric and contextual issues relevant to fisher-shark interactions, and places these within the following problem categories: on-the-water, economic context, regulatory context, data and research, and political context. Fishers noted challenging socioeconomic conditions—like costly supplies, flooded markets, low fish prices, and the role of fishers in the wider community—that threaten fishers' sustained participation. These are exacerbated by fisher-shark interactions. Participants also highlighted various contextual issues related to political context, data, and research. Many of these connected back to feelings of marginalization and a lack of recognition for fishers' experiences by other stakeholders. For example, fishers perceived certain shark research endeavors to produce invalid results because their design and execution failed to consider key differences between researchers' and fishers' experiences (e.g., traditional fishing stimuli). As stakeholders navigate issues like these, they wield different types of power. For example, fishers may refuse to participate in cooperative research or otherwise withhold data from the scientific community. And, researchers and managers have greater influence over the allocation of resources to research and management foci or regions, and access to management decisions.

Fishers described a number of innovative on-the-water strategies to mitigate on-the-water impacts of shark interactions. However, changing shark behavior has made some of these strategies more costly and less effective through time. And fishers' on-the-water adaptations and techniques do not address the various contextual issues that derive from and are relevant to fisher-shark interactions. Various off-the-water solutions may be better equipped for this purpose (Table 5).

Many of the off-the-water solutions discussed by participants require the resources, capacity, or collaboration of researchers and managers. One such solution was shark population control, which was described in various ways: developing a market and demand for shark meat, organizing shark derbies, legalizing shark take, or agency-organized shark culling programs. An investment in shark research was identified as an important prerequisite to shark population

control, to identify species present and determine whether or not they are viable candidates for sustainable harvest. Other challenges to employing a shark population control strategy emerge as we consider the feasibility of landing a shark safely, to how shark meat would be received by consumers and historically oppositional voices from local and non-local NGOs and lobbyists.

Confusion between and within stakeholder groups around territorial and federal shark legislation also complicates shark harvest and use but may benefit from outreach efforts that build on our summary of relevant legislation (Table 4). We found that the commercialization of shark meat is allowed for sharks landed legally (e.g., with fins naturally attached) within federal waters (3–200 nm) and Guam’s territorial waters, but prohibited for sharks landed within the CNMI’s territorial waters. For the CNMI, it is possible that instead of providing legal clarification useful for outreach, these conclusions simply shift problematic focus to enforcement.

While this study highlights significant research gaps in Marianas shark research, it also documents opportunities to address them collaboratively. Fishers shared enthusiasm and took initiative to aid data collection for this project and expressed interest in aiding other cooperative research endeavors. A cooperative approach can add value to research by including stakeholders in the research process and establishing grounds for collective recognition of data validity (Hartley and Robertson 2006; Wendt and Starr 2009). It also has the potential to access a broader range of data by enlisting fishers’ knowledge. Cooperative research efforts will benefit from an approach that recognizes the value of both scientific and experiential knowledge (Hartley and Robertson 2006), and welcomes both conflict in and adaptation of stakeholder views (Søreng 2006). Collaborative approaches may also benefit from inclusion of affected stakeholder groups, facilitative capacity (Mease et al. 2018; Reed 2008; Vaughan and Caldwell 2015), face-to-face dialogue, and incremental successes that promote shared understanding (Ansell and Gash 2007). Executed properly, fisher-collaborative processes have potential to bridge stakeholder disconnect and mistrust, and address power differentials by acknowledging the experiences of fishers (Iwane 2019). And, depending on its focus, research may feed into other solution-relevant outcomes like novel on-the-water strategies for fishers, or sustainable, species-specific guidance around shark harvest.

Although several solutions have the potential to alleviate socioeconomic impacts to fishers by mitigating on-the-water impacts, economic fisheries support is the only solution that provides direct relief (Table 5). In its allocation of financial resources and managerial attention to the fishing community’s socioeconomic challenges, it also represents opportunities to reconcile power differentials and feelings of marginalization.

In its summary of the problem-solution relationships that emerged from stakeholder discussions, Table 5 makes clear that no single solution cross-cuts all dimensions of the fisher-shark interaction problem. Yet, stakeholders’ discussions of success metrics highlight the importance of solutions that mitigate both on-the-water and contextual issues related to fisher-shark interactions. The examples they provided to depict various problem dimensions often illustrated their inseparability. Thus, we suggest that efforts to address these multiple fisher-shark interaction problems employ a holistic approach, utilizing multiple solutions. The solutions documented in this study represent a foundation for this problem-solving effort rather than an exhaustive list of solutions.

Table 5. Stakeholder-discussed solutions and the problem dimensions they have potential to address.

SOLUTIONS	PROBLEMS				
	On-the-water	Socioeconomic context	Regulatory context	Data + research	Political context
On-the-water strategies	Loss of catch, gear, fishing time, safety risks	Fisher costs/ effort, alleviating threats to fisher participation			
Shark harvest/ population control	Shark abundance, loss of catch, gear, inefficient use of fishing time	“Wasted” shark; Fisher costs/ effort, alleviating threats to fisher participation;			
Cooperative research	Need for novel on-the-water strategies, shark research	Fisher costs/ effort, alleviating threats to fisher participation		Need for shark research, fisher perceptions of data validity	Mistrust, disconnect, and power differentials between stakeholders
Regulatory outreach			Confusion around legality of shark-handling practices/uses		
Economic fisheries support		Fisher costs, alleviating threats to fisher participation			Lack of recognition of fishers’ economic challenges, feelings of marginalization

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Appendix: Interview Guide

Background

- 1) Before we begin, do you have any questions for me?
- 2) Age/ethnicity
- 3) Please describe yourself/your relationship to the marine environment.
 - a) How long have you been fishing/living/working in the Marianas?
 - b) How did you get into _____?
 - c) What motivates you to _____? (e.g., fish, manage, etc.)
- 4) Fisher background
 - a) What kind of fishing do you do? (e.g., fishery)
 - b) How often do you fish? (e.g., days/yr)
 - c) Do you usually fish the same areas? Where?
 - d) Do you consider fishing a hobby/source of income/etc.?
- 5) Can you describe how you share fish with others? (e.g., who initiates, are goods exchanged)

Problems + Solutions

- 1) Can you describe the relationship between what you do and sharks in the Marianas? (e.g., sharks as part of fishing v. problematic)
 - a) What kinds of issues are important here? (e.g., low/high abundance, good/bad, conservation focus)
 - b) Why?
- 2) What could/should be done to address such issues?
 - a) Who is/should be responsible for addressing such issues?
 - b) What kinds of things make it difficult for _____ to take action?
- 3) Let's imagine that at some point in the future, this situation has improved or been resolved. What might that look like?
 - a) (OR) What kind of change would be satisfying for you?
- 4) Are there other groups of people that are interested in or affected by these issues?
 - a) How is their perspective similar/different from yours? Why?

Fisheries Interactions

- 1) Can you describe your experiences with sharks?
 - a) At what point in your fishing do you typically see/detect sharks?
 - i) Timing
 - ii) Depth
- 2) Can you describe the ways that sharks impact you/the community? (e.g., shutting down the bite, low est. CPUE, participation, fishing distance)
 - a) How often/how much of your catch is typically lost to sharks? (e.g., % catch)
 - i) How often/how much of your gear is typically lost to sharks?
 - ii) How has this changed through time?
 - iii) How does this change according to fishery?

- b) How else would you describe the economic impact that sharks have on your fishing?
 - c) Are there instances when you know a shark is around, but they don't bother you?
- 3) Are there certain types of sharks that are more abundant than others?
 - i) More problematic than others?
 - ii) How does this vary according to fishery?
- 4) Have you noticed that other factors affect the likelihood or nature of shark interactions? (e.g., abundance/frequency/behavior affected by location, prey availability, depth, season, conditions, etc.)
- 5) Throughout your years fishing in the Marianas, have you noticed any changes in your shark interactions? (e.g., abundance, learned behavior, depredated spp, shark spp)
 - a) Have these changes coincided with any other changes (in the fishery)? (e.g., jigging, chumming)
 - b) What (about fishing) do you think has changed sharks' behavior?
- 6) In Hawaii, people occasionally land and sell thresher and mako sharks. Is there any local consumption of sharks, at home or on the market?

Mitigation/Management

- 1) As you're thinking about where you're going to go fishing, how much do sharks factor into your decision-making?
 - a) If there are "secret spots" or less popular spots, do sharks behave differently there?
- 2) Have you found any helpful on-the-water strategies to lessen shark impacts to you? (e.g., gear, bait, avoidance)
 - a) What kinds of factors do you think about when deciding which option works best for you?
 - b) Are there other local strategies that differ from your own?
- 3) What about off the water?
 - a) Do you prepare for fishing differently now than you did before?
 - b) In everyday life, have you made other changes to mitigate the costs of shark impacts? Market challenges?
- 4) A common theme I've been hearing is that sharks are learning the sounds and strategies of local fisheries. Can you describe any steps you've taken to limit this learning process?
- 5) What shark-related policies are you aware of?
 - a) How have they affected you (if at all)?
 - b) Are there any management steps/tools you would like to see? (e.g., shark market)
- 6) Can you describe the kinds of experiences you've had with ... fishers / people in fisheries research / management?
 - a) Federal v. local agencies

Conclusions

- 1) Thinking again about groups whose observations or perspectives of sharks differ from yours—why do you think that is? (e.g., narratives of abundance)
- 2) Is there anyone you haven't already mentioned that I can contact to learn more about the things we've discussed?

- 3) Is there anything else you think people should know about the things we've discussed?
- 4) Do you have any questions for me?