Dr. Roger Fujioka, WRRC Researcher, University of Hawaii at Manoa, Principal Investigator.

Introduction:

Vibrios are naturally occurring bacteria indigenous to marine and estuarine waters. Of the 65 known species of these bacteria, several are pathogenic to both marine animals and humans. Depending on the species involved and the nature of the exposure, infection can be asymptomatic, cause mild to severe gastroenteritis, or result in septicemia (blood infection) or wound and soft tissue infection. A total of twelve different Vibrio spp. are known to be pathogenic to man, but the following four species account for most of the human infections.

1. V. vulnificus: contracted primarily by ingestion of marine food or contact with marine waters resulting in gastroenteritis, and wound infections, often leading to septicemia and death.

2. V. parahaemolyticus: contracted primarily by ingestion of contaminated marine waters, resulting in gastroenteritis, often leading to death.

3. V. parahaemolyticus: contracted primarily by ingestion of contaminated marine foods, often leading to gastroenteritis.

4. V. alginolyticus: contracted primarily by contact with marine waters, leading to skin and ear infections.

All four of these pathogenic Vibrio spp. have been documented to cause human infections in Hawaii. V. vulnificus infections have recently resulted in two deaths related to exposure to coastal waters. One death occurred on the Big Island and a second death occurred on Oahu. V. cholerae infections have also been documented in Hawaii, though the source of these infections has not been determined. Infections of V. parahaemolyticus and V. alginolyticus have also been reported in Hawaii.

No approved methods exist for the recovery of human pathogenic Vibrio bacteria from environmental waters, thus the risk of acquiring Vibrio infections from contact with these waters has never been determined. Therefore water quality standards, which may help predict the presence of potentially pathogenic Vibrio spp., have not been established.

Project Goals and Experimental Approach:

The goal of this study is to determine the prevalence of these four human pathogenic Vibrio spp. in four categories of coastal water environments in Hawaii, and to determine the relative risk that these pathogens may pose to people who use these coastal waters for recreational purposes.

Gayatri Vithanage, a graduate research assistant at WRRC and Ph.D. candidate in Microbiology is conducting this study as part of her dissertation research. The experimental design of her study is to determine the prevalence of human pathogenic Vibrio spp. in the following four categories of coastal waters:

1) Primary swimming sites on Oahu. This category includes popular beach sites which have been designated for public swimming. The waters at these sites are characterized by active ocean water circulation and desirable water quality including low turbidity and high salinity (32-36ppt) (Figure I - pg. 3, sites A1-A20, blue dots).

2) Secondary swimming sites on Oahu. This category includes sites designated for public swimming but considered secondary sites because water quality is compromised by nearby land-based discharges - streams or storm drains. The waters at these sites are characterized by moderate ocean water circulation and some undesirable water quality parameters such as increased turbidity and low

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maintain a tight stock constraint requires substantial water conservation which could be implemented by higher consumer prices at the margin. The growth function of the stock of limu is difficult to estimate in situations where the stock is small relative to its size without predators. Thus in the third approach we use a growth constraint on the intrinsic growth rate, which can be alternatively stated as a constraint on the groundwater discharge level. The intrinsic growth rate constraint is ultimately imposed as a head-level constraint. For head constraints that represent a reasonable range of growth rates given the ocean salinity at the study site (1.8%–2%), the optimal approach paths for head, pumping, and price over time are either strictly increasing or decreasing. The head level rises over time in all scenarios as the optimal rate of extraction declines over time. With the growth constraints, desalination is never used. Again, the stricter the constraint, the more water conservation is required.
In recent years Liu has completed two federally sponsored research projects: an NSF project to develop an engineering system for open ocean mariculture using nutrient-rich deep ocean water and a U.S. Bureau of Reclamation project to develop a wind-powered reverse-osmosis system for water desalination and treatment.

Since January of 2008 Liu has been working at the National Science Foundation headquarters in Washington where he’s been serving as the environmental engineering program director. He is due to return to Hawaii this summer. The award ceremony was held in Mississippi in April. “I was very excited by the news of being selected to receive the Engineer of Distinction award,” Liu said. “It is not only a great honor for me but also presents an opportunity for me to revisit a place that has been so important to my personal and professional development.”

“A great benefit derived from the award is the greatly increased visibility of the long-term research conducted under the WRRC Ocean Outfall Biomonitoring project. The project involves a larger number of students who have extensive training in the skills and methodologies required to monitor marine ecosystems,” said Barrett. The Water Center extends congratulations to Brendan (Chip) Barrett, a long-time researcher and research assistant on the ongoing WRRC Ocean Outfall Biomonitoring project. Barrett has recently been granted a PhD from the National University of Ireland in Galway, and has won the award “A survey of the deep-sea polychaete annelids of the Porcupine Bank and adjacent areas to the west of Ireland, with particular focus on the phylogeny and taxonomy of the Family Amphinomidae Lamarck, 1818 and Genus Paramphinome M. Sars in G. O. Sars, 1872” accepted by his committee.

While at WRRC Barrett honed his taxonomic skills identifying benthic invertebrates in samples of sediment taken from around the City of Honolulu’s ocean wastewater outfalls. This identification work has contributed to the Center’s research over 20 years, and has provided valuable training experience and support for many Zoology students at the University of Hawaii. Many of these alumni have gone on to distinguish themselves in subsequent academic endeavors and research careers.

**Former Outfall Project Researcher Awarded PhD**

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A Decision Support Tool for Managing the Pipe Network of the Honolulu Board of Water Supply

Dr. Anjali Singh, Associate Professor, Civil and Environmental Engineering and Dr. Chittaranjan Ray, Professor, Civil and Environmental Engineering, University of Hawaii at Manoa

America’s water and wastewater systems face unprecedented financial problems because of aging infrastructure, deferred maintenance, and unsustainable rate structures. According to the Water Infrastructure Network (WIN, 2006) America’s water and wastewater systems will have to invest $23 billion a year more than is currently spent over the next 20 years, to meet the national environmental and public health priorities in the Clean Water Act and Safe Drinking Water Act and to replace aging and failing infrastructure.

The USEPA’s 2002 Gap Analysis Report also points out the need to invest between $331 billion and $450 billion in capital between 2000 and 2019 for the wastewater sector. Similarly, between $154 billion and $446 billion in capital spending is required for the drinking water sector during the same period (USEPA, 2002). The operation and maintenance (O&M) needs are also high. For any investment, the utility agencies are advised by the General Accounting Office (GAO, 2004) and the Environmental Protection Agency to develop comprehensive asset management plans for the repair, replacement, and upgrading of infrastructure, which will enable them to make appropriate rate adjustments over the life cycle to keep service levels adequate.

It is common for water utilities to defer maintenance because the unfunded rates that would be needed to fund this are often suppressed by city councils or boards that govern them. As a result, cities do not build funds for emergency replacement of pipes or other assets. An example is the deferred replacement and maintenance of sewer pipes in the City of Honolulu. This was blamed for a 48 million gallon sewage spill that occurred in the spring of 2006 when sustained heavy rains fell on Oahu. Finally, EPA forced the city to take action on pipeline replacement under the threat of severe fines.

Similarly many of the pipes in the Honolulu Board of Water Supply (BWS) network are near the end of their usable lifespan. The corrosive soils and saline environments found on Oahu cause excessive corrosion of cast iron pipes. As a result, the BWS experiences many pipe breaks. Broken mains often lead to flooding damage to nearby houses that the BWS’s insurer must pay for. In addition, breaks and minor consequence will be assessed in terms of risk. Statistical quality control principles will be applied and linear programming techniques will be explored.

Research Objectives: The research is for a period of one year. Tasks that will be undertaken include:

(a) Review current decision tools used by the BWS for the management of their infrastructure.
(b) Collect historical records of pipe breaks and other details such as pipe age, diameter, and material, system pressure at the break point, and other details that are readily available from BWS files.
(c) Collect other relevant information such as soil properties - resistivity, pH, organic carbon, water holding capacity, and hydraulic conductivity; and depth of burial of the pipes and pipe coupons for further analysis of pipe breaks.
(d) Prepare a decision tool that will provide probability of failure versus consequences of failure for various sections of pipes in the BWS network, and look into the feasibility of using other software for managing annual pipeline replacement.
(e) Present a decision tool that will determine for the BWS the number of miles of main that should be replaced in a given year.


The nearshore marine environment of Hawaii is a major recreational and ecological resource that supports indigenous fish and marine vegetation. Freshwater discharge from groundwater aquifers mixes with seawater along the coast to create an ecological system with lower salinity than that of ocean water. Offshore extraction of freshwater affects the salinity of the nearshore ecosystem since lower aquifer-head levels result in reduced freshwater discharge into the ocean. The state of the aquifer is thus directly linked to the cultural, recreational, and economic values of the community.

The objective of this research is to determine the optimal management scheme for groundwater resources in Hawaii - taking into consideration both the benefits of water consumption and the environmental consequences of freshwater extraction. Understanding the environmental consequences of freshwater extraction requires an assessment of the linkages between submarine groundwater discharge and the nearshore ecosystem. Native marine algae, identified by the Hawaiian word *limu*, play an important role in marine food web of endemic and other organisms. Algae can therefore serve as appropriate indicators of the surrounding environment’s overall health.

To gain a better understanding of how groundwater discharge affects the nearshore marine environment we monitored, in a controlled laboratory environment, the physiological response of a selected species of *limu* to varied levels of salinity and nutrients. We chose the edible endemic species of marine algae Gracilaria coronopifolia for our study.

**Methodology**

Our research agenda is interdisciplinary and it involves two sub-programs. The first uses a bio-hydro-economic model to solve for optimal levels of groundwater use and *G. coronopifolia* production. The second is a laboratory study of the relationship between salinity, V. vulnificus and the biological productivity of *G. coronopifolia*.

**Bio-hydro-economic Model**

The model used is an application of optimal control theory and follows the framework laid out in Krulce, Roumasset, and Wilson’s (1997) study of the Pearl Harbor aquifer. The objective is to choose the paths of groundwater extraction and desalinated-water production over time to maximize the present value of net social surplus from water. For this purpose social surplus includes both traditional water-use benefits as well as external benefits (or costs) of freshwater extraction on the nearshore ecosystem. Our particular study focuses on *G. coronopifolia* as the nearshore resource affected by submarine groundwater discharge but the model is general and can therefore be applied to any other nearshore resource.

*G. coronopifolia* was chosen for this investigation in order to assess the impact of varied levels of submarine groundwater discharge on the nearshore environment. The physiological parameters we measured include growth rate, branch development, and in vivo pigment absorption. Growth rate was measured as changes in wet-tissue mass over time and branch development was measured by quantifying the rate at which new growing tips were formed in reference to the initial tips and initial mass. To accurately measure these physiological responses to isolated variables a digital growth chamber was modified to support a unidirectional flow-through saltwater system.

In order to quantify changes in wet weight and morphology, three variables were calculated. The specific growth rate was calculated \[
\text{specific growth rate} = \frac{(\text{final wet mass} - \text{initial wet mass}) / \text{sixteen days}}{	ext{final wet mass}}
\]

The percent change in apical-tip number relative to initial-tip number was calculated in a similar manner: \[
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In order to quantify the number of apical tips in reference to initial weight, apical-tip number / mass was calculated as the tip score. The change in tip score was then calculated for each treatment in reference to initial weight, apical-tip number / mass was calculated as the tip score. The change in tip score was then calculated for each treatment in reference to initial weight.

### Preliminary Findings:

Significant differences have been found in the prevalence of pathogenic *Vibrio* spp. in the four different water categories.

**1. Primary swimming beaches**

*Oahu* had a predominance (100% of sites) of *V. alginolyticus* while *V. vulnificus* and *V. parahaemolyticus* were not recovered.

**2. Secondary swimming waters**

*Oahu* showed a predominance (100% of sites) of *V. alginolyticus*, and moderate recovery of *V. vulnificus* (33% of sites) and *V. parahaemolyticus* (33% of sites).

**3. Non-designated swimming waters**

*Oahu* had a predominance (100% of sites) of *V. alginolyticus*, moderate recovery of *V. vulnificus* (33% of sites), and a moderate-to-high recovery rate of *V. parahaemolyticus* (67% of sites).

**4. Water samples obtained from the Island of Hawaii**

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