North Pacific Research Board Project Final Report

Diverse knowledge systems for the examination of localized dynamics of sea otters and abalone populations in Sitka Sound, Alaska[1]

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ABSTRACT

In Southeast Alaska, re-established Northern sea otter (*Enhydra lutris kenyoni*) populations have cascading effects on ecosystems, communities, and marine resources. While regional scale studies provide valuable insights into patterns of these effects, the impacts of otter establishment at finer scales are less predictable. Intermittently monitored sea otter populations expand into sub-regional areas with different and, at times, undocumented histories of commercial, subsistence, traditional, and customary harvest of otter prey items like pinto abalone (*Haliotis kamtschatkana*). Limited area-specific information on harvested pinto abalone populations and infrequent records of local otter occupation, abundance, movement, and hunting patterns constrain Western scientific attempts to untangle interactions between community subsistence and target species at the local scales most relevant to harvesters. This is the basis for the NPRB Human Dimensions Project #2115: "Diverse knowledge systems for the examination of localized dynamics of sea otter and abalone populations in Sitka Sound, Alaska." Developed with the support of the Sitka Tribe of Alaska, the project couples available quantitative data on abalone and otters with information from local individuals with a history of commercial abalone harvest, subsistence harvest, experience as tour guides or divers, and from Alaska Natives, with expertise and knowledge of local refined harvest and hunting practices. Interviews and mapping exercises paired with quantitative survey data provided a higher-resolution understanding of dynamic local trends following abalone harvest, sea otter occupation, hunting, and population movement than previously available. Trends are illustrated via scientific visualizations that preserve spatial ambiguity and ensure the confidentiality of shared sensitive information. This inclusive research approach advances the collective understanding of local, harvested populations and supports tribal and stakeholder sovereignty in the management and future research of these important species. Finally, this work reinforces the power of information amassed through multiple knowledge systems to offer more comprehensive and nuanced perspectives on sea otter hunting, abalone harvest, and the complex trends following local sea otter return.

KEYWORDS:

Community Engagement, Hunting, Local Species Interactions, Local and Indigenous Knowledge, Pinto Abalone, Sea Otter, Sitka Alaska, Subsistence

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PROJECT CHRONOLOGY

Project #2115 timeline, delays, mitigation

Winter 2022

- Awarded funding for NPRB Project #2115
- **January 17th** Project MOU approved between STA and UCSC PIs Dr. Peter Raimondi, Taylor White

Spring – Summer 2022

- **March 24th:** UCSC IRB HS-FY2021-74 approved
- Following some delay by the UCSC Oaice of Sponsored Projects in accepting the award, we formally requested a no-cost project extension.
- **April 20th:** Received an extension from an initial project end date of January 31st, 2023, to the current project end date of January 31st, 2024. The initial delay by UCSC OSP centered around January 17th (2022) MOU and Project sub-award language and signatory changes.
- **May 25th:** NPRB Award released by UCSC Office of Sponsored Projects
- **June 13th:** Following rounds of MOU and Informed Consent Form edits and multiple IRB amendments, UCSC finalized and approved both documents with the Office of Sponsored Projects.
- **July 31st:** Project progress report to NPRB

Fall 2022 – Winter 2022

- Scientific visualization, project, animation collaborations and storyline drafting
- Drafts and adjustments of amended MOU reviewed between UCSC Regents and Project PIs and language revised by STA and UCSC lawyers.

Winter 2023

- Acknowledging the MOU would need to be revised and reviewed by both signing parties, we applied for an IRB extension.
- Ongoing MOU revisions
- **January 31st:** IRB extension approved, Project progress report to NPRB
- Ongoing work on animation and outreach; presentations and final report
- **November 16th:** STA Natural Resource Committee update: interviews, preliminary findings, dissemination

Spring – Summer 2023

- **April 19th:** MOU with UCSC Reagents approved by STA Tribal Council
- **May 1st:** MOU signed and completed
- **July 20th:** Natural Resource Committee Update: scientific visualization plans, progress
- **July 31st**: Project progress report to NPRB

- **July**: Project website development, recruitment
- **August 18th**: KCAW interview and public call for in-person interviews begins; akabalone.com website goes live

Fall 2023 – Winter 2023

September – January 2024 in-person and Zoom interviews

Winter 2024

- **January 9th:** Sitka Tribe of Alaska's Elder's Coaee sharing project findings, initial animation, seeking participation
- **January 18th:** Natural Resource Committee Update: shared management suggestions and approval of results for Alaska Marine Science Symposium presentation
- Final in-person interviews
- January 29th
- **January 31st:** END of project research and spending
- UCSC IRB project closure and report
- De-identification and archiving of information and materials shared

Spring 2024

- Data entry, transformations, and analyses complete
- Final report drafting
- **March 21st:** Natural Resource Committee Update: final project findings
- Metadata and data dictionary shared with NPRB, Axiom
- **April 1st, May 1st:** extensions made for final reporting
- **April 8th**: Data dictionary and Metadata files uploaded to NPRB, Axiom
- NPRB final report submitted by July 1st

Despite encountering delays, with the help of extensions outlined above, researchers were able to address challenges, interview 26 individuals, and review findings with the STA Natural Resource Committee. Select project objectives (see "Objectives") and community involvement will remain ongoing as related abalone research building from this project continues in Sitka. Additional project updates, related materials or dissemination, including forthcoming scientific visualization, radio pieces, and management suggestion documents, will be available at the project website akabalone.com. See the Objectives and Outreach sections for additional details.

INTRODUCTION

Background

Northern sea otters (*Enhydra lutris Kenyoni*) have re-occupied areas where they have been absent for over 100 years following. repatriated to the complex ecosystems from which they were removed during the fur trade over 100 years ago (Kenyon 1969, Jameson et al.,1982). As a potential resident apex predator, sea otter feeding habits and foraging behavior have significantly impacted the local marine communities they repatriate. Sea otters are blamed for the reduction of invertebrates important to communities and fisheries developed in their absence (see Woodby et al., 2000, Hebert 2014, Hoyt 2015, Davis et al., 2019). Sea otter consumption of select prey species, like sea urchins, has exposed indirect benefits to the grazed community of algae and kelps that would otherwise be grazed by persisting urchin populations (Raimondi et al., 2015, Lee et al., 2016).

Prior to the sea otter extirpation by the Euroamerican fur trade, sea otters existed along with shellfish, more recently prized for commercial harvest and historically important to local Indigenous communities (Szpak et al., 2012, Braje et al., 2013, Menzies 2015, Salomon et al., 2018). Sea otters were hunted by Indigenous people before the fur trade **(**Szpak et al., 2012, Moss et al., 2016) and in Alaska, established populations are hunted again today.

The many histories and ongoing sea otter and shellfish removal add to the dynamic ecosystem of Southeast Alaska. Still, there are noted conflicts over resources between otters and humans (Mills 1982, Carswell et al., 2015, Hebert, 2019). Available data and models are limited in their ability to predict these population trajectories at the local scales, which are important to the management of ongoing interactions. NPRB Project #2115: "Diverse knowledge systems for the examination of localized dynamics of sea otters and abalone populations in Sitka Sound, Alaska" aims to provide an understanding of the local dynamics between sea otters and pinto abalone surrounding Sitka, Alaska, an area with a history of subsistence, a range of sea otter abundances, and occupation timelines, with regular sea otter hunting.
This project pairs information from multiple knowledge systems (Western science, local and Indigenous Knowledge) to define current and historical patterns of change in marine communities following sea otter and outline pinto abalone and sea otter population dynamics during ongoing harvest and re-establishment periods.

Research Predictions

This pairing of Local and Indigenous knowledge shared during interviews explored questions surrounding the following predictions:

We expect that the local presence of sea otters, the duration of otter occupation, otter hunting practices, and the harvesting of abalone will have an impact on local abalone populations. Project predictions and applicable reasoning:

1) **Abalone and otter presence and abundance vary in locations across Sitka Sound**
    a. **Abalone abundance measures (density, reported amounts) diZer across Sitka Sound**
    b. **Otter occupation periods and abundance are diZerent across Sitka Sound**

2) **Abalone abundance measures vary with otter presence abundance and have a nonlinear response to otter occupation time, where years following sea otter occupation correlate with more significant changes in abalone populations.**

    Reasoning: Abalone are found to persist with and indirectly benefit from sea otter presence and otter removal of herbivores (Raimondi et al., 2015, Lee et al., 2016). In addition, established sea otter populations are known to diversify their initial target prey selection (Tinker et al., 2008). We, therefore, predict areas most recently occupied by otters to have the most reduced abalone densities, whereas areas noted to have the longest otter occupation times will have reduced abalone densities relative to areas without otters but higher abalone densities than those areas with recently established sea otter populations.

3) **Sea otter hunting will indirectly effect abalone abundance measures as:**
    a. **Patterns of sea otter occupation and abundance will be effected by continued hunting.**

        Reasoning: Zac Hoyt (2015) documented a fear response or perimeter of otter absence in areas of intensive hunting. We predict similar, localized patterns of hunting and otter behavioral response in and around Sitka Sound.

    b. **Areas where otters are removed or rare will correlate with higher abundances of abalone, in contrast to areas with less changed otter populations.**

        Reasoning: loss of otters (by mortality or avoidance) in areas subject to sea otter hunting may lead to changes in abalone abundance measures.

4) **Abalone densities and larger size classes will be reduced in areas of human harvest and access; however, the net effect of human harvest impact will be less than in areas with high sea otter abundance.**

    Reasoning: Predicted higher negative relationship between sea otter abundance and abalone density, particularly densities of large size classes, as sea otters are known to eat abalone (Fanshawe et al.,2003) and are more likely to target larger, higher caloric value prey (i.e., foraging theory: Charnov 1976, Stephens and Krebs 1986).

Management, Societal Context

The knowledge and history shared and applied in parallel with data collected from abalone dive surveys to examine the above predictions will provide the most holistic understanding of Sitka Sound otter, abalone, and human interactions since local colonization. With additional aims to support tribal and stakeholder sovereignty in species management and research, all findings were reviewed by the Sitka Tribe of Alaska. The Tribe and participants were engaged in disseminating and archiving shared ways of knowing.

This research aims to uncover patterns that could inform policy, conservation efforts, and resource management strategies in the Southeast, ensuring the resilience and sustainability of both abalone populations and the communities that rely on them and preventing the loss of subsistence and culturally significant species.

OBJECTIVES

1. Conduct interviews and record local and Indigenous knowledge on historical trends of pinto abalone abundance and harvest surrounding Sitka, Alaska. Note abalone population shifts (i.e., tidal location, available harvestable abalone) and purported causes of local abalone trends. Record larger ecological trends following sea otter repopulation of Sitka Sound and the perceived impact of sea otter hunting.

Information pertaining to Objectives 1 through 7 was gathered during interviews (see Appendix C2). Interviews began in September 2023, following delays in UCSC MOU and IRB approvals, additional delays around periods of COVID prevalence locally, and reviews of questions and methods with the Sitka Tribe of Alaska Natural Resource Committee Meeting. Information shared was qualitative and provided categories of shared quantitative information (i.e., many, few, none/no) per species were organized at fine scales and presented and shared at coarse scales for comparisons and trend analyses.

2. Document knowledge of abundance and available legally-sized abalone at identified harvest sites before, during, and after sea otter population establishment and before, during, or after commercial abalone fisheries.

Participants provided this information via structured questionnaires during interviews (see Chapter Appendix C2), categorized, and organized into coarse spatial scales for comparisons (see Chapter Section).

3. Determine areas of greatest historical shifts in abalone and otter population abundance.

Proportions of ‘many’ to ‘few/no’ abalone and sea otters were examined across the span of time of provided information (see Chapter Section).

4. Document local and Indigenous knowledge on areas in Sitka Sound with current high, medium, or no sea otter abundance and determine areas as longest occupied, recently established, or previously established by sea otter populations. Note the time, if known, of initial local occupation, occasional sightings, and areas of continued otter absence.

First sightings of sea otters, abundance, and time periods provided by individuals were used to determine sea otter occupation periods, previously unavailable and unknown for Sitka Sound, particularly at fine scales (Table 2, Chapter Section). These occupation periods were paired with amounts of abalone and abalone sizes over time (see Chapter Section for additional details).

5. a) Assess dynamics (e.g., movement, abundance decline) in areas of regular harvest surrounding Sitka, Alaska.

b) Identify otter hunting pressures in areas and factors, including socio-ecological factors (e.g., market, harvest guidelines, tannery access, seasonal otter movements, poor weather years) affecting yearly otter harvest.

Areas with the highest amounts of harvest were identified by participants and reinforced by the number of instances of harvest reports per area.
Themes of the socio-ecological factors predicting harvest were identified following interviews.

6. a) Assess current relationships between sea otter abundance, occupation, and harvest, shared in interviews and current quantitative data on abalone densities and size frequencies in Sitka Sound.

b) Determine whether there is a significant inverse effect of high otter abundance and recent occupation on abalone densities and size frequencies.

Local and Indigenous knowledge of abalone and sea otter populations shared during interviews and mapping exercises and paired with local quantitative data (i.e., abalone dive surveys (unpublished local density data), kelp abundance (KelpWatch), sea otter tagging information (USFWS) revealed patterns of abalone abundance and harvest before, during, and following sea otter repatriation in Sitka Sound, Alaska.

Finally, combined knowledge sources were examined in regressions that illustrated trends of sea otter impacts and interactions with hunters and subsistence abalone harvesters.

7. Catalog, protect, and preserve records of shared knowledge and history.

Participant identifiers (names, emails) were coded, and spatially sensitive information was presented at coarse scales, as approved by participants. The only scanned maps shared were in the STA encrypted hard drive at the express request of individuals. Identifiers were coded by random number and re-coded by random number prior to sharing with Axiom and STA; for those participants opting to share identity, their identifiers (names) were only included in the STA archival encrypted hard drive. Audio is included with STA encrypted hard drive (as approved by the participant), and all recorded audio is included in the Master Hard Drive. Individual participants were talked through the rare possibility of audio breach and only then either permitted or denied audio recording.

Information and materials storage

Master Encrypted Hard Drive

All metadata, video/audio recordings scanned paper consent forms, mapping exercises, survey/interview responses, and notes are on the Master Encrypted Hard Drive. Research CoPI Taylor White will have sole access to the Master Encrypted Hard Drive and will retain the master encrypted hard drive for three years following research conclusion, after which she will destroy the Master Encrypted Hard Drive.

Sitka Tribe of Alaska Offices (STA)

- Participants can request to have access to their information and data shared with STA (per STA research policy)
- Versions of georeferenced, identifiable or de-identifiable data will be retained indefinitely at STA offices on encrypted hard-drive (as consented to prior by the Participant)
- Non-participants may request from STA copies of the non-georeferenced data, the deidentified data, and certain identifiable data such as quotes and audio or visual clips that a Participant has authorized to be made publicly available that are maintained on the STA hard drive, but may not access these data unless approved by STA.

North Pacific Research Board (NPRB)

- NPRB maintains non-georeferenced/de-identified information and research findings managed by AXIOM data managers in Anchorage and made publicly available after a 2year embargo.
- This data storage (no audio, no maps) at Axiom data management was reviewed by and approved by all participants in their consent forms.

All dispositions were determined by and aligned with the approved project IRB HS-FY2021-74 and the MOU between the Sitka Tribe of Alaska and UCSC Reagents.

8. Engage with participants in the dissemination of analyses and findings and identify knowledge gaps, resulting hypotheses, and management suggestions. Co-produce a document highlighting future research recommendations for regional managers and stakeholders.

During interviews, participants indicated preferences to participate in future conversations and discussions pertaining to project findings and collective management recommendations. The co-production of the management document took an alternate route, as participant dedicated meetings would have extended outside the bounds of the project timeframe. Provided time limitations, individuals who opted for ongoing involvement and participation were individually invited to comment on findings related to their areas of expertise shared during researcher follow-up and were invited to join (online or in person) public Sitka Tribe of Alaska NRC meetings where findings, collective management suggestions, and project updates were presented and open for NRC and public comment. Acknowledging the ongoing enthusiasm of participants and the community at large on the research along with “do no harm” ethics and community reciprocity goals that extend beyond the project period, management recommendations will be presented alongside findings at an upcoming Natural History seminar in Sitka, in a radio piece, and at STA Elders Coffee hour. Participants will be invited to join and suggestions for management and key management goals will be requested in these spaces and will be added to the combined management goals included in this report. All iterations of the management suggestions will be made available for public comment on akabalone.com

9. Produce an outreach video highlighting the history of sea otter re-establishment in Sitka Sound, local trends following establishment, and current interactions between sea otters, pinto abalone populations, and community members. *Co-create a radio piece highlighting shared history, research, and community connection to dynamic marine resources.*

All the artwork and storyboarding are complete, and the project findings scientific visualization is near completion; when finished, it will be uploaded to the workspace and included on the project website: AKabalone.com. A radio piece originally designated for Indigenous podcasts: “Our Grandparents Teachings,” will instead be a part of Sitka Nature, a radio show and podcast broadcast from the same station to the same listening communities in Southeast Alaska. This change was due to a pause in the production of the initial podcast.

NPRB #2115 Chapter

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Introduction

Southeast Alaska is a dynamic system shaped by complex histories and communities that continue to subsist and adapt to resource changes (Arland et al., 1974). Most of Southeast Alaska is Lingít Aaní, Tlingít ancestral land, where Tlingit, Haida, and Tsimshian communities have managed resources in diverse and resilient ways with a complex knowledge system built from over 10,000 years subsisting in the region (Goldschmidt and Haas 1998). The time honored practice of adaptive management by Indigenous people offers valuable insight into historical ecosystem relationships (see Lee et al., 2018). Such significant relationships are not static but dynamically evolving, with human influence leaving lasting marks, which, if historically unknown, can obscure accurate understandings of ecosystems (Rohwer and Marris 2021).

It remains challenging to untangle dynamic interactions between harvester and harvested species, particularly given complex ecosystems, historical interactions, and the limited historical records or regular surveys of local population metrics. For the same reasons, assessing indirect effects experienced by lower trophic levels following predator establishment and removal is complex.

In the late 1880s, following an intensive maritime fur trade and near extirpation of sea otters (*Enhydra lutris)* (Kenyon 1969) from Southeast Alaska, researchers found a system dominated by sea urchins and shellfish populations, seemingly based on a release from predator pressures (Tegner and Dayton 2000). Ecosystems with sea otter populations are characterized by a reduced abundance of prey species, namely invertebrates (e.g., sea urchins, clams, crabs, sea cucumbers), and, in kelp forest ecosystems, increased abundancies of macroalgal species (e.g., *Macrocystis spps.*, *Laminaria spps*.)(Krech 1999). In these kelp forest ecosystems, an absence of sea otters may lead to an 'urchin barren' environment, where sea urchin populations grow, graze kelp, and eliminate algal communities (Estes and VanBlaricom 1985, Estes et al., 1998, Konar et al., 2014).

During this urchin barren period in Southeast Alaska, multiple commercial shellfish fisheries (e.g., abalone, red urchins, geoducks, sea cucumbers) were established. The first dive fishery was for pinto abalone (Gunxaa - Lingít, *Haliotis kamtschatkana*), which reported its first landings in the mid-1960s (Hebert 2014). The commercial abalone fishery closed in 1996, after fifteen years of precipitous declines in harvest following an 89% decline in abalone catch during peak harvest years (1978 to 1981)(McDougall et al., 2006; Woodby et al., 2000).

As in other fisheries, the re-establishment of sea otters was linked to negative impacts on the historically important pinto abalone dive fishery. Soon after the first recorded landings of abalone, 413 sea otters were re-introduced to areas of Southeast Alaska (Jameson et al.,1982, Pitcher 1989). Following their re-location in the mid-60s, sea otters successfully expanded into areas where the species had been absent for over 100 years. Sea otter population growth rate reached 8.6% per year from 2003 to 2011, and by the 2011 USFWS survey, the regional sea otter population had reached a count of 25,584, a third of the estimated Carrying capacity (Tinker et al.,2019); an estimate supported by most recent 2022 aerial surveys (Schutte et al., 2023) and an updated diffusion model (see Eisaguirre et al., 2021).

Following sea otter expansion into areas of historical commercial harvest, community subsistence, traditional, and customary harvest continued, with a reduced allowance of abalone per resident per day. This led to increased conflict between harvesters and the sea otter populations that continued to grow and shape the ecosystems of Southeast Alaska (Hebert 2019). Unfortunately, irregular surveys on sea otter populations have limited researchers' ability to assess the effects of otter population occupation, movement, and growth on benthic invertebrate populations, particularly at locally harvested scales. Population estimates for otters were not conducted in Southeast Alaska between 2011 (USFWS 2014) and 2022 (Schuette et al., 2023), when aerial surveys were carried out three years after the dive surveys used in this study. This limits and challenges our understanding of accurate otter occupation times, especially after 2011, a period of significant expansion and movement of sea otter populations into areas they had not occupied for over a century (USFWS 2014, Hoyt 2015, Davis et al., 2019, Schuette et al., 2023).

The significant impact of sea otter population growth and movement on marine communities is evident. Otters are commonly blamed for the reduction of invertebrates important to communities and fisheries (see Woodby et al., 2000, Hebert 2014, Hoyt 2015, Davis et al.,2019). The voracious tendencies of sea otters are driven by their metabolic demands, which require consuming nearly a quarter of their body weight daily (Costa and Kooyman 1984, Wolt et al., 2012). As predicted by optimal foraging theory (Kleiber 1961, Stephens and Krebs 1986), otters may target disproportionately large (i.e., high caloric value), easy-to-gather prey (Estes and Palmisano 1974, Ostfeld 1982). Still, sea otters are documented to eat over 150 different species (Ostfeld 1982, Estes and Bodkin 2002, Estes 2015). Following a period of occupation and a reduction of preferred energetically rich prey, sea otters show a propensity to diversify their diet and eventually specialize in specific species, which widens the breadth of their impact on the ecosystem (Tinker et al., 2008, Weitzman 2013, Hoyt 2015, LaRoche et al., 2021).

While sea otters may re-establish areas, they may also be removed by hunting, which makes examining sea otters dynamics and impacts on other species in Southeast Alaska complex.

The Marine Mammal Protection Act (1972) permits Alaska Natives to hunt sea otters and sell processed 'handicrafts' (50 CFR 18.23). While hunting remains stable at the regional scale of Southeast Alaska, otter harvest rates vary at the sub-regional scale (Raymond et al.,2019). Though hunters report tagged harvest, subsequent information on the cascading effects of local hunting is rarely included in local surveys of invertebrate populations; however, harvesters and others report and find significant impacts (see Ibarra 2021, Bolwerk 2021). Subregional information on sea otter populations is essential as local populations may experience more fluctuations due to local hunting and as hunting may change based on occupation times (Raymond et al., 2019).

Local information is necessary to assess the effects of otters on populations of benthic invertebrates like pinto abalone, which were targeted by fisheries and continue to be harvested as a subsistence, customary and traditional food (Ibarra 2021, Mills 1982). There is a growing body of work pairing Indigenous and local knowledge with Western science to improve the management and conservation of species (Armitage et al., 2019, Reid et al., 2020). In British Columbia, researchers developed a more comprehensive understanding of historic abalone populations through diverse knowledge systems of areas where sea otter populations continue to re-establish and where pinto abalone populations remain low (Lee et al., 2018).

This research explores small-scale trends in abalone density across diverse ecosystems within Sitka Sound, Alaska, areas that experience a mosaic of sea otter abundance and reoccupation timeframes. In Sitka, there is ongoing legal harvest of abalone by residents (five per person/day, in possession; 5 AAC 02.135.) and Alaska Natives are permitted to harvest sea otters under the Marine Mammal Protection Act (MMPA 1972 50 CFR 18.23). The research aims to examine and develop the collective understanding of current, historical, and future dynamics of abalone and sea otters while including and supporting the tribal and participant ('stakeholder') sovereignty in the future management and research of these important species.

This project pairs multiple 'ways of knowing' or knowledge systems: local knowledge, Indigenous Knowledge, and available Western science to address whether sea otters and humans have predictable effects on abalone populations in Southeast Alaska, namely in Sitka Sound, and if those effects and interactions are significantly altered by the ongoing hunting of sea otters and harvest of abalone.

We anticipate that local sea otter presence, duration of otter occupation, otter hunting practices, and the harvesting of abalone will impact local abalone populations. Predictions concerning local abalone abundance include:

1) *Abalone and otter presence and abundance vary across Sitka Sound*
    a. *Abalone abundance measures (density, reported amounts) diLer across Sitka Sound*
    b. *Otter occupation periods and abundance are diLerent across Sitka Sound*

2) *Abalone abundance measures vary with otter presence abundance and have a nonlinear response to otter occupation time, where years following sea otter occupation correlate with more significant changes in abalone populations.*

3) *Sea otter hunting will indirectly effect abalone abundance measures as:*
    a. *Patterns of sea otter occupation and abundance will be affected by continued hunting.*
    b. *Areas where otters are removed or rare will correlate with higher abundances of abalone, in contrast to areas with less changed otter populations*

4) *Abalone densities and larger size classes will be reduced in areas of human harvest and access; however, the net effect of human harvest impact will be less than in areas with high sea otter abundance.*

Materials, Methods

Ecological, Cultural, Historical Context

Sitka, Alaska, stands out from other regions where sea otters have been reintroduced, from Glacier Bay to Prince of Wales Islands to British Columbia and down to Washington and Oregon. Notably, Sitka Sound hosts the longest established re-introduced sea otter populations in proximity to the city. In addition, Sitka community members continue to harvest abalone and, following the sea otter reoccupation and population expansion, local Alaska Natives re-engaged with historical customary and traditional marine mammal hunting and handicraft practices. This unique juxtaposition provided an opportunity to explore the impact that human harvesting activities on sea otters and abalone have on abalone populations.

Species Interactions, Importance

The northern sea otter (*Enhydra lutris kenyoni*) is a known predator of benthic invertebrates, including abalone, significantly impacting their populations (Ebert1968, Wild and Ames 1974, Estes et al., 1981, Ostfeld 1982). Pinto abalone (*Haliotis kamtschatkana*) are the only abalone species in Alaska, and they have remained a vital subsistence food source (Mills 1982, Ibarra 2021). Since time immemorial, Indigenous people have carefully considered and adaptively managed local ecological interactions at specific harvest sites (Thornton 2011 and 2015, Turner 2020). This includes the harvest of sea otters before the fur trade (Szpak et al., 2013, Slade et al., 2021). Significant population bottlenecks were found in samples collected from early colonization periods (e.g., ancient DNA) and attributed to Indigenous hunting practices before European contact and fur trades, likely maintaining populations below their environmental carrying capacity (Larson et al., 2002, Beichman et al., 2019). Still, following the extirpation of sea otters and an extended period (generations) of attempted erasure of Indigenous communities and Indigenous Knowledge (Solomon et al., 2015), available knowledge of harvest and present-day sites is crucial to grasp these local-scale dynamics important for the continued harvest of these species.

It is understood that sea otters were reintroduced to areas in and near Sitka Sound (see Figure 1) in the late 1960s (Burris and McKnight 1973). Sea otters re-occupied areas in Sitka with differing amounts of prey resources, but with an over 10-year gap in sea otter aerial surveys from 2010 to 2022 (see USFWS 2014, Schuette et al.,2023), local understanding of sea otter occupation, abundance, and harvest in Southeast Alaska is limited. With available historical data on sea urchins, researchers found a large effect of otter occupation, where in 2009, there were reduced sea urchin populations, leading to a resurgence of kelp forests (Gorra et al., 2022). In contrast to their herbivorous urchin competitors, pinto abalone populations have shown recent signs of recovery (Bell et al., 2018). However, quantitative information on pinto abalone populations in Sitka Sound is restricted to recent SCUBA surveys (2015 to 2023), nearly 50 years following the nearest sea otter transplants (see Bell et al.,2018, White and Raimondi 2020, K. Kroeker unpublished data). Uncertainty remains in patterns related to sea otters at local levels, and trends are primarily informed by observations of sea otters and their effect on ecosystems. Certainly, sea otters have broadscale and localized effects on ecosystems and invertebrates like sea urchins (e.g., Ostfeld 1982, Estes and Bodkin 2002, Estes 2015, Davis et al., 2019, Raymond et al., 2019, Tinker et al., 2019, Gorra et al., 2022). This study aims to investigate interactions and effects of sea otter reoccupation and removal on harvested abalone populations at finer, local scales important to subsistence, customary, and traditional harvesters in Sitka, Alaska.

Study Design

Significant gaps in records regarding sea otter repatriation and abalone population dynamics in Sitka Sound persist. This project sought to apply local and Indigenous knowledge in parallel with available quantitative data to enhance understanding and illustrate an ‘enriched picture’ of local trends, species, and community interactions (as described in Tengö et al., 2014). This mixed-method approach helped address critical gaps in understanding local communities and ecological systems and to explore research questions related to the finer-scale effects of humans and sea otters.

Knowledge Systems

The incorporation of multiple knowledge systems in this project provides an opportunity to benefit all involved through a greater understanding of community dynamics critical to harvested species.

Local Knowledge is broadly defined as expertise gained through everyday experiences and interactions with the environment, including practical knowledge about local ecosystems, subsistence species, and sustainable practices that have been developed over time through interactions with the environment (Huntington 2000). Local knowledge can be passed generationally and is influenced by social constructs that affect individual and community associations with environments (Berkes 1999).

In contrast, Indigenous Knowledge (IK) is deeply rooted in generations of adaptive co-existence in a place developed by Indigenous peoples over thousands of years. It is intimately connected to culture, identity, and rights and includes a holistic understanding of the environment, incorporating spiritual, cultural, and social dimensions (Bohensky and Maru 2011).

There are inherent challenges in presenting diverse ways of knowing that validate and respect knowledge systems, particularly the potential for distortion when translating local and Indigenous Knowledge systems into a Western scientific framework. For this reason, only firsthand reports of abalone, otters, and related species are transformed into categories at spatial scales for comparisons. More qualitative information is conveyed through quotes and brief descriptions here to illustrate the shared knowledge systems in this report effectively. Unclear interpretations of shared knowledge were discussed with participants or in collaboration with Tribal Natural Resource and Cultural Resource committees.

Importantly, we include these multiple ways of knowing in concert with one another and do not test their validity. The information provided examined human and otter effects, namely the community-held belief (i.e., a broadly held perception within a community that spans the knowledge systems of its individual members) that sea otters negatively impact abalone populations.

Interview methods

Local individuals with a history of commercial abalone harvest, subsistence harvest, tour guides, divers, and Alaska Natives with additional generational knowledge of adaptive management and refined harvest and hunting practices were invited to participate in interviews in late summer of 2023 (via a local campaign including flyers posted and shared at community gatherings, radio interview and announcements, website creation with contact and participation content, outreach to Sitka's Alaska Native Brotherhood, presentation to Sitka Tribe of Alaska (STA) Natural Resource committees, Sitka Tribe of Alaska elder's coffee, and general word of mouth; additional detail in UCSC IRB HS-FY2021-74).

Twenty-six project participants were interviewed from the late summer of 2023 to January 2024. Participants included seven sea otter hunters, four tour guides, five former commercial dive fishers, eleven individuals identifying as Alaska Native, and one assistant in the historical relocation of sea otters from the Aleutians. All participants engaged in subsistence abalone harvesting, and the majority continued their practice. All agreed to varying degrees of information sharing as specified in their consent forms (see Appendix C. 'STA MOU, Informed Consent Form').

Interviews included semi-structured questions with mapping exercises and a structured questionnaire. They were dynamic, with a varied structure of questions and mapping to reduce interview fatigue. Interviews were designed to last under an hour, with the flexibility to exceed that time frame. Project interviews ranged from forty-five minutes to five hours, with an average interview length of around an hour and a half.

First, project interviews established the relationship between participants and their interactions with the local marine environment, focusing on abalone and sea otters at their harvest sites (i.e., specific geographical areas of harvest) or larger areas of expertise over time. Participant relationships to species of interest determined their semi-structured questions and mapping exercises (see Appendix C2).

Mapping exercises with semi-structured questions

Second, project semi-structured questions and mapping exercises determined areas of abalone harvest and areas of sea otter presence/absence, occupation time, abundance, and harvest to the finest scale participants felt comfortable sharing. Questions during mapping exercises explored the perceived effects of sea otter reintroduction and current and historical sea otter and abalone harvest and were interspersed with mapping exercises during the interview (see Appendix C2). These mapping exercises were akin to those done in Southern Southeast Alaska communities (Ibarra 2021), and semi-structured questions followed a model developed by Lee et al. (2019) in Haida Gwaii, with three focus areas: general ecological trends following otter population establishment, degree of change, and community management strategies (Appendix C2).

Measures at local scales

To assess human, otter, abalone, and urchin interactions at finer spatial scales, we divided the Sitka coastline into nested polygons of varying sizes, with the finest scale 'sub-small' polygons (n=23) nested in 'small' polygons (n=10), all nested within three large contiguous polygons (Sitka North, Inside, Outside, see Figure 1). These large polygons are divided based on their proximity to the city of Sitka. Access from these areas via boat or non-motorized vehicles is similar, except for the 'Outside' or outer coastal polygon, which is the largest, with an approximate center around 20km away from the nearest harbor. The approximate center of both the 'North' (i.e., north of the city of Sitka) and 'Inside' (inside Sitka Sound, nearest the city of Sitka) polygon is around 12 km from the closest harbor. The Inside and North large polygons divide the road system access. Yet, the Inside polygon incorporates the majority of the Sitka road system and is an area that provides the most access to shore picking (see Figure 1).

Spatial Scales of Knowledge

Mapping exercises during interviews were built around a spatially explicit approach to assessment. Where project participants provided information on otter and abalone abundance and harvest at the finest spatial scale, which individuals were comfortable sharing (i.e., a harvest site, a cove, or some greater area). Years of known information on the species sea otter, abalone, kelp presence, absence, and relative amount category (‘Many’, ‘Few,’ ‘None’) were delineated by individuals via color and specific numeration on a blank map and detailed further in Appendix C2: ‘Interview Questions, Methodology’). Knowledge of local sea otter occupation by year was also reported to the smallest spatial scale. These reports were then transferred into a mapped polygon framework (see Figures 1 and 2). For confidentiality purposes, all information and data shared and presented in this report are provided at the coarsest resolution to protect the confidentiality of specific harvest locations (i.e., by large polygon: North, Inside, Outside; Figure 1). The only exception to this scale of sharing was in sharing dates and locations of sea otter sightings and occupation. Sea otter occupation reports are included at the finest spatial scale provided to support more precise comparisons of localized sea otter effects. Regardless of the polygon scale, species abundance information data were aggregated to match the spatial scales, leading to spatially compatible and comparable otter and abalone data. Large polygon aggregate data is included and shared at the coarsest scale to maintain the confidentiality of harvest locations while providing major trends. Knowledge shared in areas on a map identified as Indigenous knowledge was not categorized into these spatial scales.

Local measures

Available local Western science metrics were aggregated within the geographic divisions of Sitka Sound, depending on the question explored, and were transformed and categorized at the finest spatial scale (see prediction analyses below). Western Science data contributions include University of California Santa Cruz (UCSC) abalone dive monitoring surveys, U.S. Fish and Wildlife Service (USFWS) otter tag data, otter abundance projections (using the model developed by J. Eisaguirre et al. (2021), and Kelpwatch land satellite data on kelp coverage (Bell et al., 2022, Kelpwatch.org).

Structured Questions, measured degrees of change

In addition to mapping exercises and semi-structured questions, during interviews, structured questionnaires helped to measure the degree and direction of changes to the amounts of species (i.e., abalone, kelps, gumboots, crabs, and sea urchins) in relation to sea otter reoccupation, sea otter harvest, and historical commercial abalone harvest. These trends were meant to illustrate changes in population abundancies more generally across spatial areas originally denoted by participants in mapping exercises. Abundance measures by period (e.g., pre-, during, and post-sea otter occupation) were ‘many,’ ‘few,’ and ‘none,’ or participants denoted ‘NC’ when there was no change in their relative abundance measure across periods (see Appendix C). In practice, the interviewer filled in the questionnaire with the participant by asking questions about directional shifts of specific amounts of abalone or other species during periods of otter occupation or the abalone dive fishery.

Abalone Sizes, Amount Categories

During interviews, when individuals reported trends related to abalone size, they reported they were offered abalone shells of the three size classes ‘small,’ ‘medium,’ and ‘legal’ sizes for both legal size limits before and during 1977 (≥74mm) and in the years following 1977 when the minimum size limit increased (≥89mm) (Hebert 2014). When participants report the amount for legal abalone, 'None' meant no or possibly no legal abalone; 'Few' represented less legal abalone than the maximum possession limit (≥ 5 or 30 individuals depending on the year), and 'Many' denoted many more abalone available to harvest than designated by maximum legal harvest limits. Other abalone and species amounts collected during interviews were subjective to the abundance of a species within the timeframes reported by individuals. For this reason, we explore changes in legal abalone amounts paired with quantitative local data.

Management Recommendations, Participation

Finally, participants were asked about management, including questions on community management recommendations for otters and abalone populations, barriers to current management, and strategies for future management or survey, with a focus on recommendations for local and Indigenous inclusion in processes. Management strategies and concerns participants consented to share were shared during meetings with the Sitka Tribe of Alaska Natural Resource Committee. Participants were invited to review the developing management and research plan based on project findings when presented at the Sitka Tribe of Alaska Natural Resource Committee meetings and, if requested, via researcher follow-up. There were follow-up meetings with select participants to add to or clarify their responses to interview questions and exercises, and additional communications were made with select participants to address mapping, quote, and image usage questions. Refer to the NPRB final report for the research project (#2115) for more information on management recommendations, reciprocity, and community outreach.

Participant Consent

Interviews were mainly held in person, with one online interview. Participants were provided the option to be recorded (video and audio for remote, just audio for in-person) or not to be recorded (no video or audio). Consent for a suite of options for archiving, sharing, and disseminating information, including confidential and geo-referenceable information, was collected before the interviews.

Given the exclusion of geo-referenceable information pertaining to sensitive information like harvest locations, participants could consent to either identifiable or non-identifiable sharing of public information (e.g., clear participation in the project was allowed, along with nongeographic harvest information). For recorded individuals, this meant allowing for approved quotes. For information retained and stored, all participants were required to agree to have all shared information (scrubbed identifiable and geo-referenced information) protected and stored with the co-PI on an encrypted hard drive for three years after the research concludes. Options to share and archive shared information at the STA (Sitka Tribe of Alaska) were provided, where either all identifiable/georeferenced data were allowed to be stored (including audio), or de-identified, non-geo-referenced information could be stored, or participants could opt out of archiving data at STA offices.

All dispositions were determined by and aligned with the approved project IRB# HS-FY2021-74 and the MOU between the Sitka Tribe of Alaska and UCSC Reagents (for additional details, see Appendix C1 'STA MOU with Project Informed Consent Forms').

Confidentiality Measures

Researchers safeguarded against misuse of this property by 1) securing Informed Consent before interviews, 2) permitting only one researcher, the interviewer, to know shared information attached to a georeferenced location and person, and 3) ensuring that participants understood and maintained rights to self-determination, inalienability, and confidentiality (STA Research Policy Section 2.01). All concerns were addressed and taken with the utmost seriousness, in accordance with the 'do no harm' ethics principle applied throughout the project and dissemination of findings. In addition, the UCSC Institutional Review Board (IRB) protects the rights and welfare of human subjects involved in UCSC research (project IRB# HSFY2021-74). Researchers adhered to data management recommendations by the UCSC Information Technology Services (ITS) Unit Information Security Lead (UISL) to safeguard participant confidentiality. Importantly, local sites, harvest locations, and georeferenced areas remain confidential and are not made public. Identifiable information was obscured before data storage unless explicit consent for sharing was provided by participants.

Partnerships

Researchers acknowledge the research is in Lingít Aaní, Tlingit traditional territories, including Tribal Citizens, and therefore garnered support from the Sitka Tribe of Alaska before the start of research. Permissions were agreed upon and detailed in the project MOU created between UCSC Reagents and STA (Appendix C1). As per the MOU, the STA Natural Resource Committee reviewed and interviewed methods, questions, and all major findings and reviewed and approved the public dissemination of project findings (Appendix C2). Researchers continue to maintain 'do no harm' (AAA 2012) ethics with this research in traditional territory with local community members and Tribal Citizens in future iterations of this project and findings as further outlined in MOU and consent forms (see Appendix C1).

Data Access and Permissions

For access to publicly available data or to utilize additional data not explicitly presented herein, please contact Taylor White the project Co-Principal Investigator, Data Originator. Additional permissions for detailed data use must be obtained from the Sitka Tribe of Alaska Natural Resource Department. Separate permissions may be required for requests for tag data from USFWS. Additional information on data storage, use, and allowed dissemination is in Appendix C1.

Approach

Trends in abalone and otter measures

Concern over sea otter re-introduction and occupation in Sitka is reasonable considering the magnitude of the effect otter reoccupation has had on regional populations of sea urchins (Gorra et al., 2022) and sea cucumbers (Larson et al., 2013) and the impact denoted in abalone populations elsewhere (Hines and Pearse 1982, Watson 2000, Fanshawe et al., 2003). Many fisheries continue to be 'impacted' as otters expand their range, and researchers find it challenging to manage repopulated areas, even in the absence of commercial harvest (Larson et al., 2013, Hebert 2019). Conversely, increased densities at newly established abalone monitoring sites in Sitka Sound from 2015 to 2016 (Bell et al., 2018) and more recent local reports of increased sightings of abalone muddle the otherwise clear perceived effects of sea otter presence in Sitka Sound.

To begin exploring the key predictors of otter occupation and abundance, which predicate this study on the changed abalone populations, we first examined the differences in local abalone populations and determined otter occupation periods at local scales as recorded and reported by participants and more recent otter abundance with recent modeling.

Trends in abalone densities

We plotted average mean abalone densities across available years of surveys at five monitoring sites across Sitka Sound surveyed 2015 – 2021 (Bell et al., 2018, T. White unpublished data), then examined trendlines for changes in growth and differences in overall densities across Sitka Sound. In addition, we plotted and examined differences in the densities of sizes of abalone (i.e., 'juvenile' abalone <41mm, 'adult' abalone >40mm, and legally harvestable 'legal' abalone ≥89mm) across years at monitoring sites via full factorial two-way ANOVA with size class, survey year and combined effects as predictor variables.

To examine the most comprehensive differences in mean abalone densities across locations in Sitka Sound, we calculated densities of large and legal-sized abalone (<50mm) recorded per meter square along transects at random sites and monitoring sites in Sitka Sound (from 2018 and 2019). Both random and monitoring sites had two 2 x 20 meter transects per site (see White and Raimondi 2020). A spatially nested Analysis of Variance model tested differences in abalone densities at dive survey sites nested within large polygons. The model was run with and without Sitka long-term monitoring sites. Tukey Honest Significant Difference (HSD) post hoc tests determined differences in densities recorded at random sites across polygons (Sitka North, Inside, Outside, see Figure 1) and densities at non-randomly selected monitoring sites (grouped as a separate 'monitoring location'). Transects were used in analyses as replicates, and mean densities were square root transformed to stabilize variance to meet normality assumptions.

Reported abalone abundance across time

Abalone amounts were reported relative to the individual timeframe of experience at the site or locations of participant harvest or observation. To correct the number of individual reports and better reflect the abundance of reported abalone amount categories over time, we coded the reported amount category 'Many' as '1' and categories 'Few' and 'None' as '0' per year. The sum of 'many' amount category reports per year and the combined number of 'few' and 'none' reports per year were converted to proportions (1:0) and plotted across years of information provided to explore trends in abundance over time.

Sea otter abundance, growth

Determining spatially specific sea otter effects on abalone has proven difficult. Following sea otter reintroduction, abalone populations in the region declined significantly (Woodby et al., 2000), and in some areas (e.g., areas of Prince of Wales), population densities remain low (White and Raimondi 2020). Still, as mentioned, some sites around Sitka Sound have increasing abalone densities (Bell et al., 2018) and local reports of increased recruitment (see above). Though current estimates of otter densities throughout Southeast Alaska are limited, with over ten years since the last regional aerial surveys, recent aerial surveys in 2022 allowed for new and up-to-date local models of expected sea otter abundance.

Local sea otter occupation

There are few records of the initial reoccupation of sea otters to Sitka Sound, interviews focused on the first sighting and abundance reports of sea otters to better understand otter occupation times at specific locations in Sitka Sound. Between 1965 and 1969, otters were translocated to areas approximately 70 km north (Khaz Bay, n=164) and 18 km south (Biorka Island, n=48) of Sitka (Burris and McKnight 1973, Figure 1). Northern otter populations in Khaz Bay grew and eventually moved south to occupy portions of the 'Sitka North' location by 1987 (see Figure 1, Table 1). However, Biorka Island otter populations expanded more slowly, first moving south (to the Necker Islands) and then to islands on the outside of Sitka Sound (Low Island) by 1987 (Pitcher 1989). Generally, sea otters were sighted around Sitka Sound in the late 1990s, and by 2002, otter rafts (i.e., established populations) occupied all areas of Sitka Sound in general (M. Miller Personal Communication, H. McClain 2022). Our goal is to gather most information at a local scale. Interviews were built around a spatial framework, such that each person interviewed was asked to provide information at the smallest known scale. We focused on otter abundance and period of occupancy at the smallest scale, ideally at the scale of the smallest polygons in Figure 2. Therefore, we requested knowledge of otters and harvest at the finest spatial scale, within the smallest polygon in Figure 2 or else on a blank map, which was then assigned to Figure 2 polygons. If fine-scale local knowledge was not available, we scaled information to the next coarsest resolution (i.e., larger polygon). Information shared was aggregated to match the appropriate scale for spatially compatible otter and abalone data comparisons. We used cumulative individual reports of otter absence, first sightings, and otter persistence in local areas to determine otter occupation timeframe per finest scale (Figure 2).

Cumulative sightings of participants of individual otters and established rafts determined Otter Occupation. Pre-Otter denoted no sighting of an otter (i.e., no sea otter contact for >100 years) in a respective spatial unit (polygon; see Figure 2). The occupation Period was indicated by the collective participant's irregular sightings of single individual otters (no rafts). A spatial unit was considered 'post otter' with established otter populations (i.e., regular sightings of numerous individual sea otters, with females and pups). While scaling up to coarser scales, range estimates for 'during otter occupation' increased, while post-otter establishment may differ at small polygon scales nested within a large polygon in years indicative of 'during otter occupation.'

Abalone reports across otter occupation periods

Following the examination of abalone and sea otter populations and their respective histories in Sitka Sound, we explored general trends in abalone abundance directly associated with sea otter reoccupation. Trend information was collected during structured questionnaires, where individuals reported abalone abundance across periods of sea otter re-occupation (e.g., abalone amount before, during, and following otter occupation) at locations known or harvested by participants. Reported abalone amounts ('many,' 'few,' 'none/no' abalone) from structured questionnaires were extrapolated across the locations and years of experience shared for locations provided by each participant. Questions on extrapolating amounts of subject species (i.e., legal abalone, kelp, urchins, see structured questionnaire; Appendix C2) across unclear numbers of years or areas were addressed during the interview, in research follow-up, or amounts per occupation period were not extrapolated.

Similar to binary transformations of abalone amount categories during mapping exercises, categorical amounts of abalone ('many,' 'few,' 'none') provided in relation to otter occupation periods were converted into binary values: 1 for 'many' and 0 for 'few' or 'none.' These binary values were compared for sea otter occupation effect via a nominal logistic model with otter occupation as an indicator of amounts. Only legal abalone were included in these analyses for added accuracy across reports of 'many' abalone (i.e., for legal abalone, 'many' is more than allowable harvest).

Abalone abundance reports

Mean abundances of reported abalone (many, few, or none) provided during mapping exercises, regardless of sea otter-related abundances or occupation, were plotted across time by large polygon. We added a Locally Estimated Scatterplot Smoothing (LOESS) trendline to mean plotted amounts to discern non-linear patterns in the locally reported abalone amounts. Following interviews, we linked reported amounts of abalone per location and year with the consensus sea otter occupation at the same location and time. The scatter plots included these occupation periods better to visualize potential non-linear abalone abundance changes in relation to sea otter occupation.

Trends in available measures of abalone, sea otter, and kelp

Finally, we examined potential patterns in quantitative measures of abalone (densities) related to expected sea otter abundance (Eisaguirre et al., 2021, Schutte et al., 2023) and sea otter harvest (USFWS tag data). The aim of these general comparisons in measures across large spatial scales (i.e., Sitka North, Inside, Outside polygons) was to determine whether available current data of the three polygons (2015 – 2023) reflect predicted negative effects of sea otter presence and positive effects of harvest. We included kelp abundance measures in comparisons here as a proxy for sea otter effects. This proxy is based on an abundance of research that demonstrates sea otters supporting the growth and resilience of kelp forests in part due to the reduction of herbivores such as sea urchins (Estes and Palmisano 1974, Estes and Duggins 1995, Watson and Estes 2011, Nicholson et al., 2024). Considering limited data, we determined that if kelp maintained a positive association with sea otter abundance, then the spatial scale may capture sea otter effects and provide a more accurate understanding of potential effects on abalone at similar scales.

Mean densities of pinto abalone were calculated per year per large polygon area of Sitka based on survey data from 2015 to 2016 (Bell et al., 2018), 2017 to 2021 (T. White, unpublished data), and 2022 to 2023 (K. Kroeker, unpublished data). Considering individual hunter identities were kept confidential, reported harvest dates were instead used to determine the mean number of otter tags per polygon per year. Sea otter abundance estimates were shared by USFWS and calculated by large polygon using a diffusion model (Eisaguirre et al., 2021) calibrated with 2022 aerial data from the most recent sea otter surveys in Sitka Sound (Schutte et al., 2023). Finally, kelp abundance was determined from Kelpwatch data on canopy cover kelps like giant kelp (*Macrocystis spps*.) and bull kelp (*Nereocystis luetkeana*) (see Kelpwatch.org, Bell et al., 2023). Data on emergent kelp per m^2 of the selected area was determined by mapping Sitka polygon geometry on Kelpwatch.org for all large and small spatial scales in this study (see Figures 1 and 2). Data were not available for all finer scales of this study (sub-small polygons in Figure 2). To circumvent issues with non-emergent kelp in satellite data due to cloud cover, which results in areas where kelp is present but not visible (recorded as zeros), and with the assumption of non-uniform cloud cover within years, we used medians of seasonal averages (i.e., Kelpwatch 'quarters' Q1, Q2, Q3, Q4) of emergent kelp per project polygon area. The annual medians were averaged across large polygons for analyses to determine large trends over multiple years.

All effect measures (e.g. abalone density, otter tag count, kelp densities) were standardized for comparisons by dividing the mean measures per year by the maximum value for each polygon across all years and multiplied by one hundred for a percentage. We used a Scatterplot Matrix (SPLOM) for a comprehensive review of pairwise relationships between percent maximum measures by spatial scale, averaged by year.

Local patterns of otter harvest and abalone abundance

To explore human impacts on sea otter populations and the potential indirect effects of sea otter hunting practices at local scales, sea otter hunters were asked to delineate areas of harvest in Sitka Sound (South of Krestof Sound) and note any changes to otter behaviors and movement to or from harvest areas. We predicted localized patterns of hunting and otter behavioral response in and around Sitka Sound to reflect the fear ecology described in smaller communities of Southeast Alaska, where sea otters avoided areas following intensive harvest (Hoyt 2015). Hunters were also asked to share additional information on knowledge of otters that are 'struck and lost' or mortally wounded otters that may not be captured in tag data reports. Finally, as done in studies in smaller communities of Southeast Alaska (see Ibarra 2021), hunters identified factors, socio-economic or ecological, that influenced their sea otter hunting practice (e.g., fuel, tannery accessed, seasonal otter movements, blood quantum requirements, Marine Mammal Protection Act changes, etc.). We identified common themes around hunting patterns, otter movements, and key external factors affecting hunting practices

While hunting remains stable at the regional scale of Southeast Alaska, harvest rates vary at the sub-regional scale (Raymond et al., 2019). Interviews explore hunting practices, including socioeconomic factors affecting hunters, which may define some variation (Raymond et al., 2019). Additionally, in select areas of intensive harvest, researchers have recorded a 'halo effect' or behavioral response of sea otter movement away from heavily harvested areas (Hoyt 2015). While not yet assessed, shellfish, including abalone, likely experience an indirect positive response to these harvest patterns.

To investigate potential local relationships between legal abalone abundance and relatively high amounts of sea otter harvest (USFWS tag data) per year, we used a Generalized Linear Model (GLM) with a Poisson distribution and a log link function. Maximum Likelihood Estimation (MLE) was used for parameter estimation. The significance of model terms was assessed using likelihood ratio chi-square tests. The response variable was the number of ('many') amounts with predictors: location (large polygons), time (years), and 'species ID' (abalone or otter tags). The model included third- and second-order polynomial terms for time and polygon to capture non-linear temporal and spatial trends.

Amounts ('many,' 'few,' 'none') of legal abalone per year were determined by the cumulative frequency of reports at respective polygon scales each year. For example, an individual might report 'many' legal abalone (more than the legal minimum limit) at five different sites nested within the large 'Outside' polygon in a single year. This would result in five entries of 'many' legal abalone for that polygon for the year. If additional participants also report 'many' at any sites within the 'Outside' polygon within the same year, the cumulative count for the polygon would increase accordingly. Unlike reported legal abalone amount categories, sea otter tag categories were derived from harvest data (USFWS unpublished data). First, we divided the total number of tags reported in Sitka Sound from 2003 to 2023 (USFWS unpublished data) by thirds to create thresholds between tag categories: 'Many', 'Moderate', and 'None'. The number of sea otter tags reported during a specific date and location (i.e., the number of otters taken during a specific hunt) were then assigned to large polygons (see Figure 1), and counts per hunt were then categorized relative to determined tag count tercile thresholds across Sitka Sound. To ensure the accuracy of the annual tag amount categorization method, we tested whether the mean annual tag counts per polygon could predict cumulative annual tag (amount) through linear regression.

It is known historically that Indigenous communities adaptively managed shellfish populations by the removal of sea otters from areas (refer to Szpak et al., 2012, Ibarra 2021). Therefore, it is of the utmost importance to clearly acknowledge that correlations examined here between otter tag (harvest) data and reported abalone abundance do not challenge such time-honored management practices, nor do the general comparisons presume direct causation. This examination of changes to local abalone abundance following sea otter harvest is meant to build on or potentially reframe a common community-held belief in the direct impacts of sea otters on abalone.

Subsistence harvest intensities and local effects

We examined local abalone subsistence patterns and assessed human impact on abalone populations in Sitka Sound. Abalone subsistence reports are not mandatory; therefore, harvest activity collected during mapping exercises provided the most comprehensive records of abalone recorded in the area since 1981 (see Mills 1982). Current subsistence guidelines limit abalone harvest to five large abalone (≥ 89mm, bag and possession limit). Therefore, we predicted heavily harvested areas, likely nearer to the community of Sitka, to have reduced densities of legal abalone (as recorded during 2018 and 2019 dive surveys; T White unpublished data). We corroborated assumptions that increased accessibility lends to more harvest closer to town through detailed participant reports (see Appendix C2 'Interview Questions'). This was further reinforced by the number of reported instances of harvestable abalone sightings or harvest of abalone at locations within each large polygon (refer to Figure 1).

We used multiple regression analyses to determine the relationship between densities of abalone size classes: 'juveniles' (< 41mm), 'adults' (> 40mm), and 'legal' (^{3} 89mm), and human and otter impacts as a function of distance from town. We explored the potential impacts of sea otters through a general test based on foraging theory, the idea that predators will eat and seek food in ways to minimize energy output and maximize energy gains (Charnov 1976, Stephens and Krebs 1986). Therefore, we predicted fewer large, sub-legal abalone areas away from town (i.e., nearer and within the Outside polygon). This prediction was further informed by recent findings from researchers Gorra et al. (2022), who determined an increased likelihood of sea otter sightings at an increased distance away from town during the same period as abalone density surveys (2018). Concurrently, we predicted similar or reduced amounts of legal abalone recorded at sites of increasing distance from Sitka, as both humans and sea otters target the largest abalone.

Distance to a transect was measured as a Euclidean distance in kilometers from the Petrol Marine Station a fuel dock downtown serving most non-commercial vessels in Sitka Harbors

(Eliason, New Thompson, ANB, Crescent Harbor, and Sealing Cove) to each site plotted on NOAA Chart #US5AK3FM in OpenCPN (vers. 5.0.1+0266678). ArcGIS Online was used for mapping figures, and JMP Pro17 was used in analyses and figures.

Results

Trends in abalone and otter measures

Abalone densities were variable across monitoring sites in Sitka and increased at different rates from 2015 to 2021 (Figure 3). Size class densities did not increase with increasing overall densities, but adult abalone remained at or above the 0.2 abalone/m^2 density found necessary for local population viability (T. White unpublished data) and viability for abalone populations elsewhere (see Shepherd and Partington 1995, Babcock and Keesing 1999; Figure 4). Of abalone at monitoring sites in Sitka, less than five percent were of legal size in 2015 and 2016, and legal abalone constituted one to three percent of all recorded abalone in the following years (Figure 4). Densities varied among size classes per survey year when examined ($F(10, 3.96) = 5.64$, $p < .0001$), with the largest increase in adult densities between 2018 and 2019 (Figure 4). However, between 2019 and 2020, adult densities at monitoring sites dropped from a density of 1.27 adult/m^2 to 0.576 adult/m^2 density (a 40.5% decrease). Juvenile abalone (all <41mm) were documented in increasing densities across the years; however, as small abalone are cryptic and <20mm abalone were tallied during 2015 and 2016 surveys, these densities here are likely an underestimate of small abalone measures (see Figure 4). Densities of randomly selected sites in Sitka large polygons (ref. Figure 1) during 2018 and 2019 surveys were distinctly different within and across large polygons (Table 1). Notably, overall monitoring site densities were higher than those at randomly selected sites in Sitka North, Inside, and Outside Large polygon “locations” (see Tukey HSD Table 1). Following the removal of monitoring sites from tests, densities across random sites within large polygons maintained significant differences.

Reported abalone abundance across time

Proportions of reported abalone amounts (all sizes) shared during mapping exercises declined substantially following a peak in ‘Many’ abalone amounts in the 1960s (Figure 5). Abalone proportions continued to decline through 2023 (Figure 5). Importantly, multiple participants reported declines in abalone availability in Sitka prior to sea otter establishment in areas, and there were limited reports of ‘few’ abalone before the 1980s.

First-hand reports shared began in the 1940s at sites known for generations prior, where abalone were plentiful. There was always enough to share, and abalone could be picked straight from rocks or even kelp from a boat or onshore at low tides. All participants, either electively or in response to semi-structured questions, mentioned at least one major shift in abalone populations over time. One participant referred to abalone, Dungeness crabs, and sea stars in the late 1970s:

"Everything was so abundant when I first arrived"

-Anonymous
Commercial dive fisher
Subsistence harvester; 2023

Reports of abalone pre-1980s suggested an abundance of abalone and related marine life, with few instances of population reductions at specific harvest sites. Reports from the 1980s to 1990s referenced declines in abalone populations and notable increases in local harvest participation, including scuba dive harvesting. In the early 1980s, during the region-wide peak commercial abalone harvest years (see Hebert 2014), Sitka Sound was described as having fewer abalone than commercial abalone fishing grounds to the south.
In reference to reduced commercially harvestable abalone to the south of Sitka:

"The writing was on the wall in '91' [the abalone fishery was closing]"

-Anonymous
Commercial dive fisher,
Subsistence harvester; 2024

Following the mid-late 1990s, there were reports of a noticeable reduction in abalone and changes to harvest locations in response, and mentions of sea otter impacts followed precipitous declines in abalone populations. The second commonly reported increase in abalone subsistence harvest participation was around 2020 and 2021.

Local sea otter occupation

Participants who witnessed the re-occupation of sea otters in Sitka Sound often were able to recall the location and timeframe of the first sea otter(s) they witnessed. Stages of sea otter reoccupation were determined at the smallest available local area (Table 2, Figure 2) from collated participant reports of first sightings and subsequent amounts and regularity of sea otter sightings (Table 2). Participants identified sea otter movement into Sitka Sound from the North, likely from the Khaz Bay population or from individuals transplanted farther north at Yakobi Island in 1968 (Burris and McKnight 1973). By the early 2000s, otters had expanded into most areas of Sitka Sound (see Table 2, Figure 2). Sea otters occupied patches of the Outside polygon area in the 1980s; however, reports determine the area was not considered 'occupied' until 2001, as otters had not been reported as established or regularly present throughout the multiple small areas making up the larger polygon (see Table 2, Figure 2). Populations of sea otters in the 'Outside' polygon maintained patchy densities until reports of common sightings in 2000. Additionally, in 2002, aerial surveys documented populations of sea otters at the highest densities in the 'Outside' polygon relative to other Sitka polygons (Esslinger and Bodkin 2009).

Relative to other large areas in Figure 1, Sitka North had the longest total area occupation period ranging from 25 to 40 years (including smaller area occupation in Table 2), Sitka Inside had a relatively moderate occupation of around 25 years, and though areas of the 'Outside' outer coast were long occupied (e.g., Biorka Island reintroduction site in 1968, reference Table 2, Figure 2). The whole of the Outside polygon was most recently populated with around 20 years of total area sea otter occupation. Still, some small polygons 'Inside' Sitka Sound were considered occupied only a year earlier than 'Outside' small polygons (Table 2, Figure 1).

The outer coast (Outside polygon) had the highest reported current (2023) abundance of sea otters, and, as modeled, 'Outside' otter populations were growing to meet the highest maximum value estimated (see Figure 6). The percent maximum estimated otter abundance over the years indicated that populations in the North reached around 75% of the maximum abundances reported, and Inside estimated amounts reached 93.5% of the maximum Inside abundance estimate by 2023 (Figure 6). However, the rate of increase slowed after 2020 (Figure 6). Based on multiple reports from interviews, sea otter growth likely occurred over ten years earlier than is shown in Figure 6.

Sea otters on the outer coast did not expand as quickly as those in the North. Still, their occupation meant area fishery closures. In reference to the closure of the sea urchin fishery following the first sightings of sea otters in the Outside polygon:

"It wasn't long after the otters came through… it was the next year or two because they moved slowly, they really did move slowly… and they'd [area managers] give us a little quota further and further south"

- Spencer Severson
Commercial dive fisher,
Subsistence harvester; 2023

In a relative comparison of otter abundance across large polygons in recent years (2015–2023), individuals ranked Sitka Outside polygon with the highest reported abundance of sea otters, Sitka North ranked second, and Inside sea otter populations were ranked with the lowest abundance in recent years.

The USFWS estimation of 2023 sea otter abundance based on the dispersion model Eisaguirre et al. (2021), including recent 2022 aerial surveys of sea otters in Sitka Sound (see Schutte et al., 2023), predicted 2023 otter abundance by polygon as North: mean: 0.047 otters/km^2, SD ±0.071, 90th percentile = 0.172745 otters/km^2, Inside: mean= 0.059 otters/km^2, SD ±0.081, 90th percentile= 0.198941 otters/km^2, and Outside mean= 0.066 otters/km^2, SD ±0.081, 90th percentile= 0.201123 otters/km^2.

Participants detailed additional sea otter seasonal movement, where individuals reported sea otters moving to shelter during winter. More otters were reported inside Sitka Sound in the winter or in protected outer coast areas. Sea otter abundance was noted to be very dependent on otter sex, where female otters were more commonly reported in rafts while male otters, ‘scouts’ were more often solo, roaming.

Abalone reports across otter occupation periods

Sea otter occupation periods notably shifted on the reported amounts of legal abalone, with many more reports of few abalone following occupation times, a pattern that differed based on location (large polygons; Table 3, Figure 7).

Though less commonly documented (see Hoyt 2015, LaRoche et al., 2021), sea otters do eat pinto abalone in Southeast Alaska. A diver returning to a regular harvest location in Prince of Wales, Southern Southeast Alaska, described his experience:

“I went there one year, and there’s this lone sea otter, the first I’d ever seen in Sea Otter Sound [Prince of Wales]… and he was huge… and he’s eating an abalone, right on my spot… and I went down, and there’s shells everywhere in over 65 feet of water…He [the otter] had the abalone on the surface with him, eating them without a rock, and not only that… a lot of those abalone only had one bite out of them!”

- Spencer Severson
Commercial dive fisher,
Subsistence harvester; 2023

Abalone abundance reports

There was clear variability in reports of harvestable abalone amount categories during mapping exercises (Figure 8). This was particularly true for the Sitka Inside area, where increased reports for all amount categories determined a clear decline in ‘Many’ harvestable abalone following separate reports of increased abalone harvest in the year 2000 (see Figure 8). ‘Many’ abalone declined non-linearly, with more accounts of ‘Few’ following sea otter occupation at reported sites (Figure 8).

Trends in available measures of abalone, sea otter, and kelp

When interactions between available abalone, kelp, otter harvest, and otter abundance metrics were compared (see Scatterplot Matrix Figure 9), there was a strong inverse relationship between the percent maximum otter harvest amount sum(n(tags)) and estimated sea otter abundance ($r = -0.8405$, $p = 0.0045$; Table 4). Trends were similar across large polygon scales and when presented in aggregate across Sitka Sound (Figure 9). When periods of sea otter occupation were included in bar plots of large polygon kelp density per year, later stages of occupation corresponded with generally positive increased kelp densities until 2015 (see Figure A2). Separate linear regressions for all polygons only determined the number of sea otters in a reported pod at a harvest site predicted the number of sea otters harvested in the Outside polygon from 2015 – 2023 ($F(1, 181) = 12.82$, $p = 0.0004$). Though estimated otter densities and kelp densities do not positively correlate at large scales (Figure 9, Figure A1), newly identified otter occupation periods indicated some positive effects on kelp densities (see Figure A2).

Local patterns of otter harvest and abalone abundance

Hunter reports and tag data from 2003 to 2023 indicated that the years of highest harvest amounts were 2014, 2015, and 2016 (including 2017 on the outer coast) (USFWS unpublished data). Prior to tag records included in this study, hunters reported most harvest north of the 'North' polygon. Still, during high harvest years, the North polygon had 49.4% more harvest than the 'Inside' polygon, 22.1% higher than the 'Outside' polygon. The Outside had 19% more harvest than inside those years. During the peak harvest period, 64%, 59%, and 31% of harvested otters were males in the North, Inside, and Outside polygons, respectively. The proportions of harvested males and females changed in the years following the highest amounts of recent harvest in study areas (i.e., 2017 to 2023). During and following peak years of harvest, higher proportions of females were harvested in the 'Outside' polygon, compared with North and Inside higher male to female ratios (USFWS unpublished data). Important for accurate comparison, cumulative annual tag (amounts) and derived sum (otter amount categories) had a positive relationship (regression test).

Legally, hunting must occur more than a half mile from Sitka, and hunters defined a factor impeding harvest as the cost of travel to hunt. Individuals often opportunistically harvested sea otters (i.e., en route to harvest deer and seals) and more often when there was a known client for handicrafts. On reasons for harvesting sea otters, in order of most importance:

> '*...opportunity, effort, potential market, shellfish*.'
>
> - Steve Johnson, Kiks.ádi
> Cultural bearer, Teacher,
> Subsistence, traditional, and
> customary harvester, hunter; 2023

Limitations, including gas, tannery access, required skills, reduced market demand, and necessary gear, were common reasons for limited harvest or harvest frequency and intensity changes. The opening of the local tannery in 2011 followed years of increased harvest in town, but following its closure in 2019, hunters had to pay additional costs to tan furs elsewhere.

Sea otter, behavior, occupation

Most hunters surveyed (n=5 of 7; 71%) shared experiences of sea otters moving 'farther off' following a period (ranging from a month to a year) of hunting an area (i.e., small polygon-sized area; refer to Figure 2). Sea otters would not completely vacate hunted areas but instead relocate to less accessible regions of areas (e.g., remaining otters redistribute within small polygons). Hunters shared descriptions of more skittish sea otters near boats in the last ten years (since 2013). Additionally, participants noted seasonal movements of sea otters, including observations made by non-hunters. It was reported that sea otters tend to relocate during the winter months. Specifically, a higher concentration of otters was observed within Sitka Sound during this period, while others were noted to frequent more sheltered areas along the outer coast, as depicted in the 'Outside' polygon in Figure 1.

Struck and lost otters (i.e., mortally wounded individuals that were not able to be collected) are generally not reported. Multiple hunters reported avoiding hunting in poor weather or extremely exposed locations to avoid circumstances connected to losing an otter. In addition, hunters detailed that struck and loss may be more prevalent when multiple otters are taken at a time. Where depending on the hunter's experience, if otters were not immediately attended to, some could be lost, especially in poor weather.

Local patterns of otter harvest and abalone abundance

There was a strong negative quadratic relationship between amounts of legal abalone reports and sea otter harvest intensity (chi-square = 6101362, p-value <.0001, Figure 10) over time (see interaction terms: Year*Year*Species ID 2nd polynomial tests, Table 5). The polynomial Generalized Linear Model (GLM) accounts for responses not captured by simpler models (Table 5, Figure A3 for data plots).

When sea otter harvest amounts were at their highest (2013-2016, using category data), the fewest amounts of legally harvestable abalone were reported (Figure 10) Additionally, there were more reports of 'few' abalone at harvest sites during those years (2014 – 2016; See Appendix Figure A3). This was particularly pronounced in the 'Inside' polygon of Sitka Sound, where there are the most abalone reports.

During 2018 and 2019 surveys, prior to multiple reports of increased subsistence harvest participation in 2020, mean abalone sizes were largest in the Sitka 'Outside' polygon (mean: 49 mm, SD ±18.7), where otter populations were e growing fastest, in the highest abundance. Abalone sizes were most variable in the 'North' polygon (mean: 47mm, SD ± 25.01) where sea otters have occupied for the longest periods (see Table 2), and abalone were on average, the smallest nearest town (Sitka Inside: mean: 45 mm, SD ± 21.45) (Figure A4).

An otter hunter highlighted otter harvest efforts in Sitka Sound to support abalone populations but suggested that recent human harvest may have countered his effort:

> *"I've been doing this [hunting] for over 30 years, to get this [abalone re-establishment] to happen...everywhere we were going: 'Abalone!'... last year when we went out: 'where's the abalone?'*
>
> - W. Martin, Chilkat Tlingit Hunter, Harvester, 2023

Subsistence harvest intensities and local effects

Abalone harvest was described traditionally all around Sitka Sound, from summer camps in the north to the small islands surrounding the community. Indigenous knowledge bearers stated that shells were most often left where they were harvested (i.e., on islands or shore) instead of brought to local middens, and shells would more often be discarded than kept as they were not prized like abalone species from California. Still, through time and across knowledge systems, local pinto abalone were described as a delicacy to be protected. More than one participant shared a practice of yáa at wooné – respect for all things in Lingít. This concept echoed a commonly shared sentiment, not to harvest too much; 'just enough to share.'

Many harvesters reported efforts to leave town when possible, to avoid contributing to increased harvest from accessible areas. Still, there are significant limitations to leaving town:

"Getting there can be a challenge for most folks… the cost of access can be kind of prohibitive… and a big thing with subsistence fishers is being able to harvest where they live"

- Jeff Feldpausch
Resource Protection Director
Sitka Tribe of Alaska, 2023

Following 2020, multiple participants noted increased participation by newer subsistence harvesters of abalone and a need to move harvest sites.

Individuals cited small-scale poaching as a problem and provided known sites of illegal harvest within the 'Inside' polygon (see Figure 1). This illegal harvest was especially noticeable following the 2013 regulation change, which reduced the maximum limit from 30 to 5 abalone per person, a rule that was often ignored. Participants either did not know of any larger-scale poaching or else doubted poaching pressures, often describing the difficulty of moving large amounts of fresh abalone off an island on the outer coast of Alaska.

In our examination of total abalone density and densities of juvenile, adult, and legal abalone as a function of distance away from town, total mean abalone density increased at increasing distances from the community of Sitka (Figure 11). When examined by size, large 'adult' abalone or those individuals under the legal size for human harvest (<89mm), increased with increasing distance from town (Figure 11). Though legal-sized (^{3} 89mm), abalone densities did not notably increase with distance, the combined adult and legal abalone densities were generally higher at survey sites farther away from Sitka ($F(1,46)=7.04$, $p=.0011$).

Finally, there remained a strong community-held belief generally pertaining to sea otters impacting all shellfish populations in Sitka Sound. However, when elaborated on through discussions of proposed solutions or ongoing opinions of sea otters themselves, they were not wholly negative, with most participants (n= 22) reporting more than two non-sea otter factors negatively affecting abalone populations in Sitka, namely increased abalone harvest or local predation from other species (i.e., weasels, birds). In this way, participants still identified limitations in their understanding of sea otters, or else came to understand caveats to sea otter impacts in the years following sea otter occupation:

“I was on the anti-otter bandwagon, but then it wasn’t really the otters”

- Anonymous
Commercial dive fisher
Subsistence harvester; 2023

“As I’ve thought about it more, from what I’ve seen, I don’t think sea otters currently are a massive predator of abalone in the Sitka area…If sea otters all of a sudden decided they wanted to eat abalone, they could just substantially wipe them all out”

- Anonymous
Harvester; 2024

“I used to think there is no place for both [otters, abalone]. Apparently, that’s not true!”

- Mike Miller, Lingít
Local Harvester, Hunter,
Marine Advocate; 2023

Discussion

The joining of multiple ways of knowing sea otters, abalone, and the local environment in Sitka Sound has provided deeper insight into the complex relationships between repatriating sea otters, local abalone populations, and the harvesting practices of the community. This project and its participants have extended ecological records of sea otter and abalone populations in Sitka Sound by nearly 75 years (Figure 12). More so, shared Indigenous Knowledge, deeply rooted in Lingít Aaní, provides context and extends beyond first-hand reports shared here (in Figures 5, 7, 8, and 12). In addition, local sea otter occupation periods were determined at small spatial scales, allowing insights into the finer-scale ecological roles of sea otters (Table 2). This enriched collective understanding highlights nuanced interactions between humans and otters at scales critical to local harvest (i.e., Figure 2).

While the reintroduction of sea otters to Sitka Sound initially coincided with a decrease in abalone abundance, the ongoing influence of otters on abalone population dynamics remains ambiguous. When specifically asked about changes in the availability of abalone, participants noted initial declines in harvestable abalone at local sites shortly after initial sea otter occupation and subsequent otter population movement into their harvest areas (Table 3, Figure 7). Still, prior to the establishment of sea otter sites in the 1980s, participant reports of total abalone abundance decreased (Figure 5), and harvestable abalone were described as harder to find (e.g., 'Many' abalone in Inside polygon, Figure 8). Sitka abalone populations persist despite the ongoing presence of sea otters and local harvest, albeit at significantly reduced abundances relative to historical reports (Figure 5).

Abalone densities increased across sites in Sitka Sound (from 2015 to 2020), which was unexpected considering established sea otter populations and subsistence harvest (Figures 3 and 4). Moreover, Sitka abalone densities surpassed densities recorded at similar surveys in areas of Southern Southeast Alaska, where sea otters had yet to establish populations (see White and Raimondi 2020). Still, Sitka Sound had significantly variable densities within the 'large polygon' areas used for general comparisons (e.g., Table 1, Figure 1), and monitoring sites chosen for high abalone densities (see Bell et al., 2018) showed variable rates of change in densities across sites (Figure 3). All suggest unknown localized effects on abalone populations.

Many small abalone were documented at sites indicating recruitment or abalone reproductive successes. However, very few surveyed abalone were above the minimum legal-size limit (<1 to 3% across years, Figure 4, Figure A4). These 'Legal' abalone could be the target of local subsistence harvesters and sea otters, assuming optimal foraging theory or a preference for larger prey items (see Kleiber 1961, Charnov 1976, Stephens and Krebs 1986). Still, estimated sea otter densities did not correlate with decreases in abalone densities (Table 4, Figure 9), and the Outside polygon area hosted the highest densities of estimated sea otters and surveyed abalone during the same period (Table 6, Figure 6). In addition, the negative, quadratic relationship between high amounts of sea otter harvest and legal abalone did not indicate that abalone populations benefit from sea otter removal or any resulting sea otter avoidance behavior following intensive harvest (Table 5, Figure 10).

When compared to sea otter abundance, increased human access to abalone has a pronounced negative association with abalone abundance. Distance from the community of Sitka was an appropriate measure of access based on participant reporting and individuals' attempts to leave town to avoid high-use areas despite the cost of travel and gear. Given this, survey sites had higher densities of abalone recorded at increasing distances away from town, towards areas with greater sea otter abundances (i.e., Outside, Figure 11). The neutral or positive role of sea otter presence is particularly pronounced in large, sub-legal adult abalone, sizes that are not the target of subsistence harvesters yet increased nearer higher abundances of otters (Figure 11, Figure 6).

Sea otter harvest on the outer coast could be examined as a cause for increased abalone abundance, as the highest amounts of sea otter harvest in recent years have occurred 'Outside' Sitka Sound. Importantly, harvest in the "Outside" polygon included proportionally more females (USFWS unpublished data), and female otters elsewhere have been identified more commonly as specialists compared to males (e.g., Estes et al., 2003). Though sea otters in Southeast Alaska do consume abalone, it is not abundantly clear that individual otters would specialize in abalone as prey. For individuals around to witness, the most frequently revisited theme pertaining to sea otters, was their immediate reduction in abalone population abundance within three to six months following their expansion into harvest areas.

"...let's avoid the effects felt by the initial re-establishment of sea otters again!"

- Anonymous
Subsistence harvester; 2023

Though initial effects were abundantly clear to individuals, subtler, potentially indirect effects may influence abalone and otter dynamics, as posited by one participant:

"I'm starting to wonder if sea otters do have an impact on abalone, just not in the way that we're currently thinking about them...."

"it may be, in fact, continued sustained sea otter hunting does help abalone populations, maybe we don't fully know how yet... maybe not directly from sea otters eating abalone."

- Anonymous
Harvester; 2024

Southeast Alaska is the only region where both species co-occur in significant numbers. Still, limited information exists on the effects of ongoing sea otter hunting on abalone populations, where pinto abalone are at relatively higher densities as in Sitka. Indigenous Knowledge shared during this project and the history of abalone and sea otters in Sitka Sound was limited by colonization impacts (i.e., the fur trade) and loss of language and customs (Solomon et al., 2015, Ojeda 2024). Such losses equate to a loss of cultural identity and autonomy, which is why, with individual participant permissions, project information was archived with care to be provided to the Sitka Tribe of Alaska (details in Appendix C1).

"Unfortunately, there's not a lot of cultural bearers left'"

- Steve Johnson, Kiks.ádi
Cultural bearer, Teacher,
Subsistence, traditional, and
customary harvester, hunter; 2023

There do appear to be more positive, non-linear associations between abalone and sea otter presence following a period of occupation, as seen in Figure 8, where reports of many abalone increased over longer periods of occupation time. Abalone are found to indirectly benefit from sea otter presence and otter removal of herbivores elsewhere (Raimondi et al., 2015, Lee et al., 2016). Gorra et al. (2022) reinforced this effect in Sitka when finding reduced biomasses of sea urchins, a commonly cited prey item for sea otters, in areas with increased sea otter sightings. This may indirectly translate to less effort by abalone to compete for food.

Though effects from sea otter presence or removal cannot directly be implicated on abalone populations, future work and more comprehensive and spatially precise extrapolation of different types of quantitative data, including urchins (e.g., Gorra et al., 2022), and additional years of abalone surveys could provide more evidence for patterns identified in these locations.
Importantly, this project found our collective understanding of sea otter impacts on abalone populations in Southeast Alaska is limited in two significant ways:

1. **Western Scientific limitations**: Current and historical data on local species' dynamics are often incomplete. Research frequently lacks a comprehensive grasp of the local historical interactions and community relationships with surveyed species, which likely experience direct or indirect effects of the removal of species like otters and abalone.
2. **Community-held beliefs**: There is a prevalent community-held belief that sea otters have an exclusively negative impact on the environment. This was reinforced by initial impacts of sea otter re-occupation.

These factors contribute to a constrained perception of the ecological roles that sea otters play in marine ecosystems. Still, the changing intensities of these 'roles' are not lost on community members who bear witness to local ecosystem changes over time.

"It's a perception problem... because people view things from the lens they're looking at... if you are a Dungeness fisherman -not all of them, but - if you see an otter eating a Dungeness and you have a bad year of Dungeness... it's because of the otter... right? ... it's just human nature. Whatever lens you're looking at is how you view the world."

- Mike Miller, Lingít
Local Harvester, Hunter,
Marine Advocate, 2023

This synthesis of ways of knowing these important species challenges previous assumptions of sea otter roles in Sitka Sound. These findings provide space to explore newly informed questions pertaining to significant human impacts on abalone populations and encourage additional inclusive research on the roles of resident sea otter populations and alternate factors affecting local abalone populations.

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Tables

Table 1. Results of spatially nested Analysis of Variance and Tukey Honest Significant Difference (HSD) post hoc tests comparing all possible pairwise differences in mean densities recorded at Sitka monitoring and random sites in 2018 and 2019. Sites were nested within "locations" (i.e., large polygons: Sitka North, Inside, Outside; see Figure 1). Sitka abalone monitoring sites were treated as separate locations, distinct from random abalone site surveys conducted within Sitka North, Inside and Outside large polygons or "locations." Sites sharing the letters 'A' and 'B' indicate statistically significant differences in densities between those groups. Densities were square root transformed to stabilize variance and meet normality assumptions.

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	28	14.392064	0.514002	5.6928
Error	39	3.521322	0.090290	**Prob > F**
C. Total	67	17.913386	**<.0001***	

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Location	3	3	2.224368	8.2119	**0.0002***
Site Label[Location]	25	25	12.167696	5.3905	**<.0001***

Location, Polygon			Least Sq Mean (sqroot density)
Sitka Monitoring	A		1.3931103
Sitka North		B	0.9014627
Sitka Inside		B	0.9885247
Sitka Outside		B	1.0905473

Table 2. Otter Occupation Periods in Sitka Sound. Cumulative sightings of individual otters and established rafts determined Otter Occupation Periods in Sitka Sound (in the protected areas of Krestof Sound south to West Crawfish Inlet; see Figure 1). Coarse (large polygons: North, Inside, Outside; Figure 1) and finer spatial scales (sub-and small polygons nested within large polygons) were designated as being 'pre-otter' when no otters had been sighted or reported in the area (i.e., areas of no sea otter contact for >100 years). The 'occupation period' indicates years of irregular sightings of individual otters (no rafts). Spatial units were designated as 'post otter' following surveys or reported regular sightings of numerous individual sea otters, with females and pups, in the area regularly. Relative to Sitka Sound 'Large Polygon' areas, the North had the longest sea otter occupation (since 1995), Inside moderate occupation (around 2002), and Outside had the most recent total area occupation (around 2003). Refer to Figure 2 for detailed spatial scaling in reference to sea otter reoccupation of Sitka Sound, Alaska.

Large Polygon	LPoly PreOtter	LPoly Post Otter	Small Polygon	Sub Small Polygon	Pre-Otter	Occupation Period	Post Otter
North	1978	1996	1	a	1978	1979 –1993 [a]	1994 [a]
North	1978	1996	1	b	1978	1979 –1986	1987
North	1978	1996	2	a	1992	1993–1995	1996
Inside	1992	2000	3	a	1992	1993–1995 [b]	1996
Inside	1992	2000	4	a	1992	1993 –1997 [b]	1998
Inside	1992	2000	4	b	1992	1993 –1996	1997
Inside	1992	2000	5	a	1996	1997 – 2000	2001
Inside	1992	2000	5	b	2000	2001	2002
Inside	1992	2000	5	c	2001	2002	2002
Inside	1992	2000	6	a	2000	2001	2002
Inside	1992	2000	6	b	2000	2001	2002
Inside	1992	2000	7	a	2000	2001	2002
Outside	1985	2001	8	a	2001	2002	2003
Outside	1985	2001	9	a	1999	2000-2002	2003
Outside	1985	2001	9	b	1985	1986 – 1999	2000
Outside	1985	2001	10	a[c]	(1967) [c] 1974	1975 – 2000 [d]	2001
Outside	1985	2001	10	b	1998	1999 –2000 [d]	2001
Outside	1985	2001	10	c[e]	1974 [e]	1975 –1987	1988

a: Many otters were noted in 1983 in the northern region of the 1a polygon. The area was not wholly established until 1994.

b: Described as 'during active otter occupation' in 2002 by three individuals, with sporadic sightings since 1993.

c: 1968: Biorka relocated 43 individuals to the SE side of the Biorka Island location. This was the only location within Polygon 10 with a preotter date of 1967; 1974 aerial surveys did not show document otters elsewhere until 1975, when five otters were recorded at Necker Islands (i.e., subsmall polygon 10c); then 20 otters in 1983, 8 in 1986, 47 in 1987, and 108 in 1988 (Pitcher 1989). In contrast, Biorka transplants were noted in 1988 at low densities, and commercial divers did not observe otters in the area.

d: The outside polygon had areas that were occupied in the 1980s; however, those otters did not appear to populate or regularly occupy the entire until 2001, as otters had not been established throughout the multiple small polygons making up the small polygon.

e: The Necker Islands (10c) exhibited the largest recorded rafts of sea otters population within the 'Outside' polygon by 1987, with 108 in 1988 (Pitcher 1989). The next aerial surveys in 2002 documented otters around Necker Islands at their highest abundance (Esslinger and Bodkin 2009).

Table 3. Nominal logistic analysis of the impact of sea otter occupation period (pre-, during, and post-otter occupation) on reported legal abalone abundance across large areas of Sitka Sound (Lpoly= North, Inside, Outside). Including model tests using likelihood ratio comparing full and reduced models. For analyses, amounts 'many,' 'few,' and 'none' were recoded as 1 = 'many' and 0 = both 'few' and 'none' per otter Occupation Period. The Occupation Period was determined separately via consensus among local reports and linked at the finest reported scale (see Table 2).

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	167.57154	8	335.1431	<.0001*
Full	519.06559			
Reduced	686.63712			

RSquare (U)	0.2440
AICc	1056.31
BIC	1100.46
Observations (or Sum Wgts)	1018

Effects Tests

Source	Nparm	DF	L-R ChiSquare	Prob>ChiSq
Lpoly	2	2	33.9338246	<.0001*
Occupation Period	2	2	138.805128	<.0001*
Lpoly* Occupation Period	4	4	21.5781907	0.0002*

Table 4. REML (Restricted Maximum Likelihood) analysis of pairwise relationships among mean percent max measures of abalone density, kelp density, otter tags, and estimated sea otter abundance measures across areas in Sitka Sound (2015 – 2023). There are two years of unavailable kelp data for comparisons (2022 and 2023). See Figure 9 for pairwise relationship confidence intervals.

Data sources: abalone densities from 2015 to 2016 (Bell et al.,2018), 2017 to 2021 (T. White, unpublished data), and 2022 to 2023 (K. Kroeker, unpublished data); sea otter tag data (USFWS); estimated otter abundance (USFWS; dispersion model: Eisaguirre et al., 2021; 2022 sea otter calibration data: Schutte et al.,., 2023), kelp densities (Bell et al., 2023).

	Abalone	**Kelp**	**Otter Tag**	**Estimated Otter**
Abalone	<.0001	0.7607	0.5811	0.2563
Kelp	0.7607	<.0001	0.8962	0.5821
Otter Tag	0.5811	0.8962	<.0001	**0.0045***
Estimated Otter	0.2563	0.5821	**0.0045***	<.0001

Table 5. Generalized Linear Model (GLM) of the sum of 'Many' amount categories of reported legal abalone or transformed high (i.e., 'Many') otter tag amount categories across large areas of Sitka Sound from 2003 to 2023. Model log-link function, Poisson distribution, and Maximum Likelihood Estimation for parameter estimations. Non-linear tests of eaects include secondorder (YearYear, YearSpecies ID, YearPolygon) and third-order polynomials (YearYearYear, YearYearYearSpecies ID, YearYearYear*Polygon).

Model Fit, Goodness of Fit

Model	**-LogLikelihood**	**L-R ChiSquare**	**DF**	**Prob>ChiSq**
Difference	641.4783	1282.957	17	**<.0001***
Full	582.3361			
Reduced	1223.814			

Goodness Of Fit Statistic	**ChiSquare**	**DF**	**Prob>ChiSq**
Pearson	753.6867	108	**<.0001***
Deviance	807.682	108	**<.0001***

Effects Tests (effect*effect = 2d polynomial; effect*effect*effect = 3d polynomial fit testing)

Source	**DF**	**L-R ChiSquare**	**Prob>ChiSq**
Year	1	91.95879	**<.0001***
Year*Year	1	80.60626	**<.0001***
Year*Year*Year	1	49.66288	**<.0001***
Year*Species ID	1	17.53656	**<.0001***
Year*Year*Species ID	1	383.4054	**<.0001***
Year*Year*Year*Species ID	1	2.223732	0.1359
Species ID	1	610.1362	**<.0001***
Polygon	2	232.0745	**<.0001***
Species ID*Polygon	2	120.9409	**<.0001***
Year*Polygon	2	40.51264	**<.0001***
Year*Year*Polygon	2	36.31904	**<.0001***
Year*Year*Year*Polygon	2	42.84124	**<.0001***

Table 6. Mean densities (m^2) with standard deviations of pinto abalone random site surveys in Sitka (2018, 2019). As displayed in Figure 11 with SE in place of SD.

Sitka Large Polygon	Size Class (mm)	Mean Density (ab/m²)	Standard Deviation(± ab/m²)
Sitka North	**All Sizes**	1.1	1.14646
Sitka Inside		1.3	1.06703
Sitka Outside		1.4	1.43398
Sitka North	**Legal Density (≥89)**	0.01	0.03946
Sitka Inside		0.02	0.05378
Sitka Outside		0.02	0.05259
Sitka North	**Adult Density (≥41)**	0.7	0.90276
Sitka Inside		0.8	0.77722
Sitka Outside		0.9	0.85114
Sitka North	**Juvenile Density (<41)**	0.4	0.31431
Sitka Inside		0.6	0.43281
Sitka Outside		0.5	0.52535

Figures

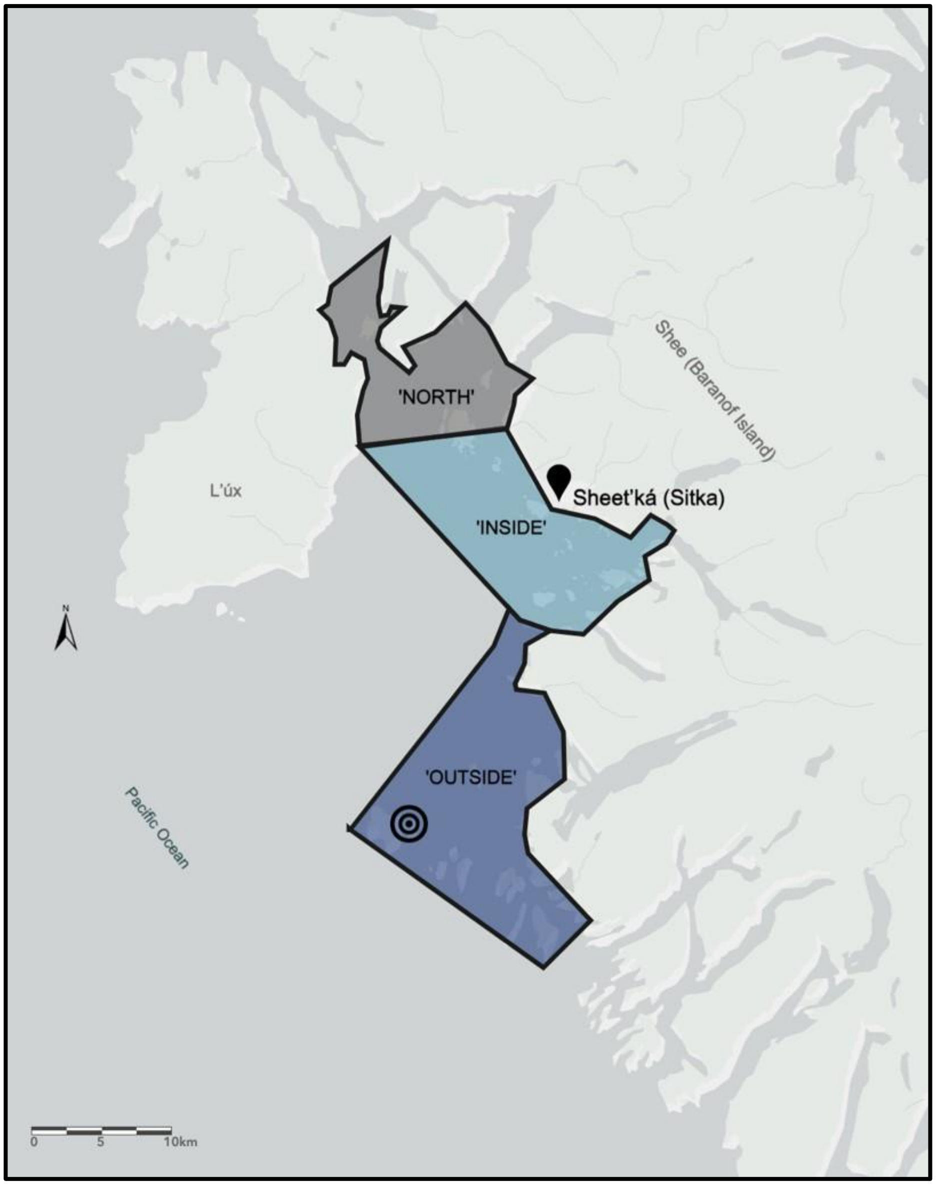

Figure 1. Geographic division of Sitka Sound, Alaska, by large polygon: 'North,' 'Inside,' and 'Outside.' Large polygons are the coarsest spatial units and are used for the public presentation of research information about abalone, sea otter, and other species' harvests. In contrast, sea otter occupation periods are shared at the finer spatial scales (small, sub-small polygons nest within these see Figure 2). The target symbol in the Outside polygon indicates the location of the sea otter transplant (n=48) in 1968 near Biorka Island (Burris and McKnight 1973).

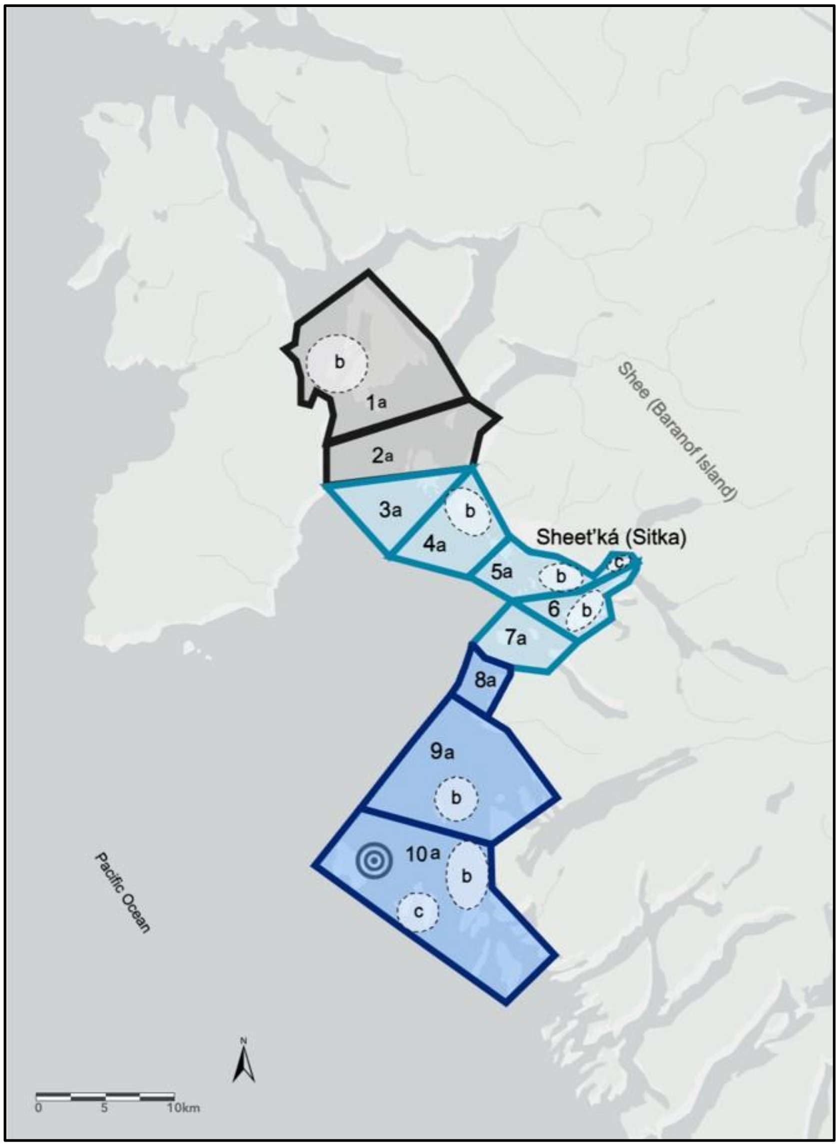

Figure 2. Spatially scaled organization of information across Sitka Sound.
Available metrics of abalone and kelp densities and otter abundance and tags, along with information related to sea otters, abalone, kelp, and other important subsistence invertebrates, were organized to at the finest spatial scale. 'Sub-small' polygons (labeled 'b' or 'c') are nested within small polygons (labeled 1a, 2a... 10a), further nested within large polygons. Small polygons outlined in black (1 and 2) indicate those associated with the large 'North' polygons (refer to Figure 1); in light blue (3,4,5,6,7) are 'Inside', and in dark blue (8,9,10). Data were aggregated in analyses to match comparable scales. The target in small polygon #10, near Biorka Island, indicates the re-introduction release site of 48 sea otters in 1968, the same year 38 otters were reintroduced to Yakobi Island (around 120km north of Sitka). 194 sea otters were released from 1965 to 1969 in Khaz Bay (around 70km north of Sitka) (Burris and McKnight 1973).

Note: Only sea otter occupation information is provided publicly at small and sub-small scales. All other information (e.g., harvest sites, amounts of harvest) is only shared at the coarsest spatial scales (i.e., 'large' polygons; reference Figure 1 and Appendix C1 'Project Informed Consent Forms').

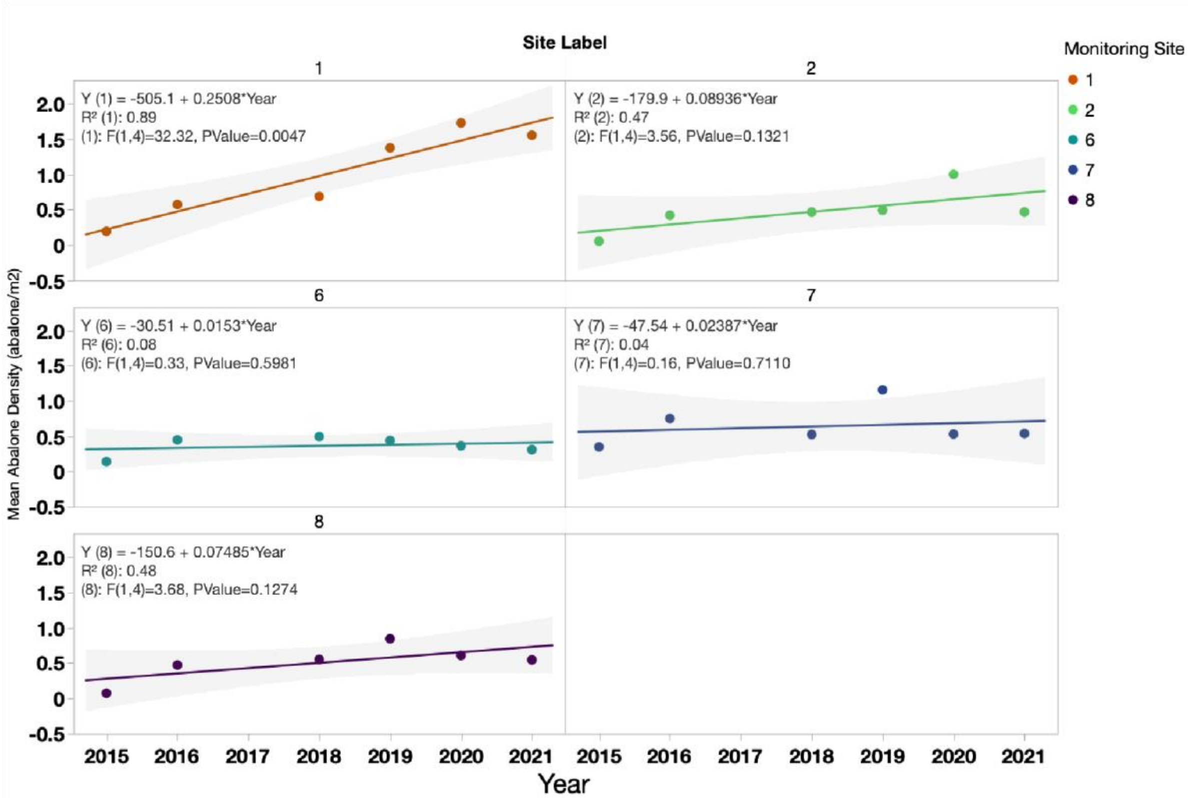

Figure 3. Annual density trendlines at Sitka abalone monitoring sites (2015 – 2021). 2017 surveys are excluded because of incompatible sample methods. 2015 and 2016 surveys used a slightly different sampling technique, with two abalone surveyors along a longer transect (2 x 30 meters versus the 2 x 20m transects surveyed by one diver). Monitoring sites 4 and 5 were only surveyed in 2015 and 2016; divers only tallied abalone < 20mm in 2015 and 2016.

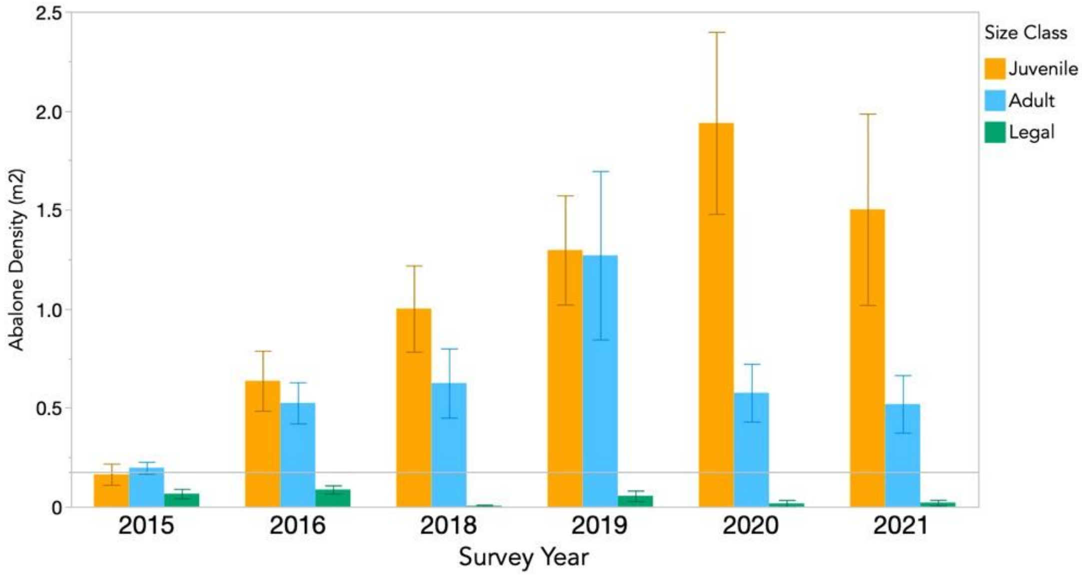

Figure 4. Pinto abalone size class densities recorded across Sitka monitoring sites by survey year (2015 – 2021). In yellow: juveniles < 41mm, in blue: adults > 40mm, and in green: legally harvestable [3] 89mm abalone. Bars represent standard deviations from the mean of the ten transects sampled (at five sites). Abalone < 20mm in length were tallied by divers during 2015 and 2016 dive surveys but included with all sizes in the following years of survey. A grey line at 0.2/m^2 indicates the density threshold determined for local pinto abalone population viability (T. White unpublished data). Error bars represent ±1 Standard Error.

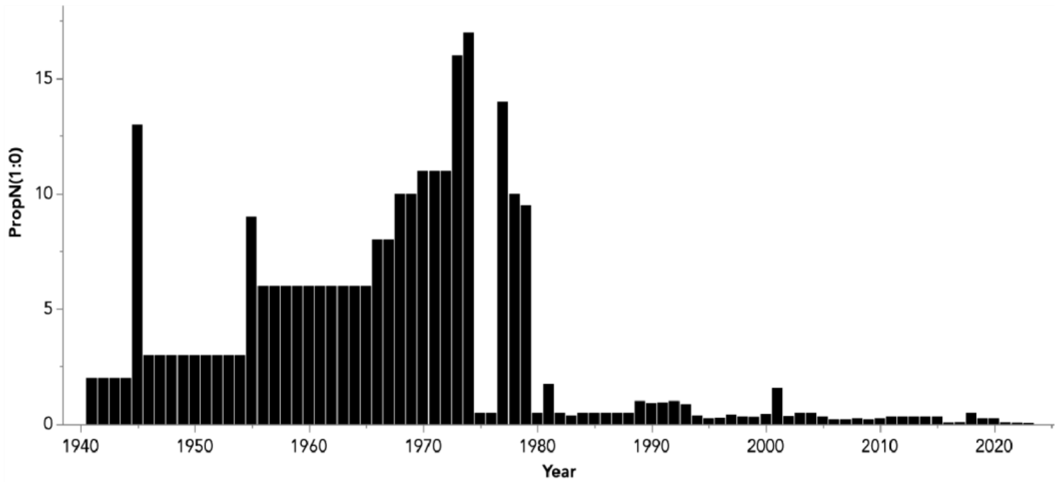

Figure 5. Proportions of 'Many' (1) abalone to the combined reports of 'Few' (0) and 'None' (0) amount categories shared over time. Abalone amounts were reported by individual participants at sites of harvest, observation, or at sites of historical importance where reports were made in the context of generational knowledge of historical absences. Sea otters were reintroduced to areas in 1968 (refer to Table 2); information from areas of Sitka Sound pertains to areas (see Figure 1) that are out of bounds of historical commercial fishing grounds.

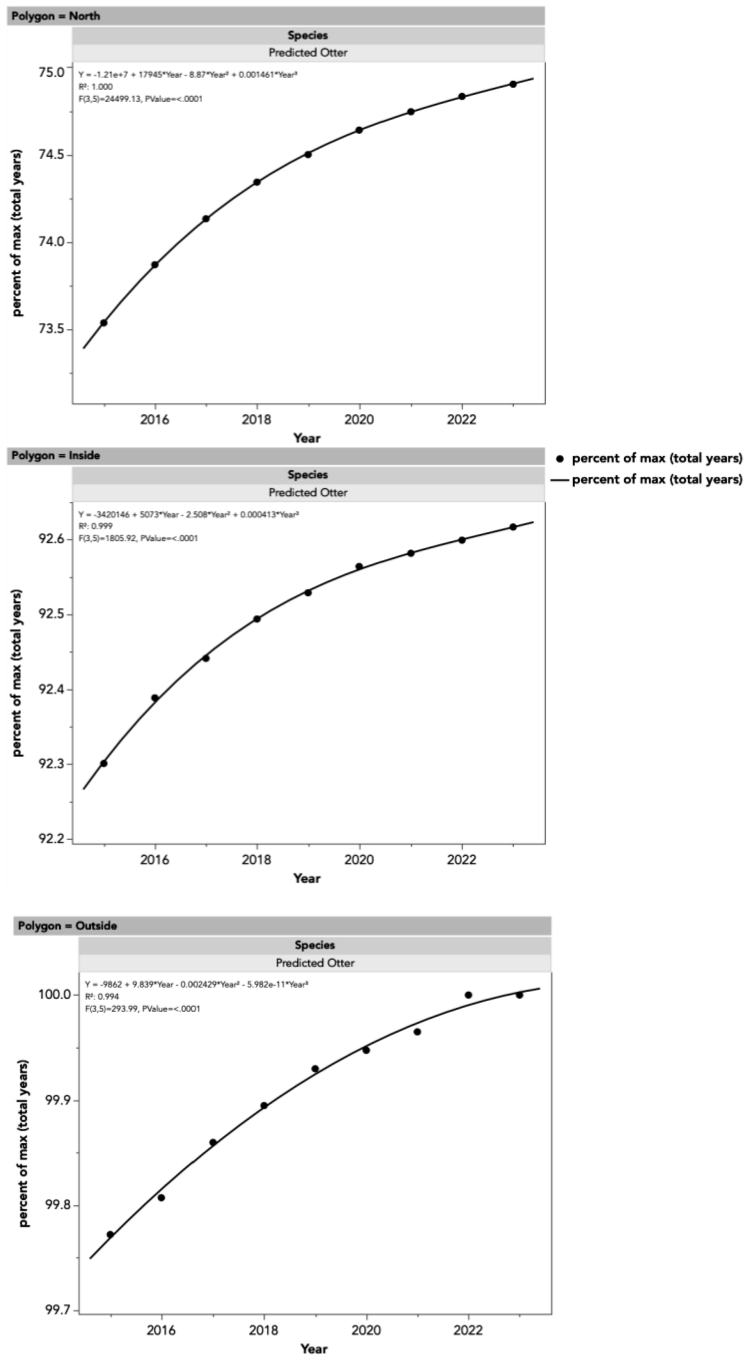

Figure 6: Percent of maximum estimated sea otter abundance per polygon area (km^2) per year (2015 – 2023). Expected otter abundance data per large polygon (km^2) provided by USFWS via modeling of otter populations, applying the diffusion model developed by J. Eisaguirre et al. (2021), calibrated with 2022 otter aerial survey data of local areas of Sitka Sound (Schutte et al.,2023). Large Polygon areas for otter calculations: North: 424.55km^2, Inside: 348.53km^2, Outside: 454.36km^2 (reference Figure 1). Estimates do not include USFWS tag information.

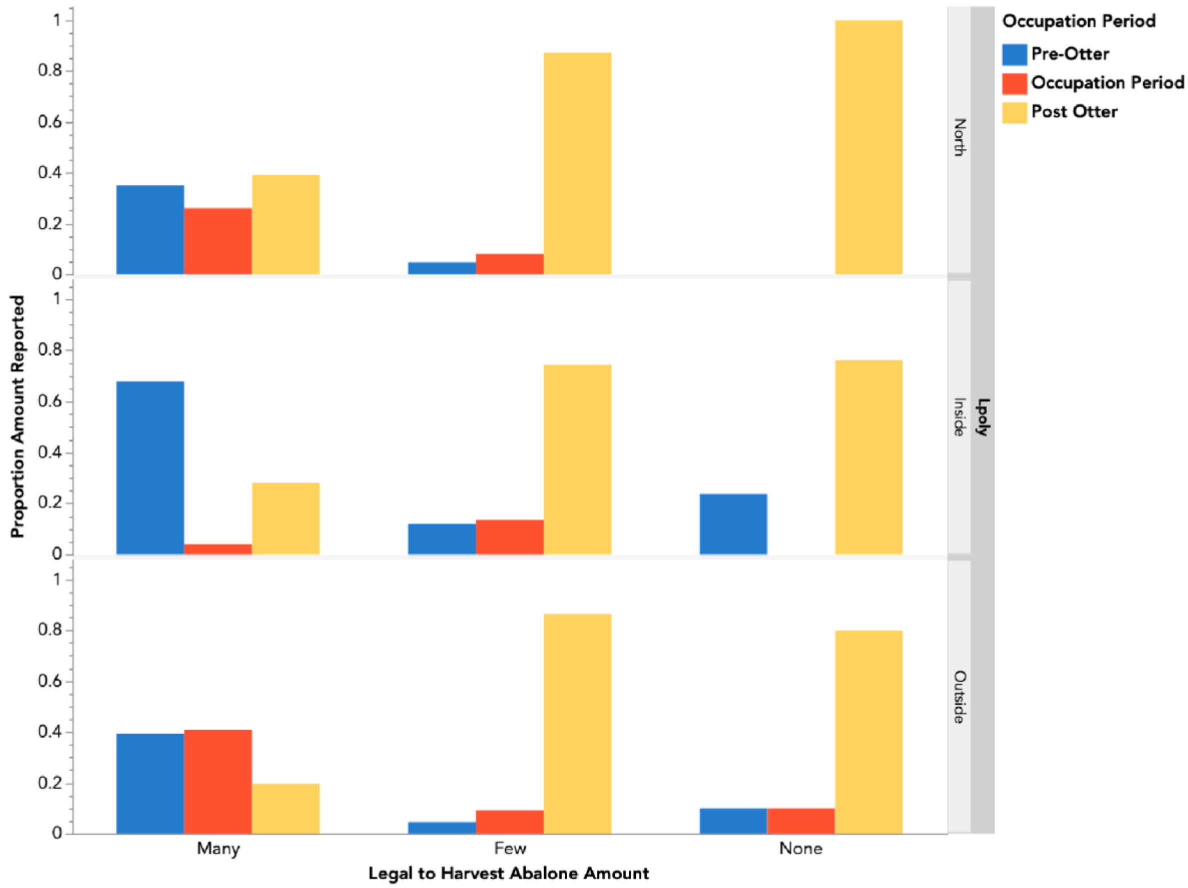

Figure 7. Legally Harvestable Abalone Across Otter Occupation Periods in Locations of Sitka Sound. Proportion reported in a structured questionnaire on the amounts of legal abalone pre-, post and following sea otter occupation at North, Inside, and Outside polygons. Bars indicate the proportions of 'Many', 'Few', or 'None' amounts of legally harvestable abalone for each occupation period and spatial scale. For legally harvestable abalone: 'Many' = enough to make or exceed the allowable harvestable limit, 'Few' = less than the allowable harvestable limit. Years of Occupation Periods in Table 2, analyses in Table 3.

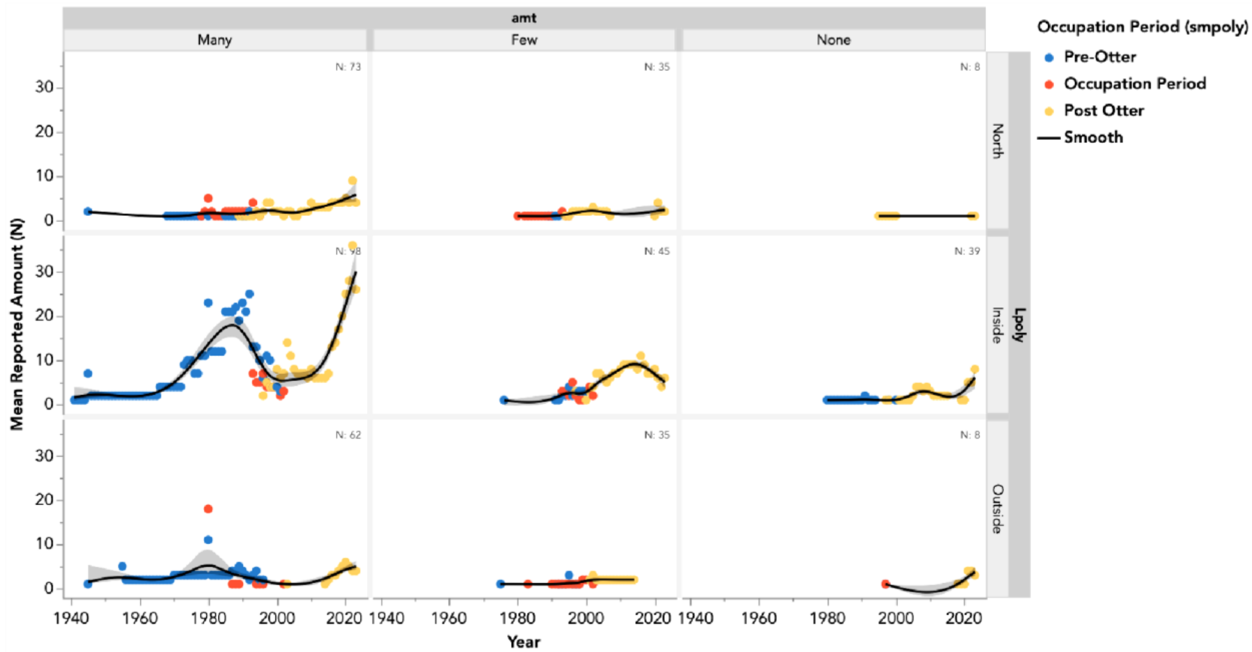

Figure 8. Reported amounts of harvestable abalone in large areas of Sitka Sound (1941-2023). Includes Locally Estimated Scatterplot Smoothing (LOESS) curves and fine scale (i.e.,'smpoly', see Figure 1). Amount category or 'amt': 'Many', 'Few,', or 'None' of harvestable ('Legal') abalone reported during mapping exercises at specific large areas of Sitka Sound (North, Inside, Outside). Sea otter occupation periods were applied later at the same spatial scale for which each category amount was reported (i.e., 'small' or 'sub-small' scale; see Table 2) and presented at the large polygon scale for confidentiality. The count per panel shows the number of reports for each amount category. These reports were independent of structured questions about the sea otter effect (used in Figure 7).

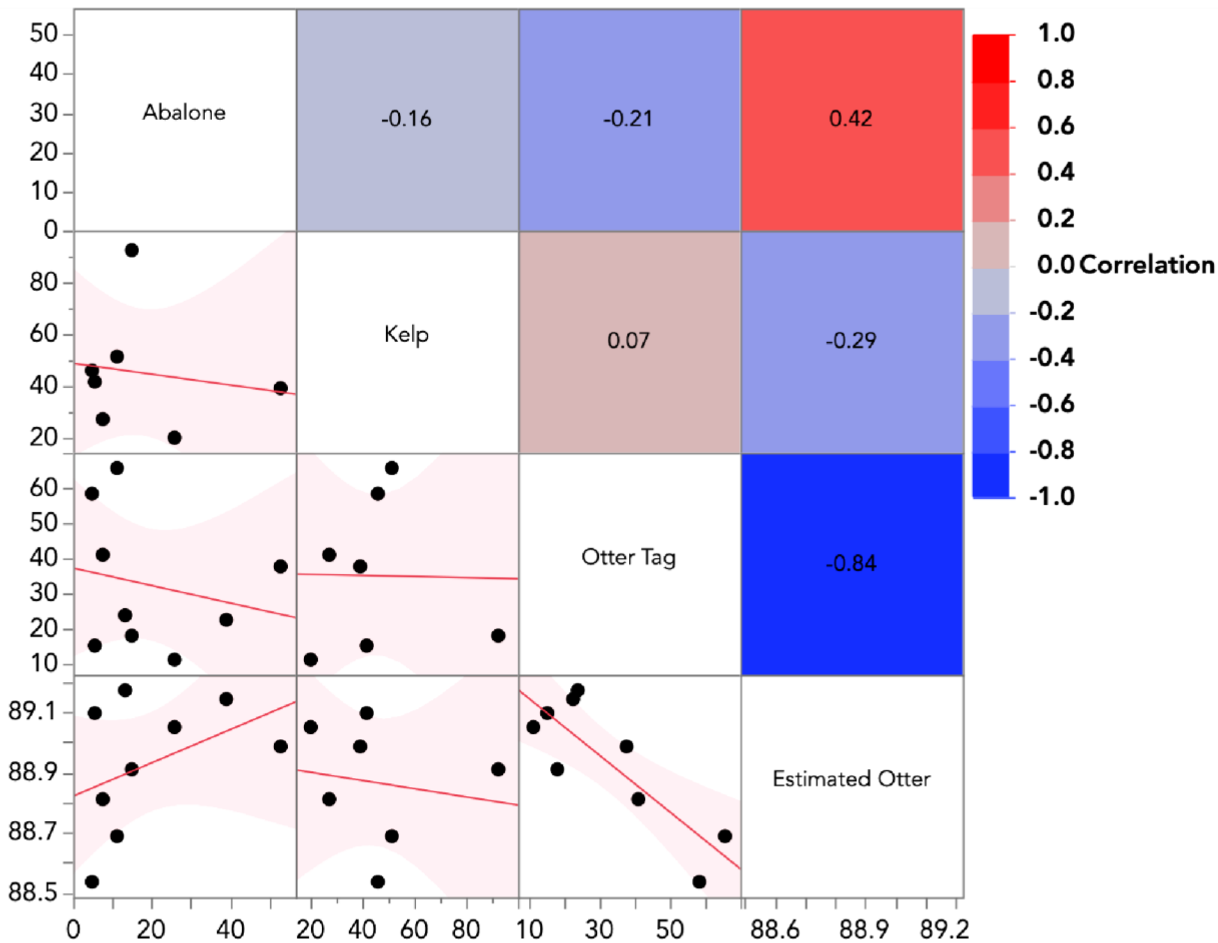

Figure 9. Scatterplot matrix (SPLOM) of mean percentage of the maximum measures of Kelp, Abalone, Otter Tag, and Estimated Sea Otters across large areas of Sitka Sound. Left: Scatterplots and lines of fit per measure; Right: r values from confidence intervals of pairwise relationships among variables with a heat map of relationship strength (red = positive, blue=negative). See Table 4 for REML significance analysis and Figure A1 for regressions over time.

Data sources: abalone densities from 2015 to 2016 (Bell et al., 2018), 2017 to 2021 (T. White, unpublished data), and 2022 to 2023 (K. Kroeker, unpublished data); sea otter tag data (USFWS); estimated otter abundance (USFWS; dispersion model: Eisaguirre et al.,2021; 2022 sea otter calibration data: Schutte et al., 2023), kelp densities (Bell et al.,2023).

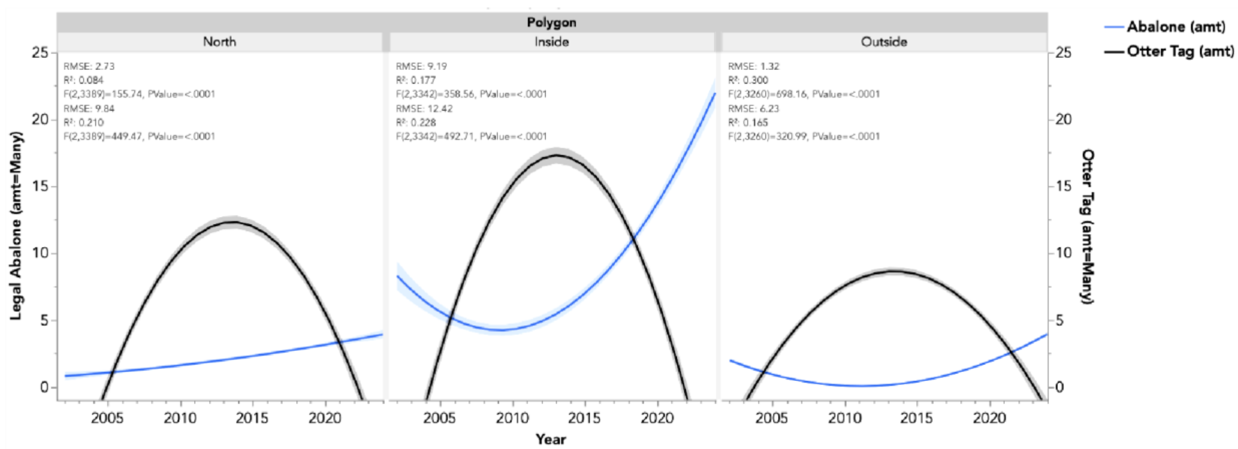

Figure 10. Generalized Linear Modeled random point output of reported ‘many’ abalone reports and ‘high’ otter harvest intensities across large areas of Sitka Sound (2003 to 2023). Included Sitka North, Inside, and Outside, and data plotted are random points generated from GLM tests, fitted with the best-fit line, quadratic fit as determined by analyses (see Table 5). Modeled output derived from raw data plotted in Figure A3.

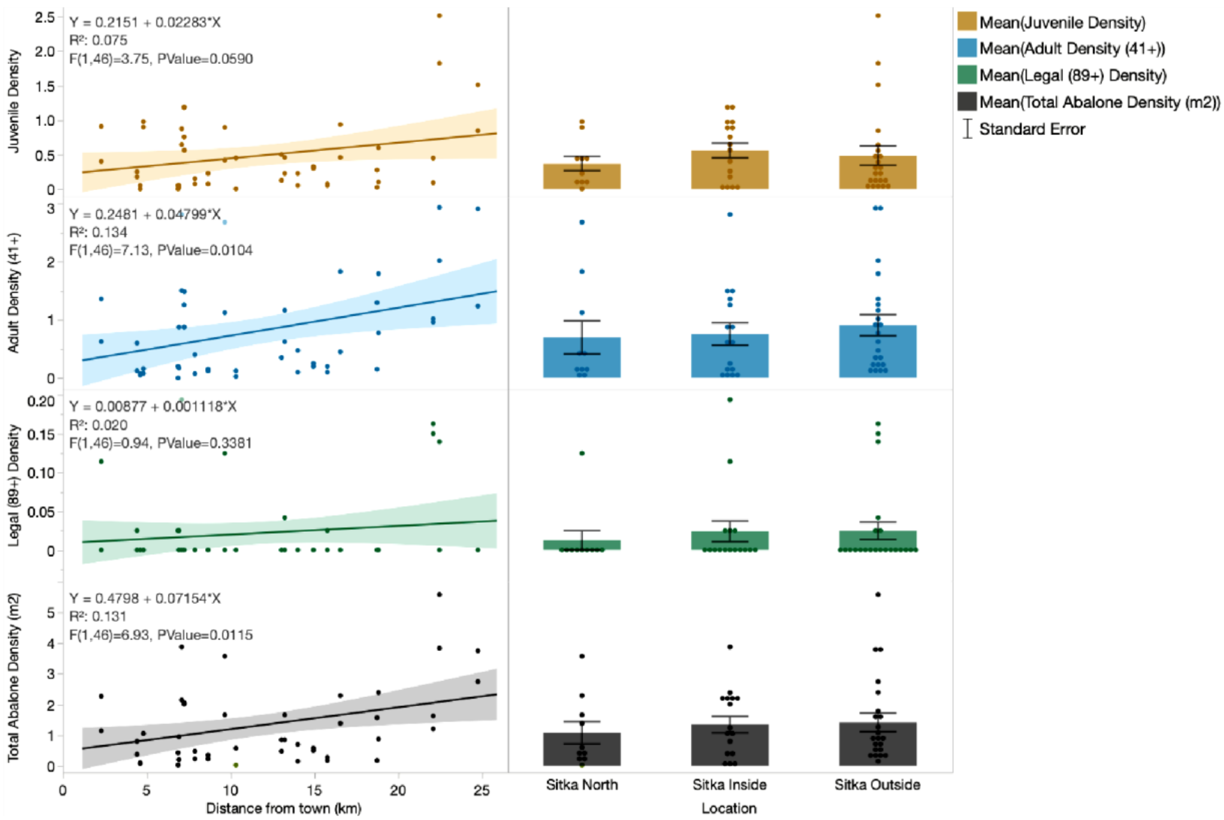

Figure 11. Abalone size class densities (count/m²) distance away from town and among locations in Sitka Sound from randomly selected sites in Sitka Sound (surveyed 2018 and 2019). Abalone densities are categorized by size class categories: 'juvenile' (< 41mm), 'adult' (^{3} 41mm), and 'legally harvestable' (^{3} 89mm) individually measured abalone. See Table 6 for densities by Sitka 'Location' (i.e., Large Polygon). Error bars represent ±1 Standard Error.

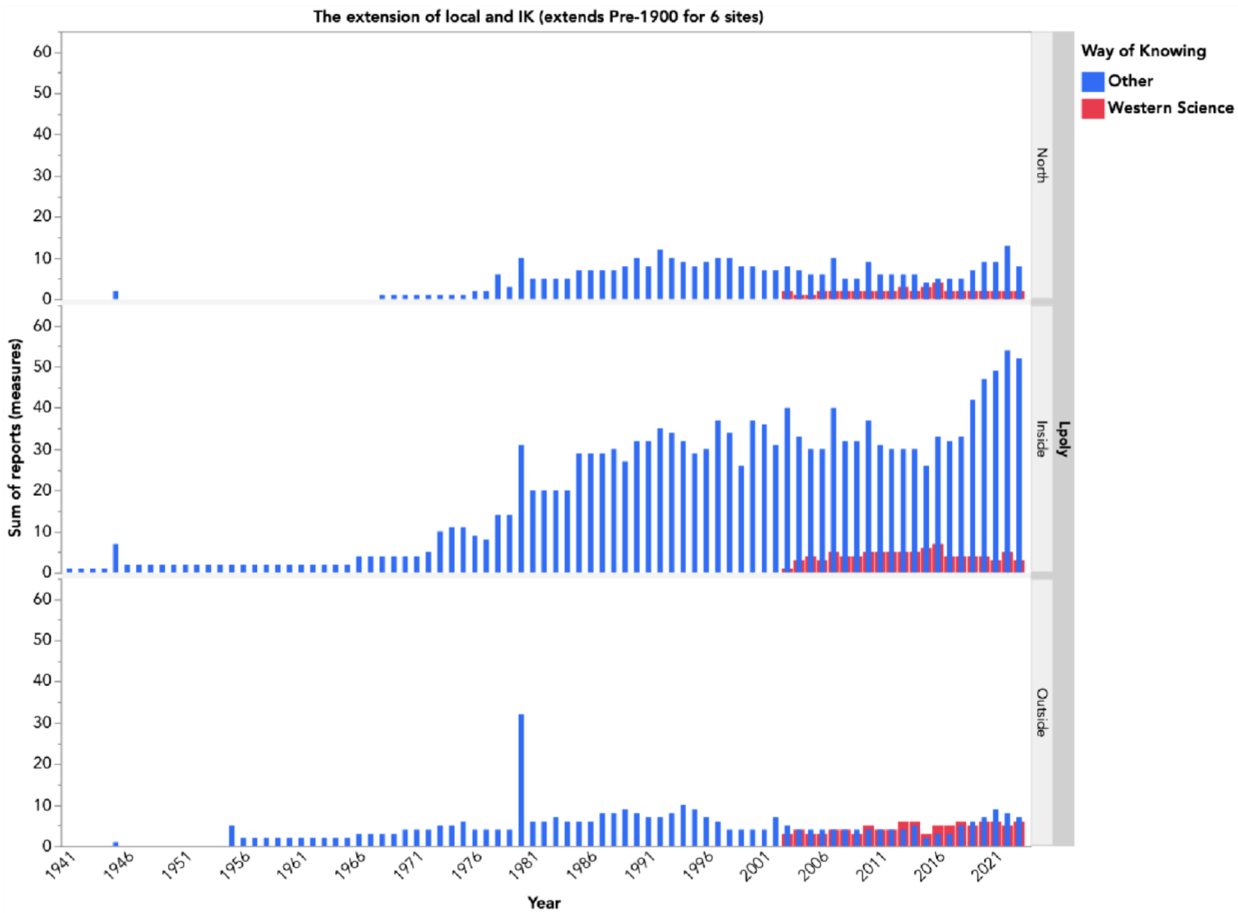

Figure 12. Project extension of shared and recorded information on abalone and sea otter harvest and sightings with available quantitative data on abalone densities and sea otter harvest.

Appendix A

Tables

Table A1. Areas (in km2) of small and large polygons (reference Figure 1). Large Polygon areas for otter calculations were larger than the sum of small polygons but included areas of likely sea otter movement: North: 424.55km^2, Inside: 348.53km^2, Outside: 454.36km^2.

Large Polygon	Small Polygon	Small Polygon Area (km2)
North	1	81.9
North	2	22.3
Inside	3	15.9
Inside	4	27.7
Inside	5	17.5
Inside	6	25.6
Outside	7	16.2
Outside	8	12
Outside	9	65.4
Outside	10	131

Table A2. The number of individual participants providing at least one report of respective amount categories per Sitka large polygon scale during elective recall in mapping exercises. See Figure 8 for total reported harvestable abalone per amount category and large polygon.

Amount Category	Large polygon	N (Individuals Reporting)
Many	North	13
Many	Inside	20
Many	Outside	10
Few	North	7
Few	Inside	12
Few	Outside	2
None/Very Few	North	2
None/Very Few	Inside	12
None/Very Few	Outside	4

Appendix B

Figures

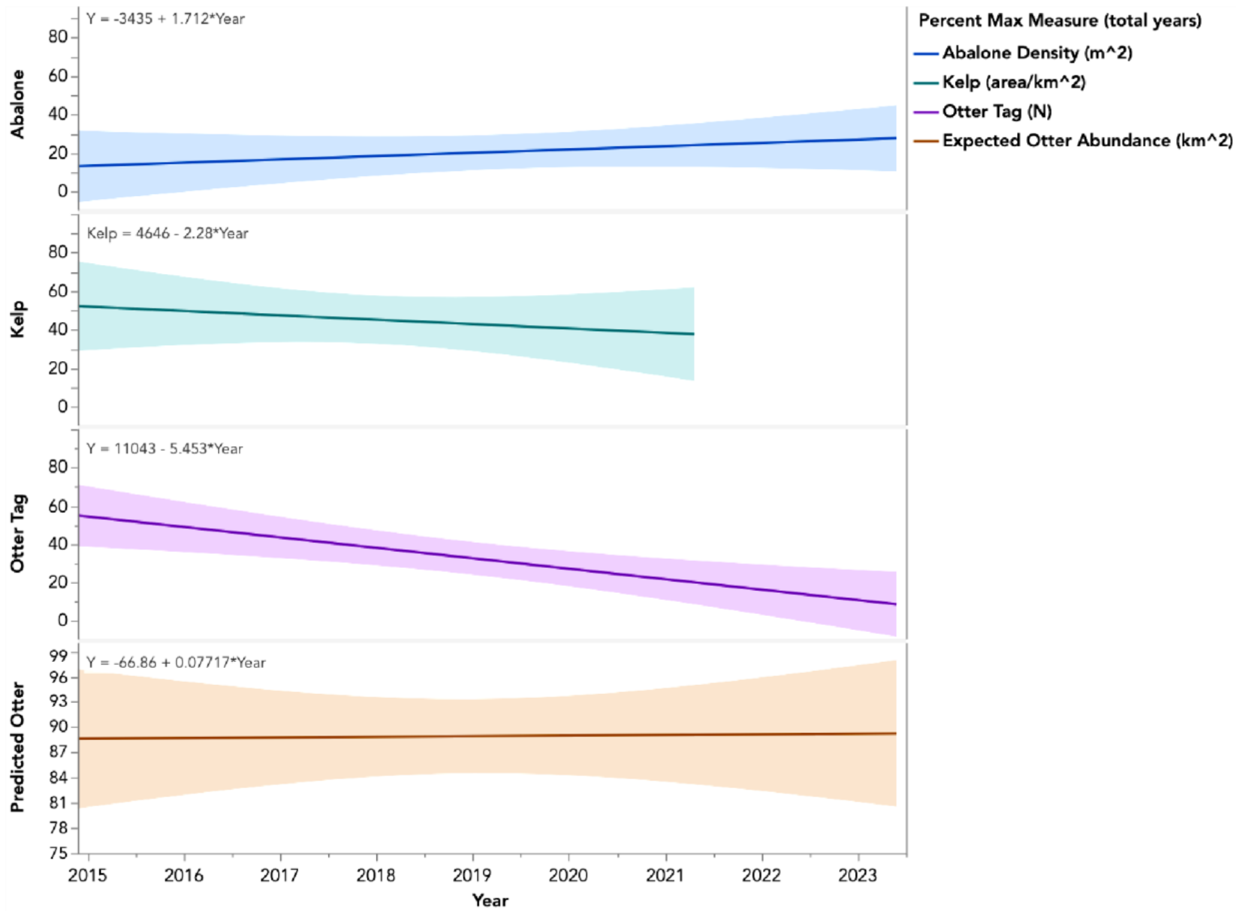

Figure A1. Percent of the maximum values of abalone densities, kelp densities, and sea otter tags (hunts) across available years for comparisons in Sitka Sound, Alaska (2015 – 2023; 2015 – 2021 for kelp data). See Scatterplot Matrix for pairwise relationships (Figure 9) and REML significance (Table 4). All Sitka Sound areas (North, Inside, Outside, refer to Figure 1).

Data sources: abalone densities from 2015 to 2016 (Bell et al.,2018), 2017 to 2021 (T. White, unpublished data), and 2022 to 2023 (K. Kroeker, unpublished data); sea otter tag data (USFWS); estimated otter abundance (USFWS; dispersion model: Eisaguirre et al.,2021; 2022 sea otter calibration data: Schutte et al., 2023), kelp densities (Bell et al.,2023).

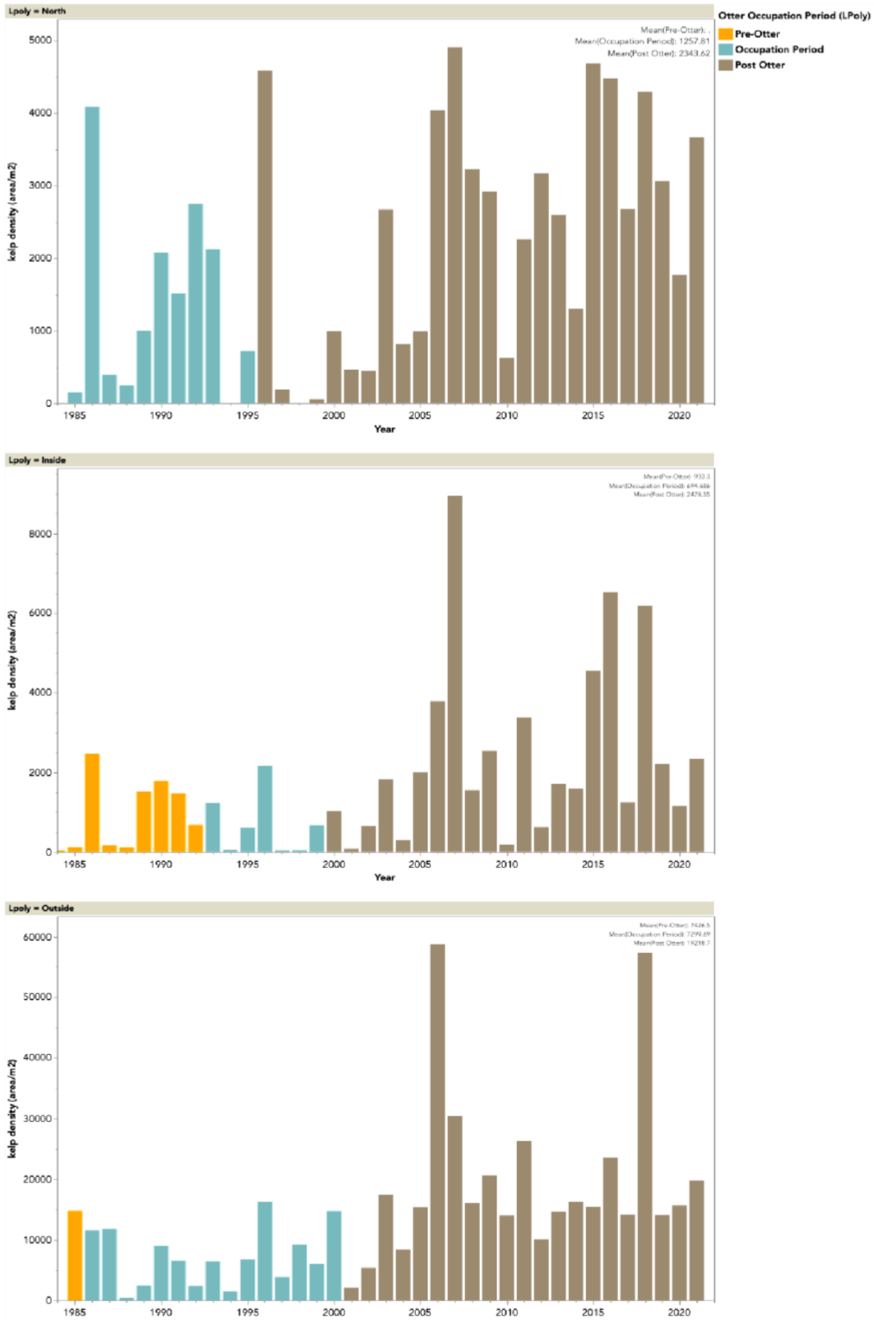

Figure A2. Kelp densities per large areas of Sitka Sound over time, with sea otter occupation period. Kelp densities from Kelpwatch.org (Bell et al.,2023), sea otter occupation from surveys, and local reporting (see Table 2).

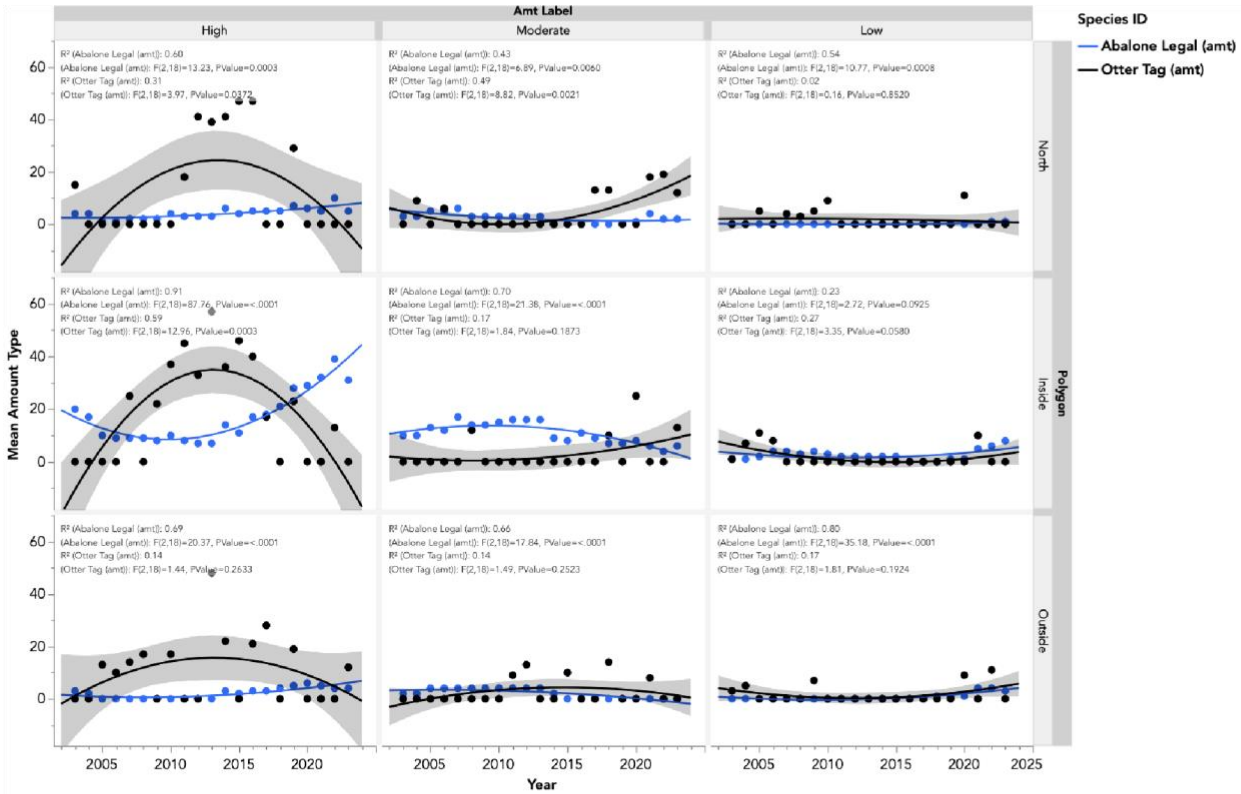

Figure A3. Legally harvestable abalone and sea otter tag amount categories in Sitka (2003 – 2023). Reports of available legal abalone at local harvest areas following different periods of sea otter occupation. Harvest amounts reported as 'many,' 'moderate,' or 'low' legally sized abalone or sea otter harvest amount categories (derived from USFWS unpublished tag data) are exchangeable with 'many,' 'few,' and 'no/none' used in GLM modeled output of these plotted raw sum (amount categories) (see Figure 10).

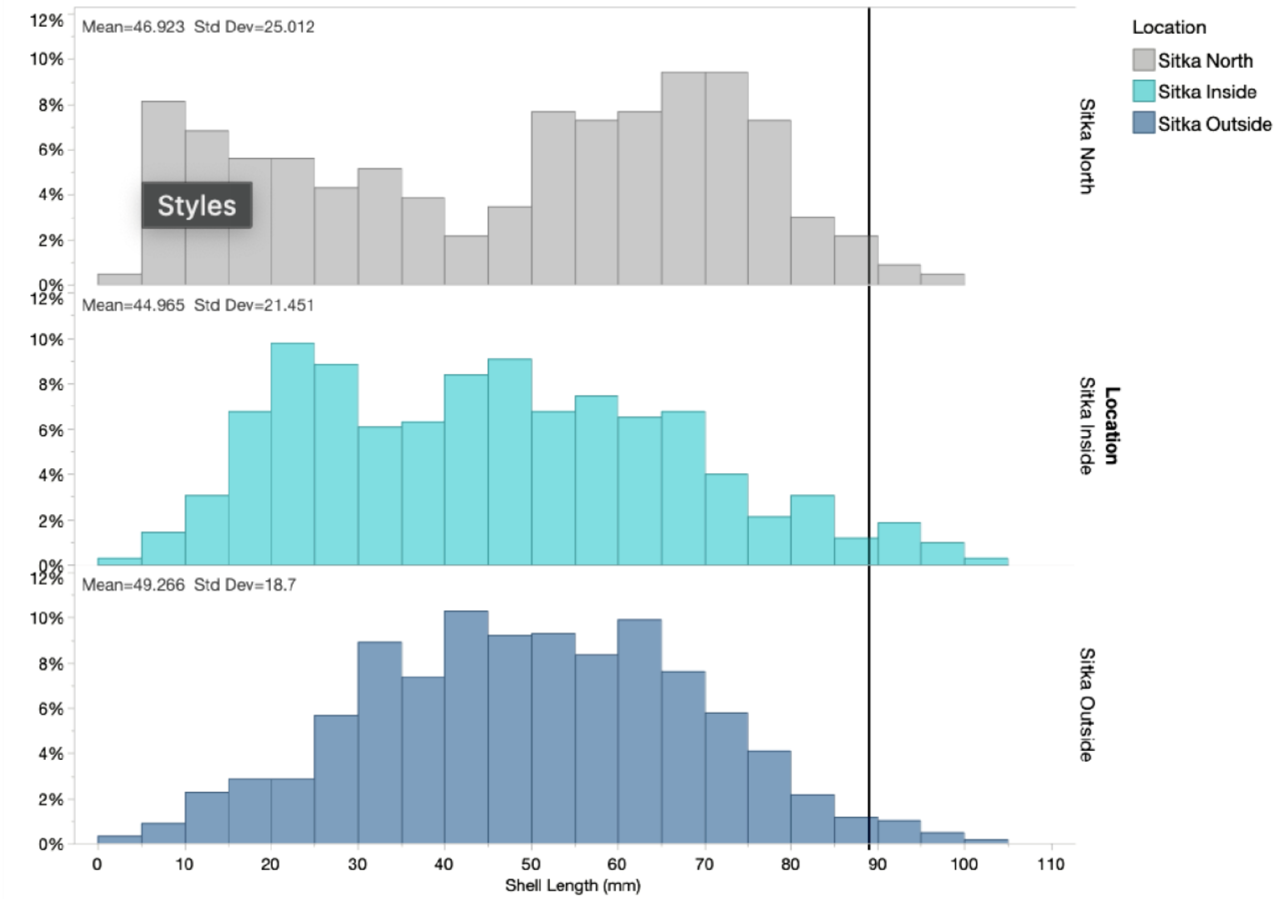

Figure A4. Size frequencies of pinto abalone were recorded at randomly selected sites in large areas of Sitka (North, Inside, Outside) in 2018 and 2019. The vertical line at 89mm indicates the minimum legal-size threshold for subsistence harvest.

Appendix C1

UCSC, STA MOU with Project Informed Consent Forms

MEMORANDUM OF UNDERSTANDING
Between
The Sitka Tribe of Alaska and
The Regents of the University of California, on behalf of its Santa Cruz campus
("UCSC" or the "University"), each a ("Party") and collectively, the ("Parties")

BACKGROUND
This Amended Memorandum of Understanding ("MOU" or "Agreement") defines the terms and understandings between the Sitka Tribe of Alaska (STA), a federally recognized Tribe, and the University for the appropriate collection, dissemination, and protection of information and data shared during, throughout, and following the completion of the Project, as defined below, and community and stakeholder outreach conducted during the Project.

MOU PURPOSE
To develop a collaboration and understandings critical to the success and completion of the Project: "Diverse knowledge systems for the examination of localized dynamics of sea otters and abalone populations in Sitka Sound, Alaska," and define terms and understandings of the collaboration that will guide appropriate access and sharing of Indigenous knowledge of current and historical harvest of sea otter and pinto abalone populations and their importance in Sitka Sound and Southeast Alaska.

PROJECT
The North Pacific Research Board (NPRB) (award #2115), "Diverse knowledge systems for the examination of localized dynamics of sea otters and abalone populations in Sitka Sound, Alaska," ("Project") will be conducted through the University's Department of Ecology and Evolutionary Biology (EEB), University researchers Taylor White (Ph.D. student) and Dr. Peter Raimondi (EEB Professor). The Project aims to draw information from multiple knowledge sources (i.e., western science, local and Indigenous knowledge), to evaluate and analyze local patterns of change in marine communities following the reestablishment of sea otter populations to Sitka Sound. The Project will also outline pinto abalone and sea otter population dynamics during the ongoing harvest of both species. Available models cannot predict these population's trajectories at the local scales important to traditional and subsistence harvesters and local stakeholders, who either directly or indirectly benefit from an abundance of both species.

Bridging knowledge sources in this way is integral to advancing our shared understanding of local sea otter and abalone dynamics and is an important step towards tribal and stakeholder sovereignty in the management and future research of the culturally and locally important sea otter and abalone populations.

UCSC researchers and participant volunteers will investigate strategies for the ongoing harvest of both abalone and sea otter populations and develop research questions from the concerns addressed in participant interviews. The process of co-developing a tangible management and research plan based on Project findings promotes creative thinking about management strategies, barriers to management, and local and regional relationship building and management communication. Project participant volunteers shall be referred to individually as a (“Participant”) or collectively as the (“Participants”).

This Project was motivated by community involvement and data discrepancies, limiting potential areaspecific understandings of pinto abalone populations, which experience diverse pressures and large ranges in recorded densities throughout Southeast Alaska, yet are uniformly managed across the region. This Project stems from Ms. Taylor White's dissertation research, parts of which will support the completion of her degree at UCSC.

MUTUAL AGREEMENTS

From interview initiation and throughout all later iterations of Project dissemination, UCSC and STA Project representatives and signatories will uphold accountability for the presentation of entrusted knowledge and a "do no harm" ethic.

Both UCSC and STA will safeguard interview records shared and address any questions or concerns in a manner timely for the successful completion of the Project.

STA RESPONSIBILITIES

1. Review and comment on the Consent to Participate in Research attached as Exhibit A (“Informed Consent”), in a timely manner (i.e., no more than 6 weeks from the date the Informed Consent is provided to STA).

2. Protect against unauthorized disclosure of archived Participant information in accordance with the Participant’s Informed Consent consisting of information that is not publicly available, whether or not embodied in a tangible medium of expression, that the STA Council determines to be within the following definition of “*Intellectual Property*” stated in Section 1.04 (d) of the STA Research Policy:

“"Intellectual Property" means intangible products of human intellect, including cultural information, knowledge, uses, skills, and practices that are developed, sustained, and passed on from generation to generation within a community, often forming part of its cultural or spiritual identity. Intellectual Property can be represented physically by means such as photographs, depictions, artwork, or written or oral descriptions.”

3. Initial review of Project findings and formats of dissemination brought forth by Ms. White during STA Natural Resource Committee or Cultural Resource Meetings. This includes the review of, and consent by, the STA Council for the University to use, the Project findings and proposed interpretation of Tribal Citizen knowledge in general Project findings and non-georeferenced maps (e.g., heat maps) of changes in areas of sea otter populations, hunting, abalone presence, and harvest, for the use in future disseminations. The STA Council hereby agrees and consents to the conduct of the research activities specified in the Informed Consent to gather and use information obtained from Participants for the purpose of including, but not limited to, providing the following Project deliverables to NPRB:
   - semiannual progress reports and a final programmatic report to the study sponsor, the North Pacific Research Board (NPRB)
   - presentations of research findings for publication by an appropriate scientific journal and presentation of project results at a scientific conference within one year of completion of the Research (January 2025)

- production of an outreach video highlighting the history of sea otter re-establishment in Sitka Sound, local trends following establishment, and current interactions between sea otters, pinto abalone populations, and community members
- a radio piece highlighting shared history, research, and the community connection to dynamic marine resources
- a collaborative document outlining future research and management recommendations following interviews with Participants.

4. Maintain indefinitely in STA archives the Research Participant's shared records, as authorized in accordance with each Participant's Informed Consent Form, on an encrypted hard drive with access permissions limited to select STA signatories designated in writing (i) by Lawrence Widmark, the Tribal Council Chair, or his successor as Tribal Council Chair, (ii) as the STA Council so determines or (iii) as otherwise required by operation of law. The STA Council may provide access to non-georeferenced data, de-identified data and certain identifiable data such as quotes and audio or visual clips that a Participant has authorized STA to be made publicly available.

Note: Georeferenced information will not be publicly available.

UNIVERSITY RESPONSIBILITIES

University Researchers acknowledge this Project will take place on Lingít Aaní with Tribal Citizens and other Participants and involves requests made to Tribal Government employees and STA resources. Following the initial STA letter of support on February 28, 2021, attached as Exhibit B, the University, through this MOU seeks STA's continued permission to conduct the Research in Lingit Aani and the continued support for the University's outreach with local community members and STA Tribal Citizens in relation to the Project. Ms. White will be the primary University researcher responsible for analyses, reports, and dissemination, as well as the primary point of contact for communications with designated STA officials. She will be responsible for maintaining the Project timeline and dissemination. Ms. White will conduct all Participant interviews regarding local and Indigenous knowledge and on the analysis, interpretation and the distribution of Participant Knowledge following the removal of those personally identifiable information ("PII") identifiers and georeferenced location information as requested by the Participant (Exhibit A).

Researchers will:

1. Endeavor to fill current and historical gaps in information on harvested pinto abalone and sea otter populations in Sitka Sound using models developed through the pairing of quantitative dive surveys and local and Indigenous knowledge.
2. Conduct Participant interviews and protect confidentiality in accordance with each Participant's Informed Consent.
3. Engage Project Participants to identify questions and provide feedback on the Research Plan.
4. Take into account and reasonably address concerns expressed by Participants or STA during the conduct of the Project and the dissemination of findings in accordance with this Agreement.
5. Ms. White will archive all Participant and Research records on an encrypted Master Hard Drive to which she will have sole access. Ms. White will maintain the Master Hard Drive for three years following the Research period, and then destroy the Master Hard Drive and all raw data records in 2027 (as required by The North Pacific Research Board project Subaward).
6. Ms. White will organize and provide Participant de-identified records in accordance with each Participant's Informed Consent, for storage at NPRB (specifically with NPRB data management at AXIOM and on an encrypted hard drive archived in a library at STA offices located at 204 Siginaka Way, Sitka.

Note: The Project Informed Consent Form (Exhibit A) requires Participant to determine the shared information and PII that may be archived at the STA office. Information permitted for STA storage will be in care of the active STA Cultural, and Community Liaison and Tribal Council Chair.

7. Researchers will share versions of the final report and provide STA a copy of the final report required by the NPRB subaward with the STA Natural and Cultural Resource committees.
8. Complete NPRB reporting requirements and Final Project Report for NPRB as stated above.

DATA INTEGRITY AND DATA SHARING

It is understood between the Parties that Project Participants may disclose Indigenous Knowledge that is considered to be "Intellectual Property" as defined in Section 1.04 (d) of the STA Research Policy on sea otters and abalone locations. The Parties agree to safeguard against misuse of such information by:

- Obtaining a Participant's Informed Consent before, throughout, and following interviews;
- Safeguarding against unauthorized disclosure of non-publicly available georeferenced maps or identifiers linked to Participants, unless required by applicable law;
- Communicating to Participants that their participation is voluntary and that their respective PII will be de-identified in the University's publication of the Research.
- Communicating to Participants that the research group will record confidential information and PII solely for conducting the Research and analysis of results. Identifiers and georeferenced information

will be scrubbed unless otherwise specified for storage by the Participant's Informed Consent form (see Exhibit "A"). Participants may keep shared notes, maps, answered questionnaires, or request such materials be destroyed following the Project or be archived at STA offices.

- Clearly addressing risks to the individual prior to their participation in the Project as described in the Informed Consent.

It is further understood and agreed by each Party that University has certain data sharing obligations with NPRB for the Project, including but not limited to providing NPRB with a copy of all de-identified Project data and associated metadata at the conclusion of the Project. The Parties agree that the University has the right to provide NPRB with a copy of all de-identified Project data and associated metadata at the conclusion of the Project.

REPORTING

Specifically, the Parties agree that the Research results from the Project, all data and meta data shall be provided by University to and used by (i) the NPRB, (ii) the University Researchers for meeting its obligations to NPRB under the Subaward and (iii) Ms. White in her dissertation, public outreach (i.e., short video and radio piece approval requests beginning in August 2022), public talks (including at the Alaska Marine Science Symposium in January 2023, January 2024) and the final project report to the North Pacific Research Board (due March 30th, 2024).

FUNDING

The Parties understand that funding to reimburse the University for the costs of conducting the Project is provided by the North Pacific Research Board (NPRB project# 2115) and that the Research results, all data and meta data with PII de-identified and identifiers to georeferenced locations removed will be provided to the NRRB.

INTELLECTUAL PROPERTY
Each Party retains all rights, title and interest in its Confidential Information and Intellectual Property (as defined by the STA Research Policy, 2018).

NO IMPLIED LICENSE
Except as provided in this Agreement, nothing in this Agreement shall be deemed to grant to a Party, either directly or indirectly or by implication, estoppel or otherwise any license under any patents, patent application or other proprietary interest of any other invention, discovery or improvement or copyrightable work of authorship of the other Party.

TERM
This MOU will be effective upon the date of the latter signature below and will remain in effect until modified or terminated.

AMENDMENT
No further amendment of the terms of this MOU will be effective unless made in writing and signed by each Party's authorized signatory.

FORCE MAJEURE
Neither Party shall be liable for any failure to perform its obligations, or delay in the performance thereof, as a result of force majeure, meaning any event or cause beyond their reasonable control, including but not limited to governmental regulations, fire, flood, earthquake, elements of nature or acts of God, labor disputes, political instability, acts of war, terrorism, riots, civil disorders, rebellions or other revolutions.

SEVERABILITY
Should any provision of this Agreement be declared invalid, illegal, void or unenforceable or shall be considered severable, the remainder of the Agreement shall be construed and remain in force as if the invalid or unenforceable provision or provisions did not exist and be binding upon the Parties.

COUNTERPARTS
This Agreement may be executed and delivered by the Parties in one or more counterparts, each of which will be an original, and each of which may be delivered by facsimile, e-mail or other functionally equivalent electronic means of transmission, and those counterparts will together constitute one and the same instrument.

AUTHORIZED SIGNATORY
Each Party represents that the individual signing this Agreement has the authority to sign on its behalf.

ENTIRE AGREEMENT
This Agreement constitutes the entire agreement and understanding between STA and the University with respect to the subject matter of this MOU and supersedes in its entirety any contemporaneous representation, all prior proposals, negotiations, agreements, understandings, representations and warranties of any form or nature, whether oral or written, and whether expressed or implied, which may have been entered into between the Parties relating to its subject matter hereof. The terms and conditions of any other instrument issued by a Party in connection with this Agreement which add to or differ from the terms and conditions of this Agreement are hereby superseded.

TERMINATION
Either Party may terminate this MOU upon 10 calendar days' notice to the other Party.

Signed for and on behalf of:
THE SITKA TRIBE OF ALASKA

By: ______________________________
Lawrence Widmark, Tribal Council Chair, SITKA TRIBE OF ALASKA

Date: ____________________

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA, ON BEHALF OF ITS SANTA CRUZ CAMPUS

DocuSigned by:
By: ______________________________
John S. Rakitan, UCSC Contracts and Grants Officer

Date: ________________________ 4/27/2023

UCSC RESEARCHERS' ACKNOWLEDGEMENT

DocuSigned by:
By: ______________________________
031903B93E9445A...
Taylor White, UCSC PhD Candidate Department of Ecology and Evolutionary Biology

Date: 4/27/2023

DocuSigned by:
By: ______________________________
Dr. Peter Raimondi, UCSC Professor, Department of Ecology and Evolutionary Biology

Date: _______________5/1/2023

UNIVERSITY OF CALIFORNIA
SANTA CRUZ
Office of Research Compliance Administration

EXHIBIT A

CONSENT TO PARTICIPATE IN RESEARCH

Study Title: Diverse knowledge systems for the examination of localized dynamics of sea otter and abalone populations in Sitka Sound, Alaska
UCSC Study # HS-FY2021-74

INTRODUCTION

You are invited to take part in a research study conducted by Taylor White ("Researcher") and Dr. Peter Raimondi from the department of Ecology & Evolutionary Biology at the University of California, Santa Cruz. Before you decide whether or not to participate in the study, you should read this form and, if there is anything you do not understand, ask questions.

There will be anywhere from 30 to 75 adult individuals (aged 18 or older) that consent to participate in in this study ("Participants" or "Stakeholder Participants"). Participants are "stakeholders" and include local sea otter harvesters, Alaska Native traditional and customary harvesters, local subsistence or historical commercial abalone harvesters, and tour guides or community members with knowledge of abalone and/or sea otter populations in Southeast Alaska.

PURPOSE

The purpose of this research is to understand local trends of pinto abalone and sea otter populations, following the re-establishment of sea otters to Sitka Sound ("Research"). Research aims to outline abalone and sea otter population dynamics during the ongoing harvest of both species. Local and Indigenous knowledge shared during interviews is integral to advancing the understanding of local sea otter and abalone dynamics and it is the first step in supporting tribal and stakeholder sovereignty in the management and future research of these culturally important Research focal species: sea otter and abalone.

To address the Research purpose, Researcher (Taylor White) will collect Participant information via:

- interviews, mapping exercises, and surveys of local and Indigenous Knowledge on historic trends of pinto abalone abundance and harvest in Sitka, Alaska
- questions that document knowledge of abundance and available legally-sized abalone at identified harvest sites before, during, and after sea otter population establishment; and before, during, or after commercial abalone fisheries
- questions that explore local and Indigenous knowledge of areas in Sitka Sound with current high, medium, or no sea otter abundance and determine areas as longest occupied, recently established, or previously established by sea otter populations
- questions on known local sea otter movement the movement and sea otter abundance changes in areas surrounding Sitka, Alaska, along with questions identifying sea otter hunting pressures in areas and factors, including socio-ecological factors that affect yearly otter harvest (e.g.,
tannery access, seasonal otter movements, poor weather years)

Participant information may be used in:

- assessments on the current relationships between sea otter abundance, occupation, and harvest, to current abalone densities and size frequencies in Sitka Sound

• determinations areas of greatest shifts in abalone and sea otter abundance to aid in understanding local patterns
• protected and archived Research records containing information released here by Participants
• Researcher presentations of Research findings and future engagement with Participant Stakeholders
• the identification of knowledge gaps, resulting hypotheses, and management suggestions with Participants Stakeholders, and co-production of a document highlighting future research recommendations for regional managers and stakeholders
• production of an outreach video highlighting the history of sea otter re-establishment in Sitka Sound, local trends following establishment, and current interactions between sea otters, pinto abalone populations, and community members
• a radio piece highlighting shared history, research, and the community connection to dynamic marine resources
• semiannual progress reports and a final programmatic report to the study sponsor, the North Pacific Research Board (NPRB)
• presentations of research findings for publication by an appropriate scientific journal and presentation of Project results at a scientific conference within one year of completion of the Research (January 2025)
• a collaborative document outlining future research and management recommendations following interviews with Participants

WHAT WILL YOU DO IN THE STUDY?

If you decide to take part in this study, you have the option to participate in:

1) a 15-minute Online Survey; or
2) an hour-long Audio/Video Recorded Interview (in person, in Sitka, or online via Zoom); or
3) an hour-long Non – Recorded Interview (in person, in Sitka, or online via Zoom)

A 15-minute Online Survey or Audio/Video Recorded or Non-Recorded Interview
Each consists of three sections: semi-structured questions to understand your relationship with abalone, and sea otters; mapping exercises for abundance and harvest information; and a structured questionnaire for a measured degree of change. The Online Survey will be abbreviated and solely on an online platform.

Note: *You may opt-out of Audio/Video recordings during Interviews*

Participant Stakeholder Meetings
If you participate in an Interview or the Online Survey, you are also invited to join additional meetings to discuss Project findings in the months following initial Project Research. All meetings are voluntary, only involve project Participant Stakeholders, and are not a requirement for initial Interview or Online Survey participation. During meetings, Participant Stakeholders will review initial trends in data, and work to address any additional questions or concerns remaining by

developing a research and management plan for Sitka Sound. There will be at least two 2-hour Participant Stakeholder meetings at Sitka's ANB Hall Sitka in fall/winter of 2022 (synchronous online joining options).

> ***Note:*** *These meetings will not be visually or audio recorded, however, de-identified meeting minutes prepared by the Researcher may be shared among Stakeholder Meeting Participants.*

RISKS OR DISCOMFORTS

The Researcher will use a data management plan to protect the confidentiality of the research data. She will follow the data management recommendation provided by the UCSC Information and Technology Services (ITS) Unit Information Security Lead (UISL) to maintain the confidentiality of information provided by Participants. If you plan to take an Online Survey, but have data security concerns with the use of your personal survey device (e.g., your laptop, tablet, phone), please request an offline, in-person digital survey.

Because of the security measures the Researcher will take to protect your confidential information, the risk of unauthorized disclosure of such information is low. However, if a third-party obtains your confidential information from a source other than the Researcher, the third-party may make an unauthorized disclosure of your confidential information. Therefore, you should take measures to protect your confidential information from disclosure to, or access by, a third-party.

What benefits can be reasonably expected?

The results of this research will contribute to:

- the understanding of local trends of pinto abalone and sea otter populations, following sea otter re-establishment and sea otter harvest;
- a clearer understanding of shellfish population trends following sea otter reintroduction, occupation, and movement, in Sitka Sound, Alaska;
- bridging gaps in available data on local dynamics of harvested abalone and sea otter populations;
- the support of tribal and stakeholder sovereignty through their involvement in data collection and co-management suggestions for sea otters, and abalone

Can you be withdrawn from the study without your consent?

You may be withdrawn from the study if you do not follow the instructions given by the study investigators.

CONFIDENTIALITY

Any and all publicly-available Project findings will not disclose your personally identifiable information unless you consent to the use of your personally-identifiable information below or the Researcher is legally obligated to disclose the information under applicable law.

Importantly, your harvest locations will not be made public, and georeferenced areas and identifiable information will be obscured before data storage *unless you consent* to share the information as provided below in this form.

Confidentiality management of:

Georeferenced Information

- will not be made publicly available by the Researcher, Taylor White
- all georeferenced data approved by Participants for storage will be maintained by STA, otherwise georeferenced locations will be obscured prior to data storage and sharing.

Paper Copies

- maps, consent forms, and question/survey responses are scanned and saved to a Master Encrypted Hard Drive
- paper copies will be shredded within 1 month of collection

Note: *Upon a Participant's request, Taylor White will provide Participants with their own completed mapping exercises, survey/interview responses.*

Confidentiality management of:

All Other Research Data

All metadata, video/audio recordings and scanned paper consent forms, mapping exercises, survey/interview responses, and notes will be kept in a Master Encrypted Hard Drive.

Taylor White will have sole access to the Master Encrypted Hard Drive and will retain the master encrypted hard drive for three years following the conclusion of the Research, and then she will destroy the Master Encrypted Hard Drive (as required by the Research funder, The North Pacific Research Board). Ms. White will use de-identifiable and non-georeferenced data in Research (as described above) and use those "scrubbed" data in scientific publications. Those data will be publicly available through the publisher.

Note: *If you need to correct the research data you provided as a result of participating in the Research, please contact Taylor as soon as possible and please note, that after the research data has been analyzed and published, it may not be possible to correct your research data.*

Two different versions of data will be distributed via encrypted hard-drives and available as follows:

Sitka Tribe of Alaska Offices (STA)

- Versions of georeferenced, identifiable or de-identifiable data will be retained indefinitely at STA offices **(as consented by the Participant on this form).** • Participants can request to have access of their data (per STA research policy) • Non-participants may request from STA copies of the non-georeferenced data, the deidentified data and certain identifiable data such as quotes and audio or visual clips that a Participant has authorized to be made publicly available that are maintained on the STA hard drive, but may not access these data unless approved by STA.

North Pacific Research Board (NPRB)

- NPRB maintains non-georeferenced/de-identified information and research findings that are managed by AXIOM data managers in Anchorage and are publicly available at any time
- NPRB reserves the right to distribute any and all information pertaining to data and analysis found in reports provided by the Researcher to NPRB
- NPRB has the right to make the de-identified and non-georeferenced data publicly available, without your additional consent.

FUTURE RESEARCH

It is essential to note that this Project includes disclosing confidential information on managed species, and use and distribution of this information must first be approved by those individuals to which information belongs. Even if coordinates are provided by Participants, they will not be included in georeferenced maps. Confidential information approved for disclosure may be published in an academic journal, included in, Ms. White's dissertation, presented at a science conference or otherwise made publicly available (see page 2 examples). In accordance with North Pacific Research Board (NPRB) project award policies, select data from the Research will be transferred to NPRB. **All georeferenced information will be obscured and identifiable information will be scrubbed prior to data transfers to NPRB and UCSC. STA will receive scrubbed data unless participants consent to share additional identifiable and georeferenced data here.**

COMPENSATION

A Participant may receive either $75 gift card or a comparably-priced gift (boots or a drybag) for participating in an Interview. For participation in the Online Survey, you may receive a $15 gift card or a comparably-priced gift (a stainless-steel cup or a coffee mug).

Note: *There will be no monetary costs to you for participating in this study.*

VOLUNTARY PARTICIPATION

Your participation is completely voluntary; you are free to change your mind at any time and quit the study. You may skip any questions you do not wish to answer. Whatever you decide will in no way affect or result in loss of compensation to which you are otherwise entitled. You can withdraw at any time by simply leaving the interview or stakeholder meeting.

RIGHTS AND CONCERNS

If you have questions about this research study, please contact Taylor White, graduate student researcher (twhite1@ucsc.edu, 907-738-1798). You may also contact the faculty member supervising this research: Dr. Peter Raimondi (raimondi@ucsc.edu, 831-459-5674). If you have any questions regarding your rights as a Participant, please contact the University of California Santa Cruz, Office of Research Compliance Administration at 831-459-1473 or orca@ucsc.edu.

Please indicate your Research participation consent below

For 15- minute Online Surveys

☐ I **consent** for the information I provide in the online survey to be used for the Research and **consent** for all de-identified information and non-georeferenced data that I provide to be made publicly available.

☐ I **consent** for some identified information that I provide to be made publicly available (i.e., quotes) and wish to be contacted of such use by the Researcher in advance.

☐ I ***do not consent*** for the information I provide in the online survey to be used for the Research or for all de-identified information and non-georeferenced data that I provide to be made publicly available.

For Interviews not audio/video recorded

☐ I **consent** for the information I provide in the Interview to be used for the Research and **consent** for all de-identified information and non-georeferenced data that I provide to be made publicly available.

☐ I ***do not consent*** for the information I provide in the Interview to be used for the Research or for all de-identified information and non-georeferenced data that I provide to be made publicly available.

For Audio/Video Recorded Interviews

☐ I **consent** to be audio/video recorded and for the information I provide in the audio/video recording to be used for the Research.

☐ I ***do not consent*** to be audio/video recorded and for the information I provide in the audio/video recording to be used for the Research.

☐ I **consent** for all de-identified information and non-georeferenced data that I provide to be made publicly available.

☐ I **consent** for some identified information that I provide to be made publicly available (e.g., quotes, audio or video clips) and wish to be contacted of such use by the Researcher in advance.

☐ I ***do not consent*** for any identifiable information I provide to be made publicly available ***Note:*** *Stakeholder Meetings will not be recorded and any notes taken will not identify individuals but will be used for the Research.*

Please indicate your Research participation consent below

Data in a hard drive stored by STA (indefinitely)

Note: *Georeferenced information will not be made public.*

☐ I **consent** for my identifiable information, identifiable research data, and identifiable georeferenced data to be maintained by STA on an encrypted hard drive.

☐ I **consent** for my identifiable information, identifiable research data, and **non-**georeferenced data to be maintained by STA on an encrypted hard drive and no georeferenced data.

☐ I ***only consent*** for my identifiable information and identifiable research data, to be maintained by STA on an encrypted hard drive. NO georeferenced data.

☐ I ***only consent*** for my georeferenced data to be maintained by STA on an encrypted hard drive.

☐ I ***do not consent*** for my identifiable information, identifiable research data, and identifiable georeferenced data to be maintained by STA on a hard drive.

Data maintained on a protected hard drive by the UCSC Researcher (Taylor White) for three years following Research conclusion

****Note:** your consent to this storage is required to participate in the Research survey**

☐ I **consent** for my personally identifiable information (including meta data, video and audio recordings, consent forms, georeferenced mapping exercises, survey/interview responses, and notes) to be stored by Taylor White for three years after the Research has been concluded, when Ms. White will destroy the MASTER Encrypted Hard Drive that contains such information.

Reminders: *Data to be maintained indefinitely in a hard drive by the sponsor (NPRB) will not contain identifiers or identifiable georeferenced information. Data to be maintained indefinitely by STA will only include the approved information you, the Participant, consent to here.*

SIGNATURE

Signing this CONSENT TO PARTICIPATE IN RESEARCH means that you have read and understood the provisions of this document and that you voluntarily agree to participate in the Research in accordance with the provisions of this document

____ _________________________ **Signature of Participant Date**

____ **Typed/printed Name**

EXHIBIT B

STA LETTER OF SUPPORT

Sitka Tribe of Alaska

Tribal Government for Sitka, Alaska

March 17, 2021

To Whom It May Concern,

Sitka Tribe of Alaska (STA) is the federally recognized tribal government for more than 4,400 enrolled tribal citizens in Sitka, Alaska, organized under the Indian Reorganization Act of 1934 as amended. STA is responsible for the health, safety, welfare, and cultural preservation of its tribal citizens and their use of the Sitka Tribe traditional territory. STA writes in support of Taylor White's application for funding to explore the factors that contribute to abalone population viability including the effects of sea otter predation.

Restoring abalone populations in the Sitka area has been a priority of the Tribal Council since 2003, when abalone numbers were in sharp decline. Fortunately, in recent years that trend has reversed, and abalone numbers and harvests are increasing. An assessment of this rebound would lead to a better understanding of the localized factors that can affect population dynamics.

STA looks forward to assisting with Ms. White on this project and in the development of an MOA to address interview content and protocols, the handling and use of culturally sensitive information or traditional ecological knowledge, and the general roles and responsibilities of each party.

If you have any questions regarding these comments, contact STA's Resource Protection Director Jeff Feldpausch at (907)747-7469 or email jeff.feldpausch@sitkatribe-nsn.gov.

Sincerely,

Lawrence Widmark
Council Chair

(907) 747- 3207 • Fax: (907) 747- 4915 • 456 Katlian Street • Sitka, Alaska 99835

Appendix C2

Project & Interview Materials

Interview Questions and Methods

PROJECT:

Diverse knowledge systems for the examination of localized dynamics of sea otters and abalone populations in Sitka Sound, Alaska

Reviewed and approved by Sitka Tribe of Alaska Natural Resource Committee and included in UCSC Institutional Review Board (IRB) (Approval #HS-FY2021-74).

Integral to this project are interviews, which will be conducted based upon agreed guidelines with participants, the Sitka Tribe of Alaska, Alaska Federation of Natives Board Policy Guidelines for Research, and University of California Santa Cruz Institutional Review Board.

Local researcher, Taylor White, interview, analyses, and dissemination manager, and Dr. Peter Raimondi, UCSC P.I. and project oversight, will maintain the 'do no harm,' anthropological ethics principle throughout the project development, research, and dissemination of findings. Specifically, they consider ongoing roles and responsibilities as researchers trained in western science, working in Lingít Aaní (Tlingit land) with Tribal Citizens and will carefully weigh the consequences of collecting and sharing local and Indigenous knowledge on essential traditional resources and managed species. Their commitment to 'do no harm' extends beyond the period of the proposed project. Therefore, the following interview methods, questions, and consent forms for review and, in future, will supply findings and any proposed dissemination of findings for review by STA.

INTERVIEW METHODS

Interviews will be recorded and include semi-structured questions with mapping exercises and a structured questionnaire. Interviews are designed to last under an hour, with the flexibility to exceed the time frame. They will also be dynamic, with a varied structure of questions and mapping to reduce interview fatigue. Mapping exercises are akin to those done in Southern Southeast Alaska communities (Ibarra 2021) and semi-structured questions follow a model developed by Lee et al.,(2018) with three focus areas: general ecological trends following otter population establishment, degree of change, and community management strategies.

Interview participants must be 'stakeholders' of abalone and/or sea otters, which includes local individuals with a history of commercial abalone harvest, subsistence harvest, tour guides, divers, and Alaska Natives, with additional generational knowledge of adaptive management and refined harvest and hunting practices.

Participants will be offered honoraria for their time and for sharing their knowledge and history. Honorarium will consist of outdoor gear: small drybag, fishing gear, boots, gloves, etc.) or a gift card of the same value (around $75, exact value TBD), and further reciprocity efforts for shared time and knowledge , which are detailed below.

Consent Confirmation

Consent form must be signed, mode of recording, video or audio (only) and information storage method confirmed prior to each interview.

Safeguards against any misuse of sensitive information shared are made through this informed consent, the approved use of shared information, and proper archiving and safe storage of information.

- Do you understand your rights of self-determination, inalienability, and confidentiality or have any questions about these?
- Are you aware you are not required to answer any question asked? - Do you consent to video and/or audio recording of this interview?

INTRODUCTION

[**Goal:** establish participant's relationship with place, harvest, abalone and sea otters through time]

Introductory Questions

1) Would you please share your full name?
2) What year were you born?
3) Who are your parents?
4) Who are your grandparents?
5) Where were you born? Where did you grow up? What communities do you call home (i.e., do you live somewhere else at different times of the year, have family ties to other areas)?
6) How many years have you resided in this community? 7) Are you a Tribal Citizen? With which tribe?

Introductory Harvest Questions 8)

Do you harvest abalone?

a) Is there a particular time of year you harvest?
b) How do you harvest abalone?
c) When did you begin harvesting abalone?
d) Where, from whom did you learn how to harvest abalone?

9) Why do you harvest abalone?
    a) Is your harvest for subsistence? What does subsistence mean to you?
    b) Would you define your harvest as a customary and traditional practice?
    c) When you harvest is it in conjunction with other harvest or directed at abalone?
    d) How important are abalone to you?

10) Did you commercially harvest abalone or participate in other commercial dive fisheries?
    a) Over what years did you commercially harvest abalone?

11) Do you harvest sea otters?
   a) Do you harvest other marine mammals?
   b) When did you begin harvesting sea otter?
   c) Where, from whom did you learn how to harvest sea otter?

12) Why do you harvest sea otter?
   a) Would you define your harvest as a customary and traditional practice?
   b) How important are sea otter to you?

MAPPING EXERCISES WITH SEMI-STRUCTURED QUESTIONS

[**Goal(s):** determine areas of abalone harvest, and areas of sea otter presence/absence, occupation time, abundance, and harvest. Understand perceived effects of sea otter reintroduction and current and historical sea otter and abalone harvest].

Mapping exercises will provide spatial context to temporal trends described in responses to the ecological semi-structured questions. The focus area is Sitka Sound (i.e., the Magoon Islands to Goddard Hot springs), but pertinent information on areas north and south of the core area will be recorded as it is provided (see Figures 1 and 2). Willing participants with knowledge of abalone and, or sea otter harvest will be asked to share areas (at a spatial scale they are comfortable disclosing and are able to recall), which encompass their own harvest of sea otter or abalone.

First participants will delineate areas of abalone and sea otter harvest on an unmarked map (i.e., 'General Mapping Exercises') and then quantify the presence of sea otters on a map within polygons predetermined based on areas of current quantitative data on abalone populations (i.e., 'Area-Specific Mapping Exercises'). Specifically, pre-drawn polygons encompass 33 abalone survey sites where divers recorded abalone density, size structure, nearest neighbor distance, habitat association, behavior, and depth. Five of these sites have been monitored annually since 2015 for abalone population dynamics (see Bell et al.,2018).

Participants who harvest sea otters, will be asked to delineate local harvest areas inside and just outside Sitka Sound and to note sea otter behaviors or movement to and from harvest areas. In addition, they will be asked to share any additional information on sea otters that are 'struck and lost,' (or mortally wounded, lost otters), and to identify which factors (e.g. fuel, tannery accessed, seasonal otter movements, blood quantum requirements, Marine Mammal Protection Act changes, etc.) affect their harvest.

Semi-structured questions interspersed with mapping exercises will focus on perceived effects of sea otters, sea otter reintroduction, sea otter hunting, commercial abalone harvest, and subsistence abalone harvest. *Semi-structured questions are interspersed with mapping exercises during the interview as follows:*

Abalone Harvest General Mapping Exercise *(On blank nautical chart, Figure 1)*

1. With a red sharpie, would you indicate areas of abalone harvest on this map (either by a direct point of harvest, or a circle encompassing the smallest area of harvest that you feel comfortable disclosing)?
2. If you commercially harvested abalone, could you outline areas of regular harvest did you harvest? Why did you choose these areas?
3. Can you number these sites by easiest to most difficult to access? (where 1 = easiest to access)

Abalone Harvest Questions

1. Around when was the last time you harvested at sites?
2. Could you show me, in reference to provided shells of legal minimum size, mature size, and juvenile abalone size, what size the majority of the abalone at sites were during your last visit?
3. How have abalone populations changed over the period of your harvest (i.e. abundance and sizes)?
4. Has your abalone harvest changed since you began? How has it changed?
5. What has affected your ability to acquire abalone? Or other subsistence resources?
6. Have you seen sea otters in your harvest areas? And if so, when did you first see sea otters in each harvest area?
7. Have you noticed other changes in the habitat surrounding areas where you regularly see or harvest sea otters or abalone?
8. [For commercial divers] Did you see any changes in the abalone populations during the dive fishery? Did those changes concern you? Why?
9. Have sea otters or commercial (shellfish) harvest affected your subsistence? How (i.e., are there trends you see in availability of certain sizes of abalone or all abalone sizes)?
10. Have you noticed an order to what sea otters eat first or what species they impact first?

Sea Otter Mapping Questions

1. When did you start observing sea otters in Sitka Sound?
2. Do you like seeing sea otters? Why?
3. With a black sharpie, can you circle where you first observed sea otters?
4. Did you notice a general pattern of sea otter movement and reoccupation in Sitka Sound following their reintroduction to the north and south of Sitka Sound in the late-60's?
5. Could you draw this pattern on the map (using arrows or whatever best describes the pattern)?
6. With a purple sharpie, can you circle any areas of recent (within 5 – 8 years) of sea otter population growth?
7. With a silver sharpie, can you circle areas where sea otters were abundant, but currently are rarely or no longer seen?

Sea Otter Harvest General Mapping Exercise (*On blank nautical chart, Figure 1)*

1. With a blue sharpie, would you indicate areas of sea otter harvest on this map (either by a direct point of harvest, or with a circle encompassing the smallest area of harvest that you feel comfortable disclosing)?
2. Do you focus your hunting to specific areas? If so, why? Would you note these on the map?
3. Have you noticed any changes in sea otter behavior in areas you regularly harvest (i.e., avoidance, or movement of sea otters)?

Sea Otter Harvest Questions

1. Has your sea otter harvest changed over time? Have you harvested more or less sea otters recently?
2. What proportion of sea otters are harvested and not tagged (i.e., struck and lost, etc.)?
3. Can you share benefits of hunting sea otters?
4. Would you like to see an increase in hunting?
5. Are there any conservation concerns for sea otters?
6. Do you focus on a particular sex of sea otter (i.e., males or females?)? Is there a reason?
7. Can you share factors that affect your hunting? (e.g., fuel, tannery accessed, seasonal otter movements, blood quantum requirements, etc.)?

Area-Specific Mapping Exercise *(On chart with polygons, Figure 2).*

1. To the best of your ability, *can you indicate (with a black sharpie on Figure 2), the smallest* polygon per numbered area (1 – 12, Figure 2) where sea otters are **currently** present (1), **currently** absent (0), or **historically** present, now absent (-1).
2. Of those ranked polygons can you rank sea otter abundance as **currently** least abundant (1), abundant (2), and most abundant (3).
3. Lastly, can you identify **current** sea otter occupation time in polygons as longest known sea otter presence (1), commonly seen but not regularly established (2), and most recently established populations (3).
4. If you have identified occupation, abundance, and sea otter presence at the smallest numbered polygon (i.e. '1a'), can you identify the ranks for each metric in the larger polygons (i.e., '1b,' '1c') per numbered area, if they are different?

STRUCTURED QUESTIONNAIRE

[**Goal:** Measure the degree of change in abalone and other species in relation to sea otters, sea otter harvest, and abalone harvest over time]

Quantitative measures will be collected through a Likert-scale structured questionnaire. Questions will focus on an assessment of the degree and direction of shifts in abalone population densities, number of harvestable abalone, and participation in harvest pre-, during, and post-otter reestablishment. When applicable, participants will detail this abalone measures pre-, during, and post-commercial dive fishery.

Based on your experience, label Many (very abundant), Few, None, or NC (No Change) in the cells below.

If you have information on separate species of import, please include the names and appropriate measures of the amount per occupation or commercial dive fishery time.

Please leave blank if you do not have information pertaining to species.

Pre- During Post – sea During Following
Species/Size Sea Otter Sea Otter re- otter Pre-Commercial Dive Commercial Commercial Dive Abundance Occupation Occupation
Establishment Fishery Dive Fishery Fishery

Large/Legal abalone abundance(3.5-4in +)	

Medium abalone abundance (2-4in)	
Small size abalone abundance (< 1in)	
Total abalone abundance	
Abalone Harvest Participation	
Sea Urchin Abundance	
Large Kelp Abundance	
Other Species: ____________	
Other Species: ____________	
NOTES/Exceptions:	

MANAGEMENT RECOMMENDATIONS

Finally, participants will be asked for suggestions on the continued management of abalone and sea otters and on any concerns regarding management or the dissemination of shared knowledge. All concerns will be addressed and taken with the utmost seriousness, in accordance with the 'do no harm' ethics principle applied throughout the project and dissemination of findings.

Management Questions

1. Would you like to see more abalone harvest?
2. Would you like to see more sea otter harvest?
3. Do you have conservation concerns for abalone and/or sea otters?
4. Can you describe what a healthy abalone and/or sea otter population would look like?
5. Can you think of any good practices to maintain healthy, harvestable populations of sea otters and/or abalone?
6. Do you know of any historic enhancement or management practices for either species?
7. Is there anything impeding the proper management of these species?
8. Do you have any suggestions for sea otter and/or harvest and management?
9. Do you have any suggestions for abalone harvest and management?
10. Can you imagine a way that sea otters, abalone, and humans could co-exist together?

Co-Produced Management Plan Involvement

1. Would you be OK if we included your suggestions, concerns, and management strategy in a research and management plan?
2. Would you like to be involved in the co-development of this research and management plan?
3. Would you like to share anything else?

<u>Consent Reminder</u> (*see Informed Consent Form)*

1. Would it be alright to contact you again with any questions I have?
2. Would you like a copy of this interview for your records?
3. Following the initial dissemination of this research, would it be OK to share store all you've shared at the Sitka Tribe of Alaska Offices? Would you prefer a different method of storage?

Overview of Project Information Collection, Archiving, and Disposition

In alignment with IRB, as outlined on all participant consent forms and in the MOU between the Sitka Tribe of Alaska and UCSC Reagents

Confidentiality management of:

<u>Georeferenced Information</u>

- was not/will not be made publicly available but may be stored by the Researcher, Taylor White
- all georeferenced data approved by Participants for storage will be maintained by STA. Otherwise, georeferenced locations were obscured by coarse spatial scale prior to data storage and sharing beyond the <u>Master Encrypted Hard</u>

<u>Paper Copies</u>

- maps, consent forms, and question/survey responses were scanned and saved to a Master Encrypted Hard Drive (maintained by T. White)
- paper copies HAVE been destroyed

No video was collected, and ALL interview audio was archived on the Master Encrypted Hard Drive (some participants opted against audio recording for added confidentiality).

<u>All Other Research Data</u>

- <u>All</u> metadata, video/audio recordings and scanned paper consent forms, mapping exercises, survey/interview responses, and notes are on the <u>Master Encrypted Hard Drive.</u>
- Taylor White will have sole access to the <u>Master Encrypted Hard Drive</u> and will retain the master encrypted hard drive for three years following the conclusion of the Research, and then she will destroy the Master Encrypted Hard Drive (as required by the Research funder, The North Pacific Research Board).
- Ms. White will use de-identifiable and non-georeferenced data in project and dissertation research and use those scrubbed data (i.e., identifiers scrubbed, precise, georeferenced locations only presented at coarsest scales) in scientific publications. Those data will be publicly available through the publisher

CONCLUSION

Paired knowledge systems provided insight into understanding the complex relationships between sea otters, abalone, and the local community that would be otherwise limited by incomplete scientific data and prevalent community-held beliefs that sea otters negatively affect the shellfish. The project and participants provided more accurate local sea otter occupation periods and abundances than previously available, which allowed the ecological roles of sea otters to be better defined. The initial reintroduction of sea otters to Sitka Sound coincided with a notable decrease in abalone numbers, yet ongoing otter influences on abalone populations are much less clear and direct. Conversely, the direct local effects of human harvesting were emphasized in more accessible areas following historical and recent increases in abalone harvest pressure. Abalone and sea otters currently and historically vary across local scales most important to harvesters. Observations at the local scale suggest that various factors contribute to changes in abalone abundance, including potential consequences of otter presence, such as their consumption of urchins. The broader depiction of interactions and histories of the marine and local communities of Sitka Sound highlights the need for nuanced approaches to managing interactions with sea otter and abalone populations.

MANAGEMENT OR POLICY IMPLICATIONS

Management strategies are built into the structure of this research. Project findings address sea otter research needs (see Davis et al., 2015), including those defined by regional managers and stakeholders for higher temporal and spatial information on sea otters and species interactions, along with improved communication between managers and local user groups (USFWS 2020).

The project findings benefit informed management through better-defined roles of sea otters, as they re-establish and restructure diverse environments along with some subtle effects of otter removal via customary hunting practices. Reported changes to abalone abundances at harvest sites often followed the "shifted baselines" concept described by Pauly (1995), where perceived present abundance is not informed by historical abundance. Specifically, at three distinct harvest sites (which remain confidential), new harvesters perceived a great abundance of abalone, yet the sites were recently abandoned by previous harvesters due to dwindling abalone populations and overharvest. These ongoing impacts of subsistence harvest in heavily trafficked areas suggest a management focus on human harvest strategies to maintain abalone populations.

This project engages local Tribal governance, local resource users, and Indigenous knowledge bearers in the research process. During project interviews, participants provided numerous concerns and suggestions regarding the ongoing management of pinto abalone and outlined the most pertinent concerns and suggestions.

Management suggestions and concerns could be categorized into conservation strategies, community engagement, and research suggestions as follows:

Suggested conservation strategies

- Develop rotational harvesting plans to prevent local depletion, possibly informed by traditional harvesting practices, including the harvest of ONLY intertidal abalone, preserving abalone from humans that find subtidal refuge
- Consider the implementation of protected areas where abalone harvesting is better otter regulated and otter harvesting is managed to promote recovery.
- Suggested rotation of personal harvest sites: "*if we knew we couldn't find 20 legal ones, then we would move on*."
- Consider implementing spatial and temporal closures to protect critical habitats and allow for population recovery.
- Station more law enforcement in heavy-use areas during low tides

Suggested community engagement

- Foster educational outreach to promote sustainable harvesting practices among new harvesters, review size limits

- Community watch of locations where there are more people, fewer people overharvest,
- Hold public talk on the current status of local abalone populations, abalone life history traits, and the challenges harvested abalone populations face (e.g., cuts and hemophilia, slow growth rates, viable densities)
- Increase public awareness about the ecological roles of sea otters and abalone, and the importance of sustainable harvesting practices.
- Develop and disperse educational materials to inform the community about the findings of the research and the need for conservation efforts.
- Review and update fishery policies and regulations to reflect current ecological conditions and community needs.

Suggested research

- Continue monitoring abalone populations, particularly with changing otter distributions.
- Establish monitoring to track sea otter densities, local prey choices, and harvest rates.
- Examine the relationship between kelp forest health and abalone populations to guide habitat conservation efforts.
- Study the interactions between abalone and other species, such as minks and sea stars, to understand their roles in ecosystem dynamics.

The above themes in participant-provided suggestions and concerns over abalone management have great potential to inform policy at the state and regional levels. These suggestions will be presented to participants and the community and then provided to the Sitka Fish and Game Advisory Committee for consideration and movement toward the Board of Fish recommendation (see Outreach section). These first-hand accounts, paired with data, provide the most comprehensive information towards better conservation efforts and resource management strategies locally and extended throughout the range of abalone in Southeast Alaska.

PUBLICATIONS

None as of final report, any publications will be posted to akabalone.com

OUTREACH

NPRB Project #2115, locally known as “Ways of Knowing Abalone and Otters” maintains the “three R’s” described by Weber-Pillwax as responsibility, respect, and reciprocity (2001) and regards the warning Smith (1999) provides against sharing “pamphlet knowledge” and defining reciprocity as a box to check instead of sharing knowledge composed and represented within the frameworks it derives. Therefore, reciprocity spanned disciplines and spheres of knowledge influence. Throughout, we fostered collaborative coordination on developing interview methods and interpreting research results, ensuring that findings are understood and agreed upon by both scientists and Indigenous knowledge holders.

Sitka Tribe of Alaska Natural Resource Committee

- **July 20th, 2023 Project Update**: scientific visualization plans, progress
- **November 16th, 2023 Update:** interviews, preliminary findings, dissemination
- **January 18th, 2024 Update:** shared management suggestions and approval of results for the Alaska Marine Science Symposium presentation
- **March 21st, 2024 Update**: final project findings

Community

Sitka Tribe of Alaska’s Elder’s Coffee: January 9th 2024, a coffee and lunch gathering of elders. Shared preliminary project findings and animation pieces, sought input, recruited additional project participants.

Sitka High School Traditional Ecological Knowledge Class, March 21st 2024, project presentation, discussion

Raven Radio (104.7, KCAW)

July 27th 2022: T.White introduces alongside local abalone working group project https://www.kcaw.org/2022/07/27/abalone-survey-will-inform-work-to-rebuild-stocksimprove-harvests/

August 18th 2023: Formal Project introduction, call for project participation https://www.kcaw.org/2023/08/18/research-seeks-to-understand-the-many-ways-ofknowing-abalone/

Late Summer 2024

Sitka Nature (Podcast/Interview): Ways of Knowing Abalone and dissertation research, featuring abalone harvest best practices. Show website: https://www.sitkanature.org/raven/

Sitka Natural History Seminar or Sitka Public Library talk: Local academic talk

STA Elder Coffee: follow-up with findings and management suggestions

September 17th, 18th **Haida Gwaii Abalone Summit; sharing project findings**
https://haidagwaiiabalone.org/

Scientific Visualization/Project Animation
Scientific visualization of project findings via an animated story including characters illustrated by local Indigenous artist Sienna Reid (Kushxeet – artist behind Xoodzí). Jessica Kendall-Bar, from Jessie KB Art & Photography, animates, incorporating her hand-drawn backdrops and conceptual inclusion of the project survey results. The final project animation will be sent to NPRB, posted on the project website (AKabalone.com), and shared widely.

Website
All project-related materials, public updates, and reports will be included on the project website: www.AKabalone.com

ACKNOWLEDGMENTS

The project was supported by the North Pacific Research Board Human Subjects Core Research Award (Project #2115).

The research took place on Lingít Aaní, Tlingit Ancestral Land. Gunalchéesh, Thank you to the Tlingit people for their continued stewardship of this place.

The success of this project hinged on the generosity of the local participants, who entrusted us with their insightful expertise and generational Indigenous knowledge of local harvest and species trends at sites in Sitka Sound.

Gunalchéesh tlien to Sitka Tribe of Alaska for pivotal support of this project, including the establishment of a Memorandum of Understanding (MOU), the archiving of project data, and the engagement of Tribal citizens within their traditional territories.

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