



A NOAA RISA Team

*Supporting Integrated Decision Making Under Climatic Variability
and Change in Hawai'i and the US-Affiliated Pacific Islands*

Annual Report

June 1, 2020 to May 31, 2021



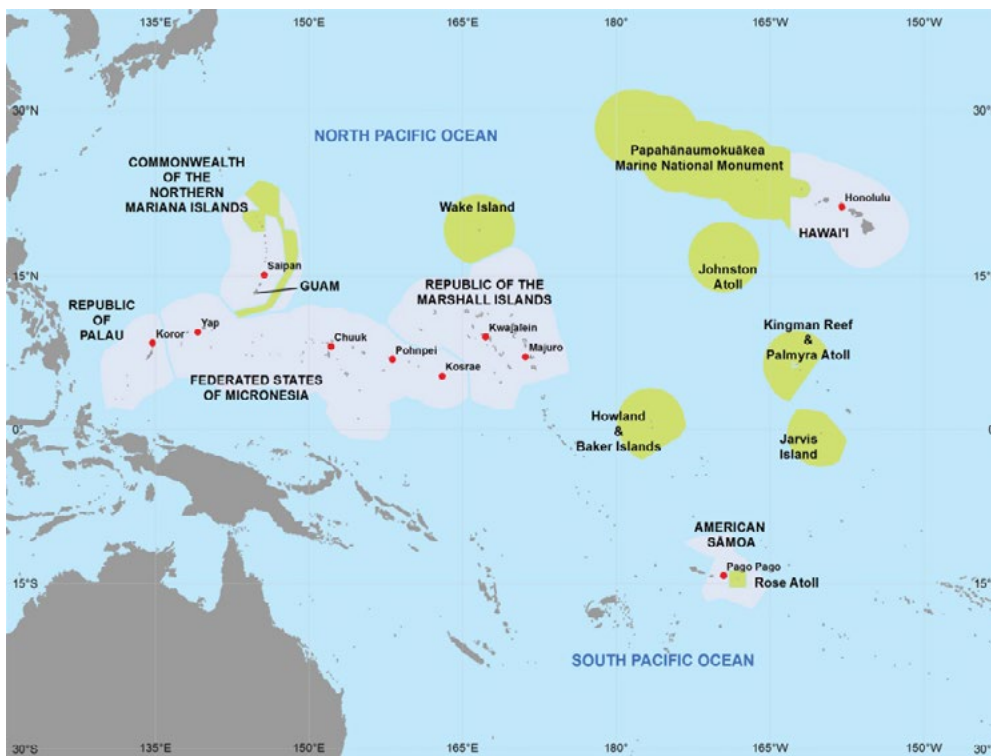
The Pacific Regional Integrated Sciences and Assessments (Pacific RISA) program supports Pacific island and coastal communities in adapting to the impacts of climate variability and change. We strive to enhance Pacific communities' abilities to understand, plan for, and respond to changing climate conditions. Our work is conducted through interdisciplinary research and partnerships with local, national, and regional stakeholders. As one of 11 RISA programs, Pacific RISA emphasizes the engagement of communities, governments, and businesses in developing effective policies to build resilience in key sectors such as water resource management, coastal and marine resources, fisheries, agriculture, tourism, disaster management, and public health.

Vision

Resilient and sustainable Pacific communities using climate information to manage risks and support practical decision-making about climate variability and change.

Mission Objectives

- Meet critical climate information needs in the Pacific Region through multidisciplinary climate research, assessment, education, and training;
- Provide integrated, locally relevant climate information to decision-makers and communities;
- Enhance regional and local capabilities to manage climate risks, build resilience in key sectors, and support sustainable development;
- Promote collaboration among Pacific regional, US national, and international institutions and programs providing climate information products and services.



Pacific RISA serves the US Pacific Islands region, which includes Hawai'i, Guam, American Sāmoa, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia, and the Republic of the Marshall Islands.

Cover photo: The unique coral reefs of O'ahu's Kāne'ōhe Bay against the backdrop of the Ko'olau Mountain Range. Coral reefs around the world face imminent threats from climate change, pollution, and other human impacts, but the corals of Kāne'ōhe Bay have proved to be resilient, thriving under conditions many predicted would decimate them. (Image credit: Krista Jaspers).

Pacific RISA Team Members

* New members in this reporting period have an asterisk before their name

Hariharasubramanian Annamalai, Senior Researcher, Meteorology, International Pacific Research Institute, University of Hawai'i, POST Building, Room 401, 1680 East-West Road, Honolulu, HI 96822; 808-956-5646 (tel); hanna@hawaii.edu

***Kelley Anderson-Tagarino**, American Sāmoa Extension Specialist, University of Hawai'i, Sea Grant Center of Excellence in Marine Science Education; 684-258-2967 (tel); kelleayat@hawaii.edu

***Kaimana Bingham**, Aloha + Dashboard and Partnerships Manager, Hawai'i Green Growth, 735 Bishop Street, Suite 424, Honolulu, HI 96813; kaimana@hawaiiigreengrowth.org

Laura Brewington, Fellow, Research Program, East-West Center; 1601 East-West Road, Honolulu, HI 96848; 808-944-7233 (tel); brewingl@eastwestcenter.org

***Mia Comeros**, PhD Student, Arc Centre of Excellence Coral Reef Studies, James Cook University; miatheresabullecer.comeros@my.jcu.edu.au

***Celeste Connors**, Adjunct Senior Fellow, East-West Center, Executive Director, Hawai'i Green Growth Local 2030 Hub, 1601 East-West Road, Honolulu, HI 96848; 808-944-7242 (tel); connorsca@gmail.com

Henry Diaz, Affiliate Faculty, Department of Geography and the Environment, 445 Saunders Hall, University of Hawai'i at Mānoa, 2424 Maile Way, Honolulu, HI 96822; 808-956-7390 (tel); hfdiaz@hawaii.edu

Oliver Elison-Timm, Associate Professor, Department of Atmospheric and Environmental Sciences, University at Albany, 1400 Washington Avenue, ES 316A, Albany, NY 12222; 518-442-3584 (tel); oeilontimm@albany.edu

Aly El-Kadi, Associate Director, Water Resources Research Center, University of Hawai'i, POST Building, Room 709A, 1680 East-West Road, Honolulu, HI 96822; 808-956-6331 (tel); elkadi@hawaii.edu

Matt Erickson, Hydrology Technician, American Sāmoa Power Authority, P.O. Box PPB, 1st Airport Road, Pago Pago, American Sāmoa, 96799; merickson@aspower.com

***Katrina Fandrich**, PhD Student, Atmospheric and Environmental Sciences, University at Albany; kfandrich@albany.edu

Carlo Fezzi, Postdoctoral Research Fellow, Department of Natural Resources and Environmental Management, University of Hawai'i, Sherman 101, 1910 East-West Road, Honolulu, HI 96822; carlo.fezzi@unitn.it

Melissa Finucane, Senior Fellow, East-West Center; Senior Behavioral and Social Scientist, RAND Corporation, 4570 Fifth Avenue, Suite 600, Pittsburg, PA 15213; 412-683-2300 ext. 4279 (tel); finucanm@eastwestcenter.org

Abby Frazier, Adjunct Fellow, East-West Center; 1601 East-West Road, Honolulu, HI 96848; 808-944-7729 (tel); frazier@eastwestcenter.org

Thomas Giambelluca, Professor, Department of Geography and the Environment, 445 Saunders Hall, University of Hawai'i, 2424 Maile Way, Honolulu, HI 96822; 808-956-7390 (tel); thomas@hawaii.edu

Whitney Goodell, Research Assistant, Department of Natural Resources and Environmental Management University of Hawai'i, Sherman 101, 1910 East-West Road, Honolulu, HI 96822; 808-956-7530 (tel); goodellw@hawaii.edu

Zena Grecni, Sustained Climate Assessment Specialist, Research Program, East-West Center, 1601 East-West Road, Honolulu, HI 96848; 808-944-7242 (tel); grecniz@eastwestcenter.org

Jan Hafner, Scientific Computer, Programmer International Pacific Research Institute, University of Hawai'i, POST Building, Room 401, 1680 East-West Road, Honolulu, HI 96822; 808-956-2530 (tel); jhafner@hawaii.edu

John Hoffmann, Director, US Geological Survey Pacific Islands Water Science Center; 1845 Wasp Blvd., B176, Honolulu, HI 96818; 808-690-9602 (tel); jphoffma@usgs.gov

Hla Htun, Graduate Research Assistant, Department of Natural Resources and Environmental Management, University of Hawai'i, Sherman 101, 1910 East-West Road, Honolulu, HI 96822; 808-956-8864 (tel); hhtun@hawaii.edu

***Kelly Hwang**, Undergraduate student, Water Resources Research Center, University of Hawai'i, 2540 Dole St., Holmes Hall 283, Honolulu, HI 96822; 808-956-7847 (tel); hwangky@hawaii.edu

Krista Jaspers, Project Assistant, Research Program, East-West Center, 1601 East-West Road, Honolulu, HI 96848; 808-944-7356 (tel); jaspersk@eastwestcenter.org

***Laura Kam**, Network Manager, Hawai'i Green Growth, 735 Bishop Street, Suite 424, Honolulu, HI 96813; laura@hawaiiigreengrowth.org

***Kainoa Keanaaina**, Graduate student, Water Resources Research Center, University of Hawai'i, 2540 Dole St., Holmes Hall 283, Honolulu, HI 96822; 808-956-7847 (tel); kainoa3@hawaii.edu

Victoria Keener, Fellow, Research Program, East-West Center; 1601 East-West Road, Honolulu, HI 96848; 808-944-7220 (tel); keener@eastwestcenter.org

Melissa Kunz, Master's Student, Department of Natural Resources and Environmental Management, University of Hawai'i, 1910 East-West Road, Honolulu, HI 96822; 808-956-7530 (tel); mmkunz@hawaii.edu

Pacific RISA Team Members

* New members in this reporting period have an asterisk before their name

Ryan Longman, Fellow, East-West Center; 1601 East-West Road, Honolulu, HI 96848; 808-944-7430 (tel); longmanR@EastWestCenter.org

John J. Marra, NOAA Pacific Regional Climate Services Director, NOAA IRC #3442, 1845 WASP Blvd., Building 176, Honolulu, HI 96814; 808-725-5974 (tel); john.marra@noaa.gov

Wendy Miles, Science Collaboration Coordinator, Science Applications Program, Interior Region 12, 300 Ala Moana Blvd., Rm. 5-231, Honolulu, HI 96850; 808-284-7636 (tel); wendy_miles@fws.gov

***Paula Moehlenkamp** Project Specialist, East West Center, Hawai'i Green Growth, 1601 East-West Road, Honolulu, HI 96848; 808-944-7423 (tel); moehlenp@eastwestcenter.org

Susanne Moser, Director and Principal Researcher, Susanne Moser Research & Consulting, Hadley, MA 01035; 831-234-8219 (tel); promundi@susannemoser.com

Kirsten Oleson, Associate Professor, Department of Natural Resources and Environmental Management, University of Hawai'i, Sherman 101, 1910 East-West Road, Honolulu, HI 96822; 808-956-8864 (tel); koleson@hawaii.edu

Anne-Charlotte Oliver, Research Assistant, Department of Natural Resources and Environmental Management University of Hawai'i, Sherman 101, 1910 East-West Road, Honolulu, HI 96822; 808-956-7530 (tel); olivera@hawaii.edu

Kristen Sanfilippo, Graduate Research Assistant, Department of Geography, 445 Saunders Hall, University of Hawai'i, 2424 Maile Way, Honolulu, HI 96822; 808-956-8465 (tel); ksanfli@hawaii.edu

Christopher Shuler, Graduate Research Assistant/Post-Doc, Water Resources Research Center, University of Hawai'i, POST Building, Room 709A, 1680 East-West Road, Honolulu, HI 96822; 808-956-6331 (tel); cshuler@hawaii.edu

Emelia von Saltza, Project Manager, Conservation International-Hawai'i, 3555 Harding Ave. Ste. 200, Honolulu, HI 96816 and Research Associate, Department of Natural Resources and Environmental Management, University of Hawai'i, Sherman 101, 1910 East-West Road, Honolulu, HI 96822; 808-956-7530 (tel)

Matthew Widlansky, Associate Director, University of Hawaii Sea Level Center, Cooperative Institute for Marine and Atmospheric Research, 1000 Pope Road, Marine Sciences Building 312, University of Hawai'i, Honolulu, HI 96822; 808-956-6161 (tel); mwidlands@hawaii.edu

Z. Chunxi Zhang, Regional Atmospheric Modeling Specialist, International Pacific Research Institute, University of Hawai'i, POST Building, Room 401, 1680 East-West Road, Honolulu, HI 96822; 808-956-3177 (tel); chunxi@hawaii.edu

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Accomplishments

Featured Accomplishment: Pacific Islands Regional Climate Assessment (PIRCA) Reports

The 2020–2021 PIRCA reports synthesize up-to-date knowledge about climate change impacts and risks and were developed in collaboration with partners from the PIRCA network throughout the Pacific. Climate assessment reports for Palau, Guam, and the Commonwealth of the Northern Mariana Islands (CNMI) were released in October 2020, November 2020, and January 2021, respectively, and the release of an assessment report for American Sāmoa followed in June 2021. These reports update the 2012 PIRCA and build on the Fourth US National Climate Assessment (NCA4), presenting trends and future projections for a set of foundational climate change indicators. Additionally, they address gaps by outlining climate change risks in key sectors and identifying research and information needs to support responses that enhance resilience and help Pacific Islands to withstand the changes to come. The PIRCA reports released thus far are used in funding proposals for adaptation projects, to inform National Adaptation Plans, and in governments' communications with the public and decision-makers at local, national, and international scales.

Shortly after the release of the assessment for the CNMI, the Pacific RISA Sustained Climate Assessment Specialist Zena Grecni, the report's lead author, was invited to testify as an expert witness in the Full Committee Hearing of the US House Committee on Natural Resources on the Insular Area Climate Change Act (H.R. 2780) on March 4, 2021. Ms. Grecni's testimony highlighted findings of the PIRCA, especially of climate change impacts uniquely affecting the US Territories and the Freely Associated States. During the hearing, Congressman Sablan of the CNMI thanked the PIRCA team for their work on the report, which the Committee used as a reference document in their consideration of the draft legislation proposing new funding and federal programs for climate change adaptation and mitigation for US Insular Areas. The PIRCA reports also informed new legislation in Guam, the [Resources Report](#) for the CNMI, and funding proposals to support National Adaptation Plan development in Palau (see [Research Highlights](#)).



The 2020–2021 PIRCA reports address gaps by outlining climate change risks in key sectors and identifying research and information needs to support responses that enhance resilience.

New Partnerships

The UN Local2030 Islands Hub: Determining Metrics of Climate Adaptation Goals in the US-Affiliated Pacific Islands

Jurisdictional-scale Pacific Island decision-makers and governments lack the time and capacity to interpret complex climate assessment reports and are collaborating as a region on developing a transferrable and stakeholder-based framework to identify locally and culturally appropriate goals, metrics, and indicators that track a given island's progress towards various climate adaptation goals. By increasing the capacity of island jurisdictions to quantify their adaptation progress, governments and sectors will be able to focus on areas that need more attention and highlight success stories, enabling data-based decision making and justification of international funding. The Pacific RISA welcomed a new team member, Paula Moehlenkamp, to facilitate collaboration between the Pacific RISA and Hawai'i Green Growth (HGG) in adding climate change indicators and metrics of progress to the Sustainable Development Goals (SDG) Dashboards created as part of the UN Local2030 Island Hub network. The Local2030 Islands Network brings together a diverse set of developed and developing island economies—nations, states, and communities—from all regions of the world. The Network promotes island solutions and leadership based on shared experiences and island culture and aims to create a community of practice around localized tracking and implementation of both SDGs and climate metrics. During the past year, Pacific RISA and the HGG met virtually with government, NGO, academic, and private-sector stakeholders from the Republic of the Marshall Islands (RMI) and the Federated States of Micronesia (FSM) to start forming working groups that will identify and collect locally available and culturally relevant climate metrics in sectors of interest. Landscape analyses have been performed to assess and identify available data and partner organizations. This process will involve stakeholder assessment in telephone and in-person interviews and requires local buy-in to assume control of the dashboard once it has been created.



President David Panuelo (Federated States of Micronesia) and his delegation meet with the HGG team and Pacific RISA Project Specialist Paula Moehlenkamp at the Pacific Club in Honolulu, Hawai'i to discuss the Local2030 Island Network collaboration and the RMI dashboard development. (Left to right) Henry Shrew (FSM Acting Consul General in Honolulu), Akillino H. Susaia (Ambassador of the FSM to the USA), Kandhi A. Elieisar (FSM Secretary of Dept of Foreign Affairs), David W. Panuelo (President of the FSM), Celeste Connors, Shelley Gustafson, Kaimana Bingham, Paula Moehlenkamp, Joses Gallen (FSM Secretary of Dept of Justice). (Image credit: Laura Kam)

The Adaptive Mind: EWC Leadership Program Women’s Empowerment Initiative Climate Change, Sustainability, and Resilience for Pacific Islands Women Leaders

The East-West Center’s Leadership Program (LP) is committed to ensuring that women in the Asia-Pacific region are effective leaders for their communities. In partnership with the Pacific RISA, the University of Hawai’i (UH) Institute for Sustainability and Resiliency, and the Aspen Global Change Institute, this project focuses on expanding and creating new professional and personal development opportunities for women and men emerging and leading in the climate change and resilience space. This collaborative partnership helps these leaders ensure that programs are evidence-based and effective. The project leverages EWC and Hawai’i-based expertise, promotes meaningful engagement with Pacific Islands leaders and communities, and provides the conditions for near- and long-term collaboration among the EWC Research Program, the University of Hawai’i, and other respected, regional organizations and institutions. Using key informant interviews and a survey, investigators will develop a robust understanding of the “adaptive mind”: the set of propensities, leadership skills, and capacities that allow people—embedded in social networks and institutions—to respond with agility, creativity, resolve, and psychological resilience to a world undergoing rapid and complex change. Based on this foundational research and synthesis, the team will assess the specific psychosocial needs and existing capacities of adaptation professionals, as well as gaps in educational opportunities across the region. This will inform the development of trainings, resources, tools, and peer-support groups.

UH Sea Level Center: Assessing Compound Effects of Seasonal Rainfall and Sea Level Extremes on Coastal Flooding in Hawai’i

Through new collaborations with partners at the UH Sea Level Center (UHSLC), Pacific RISA PI H. Annamalai and his team hope to better understand the processes that contribute to compound coastal flooding events in Hawai’i, and assess which coastlines are most vulnerable to flooding caused by combined heavy rainfall and high sea level. Compound coastal flooding events in Hawai’i will be exacerbated by more extreme rainfall events and rising sea levels due to climate change. The team plans to utilize historical observations of heavy rainfall events and high sea level anomalies to determine the likelihood of their joint occurrence, both temporally and spatially, and to determine the atmospheric and oceanic processes that contribute to increased likelihood of compound flooding events in Hawai’i.

Flooding on the North Shore of O’ahu in the winter of 2016. Episodic flooding in the Pacific Islands will increase as sea level rises. (Image credit: Steven Businger, from [Fourth National Climate Assessment Chapter 27: Hawai’i and US-Affiliated Pacific Islands](#))



UH WRRC and ASPA Partner to Develop New Weather and Hydrologic Monitoring Network

On Tutuila Island in American Sāmoa, weather monitoring and stream gauging operations were initiated by the US Geological Survey (USGS) in the 1950s. However, as of 2008, all USGS monitoring activity on Tutuila had ceased. Although the legacy data remains as a valuable tool, climate change and variability continue, creating the need for tracking changes and departures from the historical baseline. Because this information is a critical component of sustainable water management, the UH Water Resources Research Center (WRRC) and the Territory's sole water utility, American Sāmoa Power Authority (ASPA) have entered into a cooperative agreement for the purpose of developing a new weather station, stream gauging, and aquifer monitoring network. The instruments used in this network are intended to be simple, robust, and easily maintained to ensure longevity and continuity of data.



(L) Matt Erickson, former ASPA Hydrologic Technician takes a streamflow measurement to ultimately be used in calculation of runoff to rainfall ratios in the Tutuila Water Budget Model. (R) ASPA student interns and ASPA technician Matt Erickson help with weather station installation in American Sāmoa. (Image credit: Chris Shuler)

The Pacific Regional Invasive Species and Climate Change (RISCC) Management Network

In 2020, Pacific RISA PI Laura Brewington led the formation of a new Pacific Regional Invasive Species and Climate Change (RISCC) Management Network, in collaboration with the US Fish and Wildlife Service, the Pacific Islands Climate Adaptation Science Center (PI-CASC), the Hawai'i Department of Land and Natural Resources (DLNR), and the Hawai'i Coordinating Group on Alien Pest Species (CGAPS). This partnership has focused on increasing Pacific Island resilience to the interacting threats of climate change and invasive species through two main objectives: 1) tailoring research on these dual drivers of ecosystem change according to the needs of natural resource managers to aid in the development and implementation of climate-adaptive management practices; and 2) coordinated Pacific-wide strategies developed to detect and suppress the most damaging international threats in the context of a changing climate. An initial survey of natural resource managers in Hawai'i was conducted to identify gaps, needs, and levels of concern among the management community when incorporating climate change into invasive species interventions, and survey results have been used to initiate a website, listserv, and webinar series for managers and researchers to discuss the synergies between these two threats (see [Outreach](#), pg. 13). This two-way dialog will facilitate the co-development of manager-relevant invasive species research, such as mapping island-wide changes in temperature, precipitation, and native forest cover, studying how damage from past and future extreme rainfall events may weaken ecosystem resilience to or ability to recover from species invasions, and refining existing climate monitoring and prediction tools to support adaptive management priorities.

Research Highlights

Pacific Islands Region

- [Climate Change in Palau: Indicators and Considerations for Key Sectors](#) (Miles et al. 2020) was released in October 2020, the first in the series of new PIRCA reports. The report informed funding proposals to support the development of a National Adaptation Plan in Palau.
- [Climate Change in Guam: Indicators and Considerations for Key Sectors](#) (Grecni et al. 2020) was released in November 2020, the second in the series of new PIRCA reports. This report informed a bill to prohibit the burning of forest land¹ (the main contributor to destructive wildfires on Guam), as well as to explore the prospect of insuring the beaches and coral reefs of Guam’s Tumon Bay.²
- [Climate Change in the Commonwealth of the Northern Mariana Islands: Indicators and Considerations for Key Sectors](#) (Grecni et al. 2021) was released in January 2021, the third in the series of new PIRCA reports. This report informed the [Resources Report for the CNMI](#), which supports sustainable development planning efforts and next steps in the design of CNMI’s Comprehensive Sustainable Development Plan.
- PI Brewington submitted a proposal with the Coordinator of the Micronesia Regional Invasive Species Council to set up a new forest monitoring plot in Palau that will help track how Palau’s native forest species respond to new ecological regimes, such as invasion and drought.

Firefighters battle a large wildfire near LeoPalace Resort in Guam in 2018. Photo courtesy of Guam Department of Agriculture, Forestry Division. (From: [Climate Change in Guam: Indicators and Considerations for Key Sectors](#))

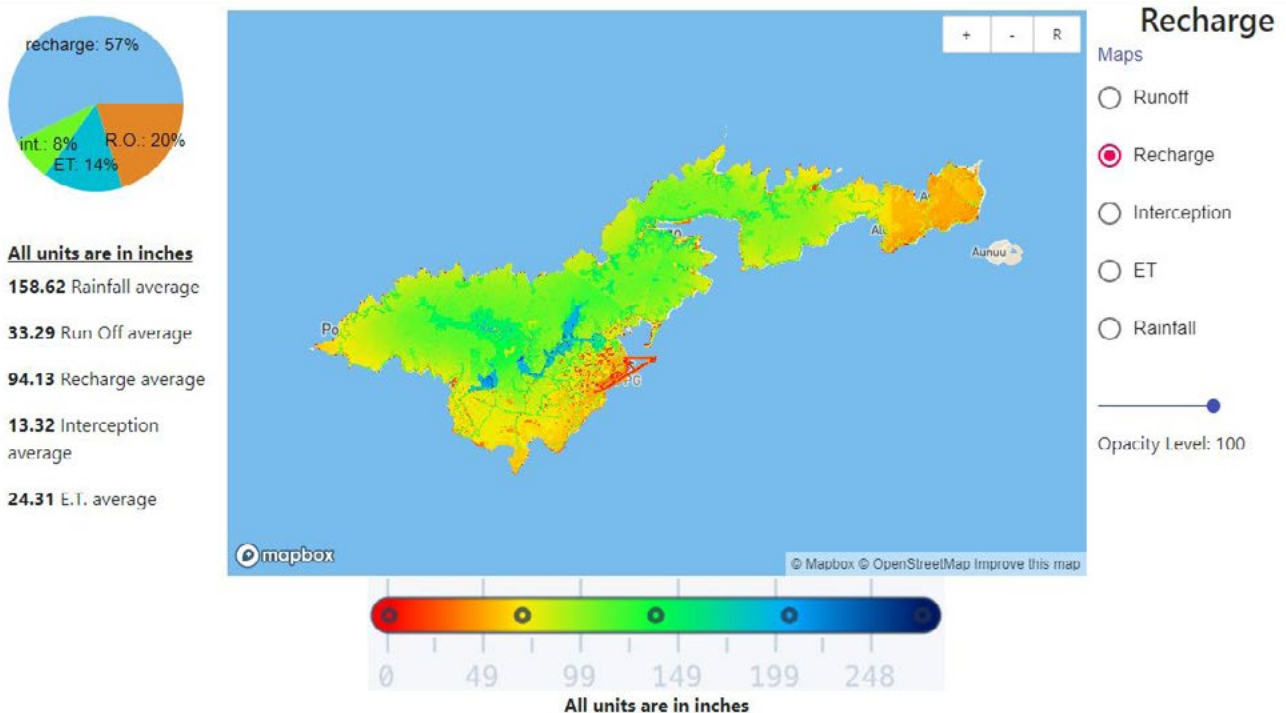


¹The Office of Sen. Sabina Perez, [Senator introduces bill to combat destructive wildfires spread by arson](#) (Pacific Daily News, 2020)

²Kaur, A., [Senators pass 13 bills during session Monday](#) (Pacific Daily News, 2020) and Limtiaco, S., [Task force discusses insurance for Tumon Bay reef](#) (Pacific Daily News, 2021)

American Sāmoa

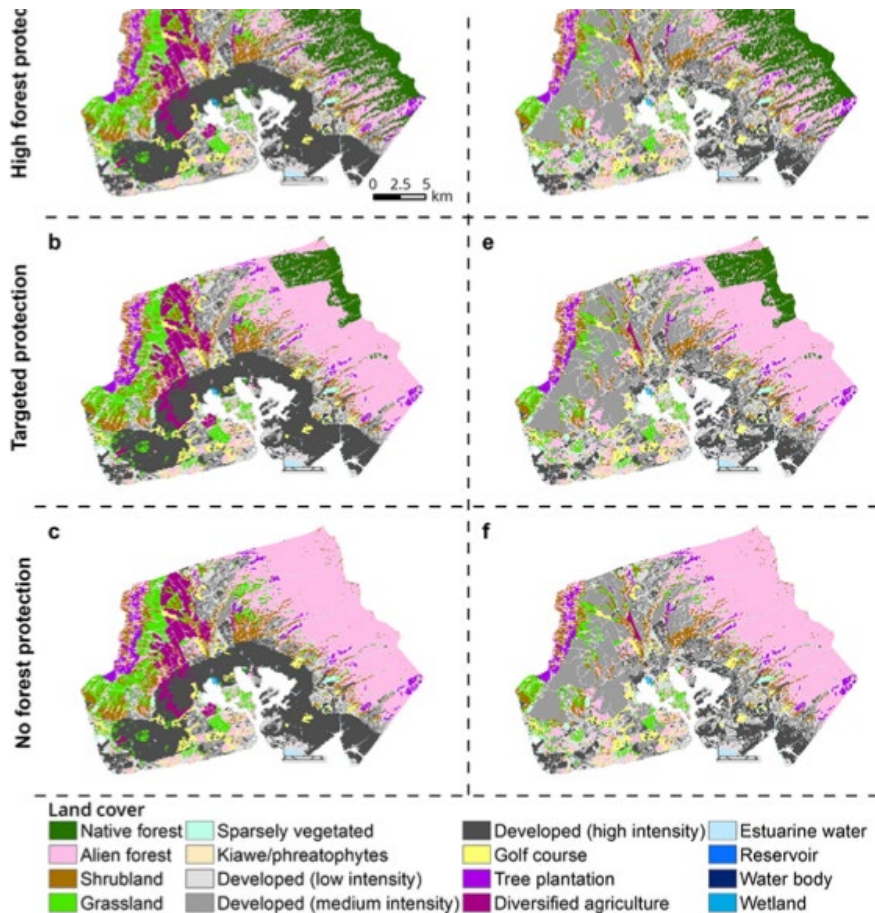
- [Climate Change in American Sāmoa: Indicators and Considerations for Key Sectors](#) (Keener et al. 2021) was released in June 2021, the fourth in the series of new PIRCA reports. Already, the report was incorporated into a hazard mitigation training for government representatives who will be revising American Sāmoa’s hazard mitigation plan.
- The American Sāmoa Power Authority intends to use hydrologic modeling products developed by post-doctoral researcher Dr. Chris Shuler (water-budget model, groundwater modeling framework) for water management decision making. This modeling framework applies an open-source, cloud-based, and process oriented paradigm to make modeling more accessible, transparent, reproducible, and stakeholder driven. (See image below and the [ASPA-UH WRRC Integrated Modeling Framework](#) webpage for more information on this project).
- A participatory scenario-building approach was used to assess groundwater recharge under future climate and land covers in Tutuila, American Sāmoa. Dr. Shuler led the development of the first high-resolution water budget model for an entire high-basaltic island within the South Pacific Convergence Zone. This, in addition to application of the model to project future conditions under both climate change and land cover change scenarios, make this project one of the more rigorous assessments of present and future water resources availability in the South Pacific Region to date. The dynamically downscaled Global Climate Model projections used indicated an increase in annual average precipitation of 11% and 18% in their Representative Concentration Pathway8.5 and RCP4.5 scenarios by the end-of century. This translated to island-wide groundwater recharge increases of 8% and 14%, respectively. Although increases in recharge roughly mirrored increases in precipitation, showing that precipitation is a primary driver of groundwater recharge, increases in surface runoff were significantly higher, on the order of 50% higher under the future scenarios. This indicated that while water resources availability may increase in the future, it will not be without consequences, likely in the form of increased flooding. Land cover scenarios showed how conversion of vegetated types to more urbanized types could result in localized reductions in recharge of up to 20%.



Screenshot of draft Tutuila Water Budget Model Web-Application Viewer. Draft available [HERE](#).

Hawai'i

- The UH-led 'Ike Wai (knowledge of water) project spans multiple scientific disciplines and connects university researchers to state and federal agencies, as well as community groups. As the Pacific RISA Groundwater Project highlighted, groundwater sustainability initiatives in Hawai'i are coupled with concerns about the effects of climate and land cover change on supply. The Pearl Harbor aquifer region of O'ahu is heavily developed and dedicated to industrial, residential, and agricultural uses, with conservation lands at the higher elevations. This study constructed a novel, spatially explicit groundwater hydrologic ecosystem services framework, which combined stakeholder-defined land cover scenarios, sustainable yield estimation using a groundwater simulation optimization approach, and economic valuation, and applied it in the most heavily



Stakeholder-informed future land cover scenarios for the Pearl Harbor aquifer:

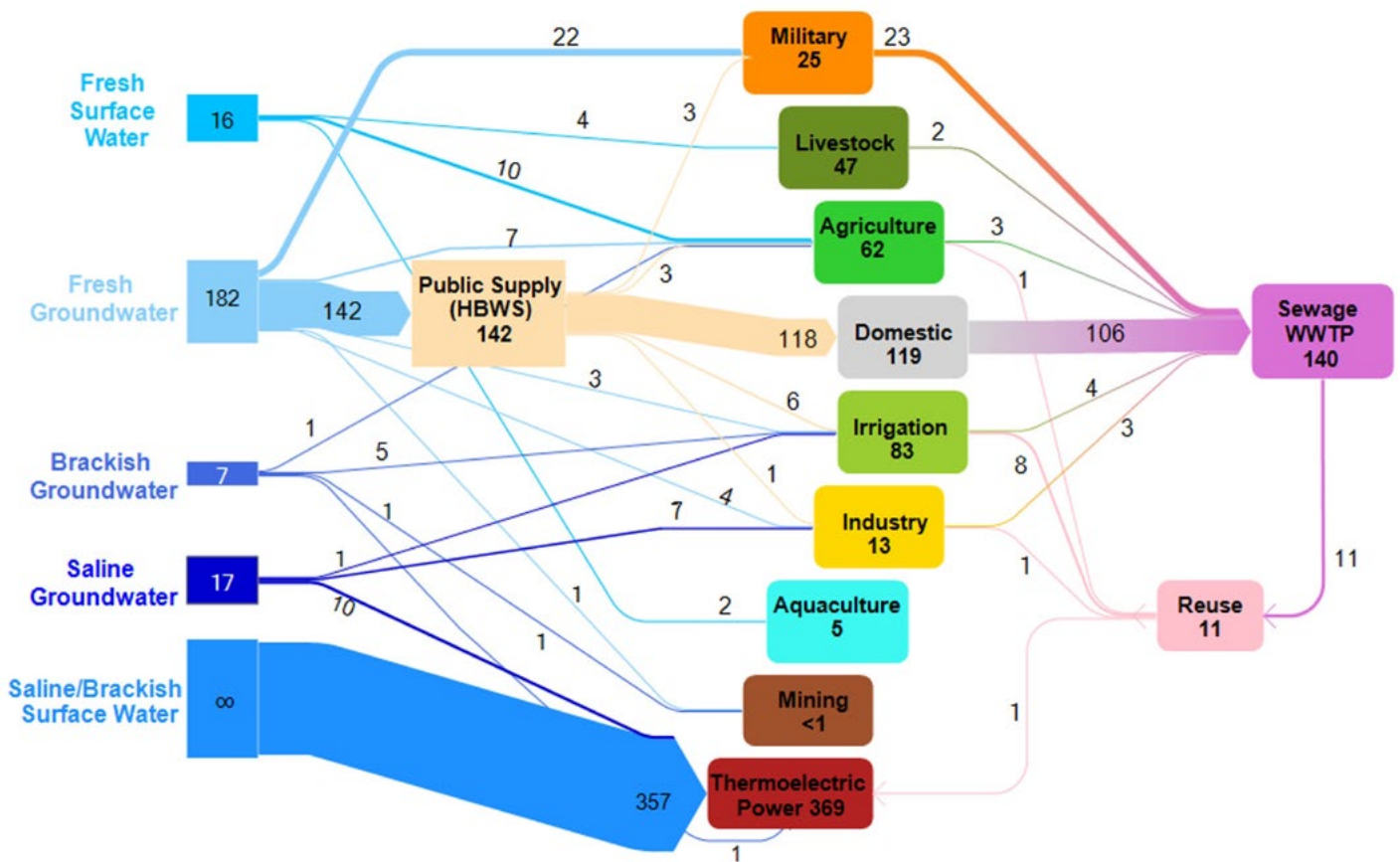
- Corridor development + high forest protection;
- Corridor development + targeted forest protection;
- Corridor development + no forest protection;
- Sprawl development + high forest protection;
- Sprawl development + targeted forest protection;
- Sprawl development + no forest protection.

From: [Effects of land-cover and watershed protection futures on sustainable groundwater management in a heavily utilized aquifer in Hawai'i \(USA\)](#)

utilized aquifer in Hawai'i. PI Brewington developed a set of future land cover scenarios for the Pearl Harbor aquifer that reflected different urban development trajectories and varying degrees of agricultural intensification or reduction and native forest protections. Sustainable yield estimates were generated for the land cover scenarios crossed with two water demand scenarios in a context of a dry future climate (RCP 8.5 mid-century). Land cover change was found to be an important, though less significant driver of changes in groundwater recharge than climate change. The degree of watershed protection, through preventing the spread of high-water-use, invasive plant species, was projected to be a much stronger land cover signal than urban development. Specifically, full forest protection increased sustainable yield by 7–11% (30–45 million liters per day) and substantially decreased treatment costs compared with no forest protection. The

results of this study demonstrated that improved understanding of the impacts of watershed management on groundwater yields and management costs—particularly in the context of climate and land cover change—is critical to informing water use planning and facilitating integrated land and water management.

- The draft water account for O’ahu developed by PI Kirsten Oleson’s lab has catalyzed discussions across agencies hosting water data on ways to synthesize existing data, providing a system-scale vantage point of freshwater. The project has spurred interest from boards of water supply, the Hawai’i Office of Environmental Quality Control, and operators of wastewater treatment plants interested in best practices. In the non-profit sector, PI Oleson has connected with Wastewater Alternatives and Innovation (WAI), whose mission is to help homeowners and communities in Hawai’i upgrade cesspools and septic systems to reduce sewage pollution and restore healthy watersheds. This project has also prompted a partnership with the Ocean Sewage Alliance in an effort to bring the sanitation sector’s role in coastal health and climate adaptation to the forefront.



Water Use on O’ahu in 2017. Water sources (left side) and use by economic sectors (middle-right). All units in mgd. Flows <0.5 mgd are not included in the diagram. Above graphic does not include rainfall or soil water estimates, losses, evaporation, evapotranspiration, consumption in product, or direct returns from sectors to the environment. Source: Kirsten Oleson.

Outreach

The Pacific RISA team experienced many delays and difficulties as the COVID-19 pandemic halted travel, eliminated in-person gatherings, froze hiring, and restricted access to campus workspaces and other resources. However, the sudden shift to a virtual world due to the pandemic provided Pacific RISA with an opportunity to innovate and expand its online presence and reach stakeholders through virtual workshops, webinars, and events in ways it had not previously explored. Pacific RISA's consistent presence on social media ([Twitter](#) and [Facebook](#)) was also an integral component in promoting events, interacting with stakeholders, and reaching an extensive audience with the release of regional reports like the PIRCA.

Climate Change, Health, and Migration in the Republic of the Marshall Islands

Shortly after the First Climate and Health Dialog was held in Majuro in January 2020, the COVID-19 pandemic forced the RMI to close its international borders for the next 18 months. Due to the inability to return, PI Brewington held follow-up virtual meetings with participants from the Dialog to identify decision-makers that could benefit from climate information that is already available (such as the existing RMI seasonal climate outlook) and link specific variables to health impacts and thresholds of action (such as drought and sea level rise). This summary information has been compiled and delivered to the Ministry of Health for inclusion in the National Adaptation Plan (see Evidence of Societal Impact, below). PI Brewington then began working with the UHSLC and Hawai'i Sea Grant to develop a sea level training module for health and disaster preparedness in the RMI. This assistance has been requested by the RMI National Disaster Management Office and the Majuro Weather Service Office, and both technical information and sector-specific trainings are to be prepared. The team expects to debut the module and an applied, real-world case study for the RMI at a hybrid in-person/virtual Pacific Islands Climate Outlook Forum (PICOF) meeting in April 2022. During the 2020 Dialog, participants also identified vector- and water-borne diseases as primary climate-related health issues, so in the months that followed PIs Brewington and Marra collaborated virtually with participants to develop two "Climate Stories" that describe the climate conditions and response decisions that surrounded these health outcomes. The new stories are being published as part of a complete set of stories from around the Pacific in an updated version of NOAA's "[Pacific Climate Storybook](#)" to be released later this year.

City and County of Honolulu Climate Change and Social Equity Guidance Document

Pacific RISA PI Victoria Keener and fellow Commissioners on the City and County of Honolulu Climate Change Commission developed the [Climate Change and Social Equity Guidance Document](#). In October 2020, the Commission, in coordination with the Climate Change, Sustainability and Resiliency (CCSR) Office's Climate Resilience and Equity Program, convened a virtual focus group representing frontline community organizations and individuals on O'ahu to obtain perspectives regarding climate change impacts and policies in the communities they serve and to incorporate these considerations into the recommendations. The sectors represented in this focus group included health, agriculture, education, human services, cultural resources, and environmental sustainability. Key climate impacts were identified as leading to reduced food security and the loss of cultural resources such as traditional crops, limu (i.e. seaweed), and fishponds. The focus group also expressed concern over inadequate infrastructure in the case of disaster events, such as emergency shelters and emergency roads to quickly leave vulnerable areas, particularly along the Wai'anae Coast. While the focus group acknowledged the significance of climate change on the environment, the group also discussed the impacts of climate change as they related to socioeconomic issues. For the communities the organizations serve, the up-front costs of upgrading to sustainable or resilient systems are often out of reach (such as solar panels or converting septic systems). Additionally, the frontline organizations noted that they were often competing against each other for limited financial resources, as opposed to collaborating to increase the reach of the resources they had, and suggested that future climate

initiatives could foster an integrated and collaborative, rather than competitive, environment. The resulting report is being utilized by the City and County of Honolulu as they draft the Climate Adaptation Plan that will help prioritize climate risks and community adaptation implementation measures over the next five years. The key recommendations of the social equity report include: centering social equity in all city climate change adaptation and mitigation plans; identifying frontline communities that are experiencing or are likely to experience chronic climate or socioeconomic stressors that could worsen the impact of climate change-induced shock; and, focusing on outreach to underserved communities through expanding accessibility options and providing information in the preferred format and languages of O‘ahu’s diverse communities. The Climate Commission acknowledges that “while climate impacts are being experienced globally, they will not be experienced equally,” and that vulnerable communities are often the first to be affected by climate change.

International Tropical Islands Water Conference

Dr. Chris Shuler Co-Chaired the virtual International Tropical Islands Water Conference in April 2021 (Pacific RISA partners also on the conference organizing committee included: PIs Tom Giambelluca and Aly El-Kadi, and collaborators Henrietta Dulai and Kelley Anderson Tagarino). This conference provided a platform for discussion among scientists, resource managers, and community members from around the world to share cutting-edge research and learn from each other’s experiences managing and understanding water resources across a broad range of tropical island settings. The conference featured virtual field trips, submitted by conference attendees, to share the unique beauty of the people, ecosystems and water of diverse tropical islands. Traditional and local knowledge was shared in multiple sessions, including an opening plenary with water mo‘olelo (stories, legends, and history), by Hannah Kihalani Springer, a steward and life-long student of cultural and natural histories of Hawai‘i.

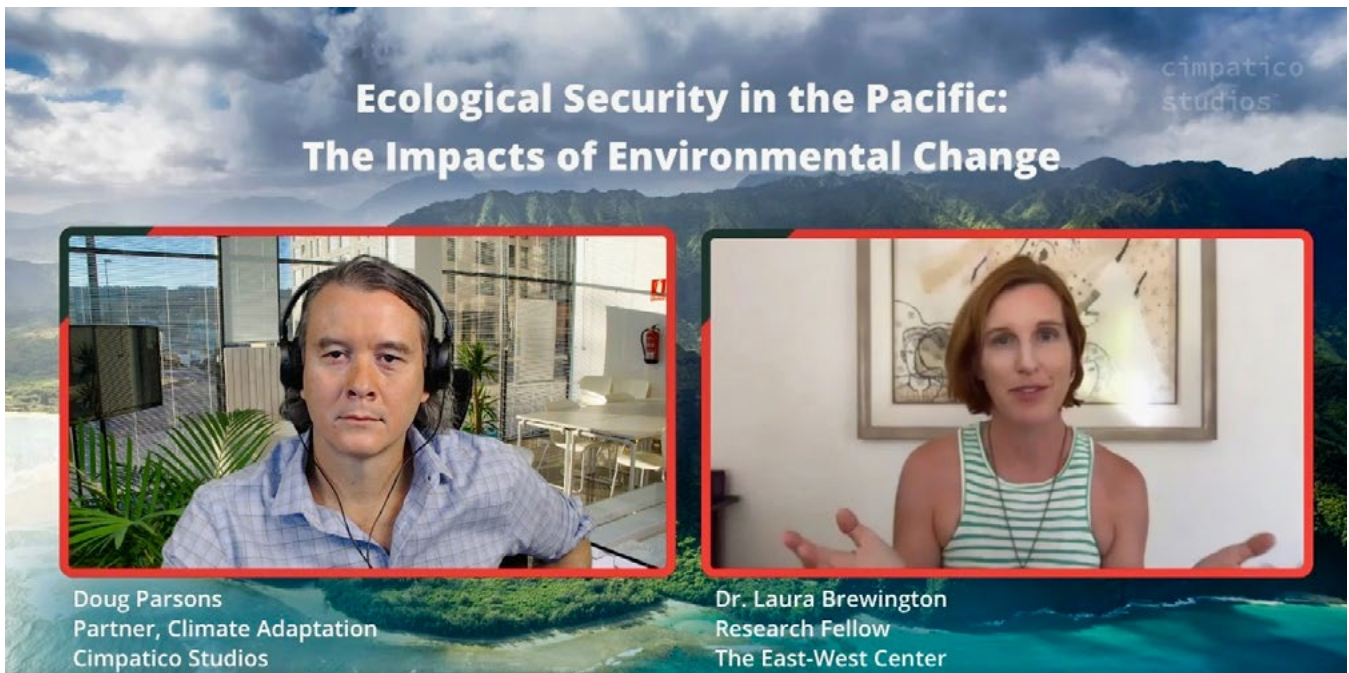
In addition to duties as conference Co-Chair, Dr. Shuler co-authored five presentations at the conference, detailing his water budget modeling work on Tutuila and on Hawai‘i Island, as well as nutrient transport evaluation and impacts of runoff on Hawai‘i Island and in American Sāmoa, respectively. RISA team members Kristen Sanfilippo and Oliver Elison Timm also presented their work in a downscaling-themed conference session, along with Katrina Frandrich, who works closely with PI Giambelluca’s team with a focus on dynamical downscaling.

Regional Security Impacts of Environmental Change

PI Brewington held multiple virtual media appearances, interviews, and briefings to US diplomats working in the region related to Pacific ecological security to reach diverse audiences, including the following:

- June 2020: “[Regional Security: the Impacts of Climate Change](#)”, East-West Center “[Insights](#)”, hosted by ThinkTech Hawai‘i. This presentation was also published online as a brief [East-West Center Wire](#) for general audiences.
- September 2020: “[Ecological Security in the Pacific](#)” with Doug Parsons, Cimpatco Studios Adaptation Channel.
- February 2021: “[Pacific Environmental Security Forum](#)”, Session 2: Water Security. The Pacific Environmental Security Forum (PESF) is the US Indo-Pacific Command’s (USINDOPACOM) program to explore solutions to environmental security issues throughout the Indo-Pacific region. The theme of the 2021 Virtual Pacific Environmental Security Forum was “Strengthening the Partnership Amid Great Challenges”, where each day focused on one working group of the Pacific Environmental Security Partnership, which 34 countries codified at the 2019 PESF in Wellington, New Zealand.

In addition, PI Brewington led the preparation for a Pacific Ecological Security Conference (PESC) that will convene island leaders and government representatives from Pacific Island nations and territories, international experts, and invasive species managers in Palau. Coordinating partners



PI Brewington is interviewed by Doug Parsons on Pacific ecological security in September 2020.

include the Government of Palau, the US Department of Agriculture, New Zealand Department of Conservation, Australia’s Commonwealth Scientific and Industrial Research Organization (CSIRO), the European Union, Sasakawa Peace Foundation, and other regional and national entities. The conference will demonstrate existing biosecurity partnerships and commitments in the region (e.g., the Regional Biosecurity Plan for Micronesia and Hawai’i), identify the top Pacific-wide priorities for invasive species management (e.g., climate change, species-specific targets, maritime transport, port facilities), and conclude with the development of a regional coordinating mechanism for ongoing collaboration, training, and financial support. The expected outcome of the PESC and subsequent coordinating activities will be a “whole of Pacific” approach to addressing critical concerns about invasive species spread and management. The PESC was originally scheduled for December 2020 and postponed due to COVID-19; plans to reschedule are currently underway.

PI Brewington and other members of the Pacific RISCC Core Team also initiated a webinar series and virtual forum event for natural resource managers in Hawai’i and the USAPI, with each event drawing more than 100 virtual participants and attendees. The new [Pacific RISCC website](#), hosted by the PI-CASC, was developed to meet the demand for more tailored information and products on the topic of invasive species and climate change. Examples of events in the past year include a summary of water resources management under climate change and invasive species challenges; planning for drought in Hawai’i Volcanoes National Park; and a statewide forum for natural resource managers and researchers to share opportunities for knowledge exchange and co-production in light of these synergistic impacts.

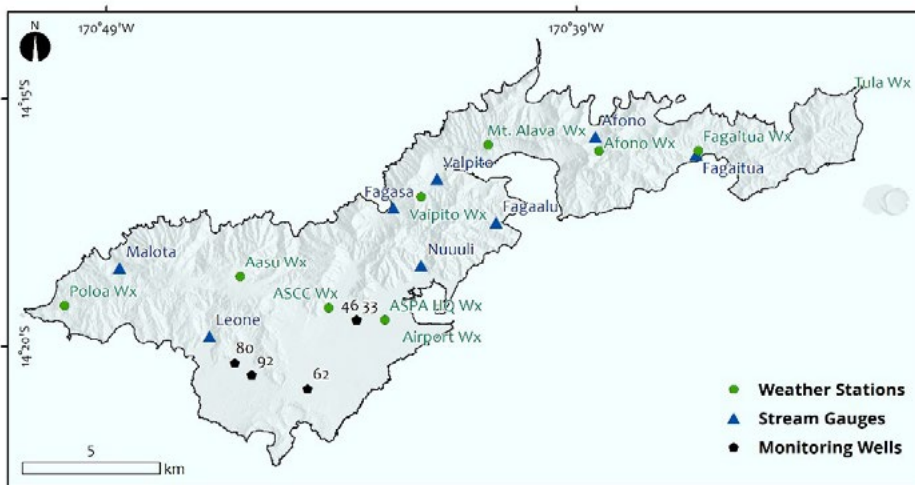
Climate and Drought Indicators in the Pacific Islands

Pacific RISA PI John Marra led the formation of the Pacific Climate Change Monitor (PCCM) Steering Committee in 2020, which has been meeting regularly to prepare the PCCM, a report that will draw on the latest meteorological and oceanographic data and information to describe historical change in Pacific Island climate in terms of a fundamental set of indicators. An outline for the report has been established, four working groups have been formed to develop content for various sections in the outline, and working group meetings along with associated content development are underway. Pacific Small Island Developing States (PSIDS) are underserved communities that will benefit from the results

of this work and the capacity building associated with it. Design of training materials for the PCCM is intended to build the capacity of National Meteorological Services and other Pacific Island stakeholders to develop and apply climate information locally. Plans to conduct this training as part of a larger Pacific Island Climate Forum are being formulated, tentatively scheduled for the week of April 25, 2022.

Community Engagement with Hydrologic Monitoring in American Sāmoa

Dr. Shuler’s weather station and steam gauge infrastructure provided ample opportunities for community engagement. Among the finalists at the 2020 American Sāmoa Island Wide Science Fair were three students supported by the UH WRRC in part or as needed through mentoring, funding, access to equipment, or data material. These three outstanding finalists focused their research on the sustainability of American Sāmoa’s water resources: overall co-winner Victor Chen, who used WRRC data for his project “Calculating Evapotranspiration on Tutuila Island with Python”; third-place winner Jade Cox for “Stormwater Infiltration Injection Well”; and finalist Mavis Liang for “How Much Water Can American Sāmoa Sustainably Harvest from Its Streams”? High School students were mentored by Dr. Shuler (RISA) and Matt Erikson (ASPA), who helped with the development of student projects and provided technical support through in-person and remote meetings. Of special note is student and mentee Victor Chen’s placement as first overall at the Science Fair.



Locations of weather stations, stream gauges, and monitoring wells currently monitoring water resources on Tutuila Island in American Sāmoa. (Source: Chris Shuler)

Impacts

Pacific RISA Internal and External Program Evaluation

The evaluation component of the Pacific RISA encompasses both internal and external projects that continually assess the role Pacific RISA plays in advancing adaptation planning in the region and thus reflect the value of the overall program. A redesigned annual data collection process involves a two-part online survey to efficiently collect existing and new project information from PIs as well as needed metrics for the NOAA Climate Program Office. PIs Keener and Finucane, along with external collaborator Dr. Susi Moser, are continuing to refine a paper that defines the functions of boundary organizations from the perspective of Pacific RISA’s stakeholders. The paper explores the importance of engaging end-users from the project outset to identify theories of impact, appropriate tracking methods, and useful indicators and metrics. This framework is being implemented across the entire NOAA RISA network.

Though delayed due to pandemic impacts, a survey to evaluate the 2020–2021 PIRCA workshops, process, and reports is currently in the IRB approval process, with plans to produce a white paper analyzing the results. The evaluation will: 1) assist Pacific RISA in understanding the reach and use of

the PIRCA reports; 2) guide Pacific RISA in improving future PIRCA products based on stakeholder feedback; and 3) identify ways RISA products can be made more helpful in meeting stakeholder climate assessment needs in the Pacific Islands. The paper will contextualize the need for the products based on the previous PIRCA evaluation; determine if stakeholders feel their needs were met and the products were inclusive, useful, and credible; and, recommend strategies for increasing effective engagement and utility in future products.

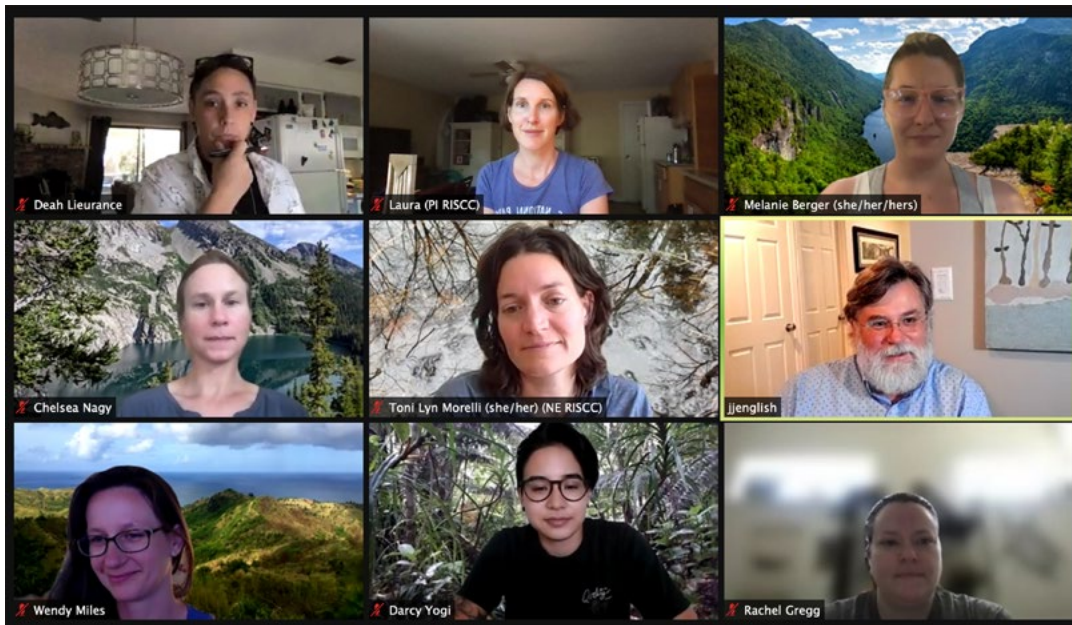
| PACIFIC RISA INTERNAL AND EXTERNAL PROGRAM EVALUATION | Stakeholder Need Known &/or Specific | Stakeholder Need Unknown &/or Generic |
|---|---|---|
| Policy/Management Solution Known and Adequate | Being Responsive – Pacific RISA elicits, or helps stakeholders identify, their own goals and resource needs and then works to meet those needs with specific, requested outputs (e.g., certain types of information to fill data gaps or training) | Being Supportive – Pacific RISA supports the advancement of policy and management solutions and the creation of political will (e.g., through creating forums for dialog, public education, training of specific users, or by connecting stakeholder groups with each other) |
| Policy/Management Solution Unknown or Inadequate | Being Generative – Pacific RISA opens the decision space to novel ideas and approaches (e.g., by identifying new policy options, new implementation strategies, creating new data/models/analysis/insights, synthesizing documents, or producing papers, reports or videos) in ways that generate new or different conversations | Being Critical – Pacific RISA advances policy and management debates by being a constructively critical, credible, outside voice on existing or missing approaches (e.g., by providing commentary, evaluating implementation and outcomes) |

Evidence of Societal Impact

Climate Change and Invasive Species Management

The 2020 Hawai'i Conservation Conference, Ola Ka 'Āina Momona: Managing for Abundance, was held virtually in September 2020. In lieu of an in-person two-day workshop with Hawai'i natural resource managers that was canceled due to the pandemic, PI Brewington and the Pacific RISCC Core Team members co-hosted an interactive forum on climate change and invasive species in partnership with the PI-CASC, the US Fish and Wildlife Service, the Hawai'i DLNR, and CGAPS. The forum, titled "Invasive Species and Climate Change: Building a New Community of Practice" first shared the results of a survey of invasive species managers in the region and coordination efforts thus far, followed by a facilitated discussion to explore topics highlighted by the survey and next steps. Nearly 400 new and seasoned practitioners, managers, and researchers participated and took advantage of this networking and information sharing opportunity, which shaped how the Pacific RISCC designed its mission and Core Team in the following year.

Early in the formation of the Pacific RISCC management network, it was noted that overrepresentation of Hawai'i within the Core Team and network would occur at the expense of the USAPI and ignore both regional capacity and needs. Therefore, in May 2021 new members were added to the Core Team from each jurisdiction in the USAPI. Several of the new members also sit on the Micronesia Regional Invasive Species Council, an important regional collaborator network with strong membership in Guam, the CNMI, and the Freely Associated States. Expanding the Pacific



Members of the National Regional Invasive Species and Climate Change (RISCC) management network meet virtually each month to plan how to grow the network and share products, tools, and resources.

RISCC Core Team will be integral in efforts to build a science and research agenda that reaches underserved and underrepresented communities throughout the USAPI. With a more representative Core Team and network membership, the RISCC plans to expand and host webinar topics based outside of Hawai'i, featuring USAPI jurisdictions and the unique challenges they face, such as the ongoing coconut rhinoceros beetle invasion in Guam and the CNMI and its interaction with more extreme hurricane events.

Analyzing Vulnerability of Military Installations in the Pacific Basin to Climate Change

Climate change has potential ramifications for US national security. This project, supported by the US Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP), aims to develop methodologies for assessing the vulnerability of coastal military installations to increases in sea level and coastal storms over the coming decades. Potential climate change impacts on coastal installations include loss or damage to mission-essential infrastructure, loss of training lands and testing areas, loss of transportation corridors and facilities, loss of natural habitat and natural resources, increased risk of storm damage, and increased risk of loss of life. Four DoD sites in the Pacific Basin are being assessed for their vulnerability to coastal flooding. The methodologies and outputs from this project, including proof-of-concept products and best-practices guidance, are expected to have applicability to US military installations in the Pacific Islands region and more broadly, to coastal regions across the US. PI Brewington is working with PI Marra to combine geographic, biophysical, and infrastructure data for analysis within a GIS modeling environment in support of an exemplar vulnerability assessment that is being conducted as part of this effort.

Marshall Islands National Adaptation Plan and Health Implications of Climate Change

As one of the lowest-lying nations in the world, residents of the RMI are experiencing changes that may affect the very habitability of their land. The public health sector is particularly influenced by sub-seasonal and seasonal changes in temperature, rainfall, and extreme events, as well as the longer-term impacts of sea-level rise and ocean acidification. With a population spread across two million square kilometers, RMI healthcare systems may be unprepared to confront these impacts, which are felt unequally across the population. To begin to address some of the unequal responses to climate impacts within the RMI, the Pacific RISA continues to inform the Marshall Islands National Adaptation Plan with input from the draft PIRCA country report and PI Brewington through the NOAA International Research and Applications Project (IRAP) project. This collaboration was facilitated

by the engagement of the IRAP team with the Marshall Islands Ministry of Health, the Office of Environmental Planning and Policy Coordination, and the Marshall Islands NDMO during the climate change and health dialog organized by PIs Brewington and Marra in Majuro in January 2020. As an outcome of the 2020 Dialog, PI Brewington also initiated a collaboration with the Pacific Islands Health Officers Association (PIHOA) to develop a dengue early-warning tool for the RMI. PIHOA hired a model developer and through regular meetings with the project team, PI Brewington is identifying sources of climate and environmental data to serve as model inputs.

Further Evidence of Pacific RISA's Societal Impact

- Hawai'i Division of Aquatic Resources (DAR) is using the economic model of coral reef restoration developed by Pacific RISA PI Oleson's lab as part of their 30x30 marine management planning effort, which focuses on developing and strengthening the effective management of Hawai'i's marine environment. Under this plan, DAR is committed to working with communities to improve management of coastal waters, and to establish 30% of Hawai'i's nearshore waters as marine management areas by 2030. The economic valuation work will continue to help decision-makers prioritize areas for restoration of land and coral reefs, build awareness of the costs of land use decisions and climate change, and highlight the value of coral reefs.
- A white paper produced in 2020 by the Honolulu Climate Commission, under the leadership of PI Keener, asserted that a supporting ordinance is needed to provide a [One Water Collaboration Framework](#) among City agencies to coordinate planning and infrastructure investment for climate resiliency. In December 2020, the Honolulu City Council adopted Ordinance 20-47 that included the One Water Framework to create an integrated freshwater panel across city departments that jointly manage issues relating to water and climate. This Ordinance also includes development of a checklist of strategic and tactical actions for One Water climate resilience and collaboration including but not limited to: research and monitoring; policies and regulations; coordinating resources; planning and engineering; public outreach; design and construction for climate change and sea level rise adaptation, with both a 2050 and 2100 time outlooks; and, prioritization of One Water climate resilience initiatives to address critical infrastructure serving economic and transportation centers and other critical facilities.
- The purpose of PI Giambelluca and his team's predictor selection and statistical downscaling work is to provide the most accurate projections of future rainfall possible for Hawai'i. These statistical downscaling results (forthcoming) will be compared to the dynamical downscaling results to attempt to reach some consensus on future increases or decreases in rainfall across Hawai'i. This work will also shed light on which geographical areas may be most difficult to capture in projections. The results will provide insight for managers and planners to prepare for the risks of flood and drought and changing patterns of rainfall and accessibility to freshwater, while enhancing management of other valuable resources in Hawai'i.

Case Studies

Kaua'i Peer-to-Peer Exchange

PI Keener and the County of Kaua'i Resiliency Team facilitated the first in a series of four "Peer-to-Peer" exchanges (January 2021) between representatives from the County of Kaua'i and representatives from the City and County of Honolulu. The meeting, which opened with an introduction from Kaua'i Mayor Derek Kawakami, drew 41 attendees to discuss strategies and lessons learned in climate resiliency planning activities and implementation across various departments, plans, and projects. This open discussion between peers is building networks that can help to inform and design the upcoming Kaua'i Resiliency Plan. Findings from the first exchange included that a strategically framed resilience plan can be used as a tactical "punch card" to track and demonstrate climate adaptation progress across many sectors; the necessity of communicating that physical risk from climate translates into financial

risk across sectors and can be used as a strategy to integrate departmental silos; and that while time consuming, on-the-ground outreach by the County to constituents from diverse communities is critical to achieve key outcomes and keep expectations realistic.

The entire Hawai'i and US-Affiliated Pacific Islands region is underserved and underrepresented in terms of investment in research, data availability, and national representation. The Pacific RISA recognizes that there are different levels of inequity and related power dynamics in any region, system, or organization. The County of Kaua'i represents community stakeholders on a rural island that has experienced multiple devastating extreme rainfall and flood events over the last several years. Furthermore, Kaua'i is often overlooked for community investment despite being marketed as an elite resort and remote-work destination. Through the Peer-to-Peer Exchange, Pacific RISA PIs are working with dozens of representatives from various Kaua'i County departments as they engage with underserved communities representing a diversity socioeconomic statuses, races, and ethnicities in development and implementation of their island-wide Climate Adaptation Plan. Additionally, although in-person attendance at the Columbia University Managed Retreat Conference was initially planned, the shift to a virtual conference meant that Pacific RISA was able to sponsor 40 virtual attendees from across more than a dozen County of Kaua'i departments, making attendance more inclusive and meaningful.

Water Accounting as an Adaptation Tool

Detailed longitudinal information on freshwater users and supply can guide resilience planning in the face of climate change. Sufficient and predictable freshwater supply is critical to many sectors of the economy, but organized information about sources and users of water is scant, limiting the ability to learn from past experience and adapt to future conditions. Water data in Hawai'i are collected and housed across various agencies, such as County Boards of Water Supply, the State Commission on Water Resources Management, federal agencies, and private entities. This disaggregation of data reduces the efficiency and efficacy of water management in Hawai'i at a time when the impacts of climate change make freshwater management more critical than ever for ecosystem and community resilience.

Using a specific set of compilation guidelines for water tables following a statistical standard set by the United Nations, known as the SEEA-Water framework, PI Oleson's lab has begun to compile water data for the counties of O'ahu and Maui. This project builds water asset, quality, and emissions accounts for the state, detailing stocks and flows between the environment and the economy for the two islands. The goal of developing the accounts is to guide policy and management choices about freshwater supply and use, including planning for resilience and adaptation as freshwater supply becomes more variable. The accounting tables will directly inform difficult choices about the water-energy-food nexus critical to Hawai'i's sustainability and security, and are envisioned as a transparent tool to help the State of Hawai'i meet sustainability goals. They can be used to track trends over time in water use and supply, as well as quality and reuse. The project is focused on O'ahu and Maui because these islands have much of the required data, partnerships have been established with multiple water-related partners and data providers, and policy makers have expressed a need for the information. The water-economy characteristics of these islands will also serve as good examples for expanding the accounts to other islands.

Thus far, the water accounting project, which has resulted in a draft O'ahu water accounting paper, has spurred interest in the State Office of Environmental Quality, and among operators of wastewater treatment plants interested in best practices. The Honolulu Board of Water Supply has already used the draft water account in an effort to synthesize data, and PI Oleson has presented the water accounting at the Pacific Water Conference, at a WRRRC seminar, for partner Ulupono Initiative, and at the Hawai'i Community Foundation. The work with other RISA partners on economic valuation has also led to development of an international workshop, which will coalesce a community of practice on economic evaluation of boundary-spanning work.

Future Plans

Forthcoming PIRCA Reports for the Marshall Islands and the Federated States of Micronesia

External evaluation has shown that Pacific RISA stakeholders want assessments to reflect more inclusively the needs and input of decision-makers from across the region. By developing a PIRCA report for each USAPI country and Territory, and with the involvement of more than 125 stakeholders in the NCA-PIRCA workshops, the 2020–2021 PIRCA is strongly focused on climate-related issues of importance to the wider Pacific Islands beyond Hawai'i. Pacific RISA Sustained Climate Assessment Specialist Zena Grecni is now coordinating the collaborative process to produce the next two reports in the PIRCA series for RMI and FSM. Although the pandemic has hindered the PIRCA team's ability to travel to RMI and FSM for in-person workshops, engagement has taken place through online meetings, calls, and emails. In RMI, the National Disaster Management Office has taken the initiative to coordinate a review of the draft PIRCA by an inter-ministry climate task force. The PIRCA reports published thus far have become valuable tools for local governments, natural resource managers, and other stakeholders and are instrumental in shaping climate policy for the Pacific Islands region.

New Methods for Determining High Sea Level Impacts

PI Annamalai is working with partners at the UH Sea Level Center to develop a new methodology for determining elevations of observed impacts from high sea levels, with respect to the coastal water levels measured by the nearest tide gauge. The team hopes to develop an efficient surveying methodology using established GPS technology, quantify the vertical uncertainty of the elevation measurements acquired, and determine if this is a feasible activity to include in future projects. It is anticipated that this effort will lead to an opportunity to reference the elevations of vulnerable coastal sites with respect to known tidal datums (e.g., Mean Sea Level or Mean Higher High Water) and water level observations from existing tide gauges. This approach will be applicable in many Pacific Island locations, many of which are very low-lying and already experience catastrophic flooding from extreme tidal events. Preliminary testing by UHSLC shows promising results. The technique is consistently measuring to within $\pm 0.03\text{m}$ the elevations of coastal sites that are known to be vulnerable to sea level inundation and/or wave run-up, and these measurements were acquired efficiently (i.e., using existing equipment and one to two technician-hours per site). After further testing, these preliminary results could be used to communicate about "Impact Datums", or elevations, by including the information on existing water level displays.

Most Significant Publications of the Year

Publication 1—This study detailed the first high-resolution water budget model developed for an entire high-basaltic island (Tutuila, American Sāmoa) within the South Pacific Convergence Zone (SPCZ). This, in addition to application of the model to project future conditions under both climate change and land cover change scenarios, made this project one of the more rigorous assessments of present and future water resources availability in the South Pacific Region to date. Because the model was developed with the goal of stakeholder engagement and use in mind, a participatory approach was applied to developing future land cover scenarios and the model was constructed and hosted on an open-source software development platform to make results available and reproducible. Present-day model results indicate that of Tutuila’s annual average of 1,490 mL/d of precipitation, 23% was lost to evaporation, 21% was discharged as surface runoff, and 56% or 827 mL/d (plus another 57 mL/d of direct infiltration), became groundwater recharge. Comparison to water budget studies from similar islands showed that Tutuila had a higher rate of recharge relative to precipitation, which was attributed to higher rainfall amounts and intensities found in the SPCZ relative to other regions. Tutuila’s unique geology, which imparts very high permeabilities to parts of the island, may contribute to this effect as well.

- Shuler, C.K., Brewington, L., & El-Kadi, A.I. (2021). A participatory approach to assessing groundwater recharge under future climate and land cover scenarios, Tutuila, American Sāmoa. *Journal of Hydrology: Regional Studies*, 34: 100785. <https://doi.org/10.1016/j.ejrh.2021.100785>

Publication 2—The work completed provides a systematic evaluation of predictor variables for possible use in a statistical downscaling model of precipitation, and serves as groundwork for future work in statistical downscaling for Hawai‘i. While predictive skill of the set of competitive models for each season is very similar from model to model based on cross-validation results, it is possible that models could produce very different results when applied to future scenarios depending on varying predictors. Some models could contain variables that better capture the global warming signal, like variables related to thermodynamics. For this reason, comparing the future rainfall projections between models of similar skill is of particular interest and may shed light on whether statistics alone are sufficient for model evaluation, or if background knowledge of the physical mechanisms of rainfall should be further incorporated into predictor selection.

- Sanfillippo, Kristen. (2020). *Predictor Selection and Model Evaluation for Future Rainfall Projection in Hawai‘i* (Master’s Thesis). University of Hawai‘i. Honolulu, Hawai‘i. <http://hdl.handle.net/10125/73340>

Publications

* Most significant Pacific RISA publications of the past year have an asterisk and an accompanying abstract on the prior page.

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- Brewington, L., Kokame, K., & Lewis, N. (In review). Climate change, health, and migration in the Pacific: A case study of the Marshall Islands. *AsiaPacific Issues*.
- Bremer, L.L., Elshall, A.S., Wada, C.A., Brewington, L., Delevaux, J.M.S., El-Kadi, A.I., Voss, C.I., & Burnett, K.M. (2021). Effects of land cover and watershed protection futures on sustainable groundwater management in a heavily utilized aquifer in Hawai'i (USA). *Hydrogeology Journal*. <https://doi.org/10.1007/s10040-021-02310-6>.
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- Coffman, M., Keener, V., Alegado, R., Fletcher, C., Mehnert, B. City and County of Honolulu Climate Change Commission. (Adopted: May 17, 2021). *Social Cost of Carbon Guidance Document*.
- Elison Timm, O, Li, S, Liu, J, Beilman, DW. (2021). On the changing relationship between North Pacific climate variability and synoptic activity over the Hawaiian Islands. *International Journal of Climatology*; 41 (Supl. 1): E1566– E1582. <https://doi.org/10.1002/joc.6789>
- Grecni, Z., Miles, W., King, R., Frazier, A., & Keener, V. (2020). Climate Change in Guam: Indicators and Considerations for Key Sectors. *Report for the Pacific Islands Regional Climate Assessment*. East-West Center, Honolulu, HI. <https://zenodo.org/record/4037481>.
- Grecni, Z., Miles, W., Greene, R., Derrington, E., Keener, V. (2021). Climate Change in the Commonwealth of the Northern Marianas Islands: Indicators and Considerations for Key Sectors. *Report for the Pacific Islands Regional Climate Assessment*. East-West Center, Honolulu, HI. <https://doi.org/10.5281/zenodo.4426942>.
- Keener, V. Alegado, R., Coffman, M., Fletcher, C., Mehnert, B. City and County of Honolulu Climate Change Commission. (Adopted: December 8, 2020). *Climate Change and Social Equity Guidance*. <https://resilientoahu.org/climate-change-commission/#guidance>.
- Keener, V., Grecni, Z., Shuler, C., Anderson Tagarino, K., & Miles, W. (2021). Climate Change in American Sāmoa: Indicators and Considerations for Key Sectors. *Report for the Pacific Islands Regional Climate Assessment*. East-West Center, Honolulu, HI. <https://doi.org/10.5281/zenodo.4663397>.
- Miles, W., Grecni, Z., Matsutaro, P., Colin, P., Keener, V. & Golbuu, Y. (2020). Climate Change in Palau: Indicators and Considerations for Key Sectors. *Report for the Pacific Islands Regional Climate Assessment*. East-West Center, Honolulu, HI. <https://doi.org/10.5281/zenodo.4124259>.
- Okuhata, B., Dulai, H., Shuler, C.K., Fackrell, J. & El-Kadi, A. (2020) Metal mobilization as an effect of anthropogenic contamination in groundwater aquifers in Tutuila, American Sāmoa. *Water* 12(8), 2118. <https://doi.org/10.3390/w12082118>.
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