Climate Change & Pacific Island Water Resources

Year 1 Initiative Overview & Progress, October 2010

Problem Statement

The global impact of climate change on watersheds and stream biota is growing, but few model systems exist for examining the changes resulting from warming and drying. Stream ecosystems are also threatened by invasive species, and a warming climate will likely exacerbate changes due to invasions. Information from our work will increase capacity to provide effective restoration and watershed management techniques to protect water resources of Hawaii as well as increase their resilience to climate change.

We have assembled a broad team of scientists and land managers to examine how climate change and invasive species are impacting watersheds of windward Hawaii Island.

These watersheds represent a model ecological system and a unique opportunity for examining climate change and invasion because the watersheds span a spectacular rainfall gradient (2,000 to 6,000 mm of rain per year), but soils and vegetation are nearly constant (young volcanic soils and *Meterosideros polymorpha* dominated forests). Further, these watersheds are very compact with just a few kilometers between stream headwaters and the shoreline. By bringing together land managers, ecologists, hydrologists, social scientists, and modelers, as well as state-of-the-science remote sensing tools and a new established climate and vegetation observing network, we are poised to address at landscape scales pressing questions about climate change and invasive species impacts on tropical water resources.

Fig 1. Shifts from native species dominated forest (top) to invasive strawberry guava (bottom) changes watershed hydrology and resilience to climate change. See Page 2.

Project Partners

- USDA Forest Service PSW
- University of Hawaii
- US Geological Survey
- Watershed Professionals Network
- Carnegie Institute of Science
- Kamehameha Schools
- Division of Aquatic Resources
- Michigan State University

Objectives

- Use state-of-the-science hydrological modeling and remote sensing to understand potential impacts of climate change and invasive plant species on water yields, water quality and stream biota across windward Hawaii Island.
- Create a stream measurement and monitoring network to compliment our terrestrial observations. This network will provide critical data for validating models scenarios, asking stream ecology questions across our wide precipitation gradient, and understanding how climate and vegetation interact on inter-annual time steps to affect stream flow, water quantity, water quality, and stream biota.

Intact stream flowing through a native Hawaiian forest.

- Develop citizen research and project-based educational opportunities in hydrology and stream ecology for K-12 and university undergraduate students, graduate students, and local community members through structured field trips, summer field courses, and carefully mentored internships.

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Defining the Project Area: Hydrologic Framework

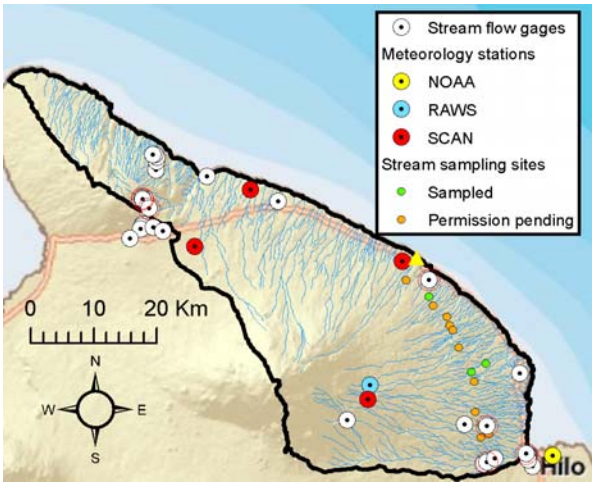

Fig 2. Project area map of the hydrologic framework for 157 mapped stream drainages, location of active stream gages, current climate stations, and biological response measurement sites. The yellow triangle represents the location for the modeled changes in water availability for an increased invasive species and no climate change scenario conducted as the pilot phase (see Fig. 3 below).

Located on the windward coast of Hawaii Island, we identified and refined the mapping of stream layers for 157 individual drainages in the ~2,000 km^2 region.

Rainfall ranges from ~2,000 to 6,000 mm per year along the ~4,200 m elevation gradient.

Streams were remapped and assigned to 157 drainage points along the shoreline, to be used as sites to evaluate modeled water flow. Six active stream gages in these drainages (see circled gages) were used for validating and calibrating the distributed model, using a 3 year period of climate and gage records to simulate the hydrograph. This allows for direct evaluation and validation that the model is reflecting the current conditions and can be used to model changing scenarios (climate change, invasive species, development, restoration, etc.). Additional gaging stations are slated to be installed in early 2011 to refine model calibration.

Working with multiple partners provides unique opportunities to pool climate change research and evaluate potential watershed restoration actions

Runoff Responses to Invasive Species & Climate Change

Using the Distributed Hydrology, Soils and Vegetation Model (DHSVM), data collected from project partners were assembled into a central platform to evaluate the effects of changing land cover, invasive species, and climate change influences on water quality and availability in the region.

The objectives of the first phase of this work involved the validation and calibration of the hydrologic model to current climate, vegetation and soils profiles, including the physical parameters that affect hydrology (evapotranspiration, root depth, canopy characteristics, soil parameters, etc.).

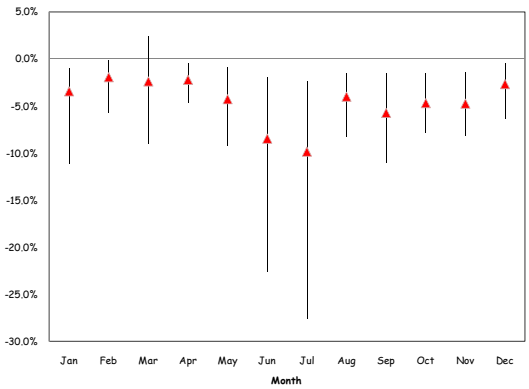

Fig 3. Percent change in monthly runoff with increased strawberry guava, holding climate a constant at Laupahoehoe (see yellow triangle in Fig. 2).

Following verification of the model, we examined the watershed level effects of biological expansion of strawberry guava into neighboring stands (100 m expansion into native forest, see Fig. 1) and evaluated the change in monthly flows over a 3 year period, as compared with the current condition (Fig 3). The resulting changes exceed 10% of available water in the dry months. Climate scenarios as well as land management options are in development to evaluate effects of water availability in the region.

Research & Development

Pacific Southwest Research Station

Establishment of Study Sites and Project Design

Long-term study sites will be established in streams along a precipitation gradient (< 2,000 to 6,000 mm mean annual precipitation), while other factors such as vegetation, soil series, substrate will be held constant. To date, right of entry has been gained to 14 different streams along the Hilo region of Hawaii Island (Fig. 2). Four long-term study reaches have already been established in these streams; four more are currently being selected. In 2010-2011, stream gages will be installed in all eight of these streams to monitor stream discharge and temperature; a subset will also measure dissolved oxygen, pH, and conductivity. Preliminary results have revealed that these streams are dominated by native organisms, such as the shrimp (opae) *Atyoida bisulcata*.

Fig. 4. Native shrimp (opae, *Atyoida bisulcata*).

Decreased stream flow is expected to have negative impacts on several ecosystem services that are vital for the well-being of Hawaii's citizens.

Biological Responses to Climate Change

Fig. 5. Hawaiian intern retrieving leaf litter packs from Manowaiopae stream, which is located on the drier end of the precipitation gradient.

Leaf litter/wood decomposition

Studies have begun examining how climate change will impact leaf litter decomposition from native and exotic trees. Leaf litter inputs to coastal areas support economically and culturally important fisheries. Decreased stream flow is expected to increase leaf decomposition and negatively impact these fisheries. Future studies will include wood.

Shrimp production

Native shrimp are an important ecological and cultural component of Hawaiian streams. Shrimp production, reproduction, recruitment, and food web structure will be measured in streams across the precipitation gradient to model how altered stream flow from climate change or diversions impact these valuable organisms.

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Flower in bloom of the ohia lehua tree (*Metrosideros polymorpha*), the most common native tree of Hawaii

This watershed initiative will provide integrated knowledge and techniques vital to increasing the resilience of native dominated tropical watersheds to climate change, while informing managers on restoration options for sustaining ecosystem goods and services.

Moving Forward, Leveraging Partnerships

- Through the alliance of research and land management organizations, this initiative will yield knowledge and tools needed to address climate change and invasive impacts on **stream biodiversity** and **watershed function.**
- This initiative will position the **Pacific Southwest Research Station** to partner with the **Pacific Northwest Research Station** to anticipate and manage climate driven changes to stream temperatures and biota, while directly supporting the knowledge needs of the **Pacific Islands Climate Change Cooperative.**
- The resulting framework will allow unprecedented coordination with the **Northern Research Station** and the **International Institute of Tropical Forestry** on national level climate change and water research.
- This partnership-based initiative will be informed by and will deliver research products directly to land managers so outcomes are rapid and relevant to society.

Timeline & Future Work

- **2010:** (i) Parameterized and calibrated DHSVM model, (ii) identify long-term study reaches in 6-8 streams , (iii) begin to sample nutrients and invertebrates from these streams (See pages 2 and 3)
- **2011:** (i) Forecast impacts of climate change and invasive species on water quantity and quality, (ii) install stream gages in each long-term study reach, (iii) develop rating curves for each stream, (iv) sample streams for nutrients and invertebrates, (v) initiate long-term leaf litter and wood decomposition study
- **2012:** (i) sample streams for nutrients, invertebrates, leaves, and wood, (ii) collect and analyze samples for stable isotopes, (iii) examine response of stream variables (flow, quality, biotic variables) to spatial variation in climate variable and compare with modeling output, (iv) adapt and validate stream focused decision support tools (e.g., NETMAP from the PNW) for Pacific Island streams, (v) develop model to determine how changes in stream flow alter native shrimp production, reproduction, and recruitment.
- **2013:** (i) sample streams for nutrients, invertebrates, leaves, and wood (ii) collect and analyze samples for stable isotopes, (iii) begin larger scale extension of "NETMAP" type DST to water resource managers on the Island of Hawaii.
- **2014:** (i) sample streams for nutrients, invertebrates, leaves, and wood, (ii) collect and analyze samples for stable isotopes, (iii) examine response of stream variables (flow, quality, biotic variables) to interannual variation in climate variables, (iv) compare findings with both gradient data and modeling output.

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