I. **Project Title:** Assessing success with the Kahekili Herbivore Management Region  
**Principle Investigator:** Dr. Celia Smith  
**Project Staff:** Meghan Dailer, Hailey Ramey and Robin Knox  
**Organization:** University of Hawaii, Manoa  
**Grant Number:** NA07NOS4000193  
**Date:** 8/1/09 to 4/30/10

II. **Executive Summary of this progress report**

Our goal is to understand the impacts of several steps taken in the Kahekili region to improve the health of that coastal area. Among these steps are following the progress of the Kahekili Herbivore Management Area established by the Division of Aquatic Resources in July 2009 as well as experiments and field observations of the nutrient supplies available to drive rapid accumulation of algal biomass in the same region. Specific questions are outlined below with our results added in those descriptions of tasks.

III. **Purpose**

A. **Detailed description of the resource management problem(s) to be addressed.**

Our goal is to understand the impacts of several steps taken in the Kahekili region to improve the health of that coastal area. Among these steps are following the progress of the Kahekili Herbivore Management Area established by the Division of Aquatic Resources in July 2009 as well as experiments and field observations of the nutrient supplies available to drive rapid accumulation of algal biomass in the same region. Specific questions are outlined below with our results added in those descriptions of tasks and approach.

B and C. **Detailed description of the question(s) asked to answer the resource management problem(s) and overarching goal(s) of the project**

1: Can one detect differences in the fish populations or benthic community with the closure of the Kahekili to the taking of key-herbivores? Does this closure result in increases of their biomass in a short time (\( \leq ~ 1 \) yr) when compared to control areas?  
2: If herbivore populations recover in \(< 1 \) yr, does that increased biomass of herbivore associate with a decline in the distribution or abundance of invasive algae at Kahekili, when compared with control areas?  
3: How quickly do the most abundant algae in the new HFMA out-compete corals for space. How persistent is their presence once space is occupied?  
4: Can in situ and in lab growth rates / isotopic signatures indicate nutrient sources?  
5: Can *Ulva fasciata* or another more mechanically tough alga be used as a bio-indicator of excessive land based nutrients in terms of concentration and source(s) when deployed at the location of concern for a specified time period? What are the rates at which these sheet-form algae respond to nutrients from land-based sources?  
6: Because we can use arrays of *Ulva fasciata* to map the effluent plume from the Lahaina Wastewater Treatment Plant in the Kahekili HFMA, can we detect changes in the plume (expansion and contraction) with high and low tourist occupancy in Lahaina?  
7: Do nutrient uptake rates and growth vary in response to altered pH?
8: Injection well effluent has a neutral pH of ~7 while coral reef communities have evolved to pH 8.2. To what extent is the algal bloom helped or hindered by nutrient rich effluent that is more acidic than usual coastal oligotrophic waters?

9: How variable is the $\delta^{15}$N signal in the effluent from the Lahaina Wastewater Reclamation Facility?

10: What are the likely major nutrient sources that sustain algal growth at control and experimental sites?

11: Can stable isotope studies reveal mixed nutrient histories? Is it possible to make a $\delta^{15}$N dilution model with nitrogen from agricultural fertilizers and sewage effluent (two major sources of nutrient enrichment on Maui) to observe the change in tissue $\delta^{15}$N values when the alga is exposed to both sources in different concentrations?

12: Conduct policy analysis to identify institutional programs through which sources of nutrients can be controlled or mitigated.

IV. Approach

Measure the “after” impacts of the Kahekili HFMA closure in the BACI design at three study areas: Kahekili Herbivore Fisheries Management Area (HFMA), and comparable West Maui reference areas, at Honokowai (north of Kahekili HFMA); and Canoe beach (south of Kahekili HFMA). (Addressing Questions 1-3) Completed and ongoing by Meghan Dailer (UH Botany), Hailey Ramey (UH Botany), and Maui-DAR

An aspect of the Maui-DAR and HCRI partnership for this project includes the surveys mentioned here. The Maui-DAR and HCRI teams assessed herbivore populations and benthic composition (coral and algae) across a broad spatial-range, but relatively narrow depth-range: at 3 ‘sites’ per ‘area’, with each site comprising two sub-sites (at 3m and 7m deep). Benthos and herbivores were surveyed across 90 transects in July 2009 and will be surveyed again in July 2010 (after one year of closure). Herbivorous fish and sea urchins were surveyed by pairs of divers swimming side-by-side down transect lines. Divers recorded the number and size (in 5cm size intervals, e.g. 0-5cm; 5-10cm, etc…) of all herbivorous fishes and sea urchins were counted by species. During each survey, all herbivorous fishes >10cm total length (TL) were counted swimming within or directly above a 5m-wide belt on the outward swim, and all herbivorous fishes <10cm TL and grazing urchins within a 2m wide belt on the return swim. Benthic surveys were comprised of 10 random photoquads (0.5m x 1.0m) per 25m transect (900 total photoquads in July 2009). The photoquads from the July were analyzed with PhotoGrid software with 50 random points per picture which were identified by substrata (i.e. turf, limestone, sand, coral rubble, and basalt) or systematically (i.e. genus species for coral, algae, and sea urchins). The Maui-DAR team will compile the fish data the HCRI team will compile the benthic composition and the sea urchin data and the combination of these data will provide the answers questions 1 – 3 above.

Monitor and experiment with algal physiology and stable isotopes in Ulva
(Addressing Questions 4-6) Completed and ongoing by Meghan Dailer and Hailey Ramey, UH Botany

Continuing monitoring from February 2009, in August/September and November we
deployed algal bioassays consisting of acclimated samples of *Ulva fasciata* in small cages at 32 sites (n=3 per site, 96 samples total) across 2100 feet of the degrading reef in the Kahekili HFMA with six transects extending seaward and 14 alongshore sites for growth rate, tissue composition and stable isotope determinations. We have expanded this monitoring effort from a sub-surface array to an array that extends to the surface with algal samples stratified throughout the water column (Figure 1). The basis for deploying algae at the surface of the water at the deeper offshore sites is that the wastewater effluent is freshwater and more buoyant than seawater, which will likely cause it to rise to the surface, so our previous arrays extending only 0.5 meters from the benthos in 6 meters of water likely underestimated the effluent plume boundaries. In accordance with the Division of Boating and Recreation, when the surface array is deployed, flyers about the project are posted at Mala boat ramp and at Kahekili Beach Park (Figure 2). As described in the flyer, the perimeter of the array consists of large (2ft by 2ft) orange buoys that charge during the day via solar panels and automatically light up at night, providing a lit perimeter for boaters. We deployed the array in February and April and will be deploying the array again in May and June. Initially, in February, the array consisted of 261 samples total, we waited for the results from the north and south end points to determine if the array area needed to be expanded (if we still found elevated nitrogen signatures). The nitrogen signatures at these locations at the surface were higher than initial values, so we added a transect in the north and relocated the two farthest south transects (Figure 3). The surface array now consists of 291 samples total and spans 900 meters of the Kahekili HFMA. A total of 552 samples have been deployed and a total of 515 samples have been processed and sent to the Hawaii.

This field work is cooperative with other researchers to have bacterial and water characteristic (temperature, salinity, dissolved oxygen and turbidity) sampling coordinanted with the algal physiological monitoring. We have assisted the HCRI-Toonen team to the affected and control sites for seep sampling collection and coordination of the algal bioassay and water quality characteristics, which will provide useful datasets. The reef community at Olowalu Maui is designated as a control site, with low nutrient impacts.

**Conduct a nutrient enrichment experiment to explore the effects of a gradient in pH as well as Nitrogen (N) and Phosphorus (P) independently and in combination on the growth and photosynthetic properties of *Ulva fasciata*.** (Addressing Questions 7 and 8) To be completed by Meghan Dailer and Hailey Ramey, UH Botany

This experiment aims to identify the effects of decreasing pH on the physiology of *Ulva fasciata*. The most practical way to conduct this experiment is still being determined.

**Monitor the isotopic signatures of the wastewater from Lahaina WWRF, freshwater seeps and other conspicuous sources of nutrient loading as well as ‘control’ sources.** (Addressing Question 9) Completed and ongoing by Meghan Dailer, Hailey Ramey and Robin Knox, UH Botany

The variability of nitrogen isotope values of the Lahaina Wastewater Reclamation Facility effluent has never been determined. We have detected the presence of effluent
seeps in the nearshore region of the Kahekili HFMA which has a signature range of 33 to 50 ‰ (determined through algal bioassays). However, further denitrification could be occurring while the effluent travels underground to the ocean. We proposed to sample the effluent at the facility extensively to determine how variable the nitrogen isotope signature is. Unfortunately we are not able to perform the study because we are no longer allowed access to the wastewater effluent (please see attached letter from Cherly Okuma, Director of the Environmental Management Division for Maui County). We are still able to deploy algal bioassays across the wastewater affected Kahekili area (mentioned above) and we will sample the freshwater seeps at Kahekili and Honolua, as well as, the reclaimed water used on the Kaanapali Golf Course (pending collaboration), fertilizer from agricultural lands and natural background sources (upland streams and oceanic water).

**Conduct literature review to identify known relationships of point and nonpoint sources of pollutants, algal blooms, coral and microbial communities (Addressing Question 10).** To be completed by Robin Knox, UH Botany

This literature review aims to identify the primary point and nonpoint sources of nutrients within the watershed feeding into the study area and the conduits of transport of these materials and substances. Another goal was to identify watershed hydrologic characteristics that influence the delivery of nutrients to coastal waters through review of existing data and literature, and reconnaissance surveys. Using readily available data we hope to develop an order of magnitude estimate of nutrient loading from point and nonpoint sources contributing nutrients to the study area and identify data needs for improving estimates.

A Freedom of Information Act request to USEPA Region 9 produced complete copies of the hard-to-obtain reports and technical appendices completed by Tetratech in the early 90’s. “Preliminary Assessment of Possible Anthropogenic Nutrient Sources in the Lahaina District of Maui”, June 1993 and “Effluent Fate Study Lahaina Wastewater Reclamation Facility, Maui Hawaii, February 1994”. A detailed review and a comparison of current to past loading rates is underway. The Tetratech reports contain information that will allow a comparison of current estimated nutrient loading rates to those estimated in the early 90’s, as well as a data gap analysis and recommendations for additional studies. The preliminary assessment report indicated that the Lahaina WWRF and agriculture (pineapple, sugar cane) were the primary sources of nutrient loading. 10-20% of the applied agricultural nutrients and essentially all of the treatment plant effluent nutrients were estimated to be released into ocean waters; however estimates were based on limited information regarding nutrient transport data and were intended to be verified by additional monitoring.

Table 1 – Nutrient loading estimates for Lahaina District (Tetratech, 1993)

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<tr>
<th>Nutrient Source</th>
<th>Nitrogen applied or injected (lbs/year)</th>
<th>Phosphorus applied or injected (lbs/yr)</th>
<th>Nitrogen reaching ocean (lbs/year)</th>
<th>Phosphorus reaching ocean (lbs/year)</th>
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It should be noted that in 1993, the wastewater treatment system did not achieve the level of denitrification and nitrogen removal seen in the current plant; the total nitrogen of effluent quality was 11.9 and 11.9 mg/L for the 1975 and 1985 treatment plants respectively. %0% of the total nitrogen from the 1975 plant was present as ammonia. Due to improved nitrogen removal in the treatment system (and the abandonment of the 1975 plant), the current estimate of the effluent total nitrogen from the Lahaina WWTF is 70,000 lbs/year, which occurs primarily as nitrate. The Tetratech 1993 report determined that a considerable part of the sustainable yield of the aquifer was from irrigation return flows that “significantly alters the hydrologic balance”. The primary regional concern identified was the high dissolved solids which may increase due to saltwater intrusion, aquifer pumpage, and nitrates from irrigation return flows. The high dissolved solids in the Lahaina effluent is one of the constraints that limits reuse of the effluent according to information presented by County of Maui reuse coordinator Steve Parabolic to the Community Working Group (appointed by Mayor Tavares to seek ways to eliminate injection wells and reuse effluent).

**Wastewater and fertilizer nitrogen mixing experiment (Addressing Question 11)** To be completed by Meghan Dailer and Hailey Ramey, UH Botany.

This experiment aimed to (1) explore the effects of wastewater effluent and agricultural fertilizers first independently and in combination on the growth and photosynthetic properties of *Ulva fasciata* and (2) observe stable isotope changes in the algal tissue when supplied with different levels of wastewater and fertilizer (e.g. 15% sewage effluent and 5% fertilizer added to low nutrient oceanic water will create what δ¹⁵N value in the alga?). Unfortunately, we are not able to perform this experiment because we are no longer allowed to access a source of wastewater. If access is granted we will perform the experiment.

Because we are not able to perform this experiment we performed a different experiment on *Ulva fasciata* that aimed to solidify the use of this alga as a bioassay for nitrogen source (as long as one source is dominant) and nitrogen concentration. This experiment used reagent grade ammonium and phosphorous solutions and aimed to reach tissue nitrogen saturation levels by providing acclimated samples (n=6 per treatment, 7 treatments) with a range of seven nitrogen and phosphorous concentrations from 0 to 275 µM NH₄⁺ and 0 to 12 µM PO₄⁻. We measured growth, photosynthetic yield, chlorophyll a, tissue nitrogen, carbon and phosphorous.

**Conduct policy analysis to identify institutional programs through which sources of nutrients can be controlled or mitigated. (Addressing Question 12)** To be completed by Robin Knox UH Botany.
Identify existing laws, regulations, policy and procedures at federal, state, and county levels that govern water quality management, and control of point and nonpoint sources of nutrients. Identify common programmatic goals and key procedural or decision-making opportunities where interagency sharing of information and expertise, or integration of management activities can enhance nutrient load reduction. Identify areas where project information can be used in management programs, and identify questions that managers need to have answered by project research and provide local technical capacity to facilitate watershed planning including identification of nutrient sources, watershed characterization, development of loading estimates, and identification of opportunities for load reductions. Robin Knox has been researching applicable laws, regulations and policies at county, state, and federal levels; coordinating efforts and participating in meetings with representatives of agencies including the US Army Corps of Engineers, and county wastewater and planning officials.

The policy issues identified and published in Dailer et al (2010) are being further developed with regard to implementation of coastal zone management programs delegated to county decision-making processes. A policy paper is in preparation to document the connections between programs in implementing pollution control and coastal zone management. Identification of coastal zone management and pollution control policy issues have arisen in public debate of issues such as the Maui County Planning Director’s decision to exempt from Special Management Area permitting and Hawaii Environmental Policy Act assessments the drilling of two new injection wells for disposal of Kahului WWRF effluents.

The County of Maui was both applicant (Division of Environmental Management) and Permit Granting Authority (Department of Planning). The Planning Director granted an exemption on the premise that there were no environmental impacts from installing two new wells, and argued that it did not meet the definition of development (subject to SMA permitting and environmental assessment), but rather was repair and maintenance of underground utilities and therefore was exempt from permitting and environmental assessment requirements.

The DIRE Coalition appealed the decision claiming it was in error, not consistent/compliant with state and federal pollution control and coastal zone management policy, laws and regulations or the Hawaii State Constitution “Water as a Public Trust” doctrine, and failed to include adequate public review and agency consultation (the County did not consult with Department of Health, DAR, EPA, or NOAA regarding potential impacts of two new injection wells). The Maui Island Planning Commission upheld the director’s decision in the April 27th hearing on the issue. The planning director subsequently resigned, remaining with the department in a West Maui planning position.

http://www.mauinews.com/page/content.detail/id/530984.html

V. Results
A. Accomplishments and findings for each III (D) objective.
B. Answers to III(C) each resource management question(s).
C. Site specific results for each location (Can place in an appendix as electronic file).
D. If significant problems developed which resulted in less than satisfactory or negative results, they should be discussed.
E. Description of need, if any, for additional work.

Results to date are outlined in sections above.

VI. Outputs (Dissemination of Project results) Outputs are defined as products (e.g. publications, models) or activities that lead to outcomes (changes in user knowledge or action).

Scientific Publications:
The researchers also submitted two manuscripts. The first was on island-wide and fine-scale surveys and algal deployments in nearshore waters to map land-based nutrients around Maui. These results show that all coastal waters near injection wells have high $\delta^{15}N$ values and are therefore impacted by sewage effluent. This manuscript also compiles annual influent, wastewater reused and effluent data from the three County of Maui Wastewater Reclamation Facilities from 1998 to 2008. Total Nitrogen Load estimates were performed.

The second manuscript was on the response of blooming (Hypnea musciformis, Ulva fasciata and Acanthophora spicifera) and non blooming (Dictyota acutiloba) species to sewage effluent in terms of photosynthetic characteristics and growth. The results mentioned in this manuscript provide managers with information that can be used in water quality management programs to set nitrogen limits to control the growth of the nuisance H. musciformis and U. fasciata.

These outputs led to outcomes of improved management knowledge: a) decision makers and the public understand that pollutants from injection wells are reaching nearshore waters and are causing or contributing to water quality impairment (nonattainment of state water quality standards) in violation of the Clean Water Act (CWA) b) the Environmental Protection Agency (EPA) and State Department of Health (DOH) gained an understanding of use of biological data in water quality management, c) regarding the Underground Injection Control (UIC) permit for the Lahaina Wastewater Reclamation Facility the manuscripts provided crucial information to the EPA that the connection of injected sewage effluent to the impairment of nearshore waters in areas with the injection wells on Maui warrants the issuance of more protective water quality-based National Pollutant Discharge Elimination System (NPDES) permits under the authority of the Clean Water Act.

These outcomes of improved management knowledge led to outcomes of changes in management behavior: a) EPA requested $\delta^{15}N$ bioassay to help identify sewage sources, b) EPA revised its draft Underground Injection Control (UIC) permit to limit current and reduce future discharges of nitrogen and bacteria (50% reduction of permitted monthly total nitrogen), c) the Mayor of Maui County sets goal for increased reuse of wastewater to reduce the use of injection wells, d) EPA required the County to seek a CWA Section 401 certification that the UIC permit supports attainment of state water quality standards, e) EPA advised the County that NPDES requirements are the driver for level of wastewater treatment needed, and f) EPA Region 9 sent a
technical team including representatives of the UIC, NPDES, water quality standards, and watershed planning programs to visit the Lahaina Wastewater Reclamation Facility and the reef at Kahekili g) the EPA issued a Clean Water Act Section 308 Order for Information requiring the County of Maui to submit effluent characterizations for nutrients, priority pollutants (including toxicants), and fecal indicator bacteria citing Dailer, et.al. as substantiating evidence) the Order indicated that EPA wants the data to assess whether there are discharges subject to the Clean Water Act and National Pollutant Discharge Elimination System regulations (which would include water quality-based pollution controls protective of aquatic ecosystems).

Disseminating the project findings to a concerned citizens group (DIRE Coalition) allowed a question of process in the granting of exemptions from permitting and environmental review requirements when authorizing construction of new injection wells in the coastal zone. The ultimate goal of these Changes in Management Behavior outcomes is to restore environmental conditions under which coral can thrive.

**New Methods** - none

**Workshops** - none

**Presentations**

Meghan Dailer  
February 2010 HCRI Progress Report  
February 2010 Maui Community College

Robin Knox  
Presentations of research findings:  
South Maui Sustainability Group  
Sustainability Science Class at UH Maui College (Dr. Joie Taylor, Instructor)  
Southwest Maui Watershed project

**Outreach**

March 2010 Participated in “Communicating Ocean Sciences” at Maui Community College where students asked a panel of researchers about communicating marine science to the media

May 2010 An article will be released in Environment Hawaii about Maui Wastewater which mentions our Marine Pollution Bulletin manuscript

Plan and participate in More Fish in the Sea event to raise public awareness about ocean impacts of land-based pollution, overdevelopment and overfishing. (Meetings January 21, February 12, March 3 and event on April 3, 2010).

Water Quality Monitoring events (2) with UH Maui College students and Instructors Frannie Coopersmith (Biology) at Ulua Beach and Donna Brown (Marine Option Program) at Kahului Harbor (More Fish in the Sea event).
Ongoing Water Quality Monitoring training and program quality control development with Hawaiian Island Humpback Whale National Marine Sanctuary (HIHWNMS) volunteers and staff. Volunteer Training for Enterococcus testing using Enterolert held April 7, 2010.

Meetings with Maui Nui Marine Resource Council and Clean Water Committee (February 1 and 3, March 1 and 3, 2001). Developed Turbidity Task Force to support citizen monitoring of runoff and ocean water quality. This project raises public awareness of the impact of land-based activity on water quality while generating data with methods and quality control adequate for reporting to DOH and EPA water quality management programs.

Assisted Honolua Bay Coalition and Whale Sanctuary in grant writing to obtain volunteer water quality monitoring program supplies for Bluewater and Turbidity Task Forces.

Assisted Community Work Day in obtaining a grant for volunteer water quality monitoring at Laie Wetland before during and after a cleanup and native plant restoration project. Project is cooperative effort with County and HIHWNMS volunteer water quality monitors and will collect stream discharge and nutrient concentrations for eight events over two years, providing valuable monitoring data for use by Southwest Maui Watershed planners to develop pollutant loading estimates. Site Reconnaissance was conducted March 17 and sampling was conducted on March 25, 2010.

Assisted CORAL Reef Alliance in design of coral monitoring data port that can be used to collect and report volunteer monitoring data on water quality and biological surveys. Conducted beta test volunteer training January 29, 2010 and presented at public launch volunteer training. http://monitoring.coral.org/about
http://www.mauinews.com/page/content.detail/id/529333.html?nav=10

Meetings with Dire Coalition Steering Committee and wider membership (February 29, April 6, April 9, April 13). Provided regulatory and technical support regarding group understanding of HCRI research findings and coastal zone and pollution control policy.

Monthly meetings serving as a member of the Maui Mayor’s Community Working Group seeking ways to reuse rather than inject wastewater.

Provided booth with research publications (UH and USGS), watershed planning and water quality information complementing DAR exhibits on fisheries and coral reef health at Whale Day 2010 (Feb 2010) and More Fish in the Sea (April 3, 2010) public outreach events.

Liaison with public officials and their staff regarding research findings and coastal zone management and pollution control policy, including Council member Wayne Nishiki, Council member and Water Resources Committee Chair Mike Victorino, Council member and mayoral candidate Sol Kahoʻohanalahala, and state house candidate Netra Halperin.

Conducted stream survey of Honokowai Valley above the stream diversion with Department of Health staff /March 23, 2010.
Conducted brief watershed reconnaissance of south and west Maui sites and Kahekili with Hudson Slay and Tina Yin, USEPA Region 9 Watersheds, Kathy Chaston NOAA, and Megan Webster Maui Land And Pineapple Company (March 12, 2010).