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Accelerating Climate Change Adaptive Capacity Through Regional Sustained Assessment and Evaluation in Hawai'i and the U.S. Affiliated Pacific Islands

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As the impacts and risks from climate change increase, the climate assessment landscape has expanded in scope and application, resulting in the desire for more information relevant to local decision-making. Some regions lack detailed climate projections and a body of consensus findings about sector-specific impacts, and there is a need for actionable, culturally cognizant, translated climate information suitable for integration into operations and management, budgeting, funding proposals, and domestic and international policy. The Pacific Islands Regional Climate Assessment, or PIRCA, is the subject of this decade-long case study illustrating the need, development, and benefit of creating and sustaining a nuanced, collaborative, and deliberately inclusive climate assessment effort among researchers and practitioners in Hawai'i and the US-Affiliated Pacific Islands (USAPI). Using external evaluations done in 2013 and 2021, and our observations as participants in the process, we describe regional adaptive capacity challenges—an important component of the decision context for PIRCA stakeholders—and analyze the role of the PIRCA network in accelerating climate adaptation. We also examine how regional and national assessments complement each other, and how assessment processes can aid in translation to sub-national decision making across the climate science-policy interface. Results reveal components of the PIRCA that are foundational to its effectiveness: framing climate information in human and decision-centric ways; use of inclusive and non-extractive methods; willingness to shift approaches to meet stakeholder objectives; leveraging the resources of the Pacific Regional Integrated Sciences and Assessments (RISA) and other boundary organizations; taking the time to build relationships; and creating a dedicated position to sustain collaborations and relationships within the region and at larger assessment scales. Our experience and the feedback received through the evaluation suggest that these lessons are transferable to other regions and scales, and that sustained and collaborative regional climate assessments can serve a key function in complementing major national and international assessments, by translating and more effectively

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targeting information to meet local needs in support of regional climate adaptation and policymaking.

Keywords: Pacific Islands, evaluation, adaptation, acceleration, climate change assessment, co-production

INTRODUCTION

The Role of Actionable Climate Assessments in Shaping Policy, Funding Priorities, and International Negotiations

Actionable climate assessments such as the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and the U.S. National Climate Assessments (NCA) have been critical in characterizing past climate trends and future projections and their impacts (e.g., USGCRP, 2017, 2018; IPCC, 2021, 2022), shaping emission mitigation goals (e.g., IPCC, 2014; UNFCCC Glasgow Climate Pact[1]; Hawai'i Act 234 and 15[2]) and setting broad research and adaptation funding priorities (e.g., USGCRP., 2012; Green Climate Fund (GCF), 2020) at global and national scales. Over the last several decades, the climate assessment landscape has evolved from mainly global and large-scale syntheses of physical mechanisms of change like those in the early IPCC and NCA products, to integrated analysis and special reports including social science and decision contexts (e.g., New et al., 2022), sectoral and regional impacts (e.g., USGCRP., 2016; USGCRP, 2018), evaluation of progress on adaptation planning and policy (e.g., Halofsky et al., 2015), mitigation pathways (IPCC, 2018), and extreme event attribution (e.g., Seneviratne et al., 2021) at smaller spatial scales (e.g., Bedsworth et al., 2018; MCC STS, 2020). There are benefits and challenges in increasing the scope and reach of climate assessments for use by regional and local decision-makers who need climate information to guide adaptation and mitigation to address rapidly emerging impacts on their communities. With the mounting financial and societal costs and risks associated with climate change, information such as climate trends and projections at finer spatial and temporal resolutions, the interactions of impacts across key sectors, and adaptation options are needed more quickly at sub-regional and sub-national, policy-relevant scales to support planning.

To accelerate the transformation of climate change science into knowledge that is useful and usable at sub-national planning scales, critical analyses of existing assessment frameworks recommend expanding cross-disciplinary collaboration, increasing the frequency of ancillary assessment products, co-developing information and tools by including information users in the assessment process, and sustaining the process using networks of both government and civil society (Lemos and Morehouse, 2005; Raes and Swart, 2007; Dilling and Lemos, 2011; Moss et al., 2019). Sustained interaction between scientists and information users, at local and regional scales, in informal networks and through climate boundary organizations can especially build trust in climate products and counterbalance misunderstanding and the perceived irrelevance of scientific information, as well as focus outputs to be stakeholder relevant (Dilling and Lemos, 2011; Wall et al., 2017; Ziaja, 2019).

Going beyond these well-established and broadly applicable recommendations, there are several unique challenges and needs in the Hawai'i and U.S. Affiliated Pacific Islands (USAPI) region that make effective local and regional climate assessments essential foundations for accelerated adaptation planning and implementation and for negotiations and global advocacy. Chief among them are widespread climate data scarcity, varied political classifications (**Figure 1**), spatial isolation, and the colonialism that burdens self-reliant populations and creates persistent funding inequities.

Need for Co-produced Climate Information and Translated Research to Strengthen Community Resilience and Adaptation Efforts

At an organizational level, the process of collaborating to develop "actionable" or "useful" climate research and information with regional and local managers and decision-makers has matured since the late 1990's (Pulwarty and Redmond, 1997; McNie, 2008; Prokopy and Power, 2015). As a framework, the co-production process emphasizes principles of stakeholder participation, interdisciplinarity, active communication, and relationship-building among project partners to foster trust in researchers and salience of scientific products for decision making and related social impact (Cash et al., 2003; Jacobs et al., 2005; Lemos and Morehouse, 2005; Moser, 2016). This process of scientific co-production can be used to lay the foundation for sustaining a robust assessment process (Lemos and Morehouse, 2005) that is applicable to adaptation planning in locations with differing geographies, demographics, climate impacts, decision-making needs, and sources of funding or available data. Co-production of research and assessments is becoming widely accepted—even demanded—as a methodological framework for increasing trust and use of scientific information in planning and management across different sectors (Lemos and Morehouse, 2005; Lemos et al., 2012; Meadow et al., 2015). Benefits of co-production include: integrated decision-relevant contexts from the conceptualization phase; increased representation and diversity of affected stakeholders; and creating credible policy-researcher networks that can accelerate actionable science (Dilling and Lemos, 2011; Ziaja, 2019). Co-production is useful in building a sustained local and regional climate assessment process by increasing bottom-up participation from diverse sectors of society, increasing climate literacy

[1]Advance text of the UNFCCC Glasgow Climate Pact https://unfccc.int/sites/default/files/resource/cma2021_L16_adv.pdf.

[2]HI Act 234, 2007 https://health.hawaii.gov/cab/files/2014/07/GM1005_.pdf; and Act 15 https://www.capitol.hawaii.gov/session2018/bills/GM1115_.PDF.

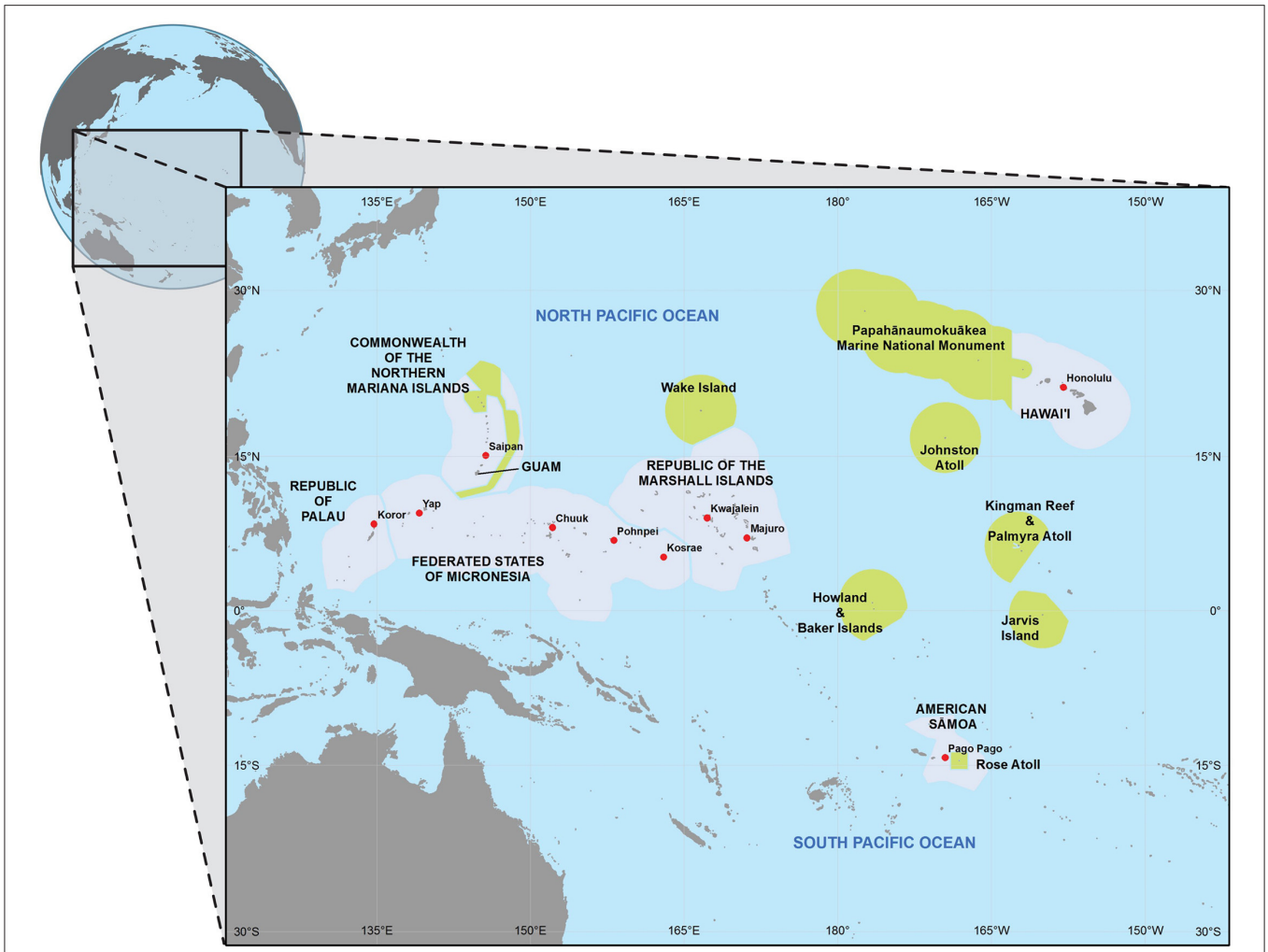

FIGURE 1 | The Pacific Islands region includes the State of Hawai'i, as well as the U.S. Affiliated Pacific Islands (USAPI): the territories of American Sāmoa and Guam; the Commonwealth of the Northern Mariana Islands (CNMI); the Republic of Palau; the Federated States of Micronesia (FSM); and the Republic of the Marshall Islands (RMI). Residents of Guam and the CNMI are U.S. citizens; those from American Sāmoa are U.S. nationals[4]. Under the Compact of Free Association (COFA), citizens of the FSM, Palau, and the RMI can live and work in the U.S. without visas, and the U.S. is obliged to provide economic assistance to COFA nations. On this map, shaded areas indicate the exclusive economic zone of each island, including Marine National Monuments (in green). [Figure from Keener et al., 2018].

and capacity in decision making contexts, establishing trust and transparency through relationship-building, and framing findings to directly address stakeholders' needs (Lemos and Morehouse, 2005; Moser, 2016; Moss et al., 2019). There are, however, also documented challenges. For instance, building such interdisciplinary science-practice relationships and networks takes time, significant human and financial resources, requires scientific data and models that match the complexity of users' environments, and is often not weighted favorably toward professional advancement in academic institutions (although this is starting to change, e.g., Purdue University tenure[3]) or in rankings of traditional research grant proposals, hindering sustaining these projects (Agrawala et al., 2001; Lemos and Morehouse, 2005; Bolson and Broad, 2013; Lemos et al., 2018; Moss et al., 2019; Meadow and Owen, 2021).

Challenges in Building Inclusive, Regionally Representative, and Sustained Assessments

There are several examples of national organizations with regional programs that utilize concepts of co-production of academic science and stakeholder participation to produce

[3]https://www.purdue.edu/provost/faculty/promotion/criteria-tenure-procedures.html

[4]Rights related to citizenship vary in the Pacific Islands. Those born in American Sāmoa and Swains Island are classified as U.S. non-citizen nationals and are not legally able to vote in federal elections or hold federal office, although they can serve in the military, have a U.S. passport, and can live and work freely in the country. U.S. citizens are also considered U.S. nationals.

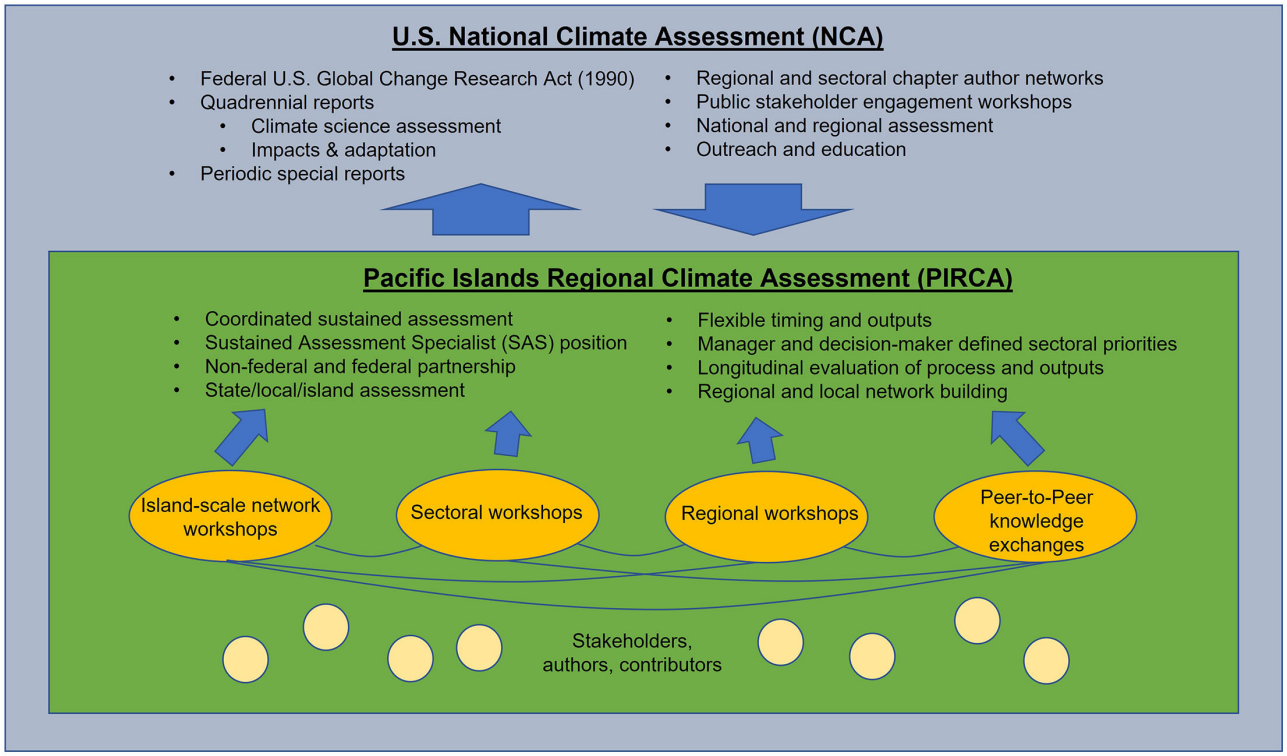

FIGURE 2 | The conceptual structure, functions, and stakeholders of the Pacific Islands Regional Climate Assessment in relationship to the U.S. National Climate Assessment (NCA), coordinated by the U.S. Global Change Research Program (USGCRP).

"actionable" environmental science, including the NOAA Regional Integrated Sciences and Assessments (RISA), Hawai'i Sea Grant, He'eia National Estuarine Research Reserve (NERR), Pacific Islands Climate Change Cooperative (PICCC, now defunct), Pacific Islands-Climate Adaptation Science Center (PI-CASC), Pacific Islands Water Science Center (PIWSC), and the Hawai'i Cooperative Extension Service, many of which have contributed significantly to Pacific Islands climate assessment products. The NOAA RISA program has been a pioneer in developing, documenting, and implementing the co-development process in climate research and assessment (McNie, 2008, 2013; Lemos et al., 2014; Parris et al., 2016; Meadow, 2017). Regionally focused and stakeholder-driven, RISAs are competitive interdisciplinary climate research programs that function as boundary organizations and span the science-policy interface. The Pacific RISA, based on the island of O'ahu, Hawai'i, serves the greater USAPI region and coordinates the Pacific Islands Regional Climate Assessment (PIRCA). The PIRCA is a collaboration of scientists, businesses, governments, and communities in Hawai'i and the USAPI founded in 2011 to inform the regional chapter for the Third NCA and create a process to exchange climate information (**Figure 2**). The PIRCA process and outputs used principles of co-production to form an inclusive network of contributors and a reliable assessment of climate knowledge for the region (Keener et al., 2012; Moser, 2013), and addressed the barriers mentioned above by leveraging coordination and human and financial resources from the Pacific RISA program, the USGCRP, the PI-CASC, the PICCC, and others, to establish a sustained assessment process. An external evaluation of the 2012 PIRCA revealed that while regional stakeholders found the network's first collaborative report highly credible and the process trustworthy, the information did not fully meet their needs, particularly in assessing sectoral impacts in the USAPI that were not addressed in-depth in the first PIRCA report (Moser, 2013).

This case study discusses the creation and ongoing activities of the PIRCA and documents its evolution through time with longitudinal external evaluations done in 2013 and 2021 (Moser, 2013, 2022 *in progress*). We analyze the climate impacts and information needs for the USAPI region, the decision context in which the PIRCA functions for a variety of regional stakeholders across different islands, the potential role the PIRCA network and reports serve in accelerating the creation of regional and local climate policy, the ways in which regional and national assessments complement each other, and identify transferable process characteristics that could be utilized to aid in translation across the climate science-policy interface.

CONTEXT: CLIMATE AND CAPACITY CHALLENGES IN HAWAIʻI AND THE U.S. AFFILIATED PACIFIC ISLANDS

The USAPI region encompasses thousands of islands, more than 300,000 square miles of land, and millions of square miles of ocean, including 50% of the U.S. Exclusive Economic Zone (**Figure 1**). The island region contains diverse geographies, climates, political classifications, cultures, languages, histories, and ecosystems that require different assessment foci and approaches that resonate with the needs of stakeholders in each location. As described eloquently in the introduction of *Indigenous Literatures from Micronesia* (Flores and Kihleng, 2019), the Pacific Islands have a complex 400-year colonial history with impacts that persist today. Starting in the 16th century, European and Asian countries and the United States successively occupied, exploited, and colonized the lands of the Indigenous peoples of Micronesia, Polynesia, and Melanesia. Hawaiʻi and Micronesia were used as important transit points, military hubs, sources of natural resources, and opportunities for European and U.S. missionaries. During these several hundred years, islands across the region were sequentially colonized by Spain, Germany, Britain, France, the United States (after the Spanish-American War), Australia, and Japan. As a consequence of colonization, the lands, waters, and people of the Pacific Islands were involved significantly in the Pacific Theater during World War II (Poyer, 1991), with resulting widespread environmental devastation and displacement of Indigenous people due to region-wide warfare and nuclear weapons testing in the Republic of the Marshall Islands (RMI) (Simon, 1997; Cocklin, 1999; Yamada and Akiyama, 2013). Following the war, American Sāmoa and much of Micronesia—as the Trust Territory of the Pacific Islands—came under U.S. administration. In the 1970's−90's, USAPI districts achieved independence with special U.S. political affiliations or became U.S. territories, ensuring U.S. military access through the present-day and economies dependent on international aid and military spending (Friedman, 1997; Overton et al., 2018). U.S. military presence in the region continues and has included construction of a missile defense system in Kwajalein, RMI, and multiple major installations in Hawaiʻi and Guam. In recent decades, Pacific Islands have been discussed in global media about climate change, with the dominant portrayal of islanders as vulnerable, frontline populations on "sinking islands" (Shea et al., 2020; Aguon, 2021) experiencing some of the most severe physical and socioeconomic impacts from anthropogenic climate change for which they bear little to no responsibility for causing. Very recently, islander-informed media narratives may be shifting toward a focus on the resilience of communities, adaptation solutions, and climate justice (Shea et al., 2020; Aguon, 2021).

Existing governance and social systems can hinder climate adaptation—planning, funding, and implementation. For example, the Commonwealth of the Northern Mariana Islands (CNMI), American Sāmoa, and Guam are ineligible for bilateral and multilateral climate finance and are excluded from UN agencies, programs, and adaptation funds (e.g., the Green Climate Fund). Meanwhile, the Freely-Associated States of the Republic of Palau, the RMI, and the Federated States of Micronesia (FSM) are systemically under-represented in regional island governance councils and are currently ineligible for U.S. Federal Emergency Management Agency (FEMA) funding. The physical realities of living on small, remote islands exacerbate vulnerabilities. For instance, Hawaiʻi has the most expensive electricity rate in the United States, and more than 85% of food is imported on most islands (Leung and Loke, 2008; Asifoa-Lagai, 2012; Keener et al., 2018). Political leaders in the Pacific Islands consistently classify climate change as their primary existential threat and advocate for aggressive mitigation policies and adaptation investment to improve regional environmental security, through, for example, the *Majuro Declaration for Climate Leadership*[5], the *Boe Declaration for Regional Security*[6], and recently, the *Kainaki II Declaration for Urgent Climate Change Action Now*[7], the strongest collective advocacy instrument issued by Pacific Islands to date to support their position at the UN Secretary-General's Climate Action Summit.

The region has historically experienced a high burden of climate disasters, sometimes resulting in wide ranging impacts to food and water security, human health, infrastructure, ecosystems, and geopolitical stability. The direct and indirect burdens of these events are often underestimated and are projected to increase with climate change (The World Bank., 2013; Keener et al., 2018). The damages resulting from weather and climate-related extremes are rarely the result of an isolated event. Rather, they are typically "compound" events, occurring in combination (Raymond et al., 2020), and with ongoing environmental, historical, and societal stresses. Recent (spatial or temporal) compound events include extreme rainfall, flooding and wildfire (Nugent et al., 2020); a particularly destructive 2018 typhoon season; land and ocean heatwaves and coral bleaching and death (Couch et al., 2017; NOAA National Centers for Environmental Information., 2020); El Niño and drought (Annamalai et al., 2015); and wave, tide, and surge events with rising sea levels (Vitousek et al., 2017). While the need for cross-sectoral climate adaptation is great, the Pacific Islands are relatively data-scarce compared to the Continental United States, and IPCC and NCA assessments are insufficient to inform island-scale policy (Keener et al., 2012; Moser, 2013; National Academies of Sciences Engineering Medicine, 2021). Although multiple international aid organizations operate within the region, there has been

[5]Pacific Islands Forum Secretariat, 5 September 2013. *Majuro Declaration for Climate Leadership*. Majuro, The Republic of the Marshall Islands. https://www.forumsec.org/wp-content/uploads/2017/11/2013-Majuro-Declaration-for-Climate-Leadership.pdf.

[6]Pacific Islands Forum Secretariat, 5 September 2018. *Boe Declaration Action Plan*. Boe, Nauru. https://www.forumsec.org/wp-content/uploads/2019/03/Updated-Brief-on-Boe-Declaration-Action-Plan-1.pdf.

[7]Pacific Islands Forum Secretariat, 11 December 2020. *Kainaki II Declaration for Urgent Climate Change Action Now: Securing the Future of our Blue Pacific*. Funafuti, Tuvalu. https://www.forumsec.org/2020/11/11/kainaki/.

limited relationship building with in-country subject matter experts, resulting in products that have not always met the climate needs of local policymakers and resource managers (Moser, 2013).

The adaptive capacity of islands when faced with increasing climate shocks and stressors is negatively affected by regional issues such as limited capacity-building, underinvestment in infrastructure, social inequality, and multiple colonial histories. In the CNMI, improper military and industrial waste disposal resulted in contaminated drinking water (Denton et al., 2014; Grecni et al., 2021). Following contamination after the impact of Super Typhoon Yutu in the CNMI in 2018, residents relied on desalinized ocean water (Gilbert, 2018). After World War II, most of Guam's population shifted from subsistence farming to a reliance on imported food (Marutani et al., 1997), which has negatively affected food security and human health. Climate impacts such as changing rainfall, higher temperatures, and more intense storms compound and hasten the decline of local crop production (Taylor et al., 2016; Grecni et al., 2020). In November 2021 on the island of Oʻahu, Hawaiʻi, it was revealed that tens of thousands of gallons of jet fuel had leaked from the World War II-era U.S. Navy Red Hill Bulk Fuel Storage Facility's underground storage tanks into the largest aquifer supplying drinking water on the island, sickening and displacing thousands of families (Jedra, 2022). As this example shows, even in the most prosperous place in the USAPI, historical impacts decreased Oʻahu's freshwater resilience in the face of continuing drought (Frazier and Giambelluca, 2017) and reduced Hawaiʻi's future ability to provide freshwater in an emergency and protect water resources—as mandated in the State Constitution—for domestic and Native Hawaiian traditional and customary uses. While downscaled climate projections and other data are needed for adaptation projects, science and data alone do not address the systemic and structural dimensions needed to successfully adapt (Finucane, 2009), and some normative co-production processes can reaffirm traditional boundaries when actors assert the dominance of Western science and reinforce notions that it is superior to other forms of knowledge (Daly and Dilling, 2019). Four-hundred years of colonialism in the region that exploited the islands for their strategic military value, resources, trade location, and other extractive purposes resulted in communities with limited capacity and a culture of drop-in consultants and researchers (Finau et al., 2000; Braun, 2021; Lett et al., 2022). These complex issues require a different approach to co-producing useable climate information that is non-extractive, culturally cognizant, flexible enough to incorporate different modes of interaction, centered around relationships and storytelling, transparent, iterative, and inclusively co-developed with resource managers and local governments to foster collective ownership and shared understanding (Amitage et al., 2011; Daly and Dilling, 2019; Aguon, 2021). In fact, assessments anywhere must consider the unique geographical, historical, and cultural contexts if they are to make useful contributions to decision making.

THE PIRCA, KEY PROGRAMMATIC ELEMENTS, AND RESULTS

The Second PIRCA: Key Elements of Assessment Co-development

Since its inception more than a decade ago, the PIRCA has incorporated feedback obtained from external evaluation to shape the ongoing assessment process and network's growth and inclusion of new expertise and areas of focus. As a result, the expertise and topic areas that the PIRCA includes were diversified in the most recent round of assessments. A frequent appeal by those interviewed and surveyed in the 2013 evaluation was to update the PIRCA regularly, incorporating new topics, including identifiable trends in top priority impacts on key economic sectors and human security, adaptation options and costs, and cultural impacts (Moser, 2013). Moreover, respondents to the first PIRCA, which was still Hawaiʻi-centric, wished for jurisdiction-specific assessments. The PIRCA coordination team recognized that to fulfill these needs, a new full-time "Sustained Assessment Specialist" (SAS) within the region was crucial, and found financial resources from multiple partners to fund the position through the Pacific RISA.

As a result of this feedback, the foci, author structure, and processes for assessment development have evolved. The most recent round of PIRCA assessments produced the Hawaiʻi and U.S. Affiliated Pacific Islands regional chapter of the Fourth NCA (Keener et al., 2018), as well as island-specific assessments for Palau (Miles et al., 2020), Guam (Grecni et al., 2020), the CNMI (Grecni et al., 2021) and American Sāmoa (Keener et al., 2021). Other reports for the RMI, the FSM, as well as the initial work for the regional chapter of the Fifth NCA are in progress as of this writing. While technical writing teams for the 2012 PIRCA were mainly subject matter experts from Hawaiʻi-based academic and federal government institutions, the 2020–2021 PIRCA authorship varied by jurisdictional report and was split between Hawaiʻi-based academics and specialists in local NGOs and governments residing in each jurisdiction. Additionally, between 25 and 50 practitioners from a wide range of management sectors were credited as Technical Contributors for each assessment. The changes in assessment characteristics in response to feedback between the first and second PIRCA, and the status of those same elements in regional contributions to recent U.S. NCAs, are presented in **Table 1**. Authors and Technical Contributors attended a workshop in their jurisdiction, which the PIRCA coordination team planned and organized in partnership with local co-authors and key points of contact from government, higher education, and NGOs (**Figure 3**). In proximity to the workshops, members of the PIRCA coordination team met with a few Technical Contributors for more in-depth conversation on key topic areas for which they had unique expertise. These meetings were *ad-hoc* or opportunistic and were arranged in connection with planning for or facilitating the local workshops (**Table 2**). Following those workshops or meetings, Technical Contributors were invited to continue refining the PIRCA report for their jurisdiction in an iterative process of reviewing drafts of

TABLE 1 | Key differences in characteristics of the first and second PIRCA, and the status of the same elements in regional contributions to recent U.S. NCAs.

Assessment	Author structure and composition	Main foci or topics	Development process (key elements)
First PIRCA (2012)	Hawai'i- and U.S. Continent-based authors and contributors (academic and federal roles)	Physical impacts (e.g., freshwater and drought, sea-level rise and coastal inundation, ecosystem impacts)	Workshops in Hawai'i, involving authors and technical experts; author drafting; review by science advisory committee
Second PIRCA (2020–2021)	USAPI- and Hawai'i-based authors (academic, USAPI government, and NGO roles); 25–50 locally based contributors per assessment	Human- and decision-centric topics (e.g., climate indicators; climate-risk management; considerations for households, families, and vulernable populations; considerations for key sectors; research and information needs)	Workshops and meetings in USAPI, involving stakeholders in variety of sectors and roles (govenment, NGO, business, and academic/research); iteravite draft development among authors and technical contributors; review by advisory committee with diverse expertise
Third NCA, Hawai'i and Pacific Islands chapter (2014)	Hawai'i-based lead and convening authors; 7 contributing authors	Ocean changes, coral reefs, and fisheries; freshwater supplies; terrestrial ecosystems; sea-level rise and coastal infrastructure; human migration	Technical input report development (PIRCA 2012) and workshops; Author chapter drafting; advisory committee review; pubic and expert review; federal agency and White House review
Fourth NCA, Hawai'i and USAPI chapter (2018)	Hawai'i-based authors; 77 technical contributors, majoirty Hawai'i-based, and a small number from USAPI	Water supplies; ecosystems and biodiversity; coastal communities; marine resources; Indigenous peoples; cumulative impacts and adaptation	Public engagement workshops (1 in Hawai'i; 1 in Guam); sectoral workshops hosted by author team; author drafting; federal agency, public, and expert review
Fifth NCA, Hawai'i and USAPI chapter (forthcoming)	USAPI-, U.S. Continent-, and Hawai'i-based authors; USAPI and Hawai'i-based technical contributors (TBD)	TBD	Regional Engagement Workshop (1 for Hawai'i and USAPI); sectoral workshops hosted by author team; author drafting; federal agency, public, and expert review

the assessment, and the PIRCA coordination team tracking and responding to all comments.

The PIRCA workshops were structured to be accessible to managers and decision-makers across a range of sectors, and to elicit feedback on an early draft of the PIRCA report to further develop the content. The PIRCA workshops linked participants to the U.S. NCA process by presenting findings from the Fourth NCA and describing a sustained assessment process in which local and regional assessments gather and synthesize climate knowledge and inform the national assessment.

Evaluation Methods

To assess how the ongoing PIRCA process is evolving and responding to expressed stakeholder needs, we conducted an evaluation between Fall 2021 and January 2022. It involved data collection from two principal sources: a survey and interviews with assessment participants and beneficiaries.

The survey was sent to a database of 222 individuals across Hawai'i and the USAPI. Respondents were approached by email; 22 of those emails were no longer functional (resulting in an actual n=200). The 29-question survey was open between October 13 and November 30, 2021 and received 60 responses—an excellent response rate of 30% in an email- and social-media saturated world during the COVID-19 pandemic. The majority of respondents were based in Hawai'i, but all jurisdictions for which the Fourth NCA chapter and PIRCA reports had been prepared were represented, as well as a few Continental U.S. respondents.

The survey questions were prepared by Moser in collaboration with the Pacific RISA team (inluding Keener and Grecni) (see survey instrument in **Appendix 1**) and focused on the Fourth NCA chapter and the jurisdictional PIRCAs, inquiring about people's involvement and contributions, their perceptions of the report's relevance, usefulness, legitimacy and credibility; the uses of the report; future assessment needs; and for respondents who knew of the first PIRCA, about improvements made based on the feedback received from the evaluation conducted in 2012–13.

Following the survey, the evaluation also involved in-depth interviews (conducted by Moser) with selected assessment contributors and observers. The Pacific RISA team provided a prioritized list of 38 potential interviewees, including representatives from all jurisdictions and the Fourth NCA chapter[8]. Of these, all the "very high" and "high" priority interview candidates (28 individuals) were approached and 21 individuals representing all PIRCA jurisdictions and the Fourth NCA chapter responded favorably and were interviewed. One interview was discontinued (due to an inability to address interview questions during a local crisis). The remaining 20 interviews were completed, with interviews lasting on average 56 min (range 27–92 min). Given the time since some portions

[8]Prioritization was done by Keener and Grecni and was based on factors such as individual's (1) direct involvement in either the Fourth NCA chapter or regional assessments as an author, contributor or reviewer; (2) direct involvement in an assessment-related workshop or event; (3) position in local government or other key decision-making bodies that is likely to have knowledge of the assessment; or (4) position in the federal government with direct knowledge of the PIRCA contribution to the NCA.

FIGURE 3 | The 2019–21 PIRCA workshops and reports explored climate change impacts and responses in U.S. Affiliated Pacific Islands. Photos on the left illustrate example climate-related impacts: **(A)** Heavy rains that produce flooding, as pictured here in Nu'uuli, American Sāmoa, become more likely as the climate warms (Photo courtesy of Valentine Vaeoso). **(B)** Human-ignited wildfires burn a sizable portion Guam's land each year. Dry conditions increase the potential for wildfire on tropical Pacific Islands, and total acres burned tends to be higher in the year following an El Niño event (Photo courtesy of Guam Department of Agriculture, Forestry Division). Pictured on the right are PIRCA workshops and events: **(C)** participants of the CNMI workshop; **(D)** participants of the Palau workshop; and **(E)** members of the PIRCA team with Guam's Lieutenant Governor and Co-Chairs of the Guam Climate Change Resiliency Commission (photo courtesy of the Pacific Islands Climate Adaptation Science Center).

of the the assessment were completed, the consistency of insights gained, and based on responses from those who were approached but declined to be interviewed suggested that additional interviews would likely not yield more useful information. Thus, the lower-priority individuals were not approached. Interviews were semi-structured, recorded, and detailed notes were taken, then analyzed for themes. Recordings were destroyed after the analysis. Some interviewees also sent written follow-up notes or documents mentioned during the interviews.

The interview questions focused on nine topics (see interview protocol in **Appendix 2**), including background of the interviewee, participation in the Fourth NCA/PIRCA, uses of the Fourth NCA outputs by stakeholders/decision- and policy-makers (at local/state and federal U.S. levels), impacts of greater inclusiveness in the Fourth NCA vs. the first PIRCA, perception of the inclusive stakeholder participation at the national level, the value of the Sustained Assessment Specialist position, other information sources for decision-makers, barriers to building greater resilience through adaptation, and emerging needs. The interview protocol was reviewed and agreed to by the Pacific RISA staff. Both the survey and interviews were determined to be "exempt" human subjects research by the East-West Center's IRB.

Evaluation Results

Familiarity, Interest, and Perceived Relevance, Legitimacy, and Credibility

A very large majority of survey respondents (>90%) and all interviewees were closely familiar with the Fourth NCA Pacific Islands chapter (released in 2018) and the jurisdictional reports (released between 2020 and 2021) - a similarly high level of awareness as was found in the evaluation of the first PIRCA. At the time of the survey, respondents confirmed that they had either heard of, read, or scanned and remembered various parts of those assessments. Of greatest interest to survey respondents in the Fourth NCA chapter were the Executive Summary, the section on coastal communities, and the section on adaptation. Those familiar with the jurisdictional PIRCA reports found the sections synthesizing key issues for managers and policymakers; implications for families, households and vulnerable populations; implications for vulnerable sectors; indicators of climate change; and on managing risks in the face of uncertainty of greatest interest.

The framing of climate change challenges in human- and decision-centric ways in the jurisdictional reports is in and of itself notable. This constitutes an innovation in response to the 2012 report (and thus does not allow for a direct

TABLE 2 | PIRCA assessment workshops including dates, locations, conveners, and expertise represented held in each jurisdiction in 2019.

Date of workshop	Workshop location	Co-hosting partners	Expertise of participants (academic or practice)
June 10, 2019	American Sāmoa Community College, Pago Pago, American Sāmoa	American Sāmoa Community College	Agriculture, coastal management, coral reef research and management, education, environmental protection, historic and cultural resources, natural resources management, public works, utilities, water management, weather forecasting
July 23, 2019	Palau National Marine Sanctuary headquarters, Koror, Palau	Republic of Palau Office of Climate Change	Agriculture, coral reef research, cultural resources, disaster management, economic development, ecosystems, energy systems, fisheries, human health, infrastructure planning, tourism, utilities
July 30, 31, 2019	Saipan, CNMI	NOAA Office for Coastal Management and CNMI Bureau of Environmental and Coastal Quality	Agriculture, coastal resources management, education, extension, fish and wildlife management, public health, natural resources management, parks and recreation, planning and development, policy and governance, public works, ocean ecosystem research and management, utilities
October 29, 2019	Governor's Complex, Adelup, Guam	Guam Climate Change Resiliency Commission; Pacific Islands Climate Adaptation Science Center; Guam Bureau of Statistics and Plans; University of Guam	Climate science, climate vulnerability assessment, climate and weather forecasting, coastal and ocean resources management, cultural resources, energy systems, environmental protection, homeland security/civil defense, nature conservation, planning, public advocacy, water and environmental research, water management

comparison of different parts of the assessment between the first and second PIRCA reports). Survey respondents found the sections they reviewed "somewhat," "very," or "extremely" useful. Leading in this regard were the sections on the implications of extreme weather and climate events for key sectors (96.7%); and on families, households and vulnerable populations (90.6%); followed closely by the key issues for managers (90.3%); climate change indictors (90.3%); and managing climate risks in the face of uncertainty (87.1%).

In write-in answers, respondents hinted at why and for what the reports were useful, including having an audience-tailored, concise, peer-reviewed summary and explanation of climate change trends and impacts for funding requests, policy briefings, education, and communication/outreach. This finding is completely consistent with the first PIRCA report. However, in comparing what respondents got out of the first (less detailed) vs. the second (jurisdictionally specific) PIRCA reports, they were six times more likely to agree than to disagree that the jurisdictional PIRCA reports provided more regionally specific climate information and more specific risk information on issues relevant to their work, and 5.7 times more likely to agree than disagree that the second PIRCA provided more information on what can be done to adapt to climate change. The few who indicated that any report sections were not useful to them either were already familiar with the issue or restricted that judgment to the less relevant synthesis of global climate change.

The legitimacy of the PIRCA process appears to also have boosted the use of the reports by decision-makers in Pacific Island jurisdictions. First, interviewees appreciated the deliberate, careful and respectful approach to co-designing the assessment process. Being mindful of not overtaxing individuals, strategically timing workshop events, respecting local culture, and working closely with island points of contact to identify all relevant stakeholders was viewed as a key ingredient in people joining the effort and viewing it as "with and for them" rather than "about them" (i.e., a non-colonial, non-extractive approach to co-design). Moreover, the engagement of practitioners and climate change professionals in the development of the assessment, particularly in identifying impacts, future risks, and adaptation options, provided the structured opportunity for authors and technical contributors to review new information regarding how the changing climate is affecting, or is expected to affect, their area of purview or expertise. As a result, assessment participants were eager to apply information gleaned through the assessment even before the reports were published. Soon after the workshop in Palau, for example, the National Office of Climate Change contacted the PIRCA coordination team to request use of the draft PIRCA in a funding proposal to support the development of the National Adaptation Plan. Familiarity with the range of experts involved in informing and producing the report also appears to have driven trust in the product among participants. Interviewees, for example, thought "all the right people were at the table." But even among the broader survey population, 86.3% of respondents felt the development of the assessments was "highly," "very" or "somewhat legitimate" (this question was not asked in the 2012 survey).

The majority of survey respondents also found the Fourth NCA regional chapter and jurisdictional reports highly credible. More than 72% of respondents found them "very" or "extremely" credible, with <2% disagreeing with that judgment – a perception of credibility nearly as high as in the 2012 PIRCA report (although the question was asked slightly differently and had

fewer levels to choose from, so can only be compared with caution). Representative of many study participants, one noted, "I now have [a] credible reference document I can use in my work and studies that talks about my island home." Others found it particularly important to have such a credible report in use with policymakers. That said, some 17% of respondents couldn't judge the assessment in this regard – suggesting maybe some opportunities to convey the qualifications of assessment participants more directly in the future.

Process Benefits

Survey respondents and interviewees appreciated their participation in the assessment beyond the involvement in co-designing the stakeholder workshops. Those involved in shaping the engagement opportunities felt deeply respected and were pleased with what was achieved. Noting that "many make the mistake of not connecting with local people," the fact that Pacific RISA did was considered foundational for the assessments' conduct and successful delivery. In addition, most survey respondents (71.4%) who participated in those events as contributors to the assessment found them at least "somewhat," "very," or "extremely valuable." (This is a slightly higher level of appreciation of these events compared to a similar, but not identical question asked about the outreach around the first PIRCA report, thus allowing comparison only with caution.) More than half of the respondents (57.1%) appreciated them as opportunities to learn from others what they are doing to address climate change; 53.6% found them valuable as opportunities to ask questions of experts; and 50%, respectively, also found them useful as opportunities to learn about adaptation, network with others, and simply be in dialogue with people about what to do. One interviewee found the workshop in their jurisdiction to be "one of the best we ever had." Experts involved in the process were glad to not just share knowledge, but also correct any information from the larger regional assessment that did not apply to their particular jurisdiction, while yet others were glad to have a forum for difficult but important conversations to occur. As one put it, "It's a chance to force these necessary conversations with local decision-makers."

The educational value of those stakeholder engagement events, together with the information contained in the reports, cannot be overestimated. More than 62% of survey respondents noted that they now have a better understanding of what climate change means to their region, and 26% felt they can now take climate change into account in their work. As such, the participation in the process, connecting with peers, and having jurisdiction-specific information at their fingertips, illustrates that the assessment was perceived as empowering. "I have useful recommendations to inform management and policy decision making."

Interviewees also spoke to another aspect of the assessment process, particularly those who had been involved in prior assessments and who had a keen understanding of the often-extreme capacity constraints in the USAPI. Uniformly, interviewees saw the value of having dedicated staff (a "Sustained Assessment Specialist," SAS) assigned to support the assessments as "critical." Particularly in a region that thrives on good relationships, having someone focused on building relationships was seen as foundational. Many interviewees were aware and deeply appreciative of the range of tasks undertaken by the SAS, including extensive outreach to obtain robust input, communication, "cat herding," editorial assistance "down to the semi-colon," finding needed data, identifying gaps in contents, and so on. One emphatically called the SAS "integral to the success of the Fourth NCA."

Evidence of Use of the PIRCA for Practical Decision-Making in a Changing Climate

Stakeholders have used the jurisdictional assessments when writing proposals for climate-related finance, communicating with the public and their peers, proposing and developing new law and policy, and integrating the information in management plans. We mention just a few examples here. As noted earlier, the PIRCA report for Palau serves as a technical resource in the development of the National Adaptation Plan. In Guam, meetings with legislators, legislative aids, and consultants to review NCA and PIRCA findings informed new legislation. Inspired by an adaptation option presented in the Guam PIRCA, one successful bill in the Territorial Legislature passed a statute that created the Tumon Bay Insurance Task Force, to be comprised of representatives from across the government of Guam, to examine the prospect and evaluate the feasibility of parametric insurance for the beaches and corals reefs of Guam's Tumon Bay (Kaur, 2020a; Public Law 35-107, 2020; Limtiaco, 2021). Other new laws prohibited the burning of forest land and established a task force to explore the possibility of establishing conservation areas on select Guam Government properties that overlay the Northern Guam Lens Aquifer to protect the island's main freshwater aquifer, considering future drought projections (Kaur, 2020b; The Office of Sen. Sabina Perez Bureau of Statistics Plans' Guam Coastal Management Program., 2020; Public Law 35-134, 2021; Public Law 35-141, 2021). A training for territorial government staff, held prior to the update of American Sāmoa's Hazard Mitigation Plan, highlighted the PIRCA assessment as a resource and invited a coordination team member to present on climate-sensitive hazards detailed in the assessment.

Actors in government, including Guam Governor Lou Leon Guerrero (Pacific Daily News Staff., 2020), publicly acknowledged the PIRCA's role in informing policy, revealing key climate change issues, and providing consolidated, relevant knowledge for local decision processes. Palau's National Climate Change Coordinator said of the Palau assessment, "This report provides a glimpse of key issues... it serves as a guide with suggestions to enhance our resilience to climate change" (NOAA Climate Program Office, 2020). Shortly after the release of the assessment for the CNMI, the report's lead author testified as an invited expert witness in a Full Committee Hearing of the U.S. House Committee on Natural Resources regarding the Insular Area Climate Change Act (H.R. 2780), which proposed new federal programs for climate change adaptation and mitigation

for U.S. Insular Areas (U.S. Congress, House, Committee on Natural Resources, 2021).

DISCUSSION

Acceleration of Information Uptake for Adaptation Decision-Making

Recent PIRCA activities demonstrate how regional assessment efforts can accelerate the flow and application of information from larger national and international climate assessments into local-level decision-making by relating key findings to local context and consolidating relevant information. In the case of the PIRCA, jurisdiction-specific assessment co-production processes helped to counter the information-overload effect and perceived irrelevance of national and international assessments by providing structure for climate researchers (some authors of the larger assessments) and local managers to review the larger assessment findings, examine their local implications in the context of key sectors, and together distill the salient knowledge for decision-making. In workshops, participants questioned the "experts" about levels of uncertainty, leading to better understanding among the group about points of consensus and factors contributing to remaining uncertainties.

The regional assessment also strengthens national and international climate assessment processes. Resource- and place-specific details captured in the PIRCA reports make the information available to a wider decision-maker audience, and to the NCA, IPCC, and other regional and international assessments that have historically not had access to fine-grained knowledge of local climate risks and adaptations. By delivering nuanced, place-based assessments in between the NCAs, regional assessment efforts can serve a key role in an integrated and sustained national assessment program (such as envisioned and described by Buizer et al., 2016).

One value of the PIRCA products to decision-makers appears to be the ability to use a single report as a resource and reference document for climate change information. One participant summarized this valuable function, saying, "Before we had the PIRCA, we had to piece together the information from other reports... so time-consuming." While various climate reports, documents, and peer-reviewed literature exists for each place, the time and capacity required to comb through it for relevant information can represent a significant barrier to timely fundraising and addressing climate change in policy and management situations. Both interviewees and survey respondents confirmed that having a consolidated state-of-knowledge helps to facilitate and accelerate the use of climate information for planning by managers without specific expertise or extra time. Meanwhile, participatory co-development of the reports meant that some decision-makers across government and NGO sectors were already familiar with, and trusted, the basic structure and content, making fact and information-finding easier.

Working in an assessment context outside of the Continental United States necessitates a nuanced approach that differs from, and can complement, that more commonly used in the NCA and international climate assessments. As a crucial point of departure, well-established multi-state and country assessments have traditionally placed a large emphasis on the findings of peer-reviewed articles and expert consensus; however, a dearth of published data and literature in the USAPI led the PIRCA team to rely on partnerships with local researchers and practitioners, in NGOs, government, and academic institutions, to source relevant data, traditional knowledge, and recent research findings, much of it "gray literature" or not yet published. Workshop discussion sessions allowed an informal prioritization of climate issues in terms of locally perceived levels of risk and consequence, and to understand, if only anecdotally, the climate impacts and risks not yet scientifically documented. Even in regions where relatively more published literature and data exist, the inclusion of local and traditional knowledge can imbue assessments with greater legitimacy and credibility among local stakeholders and allow frontline communities to enter policy discussions by bringing their own words, experiences, and forms of knowledge into decision-making spaces where they are often absent (Daly and Dilling, 2019; Davis and Ramirez-Andreotta, 2021). The PIRCA use-cases further demonstrate that bringing together various actors who hold different knowledges can promote social learning, shared understandings, and "collective ownership" (Amitage et al., 2011). Subnational assessment efforts, in their participatory development, can foster these critical functions, which are needed across all U.S. regions if adaptation is to increase.

Interviewees pointed to an important impact of the Fourth NCA Pacific Islands chapter on the overall NCA process in this regard, which can be read as an aid in the acceleration of information provision and uptake. Following the urging of one of the Fourth NCA convening lead authors, the USGCRP formally accepted Indigenous knowledge (only available in the oral tradition) as equivalent to scientific knowledge without having to be peer-reviewed. In a scientifically data-scarce and capacity-limited region such as the small-island states in the Pacific, much long-term observational information would have to be ignored if it could only be included in an assessment once it is reflected in the peer-reviewed literature. Thus, getting local and traditional ecological knowledge accepted as valid and equivalent to scientifically acquired knowledge has helped speed up the assessment process and address issues of knowledge-equity in climate adaptation planning. Combining it with the available scientific information in one report, the time to information use is significantly reduced.

Adjusting Assessment Methods to Resonate in Different Geographical Contexts

In each of the jurisdictions, PIRCA engagement linked directly or indirectly with local governance and policy entities by, for example, aligning outreach with the launch of the Guam Climate Change Commission and co-hosting a workshop with Palau's National Office of Climate Change. The format and timing of workshops adapted to fit into partners' already planned convenings and were sometimes "nested" within broader

meeting agendas. The underlying logic for the adaptable workshops approach was twofold: (1) to avoid burdening over-tapped stakeholders who participate in many, often overlapping, planning and input activities; and (2) to embed the final assessments within, or have direct relevance to, local governance frameworks and processes. This points to the notion of a "sustained assessment" that aims at building ongoing relationships between researchers/assessors and practitioners (Moss et al., 2019), rather than a "stop-and-go" approach more common in the NCAs. Ongoing relationships may limit the repeatedly needed intense ramp-up of stakeholder relationships, and also avoid drawing on the same stakeholders again and again. This is a lesson that applies widely to other NCA regions, given the frequently mentioned challenge of "stakeholder fatigue" (e.g., Cooke and Kothari, 2001; Reed, 2008; Chu et al., 2016).

That the PIRCA is a network does not imply that the engagement and co-production model is merely replicated across all jurisdictions. Interviewees repeatedly noted how the Pacific RISA team understood the need for such a nuanced approach, banking on the cognizant leadership of local contacts to frame the assessment and navigate local politics. Those relationships then enabled engagement with groups that is respectful of local culture and customs, which differ among jurisdictions. The team made decisions on the process and products that intentionally aligned with local culture, language, technology use, and values, for example translating a summary into local language (Samoan), structuring daily agendas to include cultural protocol and meetings with dignitaries or elders, and inclusion of meals with appropriate foods at workshops. A focus on key sectors, both in the structured engagement and the assessment reports, rather than the drivers of climate change impacts, further emphasized the relevance of the assessments to the stakeholders' governance and management responsibilities and purview. Regional and local climate assessment efforts that shift their methods or approach to meet the objectives and fit into the agenda of decision-making bodies may go farther in their quest for user uptake than those efforts that remain detached from local governance.

Assessment and Learning Networks as Climate Boundary Organizations

Trust in the Pacific RISA as a boundary organization and as a central player and coordinator of the PIRCA had already been built in the years leading up to the most recent round of assessments (Moser, 2013). Boundary organizations provide a distinct and helpful interface for the exchange between science and policy or practice, with accountability to both sides, and critical translating, negotiation, and interface management functions (Guston, 1999; Gustafsson and Lidskog, 2018; Ziaja, 2019). While the design of the interface varies, boundary organizations as formal networks facilitate the exchange of climate information in quickly-evolving contexts and in more informal networks (Ziaja, 2019), such as the PIRCA. The evaluation of the Fourth NCA regional chapter and jurisdictional PIRCA reports suggests that the central role of Pacific RISA has only been solidified, as the lead coordinators and authors have in many cases become the initial contacts for decision-makers seeking trusted climate information on a short timeline or interested in proposing a project to meet a local need. Pacific RISA works actively and swiftly to connect researchers with practitioners while responding to requests and questions as a trusted source of climate information. Thus its partners learn and can build up their capacity to address climate change; in turn, Pacific RISA staff learn from local partners about the realities and challenges on the ground, which informs its research agenda, and the conduct of assessments. As one interviewee concluded, "If they continue [this careful approach to assessments] with NCA5, they [Pacific RISA] will become a real flagship in the Pacific.... like SPREP for disasters"[9].

In considering the success of the Pacific RISA as a regional boundary organization effective in the NCA, a critical factor—as described above—was a dedicated and full-time science-policy boundary spanning position, the Pacific Islands SAS (NOAA Regional Integrated Science Assessments (RISA) Program, 2021). The role of the SAS was central to building relationships and maintaining the PIRCA networks in the region over years, assessment products, and as partner organizations and administrations came and went, and is a necessary role for assessment success that can be transferred across regions.

CONCLUSION

The PIRCA is a decade-long case study illustrating the need, development, and benefit of sustaining an iterative process of building trusted relationships as the all-essential foundation for a collaborative climate assessment effort with researchers and practitioners in Hawai'i and the U.S. Affiliated Pacific Islands. Because of the expansive area, diverse cultures and geographies, colonial histories, and variation in the availability of peer-reviewed literature and data, a nuanced approach to climate assessment was used that considered expertise, information, context, and outputs needed at different island scales. Regional and local climate assessment efforts that shift their methods or approach to meet the objectives and fit into the agendas of decision-making bodies in our experience go farther in their quest for user uptake than those efforts that remain detached from local governance and historical context.

Recent PIRCA activities demonstrate how regional assessment efforts can accelerate the flow and application of information from larger national and international climate assessments into local-level decision-making by relating key findings to local context and consolidating relevant information. In defining itself as a collaborative climate science boundary organization with a dedicated Sustained Assessment Specialist to coordinate and build relationships, the PIRCA is growing as a go-to trusted resource and as a network of actors that is essential for translating rigorous climate research and multiple forms of knowledge into relevant management and policy outcomes at local and regional levels. Our experience and the feedback received through the

[9]SPREP, the Secretariat of the Pacific Regional Environment Programme, is a well-known intergovernmental organization headquartered in Apia, Sāmoa (see: https://www.sprep.org/about-us).

evaluation suggest that sustained and collaborative regional climate assessments can serve a key function in complementing major national and international assessments, by more effectively targeting information needs at local and regional climate adaptation and policymaking.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study involved human participants and thus were reviewed and approved by the East-West Center IRB. The study was found to be exempt, and thus participants were not required to provide their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

VK and ZG conceived of the case study presented. VK developed the initial theory and established the framework, and ZG expanded upon and coordinated the project. VK, ZG, and SM planned the evaluation approach and developed the survey and interview questions collaboratively, integrated evaluation findings into the PIRCA process and products, and co-wrote the manuscript and provided critical insight into the findings. SM collected, analyzed the survey, and interview data. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2022.869760/full#supplementary-material

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