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Perceived Challenges to Tribally Led Shellfish Toxin Testing in Southeast Alaska: Findings From Key Informant Interviews

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Key Points:
- This study assesses barriers faced by tribally led programming to reduce shellfish toxin exposure risks in Southeast Alaska
- Environmental managers interviewed emphasized the social origins of perceived barriers, particularly related to disinvestment
- Environmental managers observed that climate change impacts interacted with social and cultural factors to complicate risk management

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Abstract Shellfish harvesting is central to coastal Alaska Native ways of life, and tribes in Southeast Alaska are committed to preserving sustainable and safe access to subsistence foods. However, consumption of non-commercially harvested shellfish puts Alaska Native communities at elevated risk of exposure to shellfish toxins. To address a lack of state or federal toxin testing for subsistence and recreational harvesting, tribes across Southeast Alaska have formed their own toxin testing and ocean monitoring program. In this study, we interviewed environmental managers responsible for tribes' testing and others with shellfish toxin expertise to report on perceptions of barriers to tribally led testing in Southeast Alaska. Tribal staff identified 40 prospective key informants to interview, including all environmental managers responsible for shellfish toxin testing at subsistence sites in Southeast Alaska. All 40 individuals were invited to participate in an interview and 27 individuals were interviewed. The most frequently discussed barriers to shellfish toxin testing in Southeast Alaska relate to logistical and staffing difficulties associated with communities' remote locations, inconsistent and inadequate funding and funding structures that increase staff burdens, risk communication challenges related to conveying exposure risks while supporting subsistence harvesting, and implications of climate change-related shifts in toxin exposures for risk perception and risk communication. Participants stressed the social origins of perceived barriers. Disinvestment may create and sustain barriers and be most severely felt in Native communities and remote places. Climate change impacts may interact with social and cultural factors to further complicate risk management.

Plain Language Summary This article shares perceived barriers to tribally led shellfish toxin testing and education in Southeast Alaska. Data is from 27 interviews with participants with knowledge and experience in shellfish toxins and harvesting in Southeast Alaska, including environmental managers responsible for toxin testing activities at community sites across the region. Barriers to community-based risk management are context specific, and investigating barriers in Native communities and remote places that may face heightened barriers is crucial. Participants stressed the social origins of perceived barriers. Disinvestment may create and sustain barriers and be most severely felt in Native communities and remote places. Climate change impacts may interact with social and cultural factors to further complicate community-based risk management.

1. Introduction

1.1. Shellfish Toxin Risks in Southeast Alaska

Shellfish harvesting is an important traditional practice for many coastal Alaska Native communities. Harvesting shellfish supports cultural continuity and connection to land and offers health benefits (Kuhnlein & Receveur, 1996). However, subsistence shellfish harvesting also poses risks of exposure to harmful shellfish toxins. Due to subsistence harvesting, Alaska Natives face higher risks of paralytic shellfish poisoning (PSP) (Harley et al., 2020), which can cause dizziness, vomiting, nausea, temporary paralysis, and death (Gessner & Middaugh, 1995). Approximately 53% of PSP cases reported in Alaska between 1993 and 2021 were in Alaska Natives despite Alaska Natives only making up 16% of Alaska's population (Newell, 2022).

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Changes to toxin exposures related to environmental shifts alter risks for subsistence harvesters and stress the need for robust testing of toxin levels and sharing of toxin data (Roland et al., 2022). Shellfish toxins are produced by harmful algal blooms (HABs) of toxin producing phytoplankton, and higher water temperatures may increase HAB frequency, intensity, and duration (Gobler et al., 2017). While research has linked perceived global increases in HABs to improved monitoring (Hallegraeff et al., 2021), increases in bloom frequency in some regions have been identified, including in the North Pacific and Alaskan Arctic, where climate change-related processes are altering the frequency, magnitude, and geographic distribution of blooms and related toxin exposures (Anderson et al., 2021; Yan et al., 2020).

Alaska is the only coastal U.S. state that does not have a state-supported toxin testing program for subsistence and recreational harvesting. To fill this gap, a tribally led toxin testing network called Southeast Alaska Tribal Ocean Research (SEATOR) was created in 2014 to test shellfish from subsistence harvesting sites across the region. Tribal partners of the SEATOR network regularly collect shellfish samples from harvesting sites, encourage community members to send their own samples for testing, and share toxin data to inform harvesting decisions.

1.2. Barriers to Community-Based Risk Management

Community-based risk management activities like toxin testing in Southeast Alaska have common benefits and challenges. Programming can support communities' access to resources necessary for environmental protection and risk reduction, enhance data coverage and exposure monitoring and prediction, and increase local engagement and agency in environmental and health protection (Johnson et al., 2015; Wehn & Almomani, 2019). However, community-based risk management may face significant barriers to expansive programming, including difficulties building community trust and engagement and securing reliable funding (Danielsen et al., 2021; Johnson et al., 2015; Raška et al., 2022).

Barriers to community-based risk management frequently stem from disinvestment and abandonment, particularly in Native communities where institutional disempowerment and neglect is a common manifestation of legacies of genocide and cultural erasure (Herrmann, 2017). Modernity narratives that dismiss Indigenous knowledge, practices, and millennia of adaptation as inadequate compared to western science and market-based fixes negate the value of Indigenous-led, context-appropriate strategies and undermine risk responses, including approaches that integrate Indigenous knowledge and culture with western science (Flint et al., 2011; Gaillard, 2007). Such assessment also overlooks resilient and prosperous precolonial histories and the destructive and disempowering effects of colonialism (Hau'Ofa, 1995).

Remote, island communities, especially, may face a dual challenge of increasing risks from climate change and shrinking investments in services and infrastructure (Mitchell-Eaton, 2021). For small, rural tribes with extremely limited investment and financial resources, neglect may block abilities to benefit from environmental and health programming available to other communities (Szaboova et al., 2020). Policy may further compromise Native lifeways. For example, in Alaska, Federal Subsistence Board classifications of rurality that define all residents of designated areas as subsistence users and require the prioritization of subsistence needs over commercial and sporting needs do not include a Native priority (U.S. Department of the Interior Federal Subsistence Management Program, n.d.), which facilitates resource competition and weakens Native hunting, fishing, and harvesting traditions and rights (University of Alaska Fairbanks Department of Tribal Governance, n.d.).

As barriers and barriers' upstream drivers are context-specific, investigating challenges to community-based risk management in different settings is crucial, particularly in Native communities and remote places that may face heightened barriers. Research has called for scrutiny of adaptation barriers and sources of barriers in island communities (Lazrus, 2012), including variation in adaptation capacities between and within communities and social and environmental contexts shaping differences (Fernandes & Pinho, 2017). In this study, we identify perceived barriers to tribally led shellfish toxin testing and education in Southeast Alaska. Considering the emphasis on community participation and social and cultural linkages in community-based adaptation programming and on traditional language and culture in Native-led public health organizing (Danielsen et al., 2021; Hilgendorf et al., 2019; Spires et al., 2014), we pay particular attention to how Alaska Native culture underpins testing activities. In evaluating perceived barriers, we examine underlying social, economic, and political contexts and note areas where targeted investments and changes may enhance program robustness.

2. Methods

2.1. Research Team and Reflexivity

This study is a collaboration between researchers at the University of Alabama at Birmingham (UAB), the University of California, San Francisco (UCSF), and the Sitka Tribe of Alaska (STA). Authors are affiliated with UAB, UCSF, STA, SEATOR, and other universities. The community-academic partnership was initiated in 2016 when academic partners were invited to support the efforts of a tribe-educational system partnership in Sitka and a tribally led environmental monitoring program. The main goals and scope of the partnership's initial project, which includes this study, were developed during multiple site visits by Dr. Gribble to meet with STA staff and identify needs and opportunities. The partnership involves shellfish toxin testing and modeling, including support for SEATOR's technical and financial capacity to conduct tests, and new culturally appropriate, tribally informed K-12 educational interventions to promote cultural literacy, environmental literacy, and awareness of STA resources to reduce shellfish poisoning risks. This work is community co-led and participatory (Key et al., 2019). Research occurring within the partnership is tailored to provide actionable, useful information for communities of Southeast Alaska and includes STA at every stage. Interviews were conducted by three members of the research team with academic and STA affiliations. Several members of the research team have professional relationships with participants and were familiar to participants. This familiarity was necessary to identify prospective key informants. This research was approved as exempt human subjects research by the University of Alabama at Birmingham Institutional Review Board. See Appendix A for a full checklist of consolidated criteria for reporting qualitative studies (COREQ) (Tong et al., 2007).

2.2. Study Design

Prospective participants were environmental managers responsible for tribes' toxin testing and others with shellfish toxin expertise invited to attend the Southeast Environmental Conference hosted by the Central Council of the Tlingit and Haida Indian Tribes of Alaska and STA from 29 August 2022 to 2 September 2022. SEATOR-affiliated staff on the research team identified 40 prospective participants with knowledge and experience in shellfish harvesting, shellfish toxins, and related topics, including all environmental managers responsible for toxin testing activities at community sites in Southeast Alaska. All prospective participants were invited via email to participate in an interview. From this group, the research team conducted 27 interviews, 25 interviews during the Southeast Environmental Conference and two via Zoom in the weeks following the conference with environmental managers unable to attend.

The 27 participants were approximately gender split (15 women, 12 men), ranged in age from 21 to 57 years (mean: 36 years), and were majority white identifying (18 identified as white, 2 as Hispanic, and 9 as Native, of which 8 identified as Alaska Native). The lab staff responsible for toxin testing is largely white identifying. Most participants had lived in Alaska for many years: 21 participants reported living in Alaska for more than 5 years (mean: 16 years). 20 participants were affiliated with SEATOR, mostly as environmental managers responsible for toxin testing activities in communities across Southeast Alaska. The remaining participants offered other valuable perspectives (e.g., experts in shellfish toxin risks).

The interview protocol was developed collaboratively by members of the author team with academic, SEATOR, and STA affiliations. Interviewers followed a semi-structured interview format, where questions were asked from a protocol, with follow-up questions. The protocol was divided into three sections that included five-point Likert scale questions and open-ended responses with follow-up questions. The first section examined participant and community perceptions of shellfish harvesting, associated risks, and toxin testing. Open-ended questions included: What do you think individuals in your community know about shellfish toxins? How do you think individuals in your community perceive shellfish toxin testing? The second section examined perceptions of the state of toxin testing in participants' communities, including testing frequency, data management, and risk communication. Open-ended questions included: Can you describe the toxin testing that you do? How do you share data? The third section examined perceived barriers and facilitators to shellfish toxin testing. Open-ended questions included: What barriers do you face to robust toxin testing? What factors make toxin testing easier? The protocol was pilot tested with STA staff and SEATOR members not part of the research team and not invited to participate in interviews.

2.3. Analysis and Findings

Analysis focused on open-ended response, which contextualized summary perceptions conveyed in Likert scale responses, presented in Table 1. Interview audio recordings were transcribed and cleaned using Otter.ai transcription software and reviewed for quality control. Members of the research team who conducted interviews worked collaboratively to identify codes based on major themes. Data was thematically coded and analyzed using Dedoose software. Each interview was coded by a minimum of two coders.

3. Results

3.1. Perceptions of Shellfish Harvesting Practices

Before describing perceived barriers to tribally led toxin testing, we share participants' observations of community shellfish toxin risk perceptions and harvesting practices to contextualize observed barriers. Summary perceptions from Likert scale responses to the first two sections of questions on participant and community perceptions of shellfish harvesting, associated risks, and toxin testing and perceptions of the state of testing indicate high levels of concern about toxins, confidence in testing and education to reduce risks, a sense that testing can be enhanced, and differences between participant sentiment and participants' perceptions of community sentiment related to risks posed by toxins and confidence in risk reduction. When asked about shellfish harvesting practices in their communities, all participants agreed that many members of their community harvest shellfish. However, participants noted that regular harvesting tended to be limited to a "handful of folks" and observed wide variation in popularity, particularly between rural and urban communities. While participants agreed somewhat that members of their community perceive shellfish toxins as dangerous, participants also described the breadth of perceptions of shellfish toxin risks and harvesting behaviors: "You have polar opposites in this region, of people who heavily rely on it, and other people that will not touch it anymore because they are afraid or haven't ever done it." (Participant 26). Participants explained that shellfish harvesting is more common in smaller and rural communities because cultural traditions are stronger and store-bought foods less accessible. Community buy-in for toxin testing appears robust. 22 of the 27 participants felt that members of their communities viewed testing as important for health and safety.

Participants noted several reasons why members of their community harvested shellfish, the most common of which was connection to land and culture (24 of the 27 participants). In describing the cultural significance of shellfish harvesting, participants stressed social benefits and wanting to share the tradition with children:

> *We grew up on beaches, we learned to harvest from beaches. That's our food source and it's something we enjoy doing. I grew up harvesting clams as a child. We would go out with my dad every winter. It'd be blowing, pouring down rain. We would go dig butter clams and then we'd have a big clam bake, and it was a lot of fun and it was great. So, these are things that we want to be beneficial to our community again. We want people to take their children out to go clam digging and enjoy eating a food that is good for them that they can also easily harvest themselves.* (Participant 8)

> *Just gathering and enjoying, laughing, and making it an event. That's another great benefit. And that also falls into the cultural practice of sharing. Sharing the knowledge, teaching the young ones this process that's been passed down to them.* (Participant 22)

Participants tied community aspects of harvesting to the cultural significance of gathering and sharing food, noting that harvesting shellfish and clam bakes support cultural continuity and offer socialization opportunities. Participants also commented on the physical benefits of shellfish harvesting and consuming this "nutritious, unprocessed food," and, observing common struggles with high food costs and limited access to healthy foods, food security benefits (11 of the 27 participants). According to participants, reductions in subsistence shellfish harvesting may remove an important local food source and lead to cultural loss for current and future generations, with direct mental health impacts. As one participant described effects of reduced subsistence harvesting, "If you think about having this tradition that you've practiced in your family for generations now being lost, that really has an impact on someone's health and wellbeing." (Participant 27).

Participants emphasized that fears of PSP toxins appeared most influential in discouraging shellfish harvesting (15 of the 27 participants). Observing high profile cases of PSP in Southeast Alaska, participants reported that

Table 1
Mean Participant Responses to Likert Scale Questions and Histograms of Response Distributions

How much do the following statements reflect your perceptions of subsistence shellfish harvesting, shellfish toxins, and shellfish toxin testing? (1: disagree strongly; 2: disagree somewhat; 3: neither agree nor disagree; 4: agree somewhat; 5: agree strongly)	
1. I think shellfish toxin education can reduce risks	4.9
2. I think shellfish toxins are dangerous to human health	4.9
3. I think shellfish toxin testing can reduce risks	4.8
4. I think shellfish toxins pose a risk to my community	4.8
5. I think shellfish toxin risks can be mitigated	4.5
6. Many members of my community engage in subsistence shellfish harvesting	4.3
7. Many members of my community perceive shellfish toxins as dangerous to human health	4.0
8. Many members of my community believe that shellfish toxin risks can be mitigated	3.8
9. I encourage members of my community to harvest shellfish	3.3
10. I encourage my friends and family to harvest shellfish	3.0
11. I harvest my own shellfish regularly	2.6
How much do the following statements reflect your perceptions of shellfish toxin testing in your community? (1: disagree strongly; 2: disagree somewhat; 3: neither agree nor disagree; 4: agree somewhat; 5: agree strongly)	
1. We test for toxins frequently	3.9
2. Our toxin testing activities are comprehensive in ensuring community safety	3.8
3. Our toxin testing activities face significant barriers to comprehensive toxin tracking (i.e., many sites tested, frequent testing, etc.)	3.7
4. Many members of my community use our toxin testing resources	3.5
5. We test for toxins at many sites	3.4
6. Our toxin testing activities have improved in recent years	3.4
How influential are the following factors as barriers to shellfish toxin testing? (1: not at all influential; 2: slightly influential; 3: moderately influential; 4: very influential; 5: extremely influential)	
1. Limited staffing	3.6
2. Limited funding	3.3
3. Limited community participation in activities	3.1
4. Slow speed of toxin testing results	3.0
5. Limited access to necessary supplies	3.0
6. Limited support from government agencies or other partners	2.9
7. Limited community awareness about activities	2.9
8. Limited training capacities	2.5
How influential are the following factors in facilitating shellfish toxin testing? (1: not at all influential; 2: slightly influential; 3: moderately influential; 4: very influential; 5: extremely influential)	
1. The SEATOR partnership	4.8
2. Support from government agencies or other partners	3.8
3. Community awareness about activities	3.6
4. Community participation in activities	3.4

poisoning fears had led some residents to stop harvesting and to not introduce their children to harvesting. In communities where toxin testing is more consistent, participants reported that greater data coverage contributed to greater community awareness and involvement in activities, including community members checking toxin levels and submitting samples for testing. These behaviors may increase confidence that harvested shellfish are toxin free and encourage harvesting. However, participants also described testing-related risk communication discouraging harvesting: "They see all these warnings against eating shellfish, and it completely puts them off from harvesting, which I don't think is necessary." (Participant 27). To mitigate these community responses, participants stressed the importance of risk communication that balances time, place, and species-specific warnings with information on risk reduction strategies and benefits of harvesting.

3.2. Perceived Barriers to Shellfish Toxin Testing

According to participants' Likert scale responses, influential barriers to toxin testing include staffing, funding, and access to materials. Participants' open-ended responses offer scrutiny into where and how perceived shortcomings arise, particularly commonly observed barriers' links to wider social and economic forces and new environmental pressures.

3.2.1. Remoteness

In describing perceived challenges to toxin testing, participants emphasized logistical difficulties associated with communities' remote locations (25 of the 27 participants). Most Southeast Alaska communities are only accessible by plane or boat, with limited road connectivity. Sending and receiving shellfish samples for testing requires SEATOR partners to ship perishable samples of recently harvested shellfish by plane to the only laboratory in Southeast Alaska that tests shellfish toxins at subsistence harvesting locations: the STA Environmental Research Laboratory (STAERL) in Sitka. Samples must remain refrigerated and shipped quickly for testing to occur, and toxin concentrations must be reported within a short enough timeframe for results to reflect recent toxin levels. Toxin concentrations can change rapidly, and week-old data or older is considered less useful for harvesters (STAERL follows FDA guidelines for data accuracy and public safety; seven days from sample collection is the FDA limit). As one participant observed, "Every day that goes by [means] those results are less meaningful." (Participant 2). Delays in shipping and subsequent delays in results can discourage residents from checking toxin levels and deter harvesting.

According to participants, logistical challenges related to remoteness also manifest within communities (16 of the 27 participants). Difficulty collecting shellfish samples may particularly frustrate testing efforts in more rural communities. Poor roads, no roads, and limited vehicle and boat availability reduce staff abilities to regularly collect samples and reduce testing frequency and the number of sites tested. Participants reported that some sites near communities that were frequented by harvesters were not regularly tested due to sites' inaccessibility:

> *Going off the road system to get to the sites that are actually utilized is problematic. So, we have to extrapolate from what's going on in our area to a nearby area, but conditions could be quite different over even a short distance.* (Participant 3)

> *If we had a boat, we would probably be testing many more sites, just so that we can get a better picture instead of relying on the sole, one site where there's two rivers pumping fresh water, and with kind of strange salinities. And it's not very representative. But that's the only place that we can access.* (Participant 18)

Participants also stressed that substantial staff time was required to collect shellfish samples, particularly from more remote sites. Emphasizing staffing and funding shortages, participants commented that sampling from these sites was often not feasible: "There's a limit on staff time, funding availability, to get out to those places." (Participant 10).

Location may also be a barrier to hiring and keeping staff. Participants stressed staffing challenges across Southeast Alaska, but particularly in remote communities (24 of the 27 participants). Participants identified housing shortages, social isolation, and low pay coupled with high costs of living as location-related barriers to recruiting and keeping staff. As one participant described the situation, "There are openings and difficulties filling positions, but especially in a very rural community, if there's not accessible housing. And you're going to be very isolated. It's hard to find people.” (Participant 17). According to participants, high staff turnover reduces testing capacities and undermines consistent risk communication. Participants described how turnover among sampling staff had reduced sample collection capabilities and decreased communities' testing frequencies and how turnover among testing staff had created communication breaks between lab staff and communities. As one participant described effects of staffing changes on testing, “In [Southeast Community], they did a lot of testing. Now they don't even have anyone in those positions and so there's just not going to be, I imagine they're not testing.” (Participant 5). Participants further commented that few training opportunities and difficulty attending opportunities exacerbated knowledge gaps associated with high staff turnover.

3.2.2. Risk Communication

Participants highlighted several risk communication challenges, including gaining and maintaining community trust and engagement and communicating toxin risks without discouraging harvesting altogether (17 of the 27 participants). Observing that awareness of toxin risks may affect harvesting behaviors, participants felt that community members knew enough about toxin risks to be concerned but not enough to know the nuance of risks and how risks might be mitigated:

> *I think their awareness of PSP shellfish toxins in mussels definitely reduces the amount of subsistence mussel harvesting that happens. People are just too scared.* (Participant 6)

> *There’s some knowledge out there, but it’s more in the realm of rumor or hearsay, like, just enough information to scare people a little bit and make them concerned, but not enough information to really be educated on the real risks and how to mitigate.* (Participant 2)

According to participants, differences in shellfish toxicity between shellfish species further complicate community understandings of risk and risk communication challenges:

> *When it comes to PSP, I think that one of the big issues is understanding that there are multiple different species of shellfish, and different species of shellfish react differently to the toxin and hold onto it longer or get rid of it faster. And I think that is where a lot of confusion and nuance comes in.* (Participant 25)

Participants reported that youth education had increased understandings of shellfish toxin risks but stressed that Sitka was the only community with shellfish-related programming in elementary, middle, and high school despite what they felt was strong need in smaller communities (13 of the 27 participants).

Breaks in testing and slow testing turnaround also affect risk communication. Radiolabeled saxitoxin is required as a laboratory standard for testing at STAERL, and supply chain issues related to the COVID-19 pandemic created a global shortage that halted testing in Southeast Alaska. While saxitoxin standard is available again, and STAERL has resumed testing, participants observed that the lapse in testing meant that the SEATOR network had to change its risk communication to discourage harvesting altogether:

> *This last year or so with the SEATOR network not being able to test shellfish on a regular basis, that really put a hinder on any of the sampling that we were doing. And the information that we were putting out to people was basically, just don't harvest right now.* (Participant 8)

According to participants, the break in testing only a few years after the program began damaged trust with communities and led to behavior changes in shellfish consumption and harvesting, including residents no longer testing shellfish for toxins or discontinuing harvesting altogether:

> *He always was giving me cockles to send out because his wife really enjoys eating cockles, but we couldn’t send them out anymore. And so, pretty soon, he got tired of me saying, I’m sorry, if I send these it’s going to be anywhere from one to three months before I’ll get you results. And he didn’t want to keep them in his freezer for that long. So, he just quit calling.* (Participant 8)

> *In the last year, since we haven’t been able to do toxin testing, there have been a number of community members who harvest their shellfish, tested regularly, who were really disappointed to see that that wasn’t there anymore. They were finally able to start harvesting and eating shellfish*

> *regularly again, and now that we're not able to provide that service, they are just no longer harvesting.* (Participant 27)

> *Many people are not willing to wait that long with an unknown timeline [for toxin testing to resume]. And a lot of people have just resorted to not eating shellfish because of it [the break in toxin testing related to saxitoxin shortage].* (Participant 20)

Participants stressed that these behavior changes demonstrated that community trust can be easily damaged by delays and inconsistencies in toxin testing and reporting.

3.2.3. Growth-Driven Funding

Participants reported inconsistent support for toxin testing and consequent uncertainty in programming (18 of the 27 participants). Funding for toxin testing and education in Southeast Alaska is entirely grant-supported, which means that support is not permanent and sustained testing requires continued funding renewal and new sources of funds. According to participants, securing new funds requires programs to continually expand to justify further support: "The nature of funding programs wanting to fund not continuous work but always something new is an absolute barrier." (Participant 26). This program survival-necessitated growth and associated new funding requirements may increase workloads and overstretch limited staff. Participants expressed feeling overburdened by grant-required activities and observed that work pressures contributed to high staff turnover and decreased capacities to test for toxins:

> *We have 13 grants between three people. So, I get pulled away from this [shellfish toxin testing activities] a lot.* (Participant 14)

> *We wear many hats. So, just finding the time to do that [collect shellfish samples for testing] is a bit of a juggle. That's one of the reasons why we weren't able to do so many [sample collections] per month.* (Participant 22)

Access to funding is not equal across Southeast Alaska. Participants reported that smaller communities with fewer staff available to support major funding applications and large grant operations received less funding, were less able to maintain robust toxin testing activities, and did not have as expansive, or any, toxin education programming.

3.2.4. SEATOR Network Support

According to participants, the SEATOR network increased support for programs, provided an infrastructure for tribes to assist each other with testing, made testing easier and more consistent across communities, and facilitated an increase in data coverage and data sharing (20 of the 27 participants). Rather than communities competing for small pools of funds, participants observed that the SEATOR network had enabled communities to apply for large grants together. As a result of these funds, participants noted support for staff salaries and greatly increased testing capacities:

> *If we were just testing for the Sitka Tribe of Alaska [rather than for all tribes in the SEATOR network], if we didn't have SEATOR, I don't think we could establish the level of support and funding to be able to have the lab to begin with. So, the partnerships are pretty critical.* (Participant 2)

> *If we didn't have them [large, external grant support], we wouldn't have this [the testing program]. Without them, a big portion of jobs wouldn't exist. That outreach and knowledge, I wouldn't have.* (Participant 13)

Participants also emphasized SEATOR's role as a hub for compiling and sharing data, which has facilitated communities' increased understanding of local and regional shellfish toxin risks:

> *I think they [the SEATOR network] are pretty important. In terms of publishing our information and making sure that the information is getting into broader datasets, because the information we're gathering could be used to perfect some of the machine learning and models that are being*

> *utilized in terms of climate change and tracking harmful algal blooms and their impact on shellfish, as well as just putting together those trend maps of looking for, regionally, what's happening with shellfish.* (Participant 10)

Observing that SEATOR had made toxin testing newly feasible for small communities, participants called for further expansion:

> *Being able to continue to build different partnerships with all the different tribes so that we all know the data that we have, we all know what's going on with them [shellfish toxins], and being able to keep these updates going, will help to ensure that these barriers start becoming less and less.* (Participant 8)

3.2.5. Shifting Toxin Exposures

Many participants perceived that increasing water temperatures and pollution had driven changes in toxin exposures in Southeast Alaska and expanded toxin exposure windows (15 of the 27 participants). Participants from more southern communities especially observed that warming waters had made HABs and related toxin exposures a year-round risk when, previously, blooms had occurred primarily in spring and summer: "Things are changing…we find PSTs [paralytic shellfish toxins] in our shellfish pretty much year-round at this point. So, it's just a matter of how much." (Participant 13). In addition to new toxin exposures in fall and winter, participants reported that increasing water temperatures had created larger blooms and higher PSP toxin levels within the traditional spring and summer "bloom season:" "There certainly is a trend toward having a longer season where PSTs are accumulating in shellfish. And so, there's harmful algal blooms happening earlier. And then they are more intense, and they are lasting longer." (Participant 10). Participants stressed that shifts in exposures increased risks to public health and that toxin testing data was crucial to predicting trends and understanding new risks:

> *It [toxin testing] gives us an idea of trends. And having that consistent collection, even if the levels are not high, gives us a chance to see trends and patterns. So that's useful information. It gives us a little bit more predictive [capacity], the ability to make wiser decisions about whether it's safe to harvest or not.* (Participant 3)

In addition to climate change-related concerns, participants reported that growing pollution in the region increased risks from harmful chemicals and shellfish toxins besides PSP toxins, such as domoic acid and okadaic acid, and commented that these new exposures required a wider testing panel.

Shifting toxin exposures may reduce the reliability of traditional knowledge that subsistence harvesters have relied on for millennia. According to participants, confidence in traditional knowledge, particularly related to safe harvesting seasons, may give harvesters a false sense of security that their shellfish are toxin free and combine with new climate change-related exposures to contribute to disparities in poisonings:

> *People just say, "you know, we've been harvesting at this beach for generations, and we've never been sick, I've never known anybody to be sick." And to just kind of downplay or dismiss the risks…especially more in the Native community, just because they do have that cultural connection.* (Participant 2)

> *Due to climate change, their traditional knowledge isn't helping them out anymore. People were getting sick, people were dying, and the vast majority of the people that were dying and are getting sick were tribal.* (Participant 1)

Participants commented that enduring trust in traditional knowledge may undermine community participation in risk reduction activities, including checking toxin levels and sending samples for testing. As one participant described possible effects of these beliefs, "They might also be a little less willing to provide samples because they've gone this long without having a problem." (Participant 10).

Participants observed that new and shifting exposures may also exacerbate logistical, communication, and funding challenges. Communities may need to test additional sites, increase testing frequency, and share new risks with the public. These changes may strain testing protocols, raise issues of data confidence, and undermine trust in testing.

4. Discussion

This study reports on the perceptions of environmental managers involved in shellfish toxin testing in Southeast Alaska as well as others with shellfish toxin expertise. Participants stressed the social origins of perceived barriers to toxin testing in Southeast Alaska, including logistical and staffing difficulties associated with communities' remote locations, inconsistent and inadequate funding and funding structures that increase staff burdens, risk communication challenges related to conveying exposure risks while supporting subsistence harvesting, and effects of climate change-related shifts in toxin exposures on risk perception and risk communication.

In discussing perceived barriers related to living in remote communities, participants emphasized structural factors, including high costs of living and a housing affordability crisis. Other research in Indigenous communities observes similar economic stress and related disinvestment driving acute impacts from climate change (Gaillard, 2007; Maldonado et al., 2013). Remote and island communities may also face especially severe environmental effects on livelihoods, difficult and expensive transportation, and limited access to essential goods and services (Kim & Bui, 2019; Roland, 2023, 2024), the consequence of national climate change adaptation and development priorities overlooking the needs of these communities (Duvat et al., 2017; Malatesta & Di Friedberg, 2017; P. D. Nunn et al., 2014). A focus on this disinvestment is important as island communities are not inherently or inevitably vulnerable despite island stereotypes that frequently drive perceptions of island vulnerability (Kelman, 2020). Indigenous and island populations have long histories of adaptation (Gaillard, 2007; Maldonado et al., 2013; Simpson, 2017) and maintain resilience-supporting sustainable livelihoods, strong traditions and identities, and close social networks (Hovgaard, 2002; Kelman, 2007).

Continuous financial and technical support is needed for community-based adaptation to be successful (Jarillo & Barnett, 2021). However, a lack of secure and sustained funding constrains tribes' risk reduction and adaptive capacities and may reflect broader neglect of Indigenous communities, particularly smaller and more remote Indigenous communities (Mitchell-Eaton, 2021). Observed funding challenges also suggest a grant industrial complex that disadvantages small communities and communities that are not already well-resourced (Smyth, 2023). Organizational development research reveals how funding pressures can limit programmatic capacities and influence the direction of community-driven environmental and public health science. Frequent funding applications and heavy monitoring and reporting requirements may draw substantial staff time and overshadow mission-related work, especially in small communities and organizations with few staff (Bonnell & Koontz, 2007; Chaffin et al., 2015; Nikolic & Koontz, 2008). As the goals of community-driven science may not align with state and federal agencies' priorities, funding needs may also prompt shifts in organizational focus, adding new tasks while creating gaps in other areas (McKinley et al., 2017; Nikolic & Koontz, 2008). In the case of community-academic partnerships and related funding streams, outcomes and timelines important to researchers (e.g., publications, novel research questions) may not always align with outcomes and timelines important to community members (e.g., tangible reductions in community risk) (Cook et al., 2013). While participants in this study noted each of these issues, particularly their prominence in smaller communities with fewer staff and resources, participants observed that the creation of the SEATOR network had enabled communities to pool resources, collaborate on funding applications, and better manage administrative burdens. Building similar coalitions in support of other Indigenous and rural community science initiatives might help address common funding challenges.

Effective shellfish toxin risk communication requires conveying both poisoning risks and the value of subsistence harvesting. However, declines in traditional harvesting practices across species in Alaska, diets increasingly reliant on heavily processed and expensive imported foods, and shifts in toxin exposures related to climate change may contribute to knowledge loss and complicate messaging. Similar to shellfish toxin testing in other contexts (Sordo et al., 2023), limited awareness of toxin risks undermines community engagement. However, also similar to other community-based adaptation programs (Danielsen et al., 2021; Spires et al., 2014; Wehn & Almomani, 2019), social and cultural factors that emphasize community participation and cultural meaning may enhance buy-in and harvesters' sense of agency in managing toxin risks.

Research in remote and island communities finds that traditional knowledge and close social networks in these communities create opportunities for effective locally driven and culturally grounded adaptation that increases self-sufficiency and limits external demands (Malatesta & Di Friedberg, 2017; McNamara et al., 2020; P. Nunn & Kumar, 2018; Sovacool, 2012). The experiences of community-led shellfish toxin testing and education activities in Southeast Alaska point to several recommendations to leverage community strengths and increase program impact. Centering Native culture and promoting traditional practices and diets in messaging and educational programming may increase community awareness of risks and engagement in activities. In the case of shellfish toxin testing specifically, risk reduction strategies might target more remote communities where toxin exposure risks are greater due to more widespread harvesting yet that receive less programmatic, financial, and technical support for risk reduction and health promotion. Common structural barriers in remote communities such as high costs of living may be addressed via targeted investments in transportation infrastructure, affordable housing, and essential goods and services (Macaulay et al., 2021). Changes to environmental policy such as the establishment of marine protected areas may also influence social and environmental contexts to improve human health (Haque et al., 2023).

As several members of the author team are affiliated with SEATOR, members of the author team were familiar with participants and were interested in the study's policy relevance and actionability. Perspectives on subsistence shellfish harvesting practices and toxin risks, testing, and education may be expanded in future research to include community members who frequently harvest shellfish, particularly individuals from smaller and more remote communities that this study identified as especially susceptible to toxin exposures.

Appendix A: Consolidated Criteria for Reporting Qualitative Studies (COREQ) Checklist

Table A1 provides additional information related to the research team, research methods, study context, analysis, findings, and interpretation.

Table A1
Consolidated Criteria for Reporting Qualitative Studies (COREQ) Checklist

Domain 1: Research team and reflexivity	
Personal Characteristics	
Researcher name, credentials, gender, Native affiliation, occupation, and experience and training	Interviewers
	Hugh B. Roland, PhD
	Identifies male
	No Native affiliation
	Postdoctoral Fellow
	Environmental sociologist with training in qualitative research methods and experience in community-based participatory research
	Jacob Kohlhoff, BS
	Identifies male
	No Native affiliation
	Environmental Education Coordinator
	Trained in relevant qualitative research techniques by Hugh Roland
	Sneha Hoysala, MPH
	Identifies female
	No Native affiliation
	Master of Public Health student during research activities
	Trained in relevant qualitative research techniques by Hugh Roland
	Non-Interviewers
	Kari Lanphier, MS
	Identifies female
	Kānaka
	Environmental Program Manager
	Expertise in harmful algal blooms, shellfish toxin analysis, community program management, and shellfish toxin risk communication

Table A1
Continued

Domain 1: Research team and reflexivity	
	Esther G. Kennedy
	Identifies female
	No Native affiliation
	Environmental Specialist and SEATOR Project Manager
	Expertise in harmful algal blooms and community program support
	Christopher Whitehead
	Identifies male
	No Native affiliation
	Environmental Program Manager
	Expertise in harmful algal blooms, shellfish biology, community program development, and project design
	Matthew O. Gribble, PhD
	Identifies male
	No Native affiliation
	Associate Professor
	Environmental epidemiologist with experience in community-based participatory research
	John Harley, PhD
	Identifies male
	No Native affiliation
	Assistant Research Professor
	Environmental toxicologist with experience in harmful algal bloom modeling and toxin dynamics in shellfish
Relationship with Participants	
Relationship established	Several members of the research team have professional relationships with participants and were familiar to participants. This familiarity was unavoidable in this small professional community and necessary to identify prospective key informants
Participant knowledge of the interviewer	Participants were informed of the research rationale when invited to participate and prior to the start of interviews
Interviewer characteristics	As several members of the author team are affiliated with STA or SEATOR, the research team is interested in the direct policy relevance of this research
Domain 2: Study design	
Theoretical framework	
Methodological orientation and Theory	Thematic analysis was used to analyze qualitative data
Participant selection	
Sampling	Purposive sampling was used by SEATOR affiliated members of the research team to identify prospective key informants. Prospective participants were environmental managers responsible for tribes' toxin testing and others with shellfish toxin expertise invited to attend the Southeast Environmental Conference hosted by the Central Council of the Tlingit and Haida Indian Tribes of Southeast Alaska and STA from 29 August 2022 to 2 September 2022. 40 prospective participants were identified, including all environmental managers responsible for shellfish toxin testing at subsistence sites in Southeast Alaska
Method of approach	Participants were invited to participate via email
Sample size	27 participants were interviewed in the study
Non-participation	13 participants either chose not to participate or could not participate because of scheduling conflicts

Table A1
Continued

Domain 1: Research team and reflexivity	
Setting	
Setting of data collection	In-person interviews were conducted in a private or semi-private setting in the same building as the Southeast Environmental Conference. Interviews with participants unable to attend the conference were conducted via Zoom
Presence of non-participants	No one was present during interviews besides participant and interviewer
Description of sample	The sample consisted of environmental managers responsible for tribes' shellfish toxin testing and others with shellfish toxin expertise invited to attend the Southeast Environmental Conference hosted by the Central Council of the Tlingit and Haida Indian Tribes of Southeast Alaska and STA from 29 August 2022 to 2 September 2022
Data collection	
Interview guide	Interviewers used a semi-structured interview format, where questions were asked from an interview protocol, with follow-up questions. Questions were organized into several sections: background demographic information, perceptions of the importance of shellfish toxin testing and education, the state of shellfish toxin testing, and barriers and facilitators to toxin testing. The protocol was pilot tested with STA staff and SEATOR members not included in the research team and not invited to participate in interviews
Repeat interviews	No repeat interviews were carried out
Audio/visual recording	Interviews were audio recorded
Field notes	Interviewers made field notes during and after interviews to note relevant contexts and identify emerging themes.
Duration	Interviews lasted from 30 min to 1 hr.
Data saturation	Data saturation considerations did not determine the end of interview conduct. Interviews were conducted with all available identified prospective participants. Following data collection, interviewers agreed that data saturation had been met
Transcripts returned	Transcripts were not returned to participants
Domain 3: Analysis and findings	
Data analysis	
Number of data coders	The three interviewers coded data. Each interview was coded by a minimum of two coders
Description of the coding tree	Parent codes included shellfish harvesting practices, reasons why people harvest, reasons why people don't harvest, PSP risk perception, toxin exposures, PSP in the community, toxin testing, strengths of toxin testing programs, challenges to toxin testing programs, community engagement, partnerships, and program suggestions
Derivation of themes	Themes were derived from the data
Software	Data analysis was conducted using Dedoose software
Participant checking	Participants did not review findings. SEATOR and STA affiliated members of the research team were involved in data analysis and provided feedback on findings
Reporting	
Quotations presented	Participant quotations are used frequently to illustrate themes and findings. Each quotation is identified with a participant number
Data and findings consistent	Participant quotations illustrate consistency between data and findings
Clarity of major themes	Results and discussion are organized by major themes
Clarity of minor themes	Heterogeneity in the data and minor themes are noted where appropriate

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

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