Title: Impacts of climate change on hydrology and primary production of three Hawaiian fishponds

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Project Goals: The aim of this project is to aid in developing tools and strategies for managing loko ʻi’a (Hawaiian fishponds) that acknowledges the potential impacts of climate change. The design of this project is to use three loko ʻi’a with unique characteristics (size, magnitude of freshwater input, connectivity to the ocean) to establish quantifiable relationships between a) groundwater inputs, b) groundwater fluxes of solutes, c) environmental factors (ex - rainfall, tides and moon phases), and d) benthic primary production. These relationships will then be used to develop models that examine the response of loko ʻi’a water quality and primary production to predictions of future rainfall and sea level. Additionally, the project will examine this socioecosystem through the perspectives of those who have a significant experience based relationship with the loko ʻi’a.

Project Products: Research products will include maps of bathymetry, groundwater springs, distribution of temperature and salinity within loko ʻi’a. These maps will be utilized by kiaʻi loko (fishpond managers) to plan for future inundation, identify different habitat zones within the loko ʻi’a for management considerations, and maximize water sampling strategies. Another product has been students and kiaʻi testing a data recording application that is run on a tablet to collect data and easily share data among kiaʻi. A user guide tailored for the needs of the kiaʻi and the format of their data was developed to visualize this data using Kibana software. Research publications will detail the variability of groundwater flow in the loko ʻi’a and predicted changes due to climate change that will be utilized to inform kiaʻi on groundwater discharge variability to develop adaptation strategies. Publications that detail the variability of primary production with salinity that will be utilized by kiaʻi to identify different habitat zones within the loko ʻi’a for management considerations, and maximize water sampling strategies.

Overall Progress: Visual and kayak-based surveys to measure depth, temperature, salinity and spring locations have been completed for all three loko ʻi’a. Depth, temperature, and salinity maps of two of the three loko ʻi’a have been completed. Time series measurements of pressure, temperature, and salinity have been ongoing at 6 locations since December 2016, and will be completed in December 2017 for one full year of data. Flow measurements at the makaha (opening in the loko ʻi’a wall) for all three ponds have been completed. Bi-weekly sampling of groundwater solutes (major ions and nutrients) within the loko ʻi’a began in February 2017 and will be complete in December 2017. Sampling of groundwater solutes (major ions, nutrients and stable isotopes of water) at 12 coastline springs is under way and will be complete by December 2017.

Fig 1. Loko ʻi’a (yellow stars) and station locations (numbered) along Keaukaha shoreline, Hilo, HI.
finished (Fig. 1). All samples will be submitted to the UH Hilo Analytical Laboratory for processing by December 2017.

To measure rates of primary production and grazing in the loko i’a, four tile set experiments in each loko i’a were completed in September and October 2017. Each experiment lasted six days and included a total of 45 tiles: five tiles per set (two grazing tiles, two non-grazing tiles, and one control tile), and three tile sets in each loko i’a: at the average lowest salinity region, highest salinity region, and one set in the adjacent marine environment. To identify different regions in the loko i’a, biweekly nutrient and weekly water quality observations were made at 8 different stations in each loko i’a between January and October 2017. Water quality samples for nutrients and chlorophyll a are completed. Water quality data was recorded in the field using makai-otto software on tablets. The software has been useful to kia’i through its time-efficient data storing and sharing abilities. Through this software, kia’i have shared masses of weekly water quality collections with the student to compile data and create the steps to visualize the data.

Kia’i were interviewed during June-July 2017 on the role of hydrology in their loko i’a and their needs regarding hydrologic information. Three categories were identified from these interviews: data management, educational outreach, and community connection. Kia’i identified Kibana visualization software as a powerful tool for presenting the hydrologic data recorded using the makai-otto software app for funding, presentation of progress, and educational purposes. We wrote a “how-to” install Kibana guide, including extra resources available to assist in the installation and operation of Kibana. Co-PI John Burns, the point of contact for these tools, submitted a proposal to the Purple Maia’a Foundation Aloha ʻĀina Challenge to improve these tools and was a first place winner for additional support of this effort.

Preliminary Findings: Water levels in the loko i’a remain higher than sea level at low tide, demonstrating that the loko i’a walls act as a barrier to the flow of water out of the ponds. Salinity in each loko i’a varies with the tides, with increases in salinity as seawater pushes into the loko i’a, and decreases in salinity as water flows seaward (Fig. 2). This difference in water level height inside and outside the loko i’a and the changes in salinity will be used to quantify daily changes in groundwater flow out of the loko i’a. The magnitude of mixing between fresh and seawater differs among the loko i’a, with some regions experiencing regular flushing with seawater, while others only experience higher salinity during the largest tides of the month.

Chemically, differences have been noted among loko i’a and at the springs along the shoreline. Analyses are underway to quantify these differences (Fig. 3).
Qualitatively, different benthic algae were observed in different salinity regions. The substrate where the tiles were deployed influence productivity, with muddy areas interfering by displacing the algae. The difference between grazing vs. non grazing tiles was not as great as expected, perhaps because cages were only big enough for juvenile herbivorous fish to feed. Lastly, an interesting observation was the presence of ‘o’opu ‘akupa (Hawaiian goby) sitting and laying eggs on the tile on numerous occasions in both Honokea Loko and Kionakapahu Loko.

**Ongoing Activities:** Time series measurements of temperature, salinity and pressure and discrete water quality samples from groundwater springs will be completed in December 2017. In the coming months, the following work will be completed: analysis of water quality samples for plankton and bacteria counts (flow cytometry); primary productivity tile experiment samples processed for Chl a, ash-free dry mass and particulate C and N; data analysis from flow measurements at two of the loko i’a makaha; and, depth, temperature and salinity maps for one remaining loko i’a (Hale o Lono). Final data analysis and manuscripts will be completed in the Spring 2018.

**Broader Impacts:** Without the help and input of many hands, this project is not made possible. During the Summer 2017, two PIPES undergraduate interns, Kainalu Steward and Candice Miner-Ching, assisted with the project. This semester, two Keaholoa STEM program students, Joelle Guerreiro and Mary Metchnek, are making flow measurements at the makaha, and two Ike Wai (EPSCoR) interns, Kainalu Steward and Uakoko Chong, are assisting in biweekly water quality collections, tile experiment deployments, chlorophyll a processing, and data organization. Four additional community members who have been instrumental in the physical labor of building tile experiments, deploying experiments, and scraping tiles.

Outreach has played a major role in informing our keiki and various community members about climate change and loko’i’a. At Honokea loko i’a, water quality and flow rate trainings have taken place for our community high schools. UH Hilo courses that visit weekly have also participated in the processes of our data collection as they shadow our work in the field and discuss the relationships in which we discover throughout this project.

Formal and informal presentations and interviews regarding this project have been active throughout the last year. Both graduate students have presented at Island Sustainability Conference, Guam (April 2017), the Hawai’i Conservation Conference, Honolulu (July 2017). Locally, they have presented to the Hilo chapter of the Sierra Club (May 2017) and the Marine Option Program Seminar Class (March 2017, October 2017). The students also lead a field trip to the loko i’a as part of their Sociology 408 Island Feminism course to discuss the effects of climate change on our island in relation to loko i’a (October 2017). We have also collaborated with the Pacific Island Climate Change Cooperative to feature the PI-CSC Manager Climate
Corps through perspectives on climate change at Honokea by kia’i loko, scientists, professors, students, and community members (September 2017).

Collaboration: Collaboration plays a central role in this project, and is necessary for loko i’a restoration while responding to climate change. The goals of this proposal were developed through an initial collaboration among kia‘i, Hawai‘i DAR manager of estuarine fisheries, and researchers from UH Hilo with expertise in hydrology, primary production, data sciences, and socioecology. Graduate students have had at least bi-weekly interactions from Dec 2016-Dec 2017 with kia‘i in order to complete their bi-weekly water quality sampling. These casual interactions have included regular project updates from students and loko i’a activities from the kia‘i (e.g. activities at the loko i’a, project-relevant updates such as impact of king tide events). DAR manager Troy Sakihara has been instrumental in demonstrating laboratory methods for processing settling tile experiments. Most of the project participants attended the PI-CSC Climate Science Boot Camp (Aug 2017). Formal meetings of all participants to discuss project activities and progress, share preliminary results, and discuss research products were held Oct 2016, Nov 2016, June 2017, and Nov 2017. All but one of these meetings was held at one of the loko i’a, which has strengthened the connection among participants and the study sites. Additionally, thesis committees met to discuss the project and progress for Ms. Kauahi in May 2017 and September 2017 and for Ms. Anthony in December 2016 and July 2017. During Summer 2017, additional talk-story sessions with kia‘i were held to introduce summer interns to each loko i’a and to interview each kia‘i regarding their needs regarding information on hydrology, water quality, primary productivity and climate change. An informative presentation that introduced this study and the data-software app for potential use through all lokoi’a in Hawaii was made to the larger loko i’a hui at the annual Hui Malama Lokoi’a gathering in Hilo (April 2017).

This project has created stronger communication along the Keaukaha coastline through the loko i’a in this community, and a tighter network that is a consistent source of support throughout the community. The project has allowed kia‘i to converse about relationships in the ecosystems that have been discovered through this project. For example, the tile experiments have sparked interest in kia‘i at Hale o Lono to do this experiment in a more controlled environment in pens in the loko i’a. Also, ‘o’opu ‘akupa were lingering on the tile sets in both Hale o Lono and Honokea Loko and discovered that they were laying eggs on the sets of each loko i’a that were at the highest salinity regions. Moreover, the tile experiment has allowed the kia‘i to see that juvenile fish species are indeed feeding on the algae on the tiles which allows them to question what those varieties are. The Kibana data visualizations of water quality data across all stations and parameters over time fascinated kia‘i, and made them eager to understand this tool to use it more actively in understanding the oxygen, salinity, and temperature relationships throughout their loko i’a ecosystems.