Developing products in support of actionable climate science: My experiences as a NCCWSC Science to Action Fellow

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Fellowship project summary for *Conserving streams in a changing climate: Developing products and approaches using an ecological stream classification*

Background and need for project

Climate change will alter ecosystems worldwide and ultimately lead to changes in biological communities and loss of both aquatic and terrestrial biodiversity (Xenopolous et al. 2005, Thomas et al. 2004, Hari et al. 2006). In response to anticipated changes, management agencies are increasingly calling for development of proactive conservation strategies (Heller and Zavaleta 2009, Hagerman et al. 2010). On high elevation tropical Pacific Islands that support perennial streams, including the five main Hawaiian Islands, amphidromous stream organisms require continuous flows to facilitate their migration between stream and ocean habitats. In the Hawaiian Islands, rainfall sustains stream base flows (Lau and Mink 2006), meaning that projected declines in rainfall and prolonged drought events will likely lead to declines in stream flow. Combined with increasing anthropogenic disturbance, these climate-driven changes may result in changes or reductions in species' ranges, loss of habitat, and/or a potential loss of species (Melillo et al. 2014). In recognition of these threats and in support of adaptive management, the Pacific Islands Climate Science Center (PICSC) has called for development of tools to identify habitats likely to change with climate (Helweg et al. 2014). Further, the Pacific Islands Climate Change Cooperative (PICCC) emphasizes supporting development of tools for managers that enable climate change adaptation strategies (PICCC 2013). A classification that identifies Hawaiian streams most likely to change with climate and that is informed by stakeholder input offers an opportunity to meet these needs.

Stream classifications characterize differences in stream types across a region of interest. They can also be used to identify common types of streams as well as unique habitats, and can be used to identify areas sensitive to disturbances or that may be candidates for conservation or restoration (Melles et al. 2014, Hawkins et al. 2000). Ecological classifications that are built on relationships between natural landscape characteristics of catchments (i.e., drainage area, stream slope, geology), climate variables, and native species distributions can aid management by identifying streams that support unique species or that are highly threatened by disturbance. Including climate variables (i.e. temperature, rainfall) along with catchment characteristics in a classification allows for the identification of stream types most likely to be altered with a changing climate. In addition, ecological classifications can offer insights on stream habitat conditions in areas where biological or flow data are limited but continuous landscape data are available. In areas like Hawai'i, where many streams are sustained by persistent rainfall but gaged systems are rare, ecological classifications that use rainfall summaries as a surrogate for flow can be used to estimate the influence of a changing climate on endemic stream organisms including fish, shrimp and snails.

As part of my dissertation research at Michigan State University, I developed a classification of Hawaiian stream reaches based on relationships between climate variables, natural landscape characteristics, and native taxa occurrence. I conducted meetings with stakeholders throughout the development of the classification, beginning with the creation of a spatial framework based on ecologically meaningful reaches. I then acquired a dataset of stream taxa of conservation importance from the Hawai'i Division of Aquatic Resources (DAR) and the Hawai'i Fish Habitat Partnership (HFHP). Next, I worked with local managers and scientists to identify a large set of landscape and climate variables theorized or previously identified as important to species distributions (Kido 2008, Parham et al. 2009). I then used a multivariate analysis to identify which were most strongly associated with these taxa. Finally, I combined these results with ecological information from local stakeholders to create the stream classification (Figure 1; Tingley et al. in prep). The classification itself is a stand-alone product that helps elucidate some of the complexity inherent in Hawai'i's stream systems by associating measurable landscape variables, including annual rainfall, with native taxa. To maximize its utility, the

classification must be shared with stakeholders in the context of current conservation and management objectives. In addition, the quantitative approach taken has utility in other regions where stream classifications have not yet been developed.

Goal and objectives

The goal of my Science to Action Fellowship project was to incorporate the stream classification into management products and demonstrate the effectiveness of the overall approach to stakeholders in other data-limited areas, ultimately enhancing adaptive climate change planning. My first objective was to engage stakeholders charged with management and conservation of Hawaiian streams and to identify ways the classification can be used to enhance decision making and prioritize conservation efforts. Based on the results of my first objective, my second objective was to generate products (i.e. maps, data summaries) to aid in making conservation decisions based on results of the stream classification. My third objective was to engage stakeholders and researchers from other regions where a stream classification may be useful to conservation. This final objective allowed me to demonstrate the utility of the approach taken in Hawai'i and assess its applicability in other regions.

Project implementation and results

Engage stakeholders and identify ways to enhance decision making and prioritization

I conducted a series of conference calls, webinars, and in-person meetings with multiple stakeholder groups in Hawai'i over the course of my fellowship to identify ways that the classification could be used for management and conservation (Table 1). In March 2015, I organized an initial webinar with stakeholders to present the stream classification approach and my goal to incorporate it into management products (Table 1). Attendees included members of the Hawai'i Fish Habitat Partnership (HFHP), the Commission of Water Resource Management (CWRM): Stream Management and Planning Branch, individual watershed partnerships, the Division of Aquatic Resources (DAR) and the US Fish and Wildlife Service (USFWS). Follow-up meetings occurred with members of CWRM Stream Management and Planning Branch and members of HFHP to identify how the classification might be used to meet their needs. Members of HFHP expressed the need to develop tools that help prioritize on-the-ground conservation projects in the context of a changing climate. Members of CWRM Stream Management and Planning Branch expressed interest in obtaining a data layer that would allow for a quick assessment of native taxa likely to be supported by a given stream reach that could be used to assess the relative value of stream flow restoration efforts.

On July 21, 2015 I traveled to Hawai'i and met in-person with members of HFHP, DAR, TNC, USFWS and CWRM Stream Management and Planning Branch. During the meeting, the utility of the classification was discussed in the context of needs of HFHP and proactive conservation in the face of climate change. We also discussed the potential to use the classification for products that aid in conservation by assessing both current conditions and potential changes in stream types with a changing climate. The utility of the classification to other initiatives was also discussed, including the identification of priority areas for conservation that account for connectivity across freshwater and marine habitats. Priority nearshore marine habitats and biological datasets are being developed by Hawai'i DAR, and when combined with the classification may aid in the identification of areas of high conservation value in the future.

An additional meeting was held with members of CWRM Stream Management and Planning Branch on Jul 23, 2015 to discuss the classification in greater detail and its potential utility. Other applications of the classification were also discussed, including the potential to explore variability within stream reach types by including fine-scale habitat data that are currently being collected.

Generate products to aid in making conservation decisions

Based on the needs identified through stakeholder meetings, I developed products for CWRM Stream Management and Planning Branch and HFHP that will be used support proactive conservation in the face of a changing climate. For CWRM, I developed a spatial data layer based on the results of the classification that identified the ecological potential of a given stream reach as represented by taxa likely to be found within the stream (Tingley et al. in prep). This spatial layer was completed in the spring of 2016.

For HFHP, I first attributed and aggregated statistically downscaled rainfall data (Timm et al. 2015) to the spatial framework used in the stream classification for two different Representative Concentration Pathway scenarios (RCPs 4.5 and 8.5) over two different time steps (mid and late century). These data represent the most comprehensive and finest resolution projected rainfall estimates that currently exist across the five largest Hawaiian Islands. Data were summarized annually and for both the wet and dry season for each stream reach. This dataset is a product in itself and will be delivered to HFHP to use and disseminate. I also used these data to create a set of maps indicating regions that may experience a shift in their ability to support stream taxa based on changes in stream reach type with changing annual rainfall, as well as those rivers that deviate from current mean dry season rainfall and that may be at greater risk for declines in baseflow associated with seasonal drought (Figure 2). These products are currently being incorporated into a larger project funded by HFHP that directly addresses needs identified through the Science to Action Fellowship, a quantitative prioritization analysis that identifies freshwater areas of high conservation value under current and future condition. The results of this project are intended to be used by HFHP to inform the selection of priority catchments for on-the-ground conservation initiatives. In addition, a comprehensive project methodology describing the prioritization analysis along with the delivery of all datasets used in the analysis will allow this product to be updatable as new climate data become available, increasing its utility.

During the last year, the stream classification has also been used to inform the National Fish Habitats Partnership's risk of disturbance assessment in Hawai'i and is being prepared for a publication in a professional journal. Continued communication with stakeholders in Hawai'i during my Science to Action Fellowship experience has improved the quality of these efforts and established relationships with managers that will ensure the classification continues to be integrated into new management products.

Engage stakeholders and researchers from other regions

I engaged with stakeholders from other regions and explored the applicability of the classification approach to other study areas through my attendance at several professional conferences and in-person meetings (Table 2). I attended and presented at the Association for Tropical Biology and Conservation Conference (ATBC) at which time I discussed the potential application of the classification approach in Puerto Rico with regional researchers. This communication led to continued discussions with multiple researchers within Puerto Rico about the need to develop a stream classification that is capable of incorporating projected climate data to assess vulnerability of native species to climate change. Several datasets were identified that could support such a project, and I intend to explore this as a potential research direction. I also presented at the 2015 Annual American Fisheries Society Meeting, the 2016 Hawai'i Stream Conservation Workshop, and through a NCCWSC sponsored webinar, all of which increased exposure to the research I have been conducting and the products being developed with support from the Science to Action Fellowship.

Experience as a fellow

Experience during my visit to NCCWSC

I visited NCCWSC headquarters in Reston, VA from May 12 to July 11, 2015. During my time in Reston, I interacted with members of NCCWSC to discuss their research and responsibilities. I attended weekly staff and science meetings during which I obtained both an understanding of how NCCWSC functions as a managing entity of the CSCs and as a leader in climate science research. I also presented my research and received valuable input from researchers within NCCWSC on my proposed project during a weekly science meeting.

Many of my exposure opportunities came from within NCCWSC thanks to my mentor Dr. Shawn Carter as well as Dr. Doug Beard and Dr. Abigail Lynch. For instance, early on in my experience I had the opportunity to attend a meeting with the Integration and Application Network (IAN) at the University of Maryland regarding the development of new efforts by NCCWSC to highlight the need for research and regional understanding of ecological drought. Through this experience, I was able to observe how NCCWSC, with support from organizations such as IAN, operates as a managing entity to help build a national vision and direct research initiatives within CSCs by assessing regional similarities and differences related to an emerging climate science topic. Towards the end of my experience in Reston, I was also able to travel to the University of Wisconsin-Madison to attend a planning meeting regarding inland fishery adaptation for global change. Researchers from the University of Wisconsin and members of the Wisconsin DNR discussed the development of a policy-relevant research initiative proposed to support the proactive management of *Sander vitreus* (walleye) in the context of changing climate. During the meeting, I was able to observe how researchers and managers can work together to develop a project that supports proactive management while also answering specific scientific questions where definable uncertainty exists, thereby maximizing the potential for results that will become actionable science.

During my two-month visit to NCCWSC headquarters, I also had the opportunity to attend non-NCCWSC sponsored meetings and events that were occurring within USGS or in Washington, DC (Table 2). For instance, I attended a two day workshop sponsored by the USGS on the potential use of unmanned aircrafts in natural resource conservation and management. I also traveled to Capitol Hill for Science Briefing on Water Resources in the US, which allowed me to gain insight into the recent Clean Water Act rule changes. During these events and at other points during my stay in Reston, I was able to meet with colleagues and establish new connections with individuals from the USGS and other agencies and organizations.

Experience outside of my visit to NCCWSC

During the remainder of my fellowship year, I had additional exposure opportunities thanks to the Science to Action Fellowship. On November 17th, I completed a NCCWSC webinar in which I discussed my fellowship experience, the Hawai'i stream classification, and its utility in understanding effects of climate change on native stream taxa (https://nccwsc.usgs.gov/webinar/520). The webinar was well attended (>50 participants) and well received. This webinar has led directly to increased interest in the project from stakeholders in Hawai'i and has also put me in contact with other individuals who believe the classification approach is applicable for needs at regional and global spatial scales. I also attended the 2016 NCCWSC-CSC Spring Quarterly Meeting where I engaged with Directors and other members of the regional CSCs. At this meeting I learned about the new directions and priorities of NCCWSC and shared my experience through the Science to Action Fellowship with the broader NCCWSC

community. Towards the end of my fellowship, I was also given the opportunity to serve as a reviewer for a proposal to NCCWSC, which allowed me to apply the knowledge I gained on actionable science and the coproduction of science during my fellowship to a real-world scenario.

Lessons learned

My experiences through the Science to Action Fellowship have given me insight into establishing and maintaining relationships with stakeholders, development and implementation of actionable science and the challenges to consider when using projected climate data to inform management or conservation decisions. My conference calls and meetings with stakeholders in Hawai'i were invaluable for identifying ways in which the classification could be used to inform decision making. However, during the first stakeholder meeting and initial follow-up conservations, I largely discussed the details of my research and the goal of my Science to Action project, without tangible management products identified. When I opened the floor to discussion, I received little feedback from stakeholders on how the classification could be used to meet their needs. As the fellowship progressed, I took the advice of my university mentor Dr. Infante and began to push specific product ideas that I had considered in the context of the needs identified in strategic plans or the websites of each organization or agency. When I implemented this approach, I found that I received comments on my proposed product that eventually led to broader discussion on what would be of use to different organizations. What I learned from this experience was that when attempting to put science into action, you cannot expect stakeholders who are less familiar with your work to immediately see its utility. By presenting a tangible product or a specific idea in the context of their organizations objectives, you can start the conversation and relate your work to their needs more effectively.

My Science to Action Fellowship project involved the integration of existing work into actionable products, but during my experiences with NCCWSC, I developed a strong appreciation for the coproduction of science and the importance of establishing connections between stakeholders, researchers and funders early on in project development. While you can take a recently completed project and turn it into actionable science, starting from ground zero with stakeholders will be most effective at creating parallel objectives that meet local conservation needs while answering scientific questions. Ideally, the goal and objectives developed for actionable climate science should address a question or concept that is uncertain and that needs to be explored or answered to effectively manage.

During my exploration of available projected climate data in Hawai'i and through discussions with members of NCCWSC, I developed an appreciation for the uncertainty inherent within projected datasets, and the importance of recognizing uncertainty while still supporting management actions. It is therefore important to integrate uncertainty in future scenarios into product development through approaches like including multiple scenarios and datasets developed using different downscaling approaches and by statistically accounting for measured uncertainty in projections. In some cases, the best approach to dealing with uncertainty is to simply be explicit with stakeholders about the uncertainty within products developed using projected datasets and to work with them to identify the value of the product despite this uncertainty. Because climate projections will continue to be developed and will likely be available at higher resolutions with lower uncertainty in the future, the most valuable products can incorporate this new information or be easily replicated as new data become available.

Therefore, supplying stakeholders with dynamic products that are easily updatable with new climate datasets are extremely valuable.

Finally, as one of the first recipients of the Science to Action Fellowship, I did not have the ability to reach out to past fellows for advice. However, some of the most valuable insight I received regarding a successful fellowship experience was through individuals who completed similar fellowships with other agencies or organizations. Therefore, I think that the establishment of a network of former Science to Action Fellowship recipients would be valuable to incoming fellows. I would suggest that past and future fellows organize an annual meeting, after the awarding of that years fellowship, to discuss their past experiences and insights. I suggest that the new fellows lead in the organization of this meeting each year to start their fellowship experience. An added benefit of such a network would be the potential for collaboration and the sharing of knowledge among a broad group of future researchers and managers who have an avid interest and see the value in conducting actionable science.

Advice to future fellows

Reach out to past fellows to improve your experience and to increase networking opportunities

After receiving the fellowship, reach out to those who have already completed the experience to gain an insider's perspective on the experience you can expect. Continued communication and interaction with past fellows will also help us establish a network of researchers committed to actionable science and improve the experience for each new fellow.

Engage with the members of NCCWSC early to direct your own experience

Do not wait until you arrive at NCCWSC to begin your experience. As soon as you find out you have been awarded the Science to Action Fellowship, set up a time to meet with your NCCWSC mentor over the phone and set up a schedule to meet periodically throughout the fellowship with both mentors. Help your mentors understand what your career goals are and the type of research or outreach you are most interested in. This will help them identify individuals within and outside NCCWSC who can help you achieve your goals. You should also work with your mentor to ensure they will be in Reston and available during your visit to NCCWSC, as their schedule is often full of travel obligations. With this information, set a time frame to visit NCCWSC, reach out to individuals identified by your mentor ahead of time to set up in-person meetings and identify any logistics for your visit that need to be addressed (i.e. building access and security clearance).

Remember that the CSCs are also a valuable resource for you during your experience and may represent opportunities for partnerships in the future. At the beginning of your experience, browse the regional CSC websites and become familiar with their current initiatives and completed projects. If your project is region-specific, identify which CSC you should know more about and reach out to its members. They will be interested in your project and will likely offer valuable advice as you move forward.

Establish a basic understanding of Science to Action and other concepts before arriving at NCCWSC

Prepare for your visit by reading literature on topics that are emphasized within the goals of the fellowship and concepts embodied by NCCWSC (e.g. actionable science, the coproduction of science, proactive conservation, managing within the confines of uncertainty). Work with your mentor early on

to identify a few key resources or papers related to these topics and read through them before arriving at NCCWSC.

Attend every meeting, seminar and workshop you can

During your time at NCCWSC headquarters, there will likely be opportunities presented to you that may not seem directly related to your project. Remember that the fellowship is not just about a product or project goal, but about your exposure to NCCWSC and the USGS. Take advantage of the broad scope of opportunities that are available to you and actively inquire about any meetings or events that you might be able to attend. Make sure to read fliers and bulletins throughout the USGS building to identify additional opportunities that individuals within NCCWSC may not be aware of. If you have interest in a meeting or activity, ask if you can join or sit in. A seemingly unrelated concept or approach might influence your project or future work.

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Figure 1. An ecological classification of stream reaches of Hawai'i (Tingley et al. in prep)

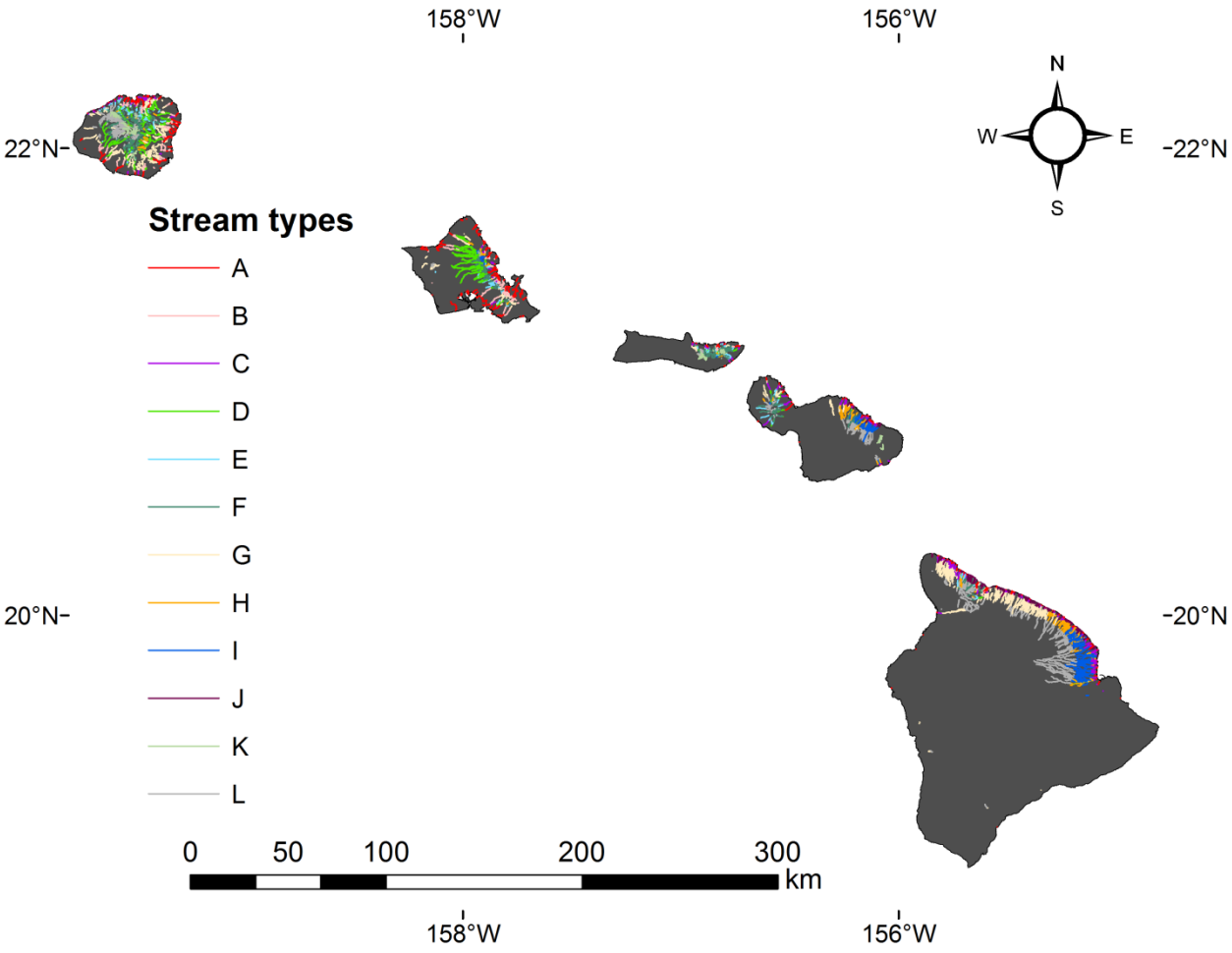

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Figure 2. An example of maps developed for HFHP that depict stream reaches that may shift in their ability to support native taxa as well as those reaches that are projected to deviate from historical average dry season rainfall. Projected climate data (Timm et al. 2015) were made available via the Asia-Pacific Data Research Center (http://apdrc.soest.hawaii.edu/projects/SD/)

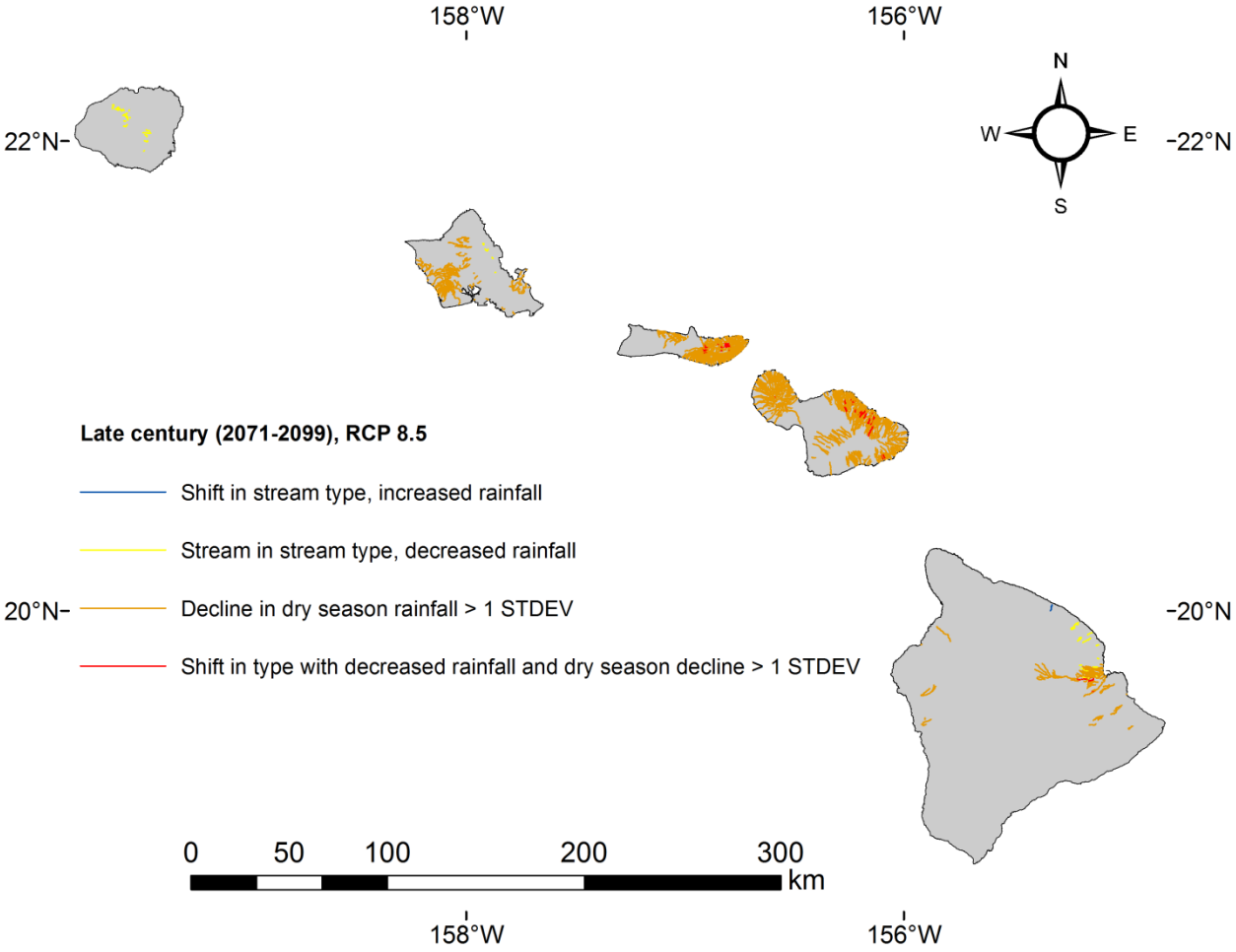

Table 1. Summary of talks, conference calls and webinars that I completed with support from the Science to Action Fellowship or that described products partly supported by the fellowship

Event	Date	Description
Initial Hawai'i Fish Habitat Partnership Webinar: Stream classification overview and potential applications	3/25/2015	Initial webinar with the Hawai'i Fish Habitat Partnership and members of other agencies to describe the stream classification and discuss creating management products
NCCWSC lab meeting	6/17/2015	Lab meeting in which I presented my stream classification in the context of the fellowship, in preparation for my trip to Honolulu
Association for Tropical Biology and Conservation Conference oral presentation	7/13/2015	Oral presentation on the stream classification approach in the context of actionable science
Follow-up Hawai'i Fish Habitat Partnership Webinar: Development of actionable products	7/21/2015	Webinar led in Honolulu to finalize stream types and discuss climate change product development
Commission of Water Resource Management: Stream Management and Planning Branch product meeting	7/23/2015	Face to face meetings with members of the CWRM Stream Management and Planning Branch to discuss product development
Oral presentation at the 2015 Annual American Fisheries Society Meeting	8/16/2015	Oral presentation on current efforts supporting the Hawai'i Fish Habitat Partnership, including the stream classification
NCCWSC Webinar	11/17/2015	NCCWSC webinar focused on my experiences during the STA fellowship and outcomes
Puerto Rico stream classification conference call	11/23/2015	Conference call with colleagues interested in a Puerto Rico stream classification
Hawai'i Stream Conservation Workshop oral presentation	2/24/2016	Oral presentation on a new project funded by the Hawai'i Fish Habitat Partnership aimed at identifying areas of high conservation value under current and future conditions

Table 2. List of events, webinars and meetings I attended while visiting NCCWSC headquarters

Event	Date(s)	Description
Integration and Application Network update and planning meeting	5/14/15	Update meeting regarding projects with the Integration and Application Network along with upcoming collaborations
Unmanned aircraft workshop	5/19/15 - 5/20/15	United States Geological Survey workshop with presentations describing current conservation research using unmanned aerial surveys
Science Briefing: Water Resources in the US	5/21/15	Science briefing on Capitol Hill related to the Clean Water Act rule changes
Pacific Islands Climate Science Center Webinar: Global Fiducials	5/22/15	Webinar describing the United States Geological Survey global fiducials dataset and the potential to establish an online fiducial database for the Hawaiian Islands
Landscape Conservation Cooperative Webinar: Strategic Steps for National Science and Adaptation Planning	6/11/15	A Landscape Conservation Cooperative (LCC) seminar describing LCC development and progress over the last 5 years
American Institute of Fishery Research Biologists networking event	6/18/15	An American Institute of Fishery Research Biologists social and networking event for young scientists
Planning meeting: Inland Fishery Adaptation for Global Change	6/23/15 - 6/24/15	Planning meeting focused on a new actionable science involving policy-relevant research on walleye
All-hands Climate Science Center meetings	Weekly	Weekly meetings with climate science center staff and regional directors during my visit to headquarters
NCCWSC Science lab meetings	Weekly	Weekly meetings to discuss individual research and/or topics of interest within the science team during my visit to headquarters
Quarterly Climate Science Center meeting	3/9/16 - 3/10/16	Quarterly meeting in Reston, VA