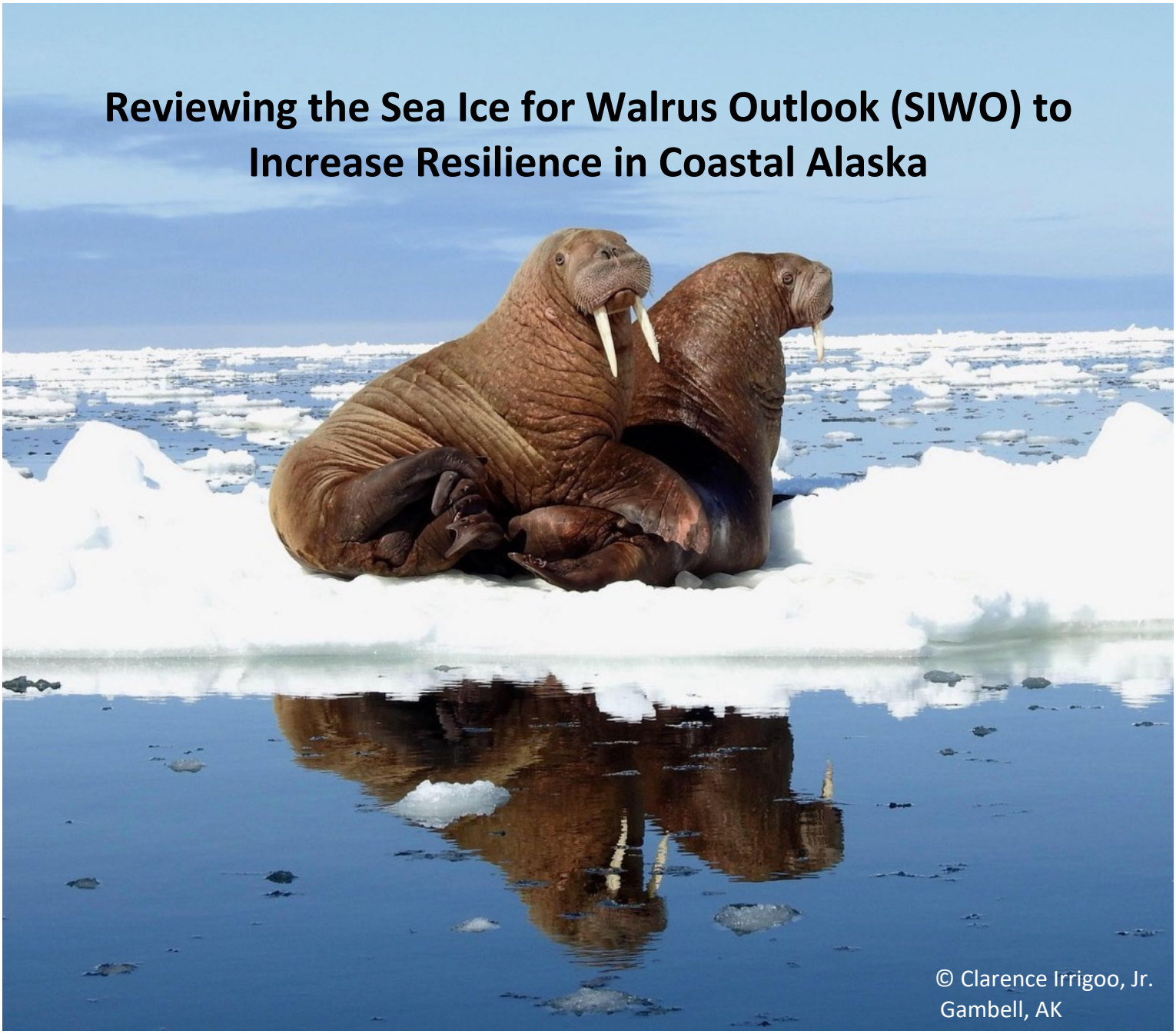
Reviewing the Sea Ice for Walrus Outlook (SIWO) to Increase Resilience in Coastal Alaska



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Recommended citation: Hendricks, A., N. Kettle, L. Sheffield Guy, O. Lee, V. Metcalf, and D. Holen, 2023. Reviewing the Sea Ice for Walrus Outlook to Increase Resilience in Coastal Alaska. International Arctic Research Center, University of Alaska Fairbanks. Fairbanks, Alaska.

ARCUS

International Arctic Research Center

Eskimo Walrus Commission
"To protect the pacific walrus population."

Sea Grant Alaska

ACCAP
Alaska Center for Climate Assessment and Policy
A NOAA RISA TEAM

1. Introduction. The Arctic is undergoing rapid environmental and socio-economic changes (Markon et al. 2018). For Arctic sea-ice, these changes include perennial sea-ice loss and declines in the duration of seasonal sea-ice presence (Kinnard et al. 2008). These changes have resulted in shifting distributions of walrus hunting locations in the Bering Sea and changes to traditional ways of understanding weather and ice conditions, which have become less reliable over time (Krupnik and Jolly 2002; Pungowiyi 2000; Metcalf and Robards 2008; Fidel et al. 2014; Walsh et al. 2016).

Alaska Native communities have called for efforts to enhance food security by increasing communication networks among scientists, decision makers, and Indigenous Knowledge holders (ICC 2015). Additionally, several workshops, climate adaptation plans, and trainings in the Bering Strait region have identified a high level of interest in reducing risks for subsistence activities, understanding sea-ice conditions, and supporting knowledge sharing among rural communities (Kettle et al. 2017; Pletnikoff et al. 2017).

Becoming informed about weather- and climate-related information resources across the Arctic is enhanced by the availability of trusted information, including Indigenous Knowledge and science. Subsistence hunters must consider sea-ice conditions, weather forecasts, walrus accessibility, and the other economic costs. However, there are several challenges in acquiring and using such information in rural Alaska, including limited or unreliable internet (Hudson et al. 2012). There is an increasing need to understand how information resources that bring together Indigenous Knowledge and science can be designed to support coastal resilience.

1.1 Sea Ice for Walrus Outlook

The Sea Ice for Walrus Outlook (SIWO, Figure 1) is an information resource designed to address needs of hunters in Alaskan Indigenous communities and others interested in sea-ice and walruses by providing information about sea-ice, weather, and walruses in the Bering Strait region (ARCUS 2022a). Below, we trace the origins of the SIWO, the process of how the weekly SIWO is produced, information provided in the weekly outlooks, and key partnerships and collaborators.

The SIWO emerged as a pilot project from the International Polar Year (IPY) 2007-2009, which was a coordinated effort aimed at strengthening connections with the Indigenous peoples and establishing observational networks (IPY 2012). The SIWO emerged from two IPY projects that focused on documenting Indigenous Knowledge and use of sea-ice (Krupnik et al. 2010) and developing a community sea-ice observation network among coastal communities (Eicken et al. 2014). The SIWO was first formally discussed among Bering Strait community representatives in January 2010 at a meeting supported by the Eskimo Walrus Commission (EWC) in Nome, Alaska (IPY 2012). The first SIWO outlook was published in April 2010.

The SIWO is managed by the Arctic Research Consortium of the U.S. (ARCUS, arcus.org), a boundary organization that "facilitates cross-boundary Arctic knowledge, research, communication, and education in the US, and with partners across the globe" (ARCUS 2022b). The SIWO is supported by multiple individuals and organizations. This includes several partner organizations that have provided significant and sustained contributions since SIWO's inception. ARCUS's SIWO partner organizations include the EWC, National Weather Service (NWS), and University of Alaska Fairbanks (UAF) International Arctic Research Center (IARC). It also includes local community observers who are considered equal partners. In spring 2022, Alaska Ocean Observing System (AOOS) and Axiom Data-Science began providing sustained support

for the SIWO via additional funding and forecast information. Funding for SIWO is provided by the National Science Foundation through a cooperative agreement with ARCUS (PLR-1928794).

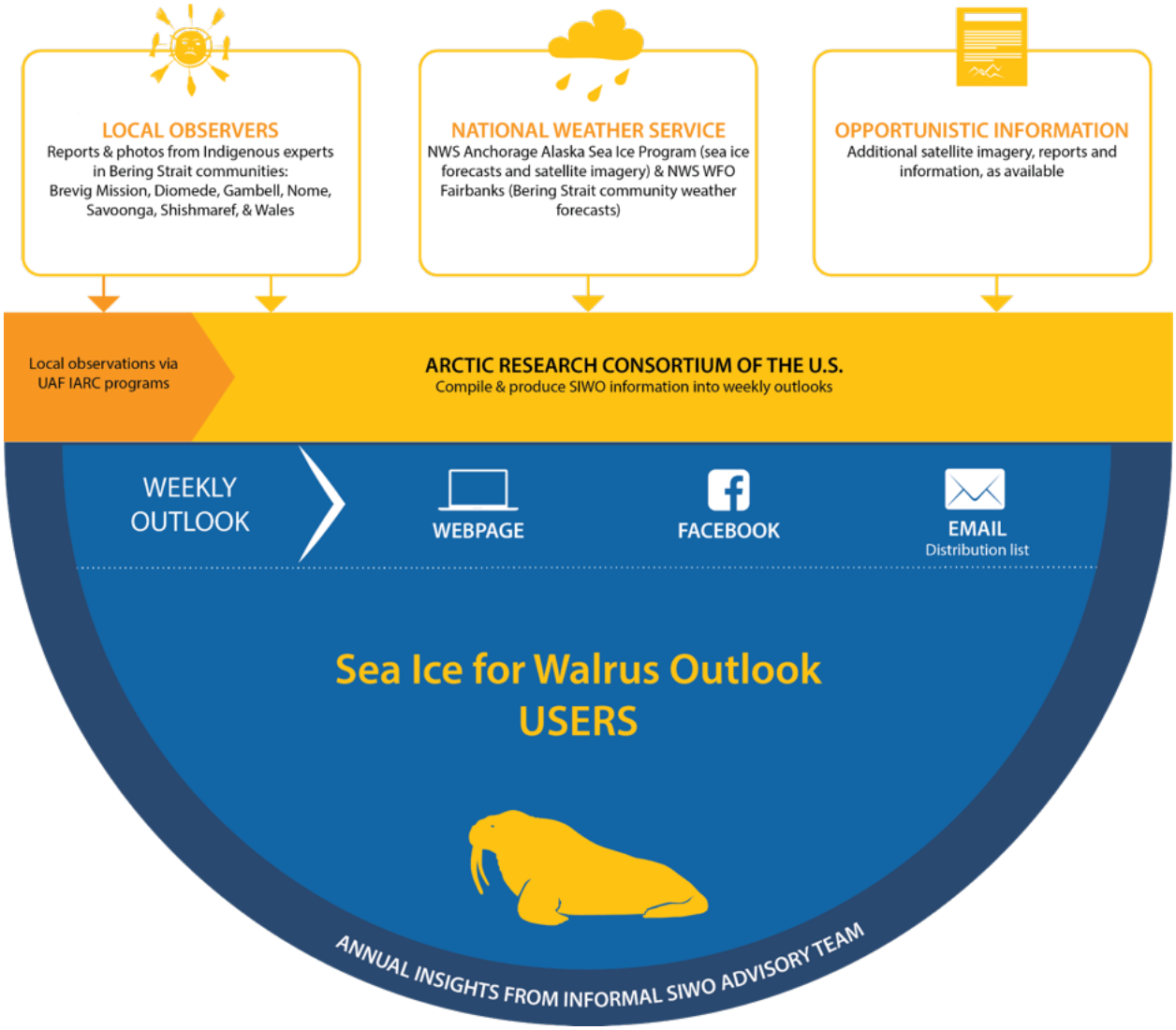

Figure 1: Sea Ice for Walrus Outlook (SIWO) organizational design.

The SIWO provides weekly outlooks during the spring walrus hunting season, typically between mid-March and mid-June, when sea-ice retreats through the Bering Strait and acts as a platform for migrating walruses. The weekly SIWO includes local observations, scientific forecasts, satellite imagery, and opportunistic information. Local observations related to sea-ice, weather, and walruses are provided via pictures and written narratives by observers from seven Bering Strait coastal communities who are active or former walrus hunters (Figure 2). Individual local observer reports are sent to the SIWO project manager at ARCUS and partner coordinator at UAF/IARC. NWS information is posted to the NWS SIWO webpage (NWS 2019) and retrieved by the SIWO project manager for inclusion in the outlook each week. The NWS provides a suite of information products, including maps of sea-ice age, maps of sea-ice concentration, forecast maps of sea-ice edge for the next five days, high-resolution satellite

images of the Bering Strait, Wales to Shishmaref, and St. Lawrence Island regions, temperature trends for the five to seven days, and wind forecasts for the next five to seven days. Detailed forecasts are made available for each of the SIWO communities. Recently, new partners AOOS and Axiom Data-Science began providing sea-ice movement forecasts for the SIWO region. Additional opportunistic sources of information, such as annotated satellite imagery or photos from volunteers, are sought out and included by the SIWO project manager and partner coordinator when available. The SIWO project manager at ARCUS compiles these observations and forecasts into the weekly outlook, which is published at noon on Fridays. Weekly outlooks are publicly accessible on the SIWO Facebook page (Facebook 2022a) and SIWO webpage on the ARCUS website (ARCUS 2022a) and a weekly email is sent to a list of subscribers. The NWS SIWO webpage is updated twice daily (NWS 2019). The first outlook was published in April 2010.

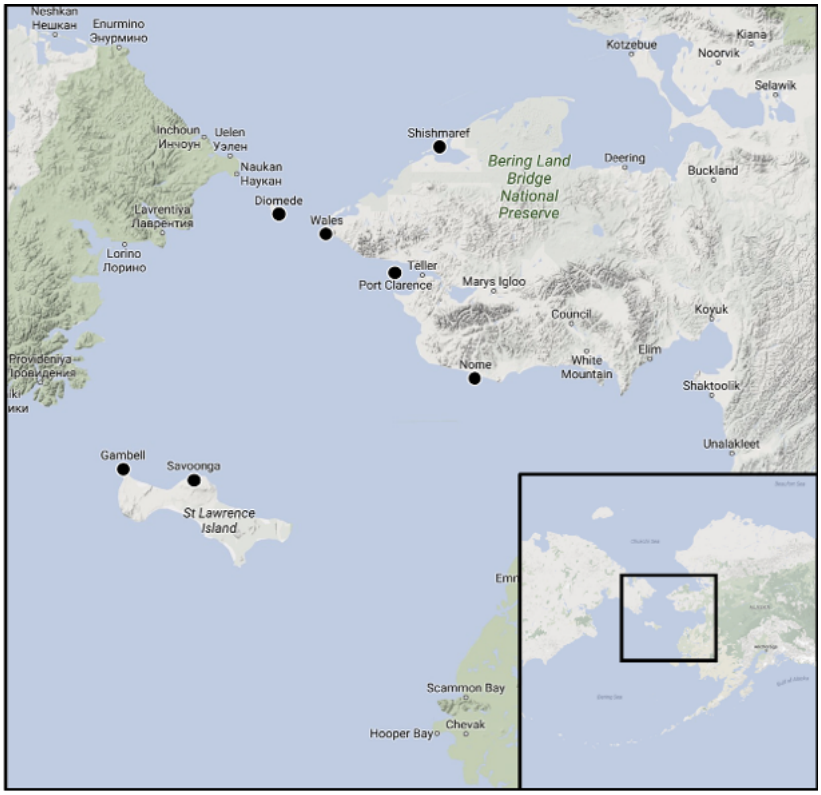

Figure 2: Sea Ice for Walrus Outlook (SIWO) observer communities in the northern Bering Sea and southern Chukchi Sea regions in Alaska (n=7).

SIWO partnering organizations collaborate with an informal and voluntary advisory team that provides broader context and ensures that the evolving needs of local observers and users are met. The advisory team does not have planning authority nor greater influence than the SIWO local observers and partners. The informal advisory team consists of several individuals who have been involved in varying capacities and involvement since 2010. The advisory team typically joins two annual meetings to provide guidance and insight. A pre-season meeting in February or March reviews the state of the sea-ice and helps to establish the start date for SIWO. A post-season meeting aims to recap the hunting season, plan for the following season, and provide an opportunity for relationship building among local observers and science partners.

Although there appears to be a high level of interest in the SIWO, more detailed feedback is needed to enhance the capacity of the SIWO to support community resilience.

1.2 Assessment Goals and Purpose

Assessing the SIWO provides an opportunity to support coastal resilience in Alaska in several manners. First, it provides a preliminary set of recommendations to the SIWO manager and partners on how the SIWO can be improved to support societal needs. Second, it contributes to a broader understanding of how processes for information sharing can be supported among local and Indigenous Knowledge holders, scientists, and climate communicators to develop more usable science across the Alaskan Arctic. Third, it explores how local observations, which are of disproportionate importance in the Arctic, can support NWS monitoring systems. The primary objectives of this project are to evaluate the SIWO to identify ways to improve its usability and optimize the impact of the SIWO based on a set of stakeholder-generated recommendations.

2. Summary of Review Methods. The SIWO is reviewed based on a set of 27 indicators (Table 1), developed from literature on evaluation and decision support. This includes five types of indicators commonly used in evaluations: inputs, processes, outcomes, outputs, and contextual factors (e.g., Kettle 2019; Wall et al. 2017). *Inputs* focus on human, social, natural, and financial capacities, including resource allocation, involvement across the science-practice boundary, leadership, and skill sets. *Processes* refer to actions taken to meet program goals, such as the frequency and level of engagement and inclusion of individuals on both sides of the science-practice boundary. *Outputs* refer to deliverables other than the weekly SIWO. *Outcomes* are more conceptual and refer to achieving project goals and perceived credibility, legitimacy, and relevance. *Contextual factors* refer to external forces that impact the SIWO and partners' capacity to provide information. Our approach to reviewing the SIWO consists of three steps discussed below: document analysis, semi-structured interviews, and a web-based questionnaire.

Table 1: Framework to evaluate the effectiveness of information resources that bring together Indigenous Knowledge and science. I = Inputs, P = Processes; OP = Outputs; OC = Outcomes, CF = Contextual Factors.

Component	Indicators	Key References
Inputs	I.1: Necessary scientific expertise	Cash et al. 2002; Meadow et al. 2016
	I.2: Necessary Indigenous Knowledge	Cash et al. 2002; Kettle 2019; Meadow et al. 2016
	I.3: Program champion(s) and leadership	McNie 2013
	I.4: Equitable commitment of time, services, funds	Elam Yua et al. 2021
	I.5: Articulated need for information resource	McNie 2013; Vaughan and Dessai 2014; Vincent et al. 2018; NRC 2009
	I.6: Pre-existing relationships	Meadow et al. 2016
	I.7: Motivations for collaborating	Wall et al. 2017; Oh and Rich 1996
	I.8: Attitude towards collaboration with Indigenous communities and individuals	Kalafatis et al. 2019
	I.9: Institutional stability	NRC 2009
	I.10: Boundary spanners and communicators	Buizer et al. 2012; Cash et al. 2003, 2006; Meadow et al. 2015, 2016

Processes	P.1: Ongoing and iterative communication and engagement	McNie 2013; Vaughan and Dessai 2014; Vincent et al. 2018; Cochran et al. 2013; NRC 2009; Dilling and Lemos 2011; Lemos et al. 2012
	P.2: Design for learning	Gerlak et al. 2018; Meadow et al. 2016; Vincent et al. 2018
	P.3: Tailoring of information	Gerlak et al. 2018; McNie 2013; Vaughan and Dessai 2014; Vincent et al. 2018
	P.4: Increasing accessibility of information	Vaughan and Dessai 2014; NRC 1999; Dilling and Lemos 2011
	P.5: Support for equitable opportunities to participate	Cash et al. 2002; Meadow et al. 2016; Vincent et al. 2018
	P.6: Transparent decision processes	Gerlak et al. 2018; Vaughan and Dessai 2014
Outputs	OP.1: Additional documents and reports	Wall et al. 2017
Outcomes	OC.1: Information perceived as salient	Cash et al. 2002; Gerlak et al. 2018; McNie 2013; Riley 2021
	OC.2: Information perceived as credible	Cash et al. 2002; Gerlak et al. 2018; McNie 2013
	OC.3: Information perceived as accessible	Gerlak et al. 2018
	OC.4: Process perceived as legitimate	Cash et al. 2003; McNie 2013; Cochran et al. 2013
	OC.5: Achievement of project goals	Wall et al. 2017
	OC.6: Partner interest in continued collaboration	Wall et al. 2017
	OC.7: Unexpected outcomes	Kettle 2019
Contextual Factors	CF.1: Budget constraints of partners (travel, time, etc.)	Wall et al. 2017
	CF.2: Personnel turnover	Kettle 2019; Wall et al. 2017
	CF.3: Technological and connectivity capacities	Wall et al. 2017

2.1 Document Analysis

A web-based search was used to identify SIWO-related documents and websites using combinations of the following keywords: sea ice for walrus outlook, Alaska, SIWO, SIPN2, ELOKA, SIZONet, and names of current advisory team members. The initial list of 46 documents was sent to the evaluation project partners for review, which resulted in an additional 25 documents, for a total of 71 documents. Content analysis was conducted to understand context, identify potential interviewees, inform the development of the interview protocol, and identify additional SIWO outputs from the SIWO (Appendix A).

2.2 Semi-structured Interviews

Interviews (n=13; 65% response rate) were conducted over the telephone and internet between February 2021 and March 2022. Potential interviewees were identified from the document analysis and feedback from the evaluation project review team. Participants were contacted via diverse modes of communication, including e-mail, Facebook Messenger, and text messaging due to telecommunication challenges in rural Alaska (Hudson et al. 2012).

Interviewees included the SIWO project manager, partner coordinator, three local observers, two NWS forecasters, five informal advisory team members, and one contributor of opportunistic information. Local observers were paid $150 for their time, knowledge, and expertise (Raymond-Yakoubian et al. 2014). Interviews lasted 45–90 minutes, and covered topics relating to their perceptions of engagement with the SIWO, including motivations for engaging with the SIWO, uses of the SIWO, information content preferences, feedback on how the SIWO is produced, recommendations to enhance usability, and perceptions of salience, credibility, and legitimacy. Interview recordings were transcribed and coded for themes relating to the evaluation indicators (Table 1).

2.3 Web-based Questionnaire

A questionnaire was implemented between March and April 2022 to obtain additional feedback from SIWO users. Survey questions focused on user backgrounds, use of the SIWO, preferences for information types, missing information, preferences for availability and access, and communication of information across user groups. Participants were recruited via announcements on the SIWO Facebook (~1000 profiles) and ARCUS SIWO webpage, the SIWO mailing list (n=46), and emails to Tribal offices (n=21). Participants had the opportunity to win one of five $50 Visa gift cards. The questionnaire received 35 responses (3.5% response rate). In addition to telecommunication challenges, the low response rate may be related to Facebook account users being under 18 years old, individuals who follow the Facebook SIWO page but have limited engagement, and limited participant availability when the survey was disseminated. Respondent roles included walrus hunters (n=14), Bering Strait residents (n=15), scientists (n=15), and a natural resource manager (n=1); several participants identified as having multiple roles (29%). Affiliations included local or tribal government (43%), federal government (40%), state government (37%), Alaska Native corporations (23%), non-profit organizations (17%), universities (17%), and local community businesses (15%). Nine participants provided the name of their community in the Bering Strait region. This included three communities who have SIWO observers and two communities who do not currently have a SIWO observer.

3. SIWO Review Findings. Analysis of documents, interview transcripts, and questionnaire responses provided insights into several indicators of production, access, use, and perceptions of usability for the SIWO. The following subsections outline the input, process, output, outcome, and contextual factor indicators for the SIWO (Table 1). For a detailed assessment of the questionnaire findings, see Hendricks et al. 2022.

3.1 Inputs

The SIWO is supported by several human, financial, and social capacities. The SIWO project manager, partner coordinator, local observers, and informal advisory team members hold significant experience and expertise in Indigenous Knowledge and science that provide capacity for providing information on weather and sea-ice conditions relevant to walrus hunting and safe travel (I.1-2). Local observers, many of whom are walrus hunters from Bering Strait coastal communities, maintain close connections to the land and waters and are experts at observing the environment. Staff from the NWS Alaska Sea Ice Program (ASIP) hold extensive experience in sea-ice forecasting and producing daily sea-ice analysis and monthly sea-ice outlooks in Alaska (Heim and Schreck 2016). Forecasters for the SIWO at the Fairbanks Weather Forecasting Office have expertise in weather forecasting, as well as coastal and river hydrology and flooding, and experience working with partners to deliver weather information (Buzard et al. 2021). At the

same time, NWS forecasters and local observers suggested that **increasing the capacity of local observers to provide scientific observations could provide accurate local information on variables such as wind speed and direction**. SIWO advisory team members are experts in coastal sea-ice dynamics and hazards (Eicken and Mahoney 2015), marine mammals (Sheffield and Grebmeier 2009), cultural anthropology (Krupnik 2019), and Indigenous participation in research and engagement in the Bering Strait (Metcalf and Robards 2008). Additional capacity for scientific forecasting, climate insights, and science communication (I.10) is provided by a climate specialist at the Alaska Center for Climate Assessment and Policy (ACCAP), who is also a retired forecaster for the NWS Fairbanks and Nome Weather Forecasting Offices. The ACCAP climate specialist maintains a long-standing social media page (Facebook 2022b) to share accessible regional weather and climate information and is a trusted source of information in western Alaska (Thoman et al. 2020). Additional capacity for insight into Alaska Native culture and values is provided by a local advocate and leader in the walrus hunting community who spans a boundary with science and policy (Metcalf and Robards 2008) (I.10). A few advisory team members remarked on this boundary spanner's advocatory voice during periods of limited funding for the SIWO, as well as their important perspectives on how SIWO stipends contribute to the local economies and wellbeing. All SIWO advisory team members have worked or lived in the Bering Strait and are aware of the myriad environmental concerns of local observers and regional community residents. One advisory team member commented on their desire to see more invited to participate as local observers for the SIWO, and one local observer hopes to see more youth involvement invited to the SIWO, as youth are important as future leaders and hunters.

Strong leadership with a personal touch is a driving force for sustainability of local observer participation in the SIWO (I.3). Many interviewees (n=5) commented on the SIWO project manager's respectful approach to managing the SIWO as highly beneficial for supporting engagement and feedback from local observers: *"[they do] a really good job of letting there be space to ask one of the observers a question or something. [They] always seem very calm and patient and respectful"* (Interview 04).

Guidance for what local SIWO observers should include in their weekly observations are provided on the SIWO webpage (arcus.org/siwo/submit). Local observer stipends aim to compensate and recognize the time, expertise, and expenses for gathering, preparing, and submitting weekly reports (I.4). Beginning in 2017, local observers began receiving $40 weekly stipends, which led to more frequent and reliable observations. However, most of the **local observers, members of the advisory team, and project manager do not view the $40 stipend as sufficient,** as observers routinely provide self-services like internet and fuel to support their weekly observations, which can routinely take longer than an hour to prepare. One local observer described the time commitment as follows: "*I do these observations and it doesn't take an hour and it doesn't take two hours. Sometimes it'll take three hours. On a really bad day, it'll take four hours and so time is money"* (Interview 13). **Local observers also commented that they would be able to provide more detailed and frequent observations with additional funding.** An advisory team member and local observer both suggested that nearly doubling the stipend may provide a more equitable level of compensation.

The need for developing a platform to support sharing of Indigenous observations and science was articulated after the extremely low sea-ice years of 2007 and 2008 (Eicken et al. 2014) (I.5). Local observers working with scientists identified key challenges that emerged with respect to accessing marine mammals. The emergent challenge focused on navigating less

predictable and more dangerous sea-ice. Conversations between scientists and the EWC highlighted impacts of changing conditions at local scales and prompted a reframing of an emerging pan-Arctic seasonal outlook to focus on providing helpful and useful information for Bering Strait communities, which eventually became the SIWO.

Pre-existing relationships among local observers, the SIWO project manager and partner coordinator, and Bering Strait residents served key functions in the development and usability of the SIWO (I.6). Indeed, the SIWO was intentionally designed to leverage existing relationships in order to sustain relationships and increase trust, which are key for recruiting local observers in Alaska Native communities. Most of the SIWO interviewees, including the SIWO project manager, partner coordinator, advisory team members, and NWS forecasters, have worked extensively and built relationships with local observers and residents in the Bering Strait region. Further, time spent in coastal communities facilitated the development of personal connections with Alaska Native hunters, which was highlighted by the SIWO project manager, partner coordinator, and advisory team members as important for promoting open feedback on the effectiveness of the SIWO. Additionally, the SIWO project manager credits their time spent living on St. Lawrence Island as critical in providing insights into managing the SIWO and developing relationships with local observers and partners. For example, this experience provided insights into learning about key issues on information access and use for Bering Strait communities. It also enabled the SIWO manager to reach out to friends in the Bering Strait for input on effectively managing the SIWO to better serve communities.

Motivations for supporting the SIWO varied across individuals and groups (I.7). Local observers are motivated to share observations with hunters and community members to support safe travel. One local observer remarked that sharing observations with the SIWO is where they can make a difference:

> The sea-ice breakup, the movement, it's affecting a lot of us. That's where I come into play. That's where I feel that I can make a difference is that I can tell you that this is happening in [my community] (Interview 13).

Similarly, NWS staff participation is motivated by a desire to provide weather-related information resources for public safety and communicate directly with Alaska communities (NOAA 2017). Several advisory team members remarked on SIWO manager's friendly and casual approach as a motivating factor for their continued participation despite other commitments. One advisory team member appreciated the manageable scale of the SIWO and a shared desire for the SIWO to continue among collaborators.

Members of the SIWO partnership exhibited attitudes and intentions towards collaboration with Indigenous communities, which laid the foundation for providing effective information resources (I.8). Several advisory team members and local observers emphasized the importance of listening to communities and local observer partners about what is important, rather than approaching a project or partnership with preconceived ideas of what is useful or helpful. The project manager, partner coordinator, and advisory team members are committed to the SIWO and regard the SIWO as more than a job. One advisory team member shared hindsight into key components of an equitable local observer partnership that should be established prior to the start of a project, including securing funding for local observer stipends and agreeing upon pragmatic expectations of time commitments. Several advisory team members and local observers also discussed the importance of making engagements valuable to local observers by learning more about what motivates local observers to partner with scientists to share

environmental observations. Finally, participants honored and respected the value of Indigenous Knowledge. The SIWO project manager commented on the knowledge of a local observer:

> His knowledge about seabirds was tremendous. As a 17-year-old he knew more than we could ever possibly know… he was equally valuable as a scientist to any of us who had the, you know, graduate degrees (Interview 01).

ARCUS has provided long-term institutional stability by hosting SIWO operations since 2010, supporting project management, information dissemination, and relationship building (I.9). The SIWO project manager and partner coordinator utilize ARCUS social media accounts and web servers to share information and announcements. The long-term institutional stability provides a foundation for facilitating the maintenance of networks of scientists and stakeholders to interact and support the iterative development and refinement of the SIWO (NRC 2009).

3.2 Process

Ongoing and iterative communication supported relationship building and engagement of SIWO project partners (P.1). Annual meetings, specifically post-season meetings, provide a venue for building relationships and cultural and contextual understanding among local observers, scientists, and the NWS. Agendas for each meeting are sent to participants prior to the meeting, which is scheduled around participants' availability. One SIWO advisory team member remarked that the post-season meeting *"gives people of different backgrounds, different experiences a chance to connect, clarify, and revisit things that have been discussed in the past"* (Interview 05). Post-season meetings also facilitate space for local observers to share context and insights into information needs. For example, at one post-season meeting, a local observer shared concerns about search and rescue events, which led to dialog on how the NWS and local observers can better coordinate when ice conditions become especially dangerous. Although annual meetings provide an opportunity to build relationships and understanding among SIWO partners, there is limited participation from local observers.

Check-ins with local observers via phone calls, text messages, and Facebook messages throughout the spring season and leading up to annual meetings help the SIWO manager, partner coordinator, and local observers stay connected. Check-ins are viewed as helpful for knowing when to ask alternative local observers to report when a regular SIWO observer may be unavailable. However, there is limited presence of local observers at some annual virtual meetings due to competing time commitments and connectivity issues. In-person meetings such the inaugural in-person meeting planned for November 2020 in Nome, AK, which was postponed due to COVID and a government shutdown, are viewed as especially important by the SIWO project manager, partner coordinator, and several advisory team members for building relationships and trust.

A design for learning enables the SIWO to respond to the needs of partners and users (P.2). Annual SIWO meetings provide an avenue for actionable feedback to improve the SIWO. For example, local observer feedback on the need for sustained presence of the SIWO throughout the year, beyond the walrus-hunting period, led to more regular posting and interaction through the SIWO Facebook page and increased engagement among local observers, users, and scientists. Additionally, the SIWO project partnered with AOOS and Axiom Data-Science to provide sea-ice movement forecast videos in response to hunter and local community information needs. The SIWO also coordinated an external program review (summarized by this report) to identify opportunities to improve project processes and outcomes.

Tailoring of information is driven by community needs and capacities of local observers and directed by conversations at annual meetings (P.3). Local observers in coordination with the SIWO manager and NWS forecasters establish season start dates at annual pre-season meetings, which are tailored to each community and are flexible as sea-ice conditions change. The SIWO manager remarked on the benefits of having a narrower geographic and seasonal focus, which affords more flexibility to meet needs of users facing dynamic environmental conditions. Written forecasts from the NWS are tailored to individual SIWO communities, and the best available satellite images are chosen from multiple sources to display the clearest pictures of sea-ice features. Some satellite images are annotated to point out specific types of ice and cloud features, which increases usability for users who may be less familiar with satellite images. Local observers tailor their weekly reports based on what they perceive as important to share, which may include sea-ice, weather, marine mammals, and other information related to the environment and safe maritime travel. However, **one local observer felt that focusing information on sea-ice and walruses can exclude other relevant information.** Several participants stated that **providing a more holistic picture of environmental conditions could improve the relevance of the SIWO.** One participant suggested partnering with the Local Environmental Observer (LEO) network to expand the scope of environmental information provided in the weekly SIWO.

Several approaches are taken to enhance accessibility of information in the SIWO, such as reducing technical language (jargon), compressing images, and using social media (P.4). The NWS utilizes language preferred by local observers for both wind speeds and ice conditions in weekly SIWOs. For example, one NWS ASIP forecaster explained how they use SIWO-specific language to describe sea-ice conditions, such as ‘very close packed ice’ and ‘vast flows’, which are not commonly used in routine NWS products. To help reduce internet data usage for viewing photos and images, the SIWO manager and partner coordinator compress image files to reduce file data sizes. All local observers stated that **social media was a massive advancement to increasing access to the SIWO and Facebook is the most popular access platform for sharing information.** However, several interviewees had **concerns about equity in sharing information as some individuals have limited or no access to the internet.** Sharing the SIWO over local radio channels was suggested to increase equitability in sharing information in rural Alaska. Others suggested posting paper copies in communities, an approach that was attempted earlier but not perceived as effective in earlier personal communications between the SIWO manager and regional residents.

Equitable opportunities for local observers to engage in the development of the SIWO increased since its inception in 2010 (P.5). Participants credit SIWO leadership’s respectful and inclusive approach toward engaging local observers as beneficial for increasing equitable opportunities to participate in the SIWO. At the same time, scheduling conflicts and internet connectivity remain a barrier for some local observers to participate in meetings. Concerns about the transparency of decisions being made during the production of the weekly SIWO were not identified (P.6).

3.3 Outputs

Beyond the weekly SIWO, 71 SIWO-related documents were identified, including conference abstracts, gray literature, news and web articles, and webinar and radio recordings (Figure 3, OP.1). SIWO partner organizations, advisory team members, and local observers are authors on 70% (n=49) of the materials. Gray literature was the most common document type

(44%) and included workshop reports and white papers that emphasized the importance of community-based monitoring and scientific information to support resilience (Sheffield Guy et al. 2017; Johnson et al. 2016). Abstracts were identified at national and regional conferences where speakers gave overviews of the SIWO as a novel resource and shared challenges to providing an information resource in coastal communities in Alaska. News and web articles highlighted the SIWO as a community-based monitoring program that documents changes in sea-ice and animal behavior during a time of extreme environmental change (Campbell 2015). At the same time, several advisory team members impressed the importance of developing additional reports and datasets to increase the impact of the SIWO (OC.1). This includes **developing a report that synthesizes broader lessons learned about bringing together science and Indigenous Knowledge to provide information resources for coastal communities** across the Bering Strait region. Interviewees across all groups also articulated **a need for a synthesis report of SIWO observations that span the duration of the SIWO** to support planning related to food security and other environmental change contexts, as well as for the NWS to better understand localized weather, sea-ice, and ocean processes. Such documented local observations were also identified as useful for future generations by a local observer.

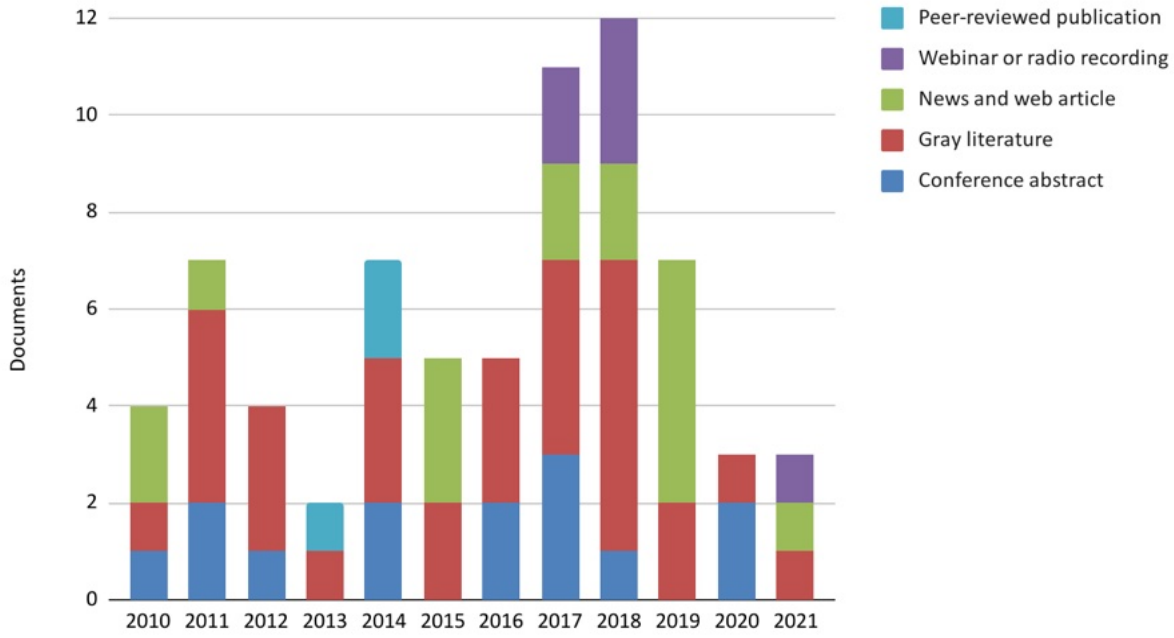

Figure 3: SIWO-related documents, 2010-2021 (n=71).

3.4 Outcomes

Participants provided several insights into the perceived relevance of information in the weekly SIWO, including the source of the information, type of environmental variable, and timing of when the information was available (OC.1). Local observations within users' communities and from nearby communities were both perceived as relevant (Figure 4, OC.1). Written descriptions of observations were considered at least *very valuable* when the observations occurred inside (47%) and outside (38%) of the community where the user resides.

Photo observations were considered as at least *very valuable* by participants when the observations were taken inside (32%) and outside their community (38%). One local observer commented on their use of observations from SIWO observers in other communities to understand the timing of sea-ice movement surrounding their community: *"when [ice] breaks off in front of Nome and it goes north with the current…I will have an idea of when the ice will be close…"* (Interview 10). At the same time, a more holistic resource for hunters would include additional environmental observations, like seabirds and whales, to give a more complete picture of the walrus hunting season.

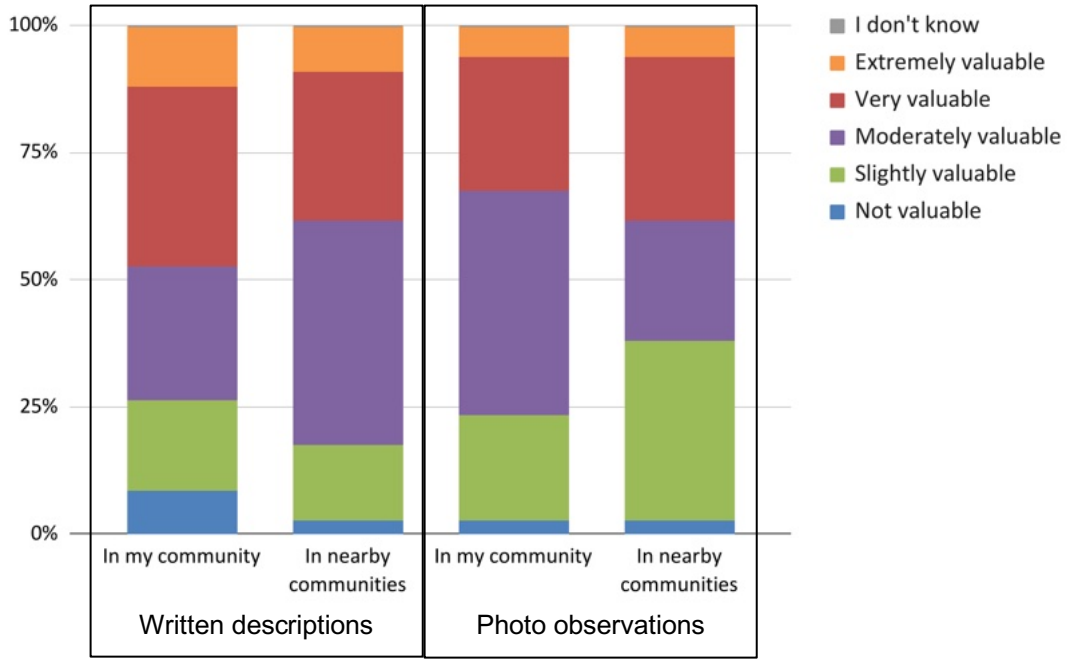

Figure 4: Value of community-based observations in the SIWO. Survey question: *"Please rate the value of the following information provided by local observers who live in coastal communities across western Alaska."* (n=34). The left panel is written descriptions; the right panel is photo observations.

There are some differences in the perceived relevance of information concerning wind speed (OC.1). For example, local observers expressed a higher level of perceived relevance for wind conditions during interviews than hunters did in the questionnaire. The lower level of perceived relevance of wind information among questionnaire participants is postulated to be related to participants responding to the importance of wind data in isolation from other environmental conditions. For example, local observers commented on the relevance of wind information in relation to ocean currents and tides, which can influence the size of waves and swells, and were noted in interviews as concerning environmental conditions for travelers.

Sea-ice observations from local observers are particularly useful for NWS ASIP products (OC.1). During times when the clarity of satellite images of sea-ice is limited by image resolution or cloud cover, ASIP has referenced local observations from the SIWO to validate sea-ice analyses. For example, when ASIP noted unusual sea-ice conditions in satellite images, the forecaster was able to contact the SIWO manager who confirmed with local observers that a rare occurrence of multi-year ice was flowing south through the Bering Strait.

There are also variations in the perceived relevance of information provided by the NWS (Figure 5; OC.1). Information about sea-ice was perceived to be the most important type of information provided by the NWS. Maps of sea-ice concentration and satellite images are considered either *very* or *extremely valuable* by half (50%) of the survey participants. Most walrus hunters (64%) considered satellite imagery to be either *very* or *extremely valuable*. Satellite images are an important scientific resource for assessing sea-ice and weather conditions beyond what is observable from land or boat and provide a bridge between scales of information needs. One local observer shared that they were able to discern the thickness of sea-ice from satellite images, which is important for considering the safety of navigating boats through fields of ice.

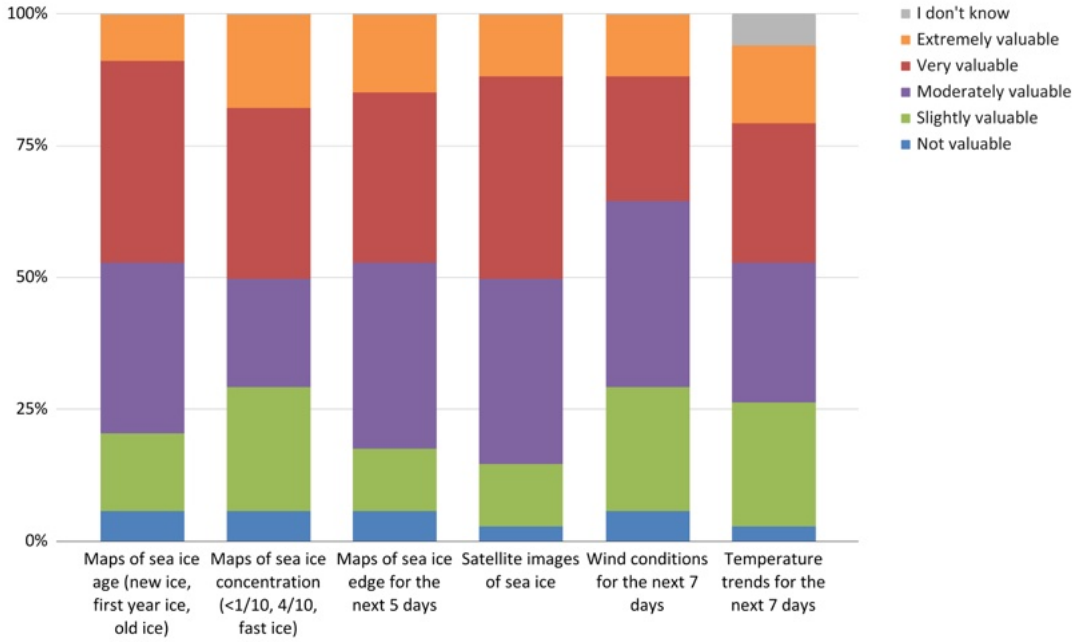

Figure 5: Value of scientific information provided by the NWS. Survey question: *"Please rate the value of the following information provided by the National Weather Service."* (n=34).

Opportunistic information provided by a climate specialist at ACCAP is perceived to be highly relevant for SIWO users, with 73% of users (n=33) finding this information to be at least *very valuable* (OC.1). The high level of perceived relevance of this information is likely due to the provider's name recognition stemming from an extensive history of providing credible information in the region (Facebook, 2022b), familiarity with local and regional environmental conditions and concerns, and provision of some information not typically included in NWS forecasts for the SIWO, like ocean temperatures and seasonal summaries.

The majority (75%) of survey respondents find having information provided by both knowledge systems at least *very valuable* (OC.1). However, there are differences in how individuals perceived the value of both knowledge systems. For example, local observers and a few advisory team members remarked that hunters still rely heavily on their day-to-day observation and Indigenous Knowledge to inform their traveling for hunting.

Information in the weekly SIWO is shared across groups with varying frequency (OC.1). Walrus hunters shared information at weekly and monthly frequencies with residents in other

Bering Strait communities (43%, respectively), and monthly with natural resource management agencies (43%). More than half of other Bering Strait community members indicated that they talk about or share information in the SIWO at monthly frequencies with hunters or residents within their own community (58%), and half indicated they talk about or share information in the SIWO weekly with residents in other Bering Strait communities (50%). Half also indicated they talk about or share information in the SIWO monthly with natural resource management agencies (50%).

Extending the period of time when the SIWO is available and including additional information types are identified as important in enhancing the relevance of the SIWO (OC.1). Local observers in interviews commented that information in the SIWO would be helpful during the early sea-ice formation period, typically during November and December, which would be useful for having a more informed understanding of seasonal sea-ice conditions. This is consistent with feedback from an early survey on the SIWO (EWC 2010). Most survey participants (56%, n=32) indicated that information in the SIWO would also be at least *very valuable* after sea-ice recedes in June, which is consistent with a previous related survey where participants commented that they would like to see the SIWO be produced year-round (PacMARS 2013). Local observers remarked that extending the SIWO season would also increase the usefulness for the hunting of other marine mammals, like seals and bowhead whales.

Additional information viewed as important to enhance the relevance of the SIWO include ocean current speed and direction, and air visibility. This additional information was desired by most survey participants (OC.1) and discussed in the context of safety during maritime travel, such as understanding currents for ice drift and route-finding. A small minority of participants desired information about tides (18%), drone footage (15%), and live webcam footage (12%). One hunter commented in the survey against the use of drones: *"no drones. they are invasive & disturb the peace."* Two additional communities were identified whose observations would be valuable for users and increase relevance of the SIWO; these communities are Elim because they also hunt walruses, and Shaktoolik because they have similar environmental concerns, such as storms and coastal erosion. One advisory team member also suggested expanding the SIWO to Yukon-Kuskokwim Delta coastal communities, a region south of the Bering Strait. In the past the SIWO manager has provided custom satellite images and information for this region based on a Facebook request, as the SIWO does not have a local observer in this region. No concerns were expressed about SIWO partners being disrespectful of divergent views and backgrounds, treatment of opposing views, or other concerns about legitimacy (OC. 6).

Overall, the SIWO manager, partner coordinator, advisory team members, local observers, and users expressed limited concerns about the credibility for information within the SIWO (OC.2). However, there are some concerns regarding the accuracy of the NWS sea-ice and weather forecasts. Although NWS forecasts are updated twice daily under normal operations, this information is only shared once per week on the SIWO Facebook page and the ARCUS SIWO site, when the weekly SIWO is shared. In this context, over half (52%) of the participants are at least *very concerned* about the accuracy of the maps of sea-ice age; nearly half of the participants are at least *very concerned* about the accuracy of maps of sea-ice concentration (48%) and wind conditions (45%) (Figure 6). In describing credibility concerns about NWS forecasts, one local observer stated, *"I've noticed that… [captains will] go that direction a day or two after the ice map just to find out that ice is not where it was a couple days ago"* (Interview 12). Social media is considered especially effective in providing credible

information, as it enabled more frequent updates. SIWO observations of the rapidly changing sea-ice and wind conditions are consistent with other observations and research on these conditions in the Bering Sea region (Raymond-Yakoubian et al. 2014).

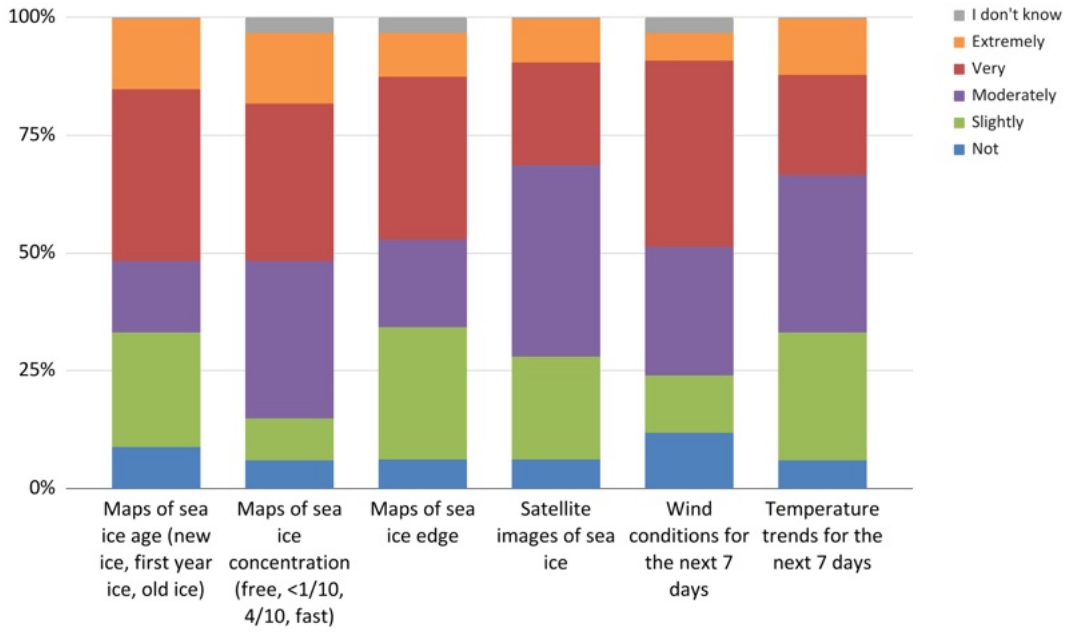

Figure 6: Perceptions of concern for the accuracy of NWS information. Survey questions: *"How concerned are you about the accuracy of scientific forecast information in the SIWO?"* (n=33)

The SIWO is accessed via multiple platforms (OC.3; Figure 7). Those who access the SIWO through Facebook accessed it more frequently than the ARCUS SIWO page and NWS SIWO page. Facebook users generally had the most weekly users (23%) compared to the ARCUS page (10%) and NWS page (17%). Nearly half of the participants access the ARCUS SIWO page monthly (47%). Many respondents access the NWS SIWO page bi-weekly (43%).

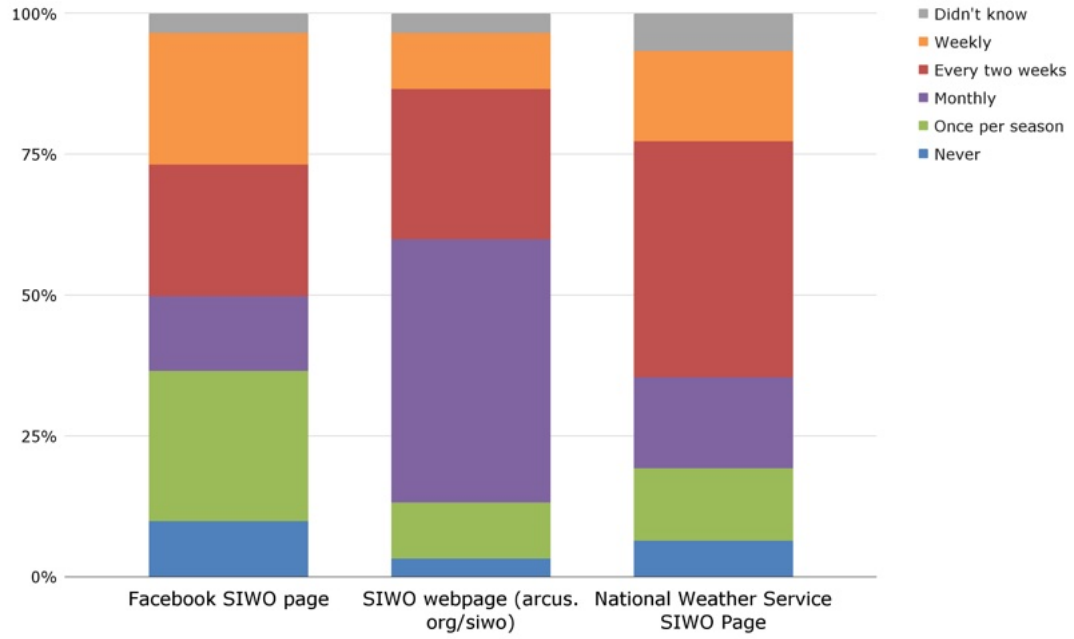

Figure 7: Frequency of SIWO access across different platforms. Survey question: *"How often do you access the SIWO from the following platforms?"* (n=30)

Participants identified factors that limited the accessibility of the SIWO, including internet access, technical language, and time (OC.3; Figure 8). Technical language ("jargon") was perceived as the greatest barrier impeding accessibility, with half of the questionnaire participants indicating that this factor was at least *very challenging*. Specific examples of jargon perceived as especially problematic were not identified. Limited internet connectivity and time were also considered factors that were *very or extremely challenging* for impacting access by 43% of respondents. **A few interviewees suggested non-internet-based access options**, like paper copies of the weekly outlook posted at local mercantiles, post offices, tribal offices, or school buildings, and radio or TV broadcasts could increase SIWO accessibility and use. Additional challenges identified in the interviews include lack of access to transportation to places where the SIWO might be available.

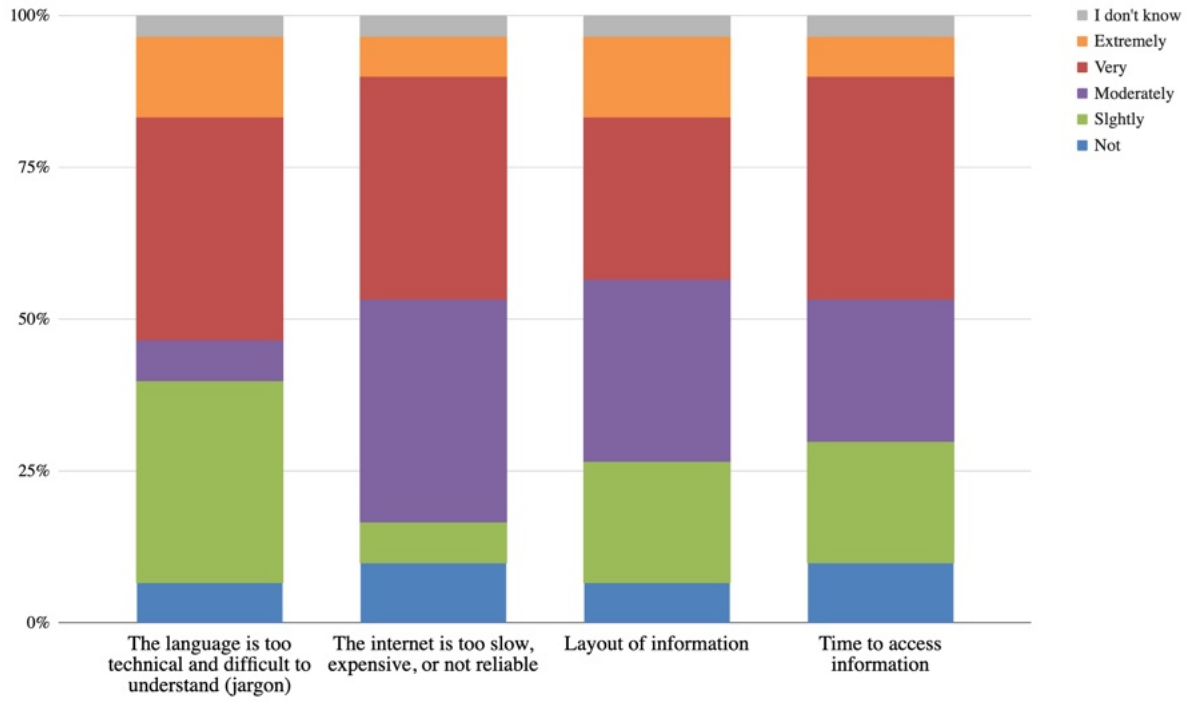

Figure 8: Factors affecting access to the SIWO. Survey question: *"How much are the following factors a challenge to accessing the SIWO?"* (n=30)

Nearly all participants are interested in continued collaboration with the SIWO, as long as it continues to be useful (OC.6). Advisory team members discussed the rewarding nature of working with the SIWO and all local observers interviewed expressed interest in continuing to provide observations and feedback. One participant discussed the value of the SIWO in providing accessible insights into village and subsistence lifestyles.

> I think one of the great values of SIWO is to show the world the human face of what subsistence in the Bering Strait region means…I promote SIWO as an example of western science and Indigenous communities working together…I think that SIWO is a perfect vehicle for helping people in distant places who have no actual conception of what a mixed-cash-economy means. SIWO is one way to help them start to understand what it is and why it matters. (Interview 02)

Participants from all groups felt that goal of the SIWO—to provide information about sea-ice, weather, and walruses in the Bering Strait for addressing needs of subsistence hunters in Alaskan Indigenous communities and others interested in sea-ice and walruses—as well as broader goals of NWS, EWC, and local observers are being achieved (OC.5). Overall, participants used the SIWO for general interest (49%), research (31%), policy-making (26%), management (26%), an information reference for hunting, fishing, or traveling (23%), and emergency services (17%) (Figure 9). These findings are consistent with previous reports that suggest users largely accessed the SIWO for general curiosity (AOOS 2013). Walrus hunters use the SIWO predominantly for general interest (57%), information reference making for hunting, fishing, or traveling (50%), policy-making (43%), and emergency services (43%). Participants feel that the SIWO is at least *very helpful* for understanding weather and sea-ice conditions relevant to walruses (59%), saving time by compiling information in one location (43%),

learning about walrus hunting from experiences shared by local observers (40%), and staying connected to subsistence activities in their home community (37%).

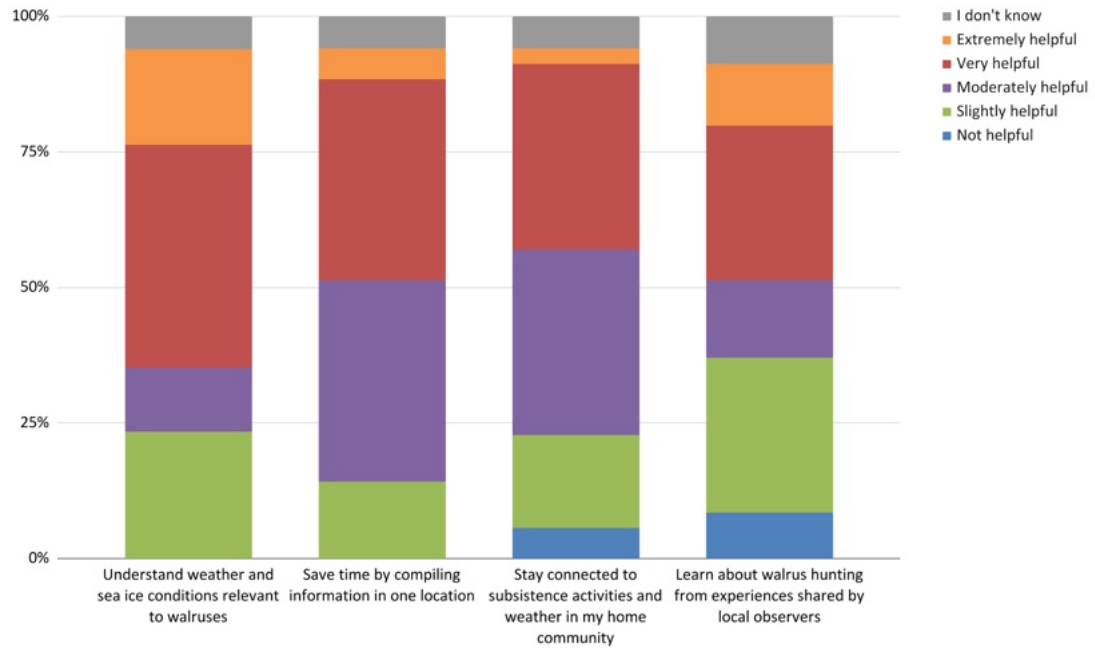

Figure 9: Participant use of SIWO. Survey question: "*To what extent has information in the SIWO been helpful for you in the following ways?"* (n=35).

Other notable outcomes related to supporting the goals of the SIWO included providing information for disaster claims and extreme events, building perspective for outsiders, and using SIWO to support regional communication (OC.5). Local observations from archived weekly SIWOs were used as evidence for several emergency disaster claims for the SIWO communities of the Native Villages of Diomede, Gambell, Savoonga, and Shishmaref, who were facing food shortages after seasons and years of low marine harvest numbers. In September 2022, the SIWO Facebook page shared timely NWS products to support planning and response efforts for Typhoon Merbok, including special weather statements, opportunistic social media posts, a satellite video of the storm over the Bering Sea, and a link to a live weather camera in Nome. Participants also provided suggestions to enhance SIWO's goal to be a resource for coastal communities. **Multiple interviewees suggested a synthesized report of archived local SIWO observations could be used as a resource for documenting local knowledge and change, and this in turn could be used in resource management, climate adaptation, planning,** and as a resource for NWS staff to become more familiar with regional weather and sea-ice features.

Beyond the initial goals of the SIWO, there were some unanticipated outcomes (OC.7). For example, several participants remarked on the impact partnering with the SIWO has had on their perspectives of what makes scientific information important and insights into village life. *"SIWO has helped me be a better human being, and it's helped me be a better science, weather, climate communicator because of the ability to link the western science with the things that are important to people"* (Interview 02).

3.5 Contextual Factors

Contextual factors, including budget and time constraints, personnel turnover, and technological capacities (CF.1-3), conditioned several aspects of the effectiveness of the SIWO. Local observers had some time constraints in providing observations and attending meetings due to high priority commitments, such as seasonal hunting and fishing activities that serve a key role in cultural values, ways of knowing, and maintaining connection to the land, waters, and place (CF.1). Multiple participants commented on how SIWO operated on a *"shoestring budget"*, and increased funding would enable additional relationship building through in-person meetings.

There was some turnover in local SIWO observers over time (CF.2), as local observers aged and passed away. In the event a SIWO local observer was unable to return, new local observers have been recruited by the SIWO project manager, partner coordinator, and other SIWO local observers. Participation from the NWS expanded to include forecasters at the Fairbanks Weather Forecasting Office, which is the office responsible for the Bering Strait weather forecasts, while forecasters at the sea-ice desk in Anchorage continued to provide sea-ice and marine forecasts for the SIWO. Due to the limited timing of availability of the SIWO during the spring and the nature of shiftwork at the NWS, the NWS Fairbanks office does not train all forecasters to produce SIWO forecasts and instead relies on a few forecasters for the tailored information each season. While the advisory team is informal and on a voluntary basis, many advisory team members remain committed to advising the SIWO and maintaining their relationships with other advisory team members, SIWO project manager and partner coordinator, and local observers. Some advisory team members discussed having to step back over time due to higher priority obligations.

There were some challenges associated with remote forms of communication that impeded engagement efforts, especially for local observers (CF.3). For example, several interviewees noted that connectivity issues with video conferencing increased chances for missed social cues, which can limit relationship building and impede participants feeling comfortable and knowing when to interject in the conversation. These findings are consistent with the document analysis, which revealed internet connectivity as a significant barrier to information access and community engagement in the Bering Strait (n=14, 26%). Emerging efforts to increase broadband access across rural Alaska offers the potential to overcome some barriers to remote engagement and access to the SIWO (DeMarban 2022). Other contextual factors included COVID-19, which has delayed efforts to support in-person networking among SIWO partners and impeded travel to SIWO communities.

4. Preliminary recommendations to improve the SIWO. Several preliminary recommendations are provided below to improve the SIWO.

4.1 Geographic and Seasonal Scope

- Consider expanding the geographic coverage of the SIWO local observer network. This is desired to increase access to local observations, information, and resources for other communities that both rely on walruses and other marine mammals and share similar environmental concerns (e.g., storms and coastal erosion). Participants identified the following areas as candidates for expansion: Bering Sea coastal communities in the Yukon-Kuskokwim Delta region, Elim, and Shaktoolik.
- Consider extending the seasonal scope of the SIWO. A longer season could include the periods of sea-ice formation, typically November and December. Information about ocean temperatures, currents, and winds during the formative months are useful for better

understanding sea-ice conditions during the spring season. Local observations and NWS forecasts would also be useful during the ice-free period; however, more detailed information is needed on what types of information are desired during the ice-free period.

4.2 Information Content

- Provide additional content in the weekly SIWO. Information about ocean currents and visibility are perceived as particularly valuable additions. There is a low level of interest in data from drones and one hunter expressed concerns about the invasive nature of this observation collection method. Integrating information from other local observer and scientific monitoring networks could also expand the types and frequency of environmental observations and provide a more holistic view of local observations.
- Reduce technical language in the SIWO. Although several efforts have been made to increase the accessibility of information, technical jargon remains a key issue impeding access. No specific terms were identified as problematic in the review.

4.3 Team Meetings

- Organize in-person meetings. Although the virtual pre- and post-season SIWO meets are important for facilitating engagement and feedback, additional in-person meetings are desired by local observers, SIWO project manager and partner coordinator, and advisory team members to further build relationships. One advisory team member suggested that the meeting occur semi-annually.
- Increase local observer participation in annual SIWO meetings. Although post-season meetings are structured to facilitate feedback and relationship building among all SIWO partners, there is limited participation from local observers.

4.4 Additional Outputs

- Synthesize SIWO local observations (2010-present). Synthesizing and documenting archived local observations provides further opportunities to expand the goal of the SIWO (OC.5) by providing a historical record of observed changes for future generations, informing community-level planning and management decisions, and increasing scientist and forecaster understanding of the region. Local information in locally useful forms also increase data sovereignty.
- Develop a report that synthesizes broader lessons learned. Insights and reflections could focus on bringing together science and Indigenous Knowledge to provide information resources for coastal communities across the Bering Strait region (OP.1).

4.5 Other Suggestions

- Increase observer weekly stipends. The current weekly stipend serves a critical role in compensating local observers for some of their knowledge and experience, time, and resources to make their observations. However, the current level of funding does not cover all local observer expenses (I.4). Two participants suggested considering doubling the current weekly stipend to provide adequate compensation for existing observations.
- Provide local observers with weather observation equipment to help users and scientists have access to more accurate localized weather information, especially for wind. This recommendation was provided by one local observer.

- Explore non-internet options for expanding access. Broadcasting weekly outlooks over local radio or TV stations may increase access to the SIWO for individuals with limited internet availability. Posting printed copies of the SIWO at post offices, tribal offices, and local mercantiles could also increase accessibility, though the effectiveness of past efforts is mixed.
- Explore opportunities to expand the local participation with the SIWO. Two advisory team members suggested connecting with local search and rescue crews, who often also rely on similar environmental observations to inform search and rescue operations. Other participants suggested encouraging the invitation of women and youth to become involved in the SIWO. There may also be opportunities for existing local observers to offer insights into improving and bias correcting regional NWS products, where social media could be further utilized as a two-way communication tool between forecasters and local observers for more feedback on forecast products.

5. Challenges in reviewing the SIWO. There were some challenges in the SIWO review. First, limited telecommunication infrastructure and COVID-19 travel restrictions reduced opportunities for the evaluator to interact in-person with Bering Strait residents, SIWO users, members of the SIWO advisory team, and local SIWO observers (NSHC 2022). Face-to-face communication is an important component of building trusting relationships in Alaska Native communities and getting feedback (Cvitanovicet et al. 2021). Interviewees lamented that the evaluator did not have the opportunity to travel to the region and meet the people in person. Poor weather conditions also impeded communication with interviewees, including willing participants not being able to participate, and portions of audio recordings that were not audible, both due to weather and telecommunication infrastructure. Second, although several steps were taken to enhance opportunities for feedback from participants from multiple backgrounds, including a document analysis, questionnaires, and interviews, feedback from the interviews may be biased towards individuals who are more connected to SIWO efforts. People less connected directly to the SIWO may have different perceptions of its usability (Lemos et al. 2012).

6. Discussion and Conclusion. This report summarized a review of SIWO and outlined a preliminary set of recommendations to increase its usability and impact. We conclude by discussing insights for other emergent and existing programs interested in providing information and resources to support coastal resilience in Alaska rural and Indigenous communities

Providing resources that are relevant to the information needs of residents in the Bering Strait is enhanced by using both Indigenous Knowledge and science. The review of the SIWO suggests that efforts to bring knowledge sources together are effective in providing information. This approach to providing information benefits from having the flexibility to respect cultural sensitivities associated with the Indigenous Knowledge and allows communities to maintain knowledge sovereignty and knowledge-holder recognition. Additional research is needed to further understand how individuals process both knowledge sources together, as this may provide further insights into how Indigenous Knowledge and science can be brought together for information resources.

Local observations of weather and environmental-related conditions serve a key role in providing situational awareness in the Arctic, especially due to several operational and logistical challenges of providing site-specific weather and climate information. Beyond providing

information that can support rural communities, local observations have the potential to support NWS forecast products.

Providing information services in rural Alaskan communities requires additional budget considerations. First, financial support for local observers extends beyond funding for local observer time and expertise, as observers have additional expenses that often include vehicle (boat, snowmachine) maintenance, fuel, data and internet costs, and observation equipment (e.g., cameras). Second, ongoing engagement activities serve a critical role in supporting ongoing relationship building and providing opportunities for feedback and learning. Our findings from the review of the SIWO are consistent with other research emphasizing the importance of in-person meetings in building familiarity and trust and supporting transparency (Elam Yua et al. 2022). Providing equitable funding for local observers to contribute to and participate in SIWO activities is consistent with recommendations for increasing justice (White House 2022; Elam Yua et al. 2022).

Although social media provides an effective medium for community engagement and dissemination of information for some people in rural Alaska, internet access remains a significant challenge in developing and providing accessible information resources in rural Alaska. Although several strategies can mitigate internet challenges, such as compressing images, limiting video content, providing non-internet-based alternatives for access, and providing alternative teleconference access to video conferencing, these issues remain significant obstacles for equitable participation and engagement. Efforts to enhance equitability in access to information may be more effective when multiple options are provided that align with user capacities and constraints (e.g., internet- and non-internet-based strategies).

Leveraging existing networks and long-term relationships serves as a foundation for creating and providing effective resources to support coastal resilience in Alaska. A history of respectful collaboration among partners can help shape and drive programs that can withstand programmatic obstacles. Partners may feel they can be more candid and honest with people they have worked with in the past. Pre-existing networks and relationships can also make it easier to bring in additional partners who are already trusted.

Evaluation provides an opportunity to understand the extent that projects are achieving their desired goals and develop sets of recommended changes that can be used as a basis for thinking strategically about programmatic changes. The review of the SIWO provided several user-generated recommendations to improve the process and outcomes and strengthen the program. Many of these recommendations extend beyond the SIWO, such as providing equitable compensation for local observer expertise and the time and resources it takes to provide observations, exploring non-internet options for expanding information access, and sharing broader lessons about supporting community needs through partnerships. Aligning programmatic reviews with funding cycles may be especially helpful in meeting local needs, especially to enable timely updates in response to dynamic community needs.

7. Acknowledgements. This research project was based at the University of Alaska Fairbanks, Troth Yeddha' Campus, which is located on the ancestral homelands of the Lower Tanana Dené People. The reviewers wish to thank the interviewees and questionnaire participants for their time and insightful feedback. The reviewers also thank Gay Sheffield for her thoughtful comments and feedback throughout the project. This research was supported by Alaska Sea Grant and the Alaska Center for Climate Assessment and Policy (NA16OAR4310162; NA21OAR4310314).

8. Credits. LSG, NK, VM, GS, OL, and DH conceptualized the project. NK and AH developed the evaluation methodology. AH and NK developed the questionnaire and interview protocol, with feedback from VM, GS, OL, and LSG. AH conducted the interviews and analyzed the data. AH led the writing of the report in collaboration with NK. LSG, OL, VM reviewed and edited the report. NK administered the project. NK, LSG, VM, GS, and OL secured funding for the project.

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