Hawai‘i Institute of Marine Biology
Northwestern Hawaiian Islands
Coral Reef Research Partnership

Quarterly Progress Reports II-III
August, 2005-March, 2006

Report submitted by Malia Rivera and Jo-Ann Leong

April 21, 2006

Photo credits: Front cover and back cover-reef at French Frigate Shoals. Upper left, reef at Pearl and Hermes. Photos by James Watt.

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Acknowledgments. Hawaii Institute of Marine Biology (HIMB) acknowledges the support of Senator Daniel K. Inouye's Office, the National Marine Sanctuary Program (NMSP), the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (NWHICRER), State of Hawaii Department of Land and Natural Resources (DLNR) Division of Aquatic Resources, US Fish and Wildlife Service, NOAA Fisheries, and the numerous University of Hawaii partners involved in this project. Funding provided by NMSP MOA 2005-008/66832. Photos provided by NOAA NWHICRER and HIMB.

Aerial photo of Moku o Lo‘e (Coconut Island) by Brent Daniel.

Background

The Hawai‘i Institute of Marine Biology (School of Ocean and Earth Science and Technology, University of Hawai‘i at Mānoa) signed a memorandum of agreement with National Marine Sanctuary Program (NOS, NOAA) on March 28, 2005, to assist the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (NWHICRER) with scientific research required for the development of a science-based ecosystem management plan. With this overriding objective, a scope of work was developed to:

1. Understand the population structures of bottomfish, lobsters, reef fish, endemic coral species, and adult predator species in the NWHI.
2. Characterize the genetic diversity of corals in the NWHI and determine the background levels of coral health in the NWHI.
3. Support mapping activities that will be used in the Sanctuary designation and management zones.
4. Identify the pool of invasive species in the Main Hawaiian Islands (MHI) and develop measures to present the spread of these species to the NWHI.
5. Support sound ecosystem management.

The Hawaiian Archipelago is located at 19°-28° N to 155°-178° E and spans approximately 1,200 miles of the Pacific Ocean. The lower main eight Hawaiian Islands are home to a growing population of more than a million people. In the northern reaches of the Hawaiian Archipelago are a series of tiny islands, atolls, and shoals that make up the Northwestern Hawaiian Islands (NWHI) and that are largely uninhabited. The pristine beauty and unique ecosystem of the NWHI was recognized in 2001 when Executive order #13178 created the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, the largest marine protected area in the United States. The total area of the reserve is 84 million acres and is home to an estimated 7,000 species including fishes, invertebrates, marine mammals and birds. The full extent of its biodiversity is largely unknown. However, estimates have been made that approximately a quarter of the 7,000 species are found nowhere else on Earth.

Hawai‘i is one of the most isolated yet populated areas on Earth; and, this site provides a unique ecosystem to compare relatively pristine coral reefs in the northern end of the Archipelago with those that are influenced by human activities in the southern end. This "gradient" of human disturbance on coral reefs offer scientists an opportunity to examine species diversity and function under different environmental conditions, with the aim of developing best practices for the maintenance of a healthy coral reef ecosystem in the NWHI. The Sanctuary Vision: "*That the vast coral reefs, ecosystems, and resources of the Northwestern Hawaiian islands (NWHI) - unique in the world - be healthy and diverse forever"* is the guiding principle in the design of the research objectives proposed for the NWHICRER-HIMB partnership.

Summary of Activities

The Hawai‘i Institute of Marine Biology has been able to complete two sampling cruises to the Northwestern Hawaiian Islands since the research partnership was initiated in April, 2005. No permits were issued from the Fish & Wildlife Service for sampling invertebrate species on the May 14-June 7, 2005 cruise. However, collections of reef fish were obtained. On the second cruise from September 15 to October 6, 2005, HIMB scientists were able to collect invertebrates and bacterial community samples from diseased and healthy corals. The preliminary results of the second quarter of research are presented here.

- The yellow tang shows statistically significant genetic structure, indicating that the Hawaiian archipelago is not a single highly-connected ecosystem.

- Apex predators in this study exhibit wide ranging intra-atoll movements (up to 30 km). Grey reef sharks, thought to be highly territorial, move up to 260 km between NWHI atolls.

- Several apex predator species show significant diel periodicity in their movement patterns. The movements of ulua (Giant Trevally) at French Frigate Shoals were found to have significant lunar periodicity.

- Low levels of coral disease were observed at most of the sites in the NWHI. Low levels of disease incidence may be normal for healthy reefs. The exception is an outbreak of *Acropora* white syndrome at French Frigate Shoals. This disease had a significant impact on the *Acropora* in the Marshall Islands and warrants further monitoring.

- No significant bleaching was observed on any of the reefs during the Fall 2005 surveys.

- *Acropora cytherea* samples were taken at French Frigate Shoals. Healthy corals contained clade C symbionts and diseased corals had clade A symbionts. These findings suggest that symbiont clade may play a role in maintaining coral health.

- The alien hydroid *Pennaria disticha* has spread extensively in the NWHI but does not appear to be invasive.

- Fish Attraction Devices (FAD) deployed by the State of Hawai‘i may be an important transport mechanism for alien marine species and appropriate management strategies can be instituted to minimize this problem.

- Contrary to previous reports, *Carijoa riseii* (Snowflake coral) in Hawai‘i did not originate from the Caribbean or Atlantic Oceans; rather, its closest relative appears to be in the Indo-Pacific. There also appears to have been multiple introductions of *Carijoa* into Hawai‘i.

- The NWHI represent a valuable biological resource that is pristine compared to the MHI.

The following pages provide detailed descriptions of the research progress.

Northwestern Hawaiian Islands Connectivity Studies

Projects:

- ✓ **Genetic resolution of stock structure in deep water snappers Ehu and Onaga (B. Bowen & R. Toonen)**
- ✓ **Connectivity of NWHI reef communities (B. Bowen & R. Toonen)**
- ✓ **Connectivity among coral reef invertebrates across the Hawaiian Archipelago (R. Toonen & B. Bowen)**

A survey of fish and invertebrate species across the NWHI is required to assess the level of connectivity between the isolated reef habitats of the NWHI and the Main Hawaiian Islands (MHI). Genetic analysis of 30 fish and 30 invertebrate species at the major atolls of the NWHI is being conducted with techniques similar to those used to determine relatedness in parental testing and forensic investigations in humans. The Functional Genomics Core Facility at HIMB makes is possible to conduct this work in a cost-effective manner and Facility is available to the broader scientific community. The equipment for the research facility was purchased with NSF funding.

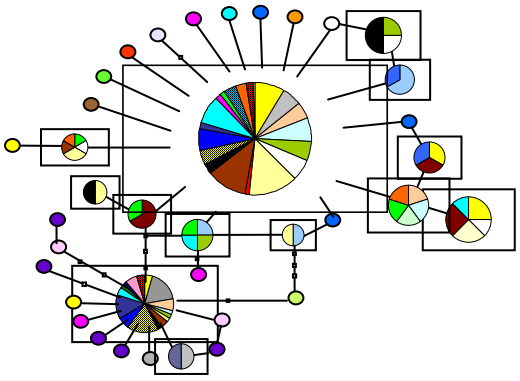
Assessing connectivity through genetic surveys will augment substantially the scientific foundation for conservation management strategies. Specifically, this research will establish whether reef ecosystems of the Northwestern Hawaiian Islands are isolated management units (as preliminary data indicate) or components of a large interactive ecosystem. In the former case, each reef ecosystem will have to recover from environmental insults (whether human or natural) without significant input from other reef ecosystems. A corresponding conservation mandate would be that each ecosystem is an independent management unit.

An ongoing debate about the NWHI is whether this is a series of relatively fragile (isolated) ecosystems, or whether it is a single robust ecosystem that can sustain extraction of resources. There is also a direct management concern about whether the NWHI serves as a source or a sink for the main Hawaiian Islands. The assays of population connectivity may settle this issue in a format that has statistical power and scientific credibility.

In the first reporting period, we have assembled an outstanding team of scientists, including Illiana Baums (Ph.D., coral genetics), Matt Craig (Ph.D., fish genetics), Kim Selkoe (Ph.D., fish genetics), Luiz Rocha (Ph.D. fish genetics, arriving January 2006), Jeff Eble, Michelle Gaither, Tonatiuh Trejo, Jennifer Schultz (grad students, fish), Kim Weersing, Chris Bird, Greg Concepcion, Joe O'Malley, Matt Iacchei (grad students, invertebrates), Van Nicholas Velasco, Carly Allen, and Laurie Saurenson (undergraduate student assistants).

To date we have placed personnel on two research cruises, using the newly-outfitted Hi'ialakai to visit eight locations in the NWHI. On these cruises we have collected tissue specimens (fin clips, coral fragments, and small tissue clips) from over 1,000 fish and invertebrates. Hence we are making substantial progress in field activities. However, because of permitting issues, we

were unable to collect invertebrates until the second cruise, and have made far less progress on the invertebrate studies as a result of that delay.



In the lab, we have sequenced mitochondrial DNA from three species; the flame angelfish, large-scale squirrelfish, and yellow tang. The first two are known to disperse on ocean currents as larvae, and appear to have a single population in the NWHI. The last shows statistically significant genetic structure, suggesting that for yellow tang, the Hawaiian archipelago is not a single highly-connected ecosystem. We will have to assess the situation carefully with other species to determine whether the findings with yellow tang are more common for taxa in the NWHI.

The multi-species approach to assess population connectivity in the Hawaiian archipelago will be incorporated into a broader framework (funded by the National Science Foundation) to examine the phylogeography of many of these same species throughout the Indo-Pacific. This will provide a comparative framework to bolster the scientific foundations for implementing the NWHI National Marine Sanctuary. The National Marine Sanctuary Program has required these connectivity studies to assist them in drafting their conservation programs, particularly in the placement of no-take zones. This information will also be critical to assessing the patterns and magnitude of connection between the no-take Hawaiian Islands National Wildlife Refuge (NWR) and the main Hawaiian Islands.

Project:

- ✓ **Movements of apex predators along the Hawaiian Archipelago (K. Holland & C. Meyer)**

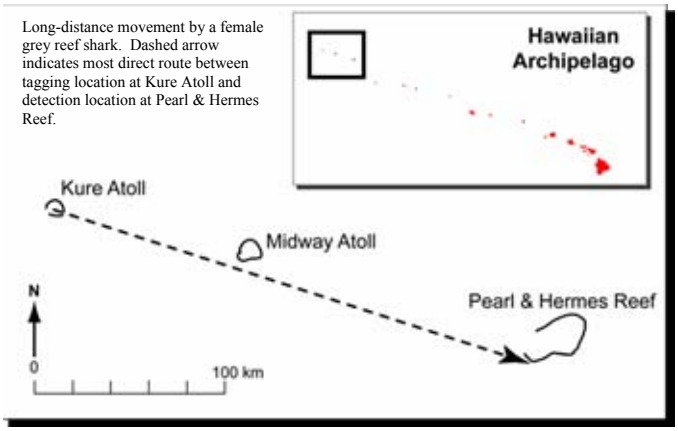
We are using acoustic monitoring to quantify movements of transmitter-equipped apex predators (sharks and large fishes) along the Hawaiian archipelago. To date we have tagged 107 apex predators with acoustic transmitters at 5 NWHI atolls (Table 1), and deployed 18 underwater receivers at 6 NWHI atolls, reefs and pinnacles (Table 2).

Table 1. Acoustic transmitter deployments by species

Species Name	Hawaiian Name	English Name	Number Equipped With Transmitters
Aprion virescens	Uku	Green Jobfish	28
Caranx ignobilis	Ulua aukea	Giant Trevally	32
Caranx melampygus	Ōmilu	Bluefin Trevally	2
Carcharhinus amblyrhynchos	Manō	Grey Reef Shark	5
Carcharhinus galapagensis	Manō	Galapagos Shark	29
Galeocerdo cuvier	Manō	Tiger Shark	10
Triaenodon obesus	Manō lālākea	Whitetip Reef Shark	1
TOTAL			**107**

Table 2. Acoustic receiver deployments by NWHI atoll.

NWHI Location	Number of Acoustic Receivers Deployed
Kure Atoll	3
Midway Atoll	3
Pearl and Hermes Reef	4
Maro Reef	2
French Frigate Shoals Atoll	5
Mokumanamana	1
TOTAL	18



In September 2005 we recovered, downloaded and redeployed 17 underwater receivers at five atolls during the May 2005 NOAA-NWHICRER research cruise. These receivers had detected 56 (80%) of 70 apex predators tagged during the May 2005 cruise, yielding 28,396 total detections. Our significant findings to date are (1) grey reef sharks (*Carcharhinus amblyrhynchos*) move up to 260 km between NWHI atolls, (2) all species tagged exhibit wide ranging intra-atoll movements (up to 30 km), (3) several apex predator species show significant diel periodicity in their movement patterns, and (4) giant trevally (*Caranx ignobilis*) show significant lunar periodicity in detections at FFS atoll.

Coral Health Assessment Program Studies

Project:

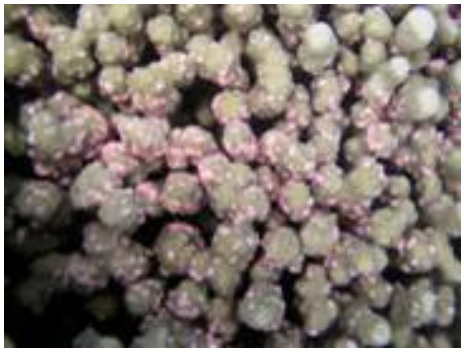
- ✓ **Coral health in the Northwestern Hawaiian Islands (G. Aeby, with assistance from E. Cox)**

Population Parameters—During the September/October 2005 cruise, 1,925 m^2 were surveyed at 40 sites within 6 reef sites at Necker, French Frigate Shoals, Maro, Pearl & Hermes, Midway, and Kure. A total of 6,873 Anthozoan colonies were tallied. At all reef systems visited, *Porites lobata* was a dominant coral, only outnumbered in colony counts by *Pocillopora meandrina* at Kure. The other dominant corals included *Pocillopora meandrina*, *Montipora capitata*, *Montipora flabellata*, and *Porites compressa*. Coral cover as indicated by the line-intercept method ranged from <1% to 63% and varied among sites with Maro having the highest average coral cover (43.1%) and Midway having the lowest average coral cover (7.8%).

Size class distributions can be used to provide information about population dynamics, with the

presence of large size classes suggesting a mature community, while those with smaller classes represent populations recovering from disturbance. *Porites lobata* size class distributions indicate that transects at Midway and Pearl & Hermes were dominated by small size classes (78% and 68% respectively). Maro and French Frigate Shoals transects had the highest percentages of the largest size classes. For *Pocillopora meandrina*, large colonies were most common on transects at Kure and Maro, with small colonies dominating at Midway, Pearl & Hermes, French Frigate Shoals, and Mokumanamana. *Montipora capitata* size class distributions were skewed to the smaller size classes except at Maro and Pearl & Hermes. It should be noted, however, that for these comparisons all types of habitats are lumped. Proper comparisons should take into account habitat type.

Disease studies—Quantitative surveys of coral disease were initiated in 2003 to assess the frequency and abundance of disease on the reefs of the NWHI. Re-surveys of these sites have since been conducted on an annual basis to monitor the health of corals through time. In 2005, 40 sites were re-surveyed for coral disease with a total of 11,425 m^2 of reef being examined for disease. As in prior years, it was found that coral disease in the NWHI is widespread but is found at low levels (avg. prevalence = 4.1 $\pm$0.77) indicative of a healthy population. The exception is an outbreak of *Acropora* white syndrome at French Frigate Shoals. *Acropora* white syndrome has resulted in significant reduction of this species within the Marshall Islands, so we are investigating this disease further in the NWHI. A total of 12 different coral diseases affecting the four major genera of coral (*Porites, Montipora, Pocillopora*, and *Acropora*) have now been described from the NWHI. No new disease states were found in 2005. Some of these diseases, such as *Porites* trematodiasis are widespread (all islands) and frequently encountered during surveys (FOC=84.2%) whereas other diseases, such as *Porites* brown necrotizing disease, are rare and found at limited areas (PHR, LIS) with low occurrence (FOC=2.6%).



Bleaching—No significant bleaching was observed on any of the reefs during the September, 2005 surveys.

Coral predators—Three species of coral predators are being monitored on an annual basis during surveys in the NWHI. These include the Crown-of-Thorns starfish (*Acanthaster planci*), *Drupella* sp. snails that feed on Pocilloporids and Montiporids and *Corallophilia violacea*, a snail that specializes on *Porites*. Their numbers and frequency of occurrence continue to be low within the NWHI and do not appear to represent a significant threat.

Fish disease—Butterflyfish within the main Hawaiian Islands are known to be vulnerable to cutaneous tumors that are easily visible externally. Studies of this disease within the main Hawaiian Islands are currently underway by Aeby and Work. During the September, 2005 cruise, butterflyfish that were collected for molecular studies were examined externally for

presence of tumors. One hundred and eighty-one butterfly fish were examined from five different species *(Chaetodon miliaris, C. lunulatus, C. fremblii, C. multicinctus, C. kleinii).* No tumors were found on any of the fish. This is in contrast to the butterfly fish examined in the main Hawaiian Islands that have an average prevalence of tumors of 2.5%.

In May, 2005 members of the fish team noticed a strange discoloration of some kole (*Ctenochaetus strigosus*). These individuals were captured and given to G. Aeby and T. Work for necropsy. They found discolored fish to be in extremely poor body condition and tissues were collected for follow-up histopathological analysis. During the September, 2005 survey an additional 31 kole were necropsied. These included both affected individuals and some apparently healthy individuals as controls. All tissues will be processed and analyzed by Dr. Work, USGS once funding has been procured. Fish had originally been collected for molecular analyses.

Project:

- ✓ **Assessing the diversity of microbes associated with healthy and health-compromised corals in the Northwestern Hawaiian Islands (M. Rappé, with assistance from J. Salerno, A. Apprill & E. Hambleton)**

Microbial pathogens have been identified as the causative agents for a variety of diseases that have devastated coral reefs worldwide. Less well-known, however, are the diverse communities of microorganisms hosted by healthy corals that promote positive interactions such as facilitating macronutrient acquisition and transfer, organic carbon transformations and, perhaps most importantly, aiding in the coral's resistance to invasion by pathogens. Currently, determining the etiologies of the vast number of coral diseases is complicated by our lack of understanding of the functional role that coral-associated microbes play in host health under normal conditions. The purpose of this study is to identify microbes associated with different species of healthy and health-compromised corals in the Northwestern Hawaiian Islands and to determine if microbial pathogens or invasive microbial species are present on NWHI reefs and reef water.

Thus far, sample collections have been made on two cruises to the Northwestern Hawaiian Islands (May 2005 and September 2005), which are summarized in Table 3. Common and ecologically important coral species were targeted for microbial community analysis including *Porites lobata*, *Porites compressa*, *Pocillopora meandrina*, and *Montipora capitata*. Using SCUBA and underwater tools, three sub-samples (consisting of coral tissue, overlying mucus layer, and underlying skeleton) were taken from each coral colony, with at least five colonies sampled per species per site. Our sampling strategy focused on collecting from healthy coral colonies; however, diseased and/or bleached colonies were sampled opportunistically when encountered. Samples were collected from various habitats (e.g. fore reef, back reef, lagoon) at each atoll/island. Seawater samples were also taken adjacent to the sampled coral heads for comparison and to analyze the seawater for the presence of potential invasive, free-living microorganisms. Samples were processed and

stored in the -37 °C freezer aboard the NOAA R/V Hi'ialakai. All samples were then transported to the Hawai'i Institute of Marine Biology (HIMB) on Coconut Island for further processing and molecular analysis in the Laboratory for Aquatic Microbial Ecology under the direction of Dr. Michael Rappé. Samples collected from both cruises will be integrated into an on-going time-series study of seasonal changes in coral associated microbes (CAM) diversity in the NWHI.

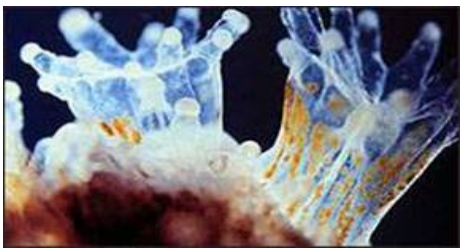
Table 3: CAM sample inventory from May 2005 and September 2005 cruises.

DATE	ATOLL	SITE	HABITAT	SPECIES	# COLONIES	# SAMPLES
18-May-05	FFS	TC21	fore reef	*Porites lobata*	2	6
19-May-05	FFS	R16	fore reef	*Porites lobata*	2	6
22-May-05	Maro	TC22	patch reef	*Porites lobata*	1	4
22-May-05	Maro	8	patch reef	*Porites lobata*	3	9
22-May-05	Maro	8	patch reef	*Pocillopora meandrina*	3	9
25-May-05	P&H	TC32	back reef	*Pocillopora meandrina*	3	9
27-May-05	P&H	44	fore reef	*Porites lobata*	3	9
5-Jun-05	FFS	Rapture Reef	fore reef	*Acropora cythaerea*	3	9
17-Sep-05	FFS	33	lagoon	*Porites lobata*	5	15
17-Sep-05	FFS	23	back reef	*Porites lobata*	5	15
18-Sep-05	FFS	H6	fore reef	*Porites lobata*	3	9
18-Sep-05	FFS	R46	coastal	*Porites lobata*	4	12
18-Sep-05	FFS	R46	coastal	*Acropora cytherea*	4	12
19-Sep-05	FFS	12	patch reef	*Acropora cytherea*	11	39
21-Sep-05	Maro	R12	patch reef	*Porites lobata*	7	21
21-Sep-05	Maro	R12	patch reef	*Montipora capitata*	4	8
22-Sep-05	Maro	22	patch reef	*Porites lobata*	7	21
22-Sep-05	Maro	6	patch reef	*Porites lobata*	8	24
22-Sep-05	Maro	6	patch reef	*Montipora capitata*	9	27
24-Sep-05	P&H	31	back reef	*Porites lobata*	10	30
24-Sep-05	P&H	31	back reef	*Montipora capitata*	5	15
25-Sep-05	P&H	R32	back reef	*Porites lobata*	5	15
25-Sep-05	P&H	R31	back reef	*Porites compressa*	7	21
25-Sep-05	P&H	33	fore reef	*Porites lobata*	4	12
25-Sep-05	P&H	R26	fore reef	*Porites lobata*	5	15
26-Sep-05	P&H	26	back reef	*Montipora capitata*	8	36
26-Sep-05	P&H	R39	fore reef	*Porites lobata*	5	15
26-Sep-05	P&H	R44	fore reef	*Porites lobata*	6	21
27-Sep-05	Midway	R3	fore reef	*Porites lobata*	6	18
27-Sep-05	Midway	R7	fore reef	*Porites lobata*	8	24
28-Sep-05	Midway	H21	back reef	*Montipora capitata*	5	3
28-Sep-05	Midway	1	back reef	*Montipora capitata*	6	18
28-Sep-05	Midway	2	fore reef	*Porites lobata*	5	15
29-Sep-05	Kure	2	fore reef	*Porites lobata*	6	18
29-Sep-05	Kure	2	fore reef	*Pocillopora meandrina*	7	21
29-Sep-05	Kure	R33	fore reef	*Porites lobata*	5	15
29-Sep-05	Kure	R33	fore reef	*Pocillopora meandrina*	5	15
29-Sep-05	Kure	R36	back reef	*Pocillopora meandrina*	5	15
30-Sep-05	Kure	14	back reef	*Montipora capitata*	8	24
30-Sep-05	Kure	17	back reef	*Porites lobata*	7	21
30-Sep-05	Kure	18	back reef	*Porites compressa*	5	15
4-Oct-05	Necker	4	rocky shore	*Porites lobata*	10	30
4-Oct-05	Necker	2	rocky shore	*Porites lobata*	5	15
4-Oct-05	Necker	2	rocky shore	*Pocillopora meandrina*	5	15
4-Oct-05	Necker	Shark's Bay	rocky shore	*Porites lobata*	5	15
totals					**245**	**741**

In the Laboratory for Aquatic Microbial Ecology, CAM communities associated with each coral species are being assessed through molecular biological analyses of microbial 16S rRNA genes. During this reporting period, techniques for CAM DNA extraction and amplification were optimized on a coral species-specific basis in a comprehensive fashion in order to facilitate future high throughput, rapid processing of NWHI samples. Briefly, five methods of DNA extraction have been tested on three coral species common to Hawaiian reefs. We have discovered that the quantity and quality of DNA obtained from each extraction method varied within each coral species, and that the optimal extraction protocol differed between the three species of coral studied. Currently, polymerase chain reaction-amplified CAM DNA is being used in a community fingerprinting technique known as terminal restriction fragment length polymorphism (TRFLP). This technique assesses the diversity and relative abundance of microbial species associated with individual corals. In addition, all previously published nucleic acid sequence and community fingerprint data have been compiled into a database for the rapid identification of the microbial taxa based on their phylogenetically-informative and discriminative signatures.

Project:

- ✓ **Does the coral-dinoflagellate assemblage correlate with disease susceptibility? (R. Gates, with assistance from M. Stat)**



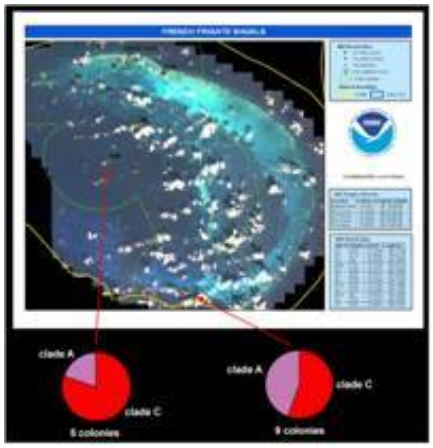
Our research examines whether there is a correlation between a symbiotic algae (dinoflagellate) and coral health and disease, as well as whether coral morphology correlates with health and disease resistance. Coral

samples were collected during September/October 2005, and each colony has been photographed to ascertain whether morphology correlates with health and/or disease. The samples collected have been divided between the Toonen lab (coral genetics), Rappé lab (microbial flora), and Gates lab (zooxanthellae genetics, biological traits) for comparative analysis. DNA extraction, PCR and RFLP of nuclear ssu rDNA to identify the *Symbiodinium* clade present in the coral colonies is ongoing.

Table 4: Coral samples collected during Fall Hi'ialakai research cruise.

Coral Species	Number of Colonies	Location
Acropora cytherea	15	French Frigate Shoals
Montipora capitata	13	Maro Reef
	13	Pearl and Hermes Atoll
	11	Midway Island
	8	Kure Atoll
Porites compresssa	7	Pearl and Hermes Atoll
	5	Kure Atoll
Porites lobata	17	French Frigate Shoals
	21	Necker Island
	22	Maro Reef
	35	Pearl and Hermes Atoll
	19	Midway Island
	18	Kure Atoll
Pocillopora meandrina	5	Necker Island
	17	Kure Atoll

Results to date-*A. cytherea* contain either *Symbiodinium* clade A or clade C. The colonies were sampled from two regions at French Frigate Shoals. At one location (five colonies), four colonies contained clade C and one contained clade A *Symbiodinium*. There was evidence of *Acropora* white syndrome at the second site at French Frigate Shoals, and both healthy colonies and those showing symptoms of white syndrome were sampled. The colonies that appeared healthy (five colonies) contained *Symbiodinium* clade C, while the colonies with white syndrome (four colonies) contained clade A *Symbiodinium*. *Symbiodinium* clade analysis of the remaining coral species is ongoing.



If these findings are confirmed in ongoing studies, these results will provide the context for using *Symbiodinium* identify as a predictive tool for determine disease susceptibility in corals and examining the role of the *Symbiodinium* symbiont in maintaining the health of its host coral.

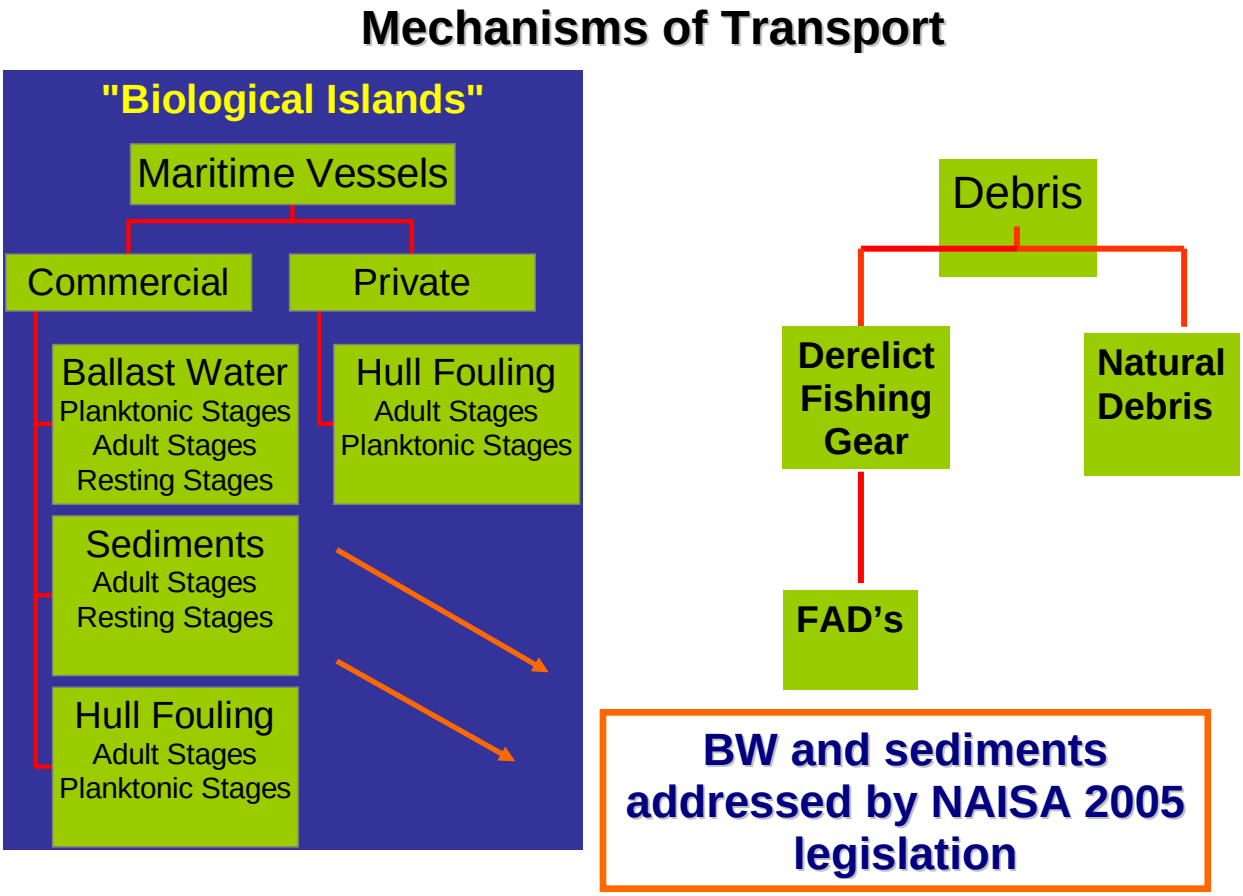
Invasive Marine Species Studies

Project:

- ✓ **Reducing potential impacts of invasive marine species in the NWHICRER (P. Jokiel, with assistance from K. Rodgers & S. Godwin)**

We are continuing to add information to a document that will be submitted in final form by the end of the funding year. Some major points covered in the draft document are as follows:

1. Populations of alien marine species that have already colonized areas of the MHI represent the most likely source of invasive species in the NWHI based on the proximity and pattern of ship movements associated with the MHI.
2. The majority of alien marine species that are currently known from the Hawaiian Archipelago are found in harbor and bay habitats and have not colonized high energy reef habitats.
3. The few alien species known from the NWHI are restricted to the anthropogenic habitats at Midway Atoll and French Frigate Shoals. Only one, the hydroid *Pennaria disticha* has spread extensively in the NWHI but neither this or other species has exhibited invasive characteristics at this time.
4. Marine debris has been shown to have the ability to transport non-indigenous species to the NWHI. Modes of transport such as derelict fish nets are problematic to manage but the impact of other anthropogenic debris, such as Fish Attraction Devices (FAD) deployed by the State of Hawai‘i, can be minimized.



Some of our recommendations to date are:

1. It will be important to establish formal administrative rules and codes of conduct to minimize exposure from the variety of potential transport mechanisms for non-indigenous transport to the NWHI.
2. Continue activities pertaining to species richness and diversity as part of establishing baseline information, and pursue research pertaining to biogeography focused on connectivity and larval transport.

3. Include the issue of marine non-indigenous species in education and outreach activities
4. Integrate the concepts of marine non-indigenous species and invasive behavior into the mindset of monitoring and assessment activities occurring in the NWHI.

*Draft Report of 12/12/05. 50 pp. The draft report includes all information known about this question and has been submitted to the Reserve for comment.

Project:

- ✓ **Molecular tools for invasive species in Hawai‘i (R. Toonen, with assistance from S. Godwin)**

Together with funding from Hawai‘i Sea Grant, Hawai‘i Coral Reef Initiative and the Hawai‘i Invasive Species Council, we have been working on developing molecular tools to identify the source of invasive species introductions into the Hawaiian Archipelago.

Evaluating the relative risk of introductions requires detailed surveys of the presence and abundance of invasive species on ships hulls, ballast water, and derelict fishing gear (see report by Godwin et al.). Although the presence or absence of fouling on any individual ship hull or competent larvae in ballast water tells us that such transport is possible, those data do not provide us with the actual source of any introduction. Molecular data provide us with a tool by which to examine the history of species movement, and we are currently developing the tools to go beyond what **might** have happened to what **most likely** happened.

In particular, we have focused on learning where did *Carijoa riisei* in Hawai‘i originate. Our accomplishments to date:

- We have developed and tested two new mitochondrial DNA (mtDNA) markers which can provide reliable sequencing results to support our phlogeographic analysis (Concepcion et al., 2006, in press); this is a significant achievement because mtDNA markers commonly used in other organisms have repeatedly proven useless in octocorals (reviewed by Shearer et al. 2002).

- We are working on developing useful nuclear DNA (nDNA) markers, but we expect difficulty in this process. To date, no lab in the world has successfully isolated nuclear intron markers from any octocoral due to significant technical issues with these organisms. Despite the difficulties, however, we are already collecting DNA sequence data from one nuclear marker, and are trying to develop others. The Cnidarian Tree of Life consortium is extremely interested in our progress, and offers of collaboration are coming in from around the world based on our recent success.

- *Carijoa* samples from the islands of O'ahu, Maui, Kaua'i, and Hawai'i have been sequenced. Additional *Carijoa* spp. samples have been secured from over 20 locations in the Pacific and Atlantic. We are currently working on these samples, and in total have >250 individuals sequenced for our mtDNA markers. We are now working on increasing this global sampling to determine the distribution of genetic variants in *Carijoa* populations world-wide in our effort to identify the source population from which *Carijoa* in Hawai'i originated.

- Samples from outside Hawai'i have been secured in collaboration with individuals from several organizations including: Bishop Museum; Museum and Art Gallery of the Northern Territory, Australia; Florida Museum of Natural History; Coral Reef Research Foundation, Palau; University of the Virgin Islands, US Geological Survey, University of Puerto Rico; Universidade de Madeira; Tel Aviv University.

- In addition, octocoral samples from several different taxonomic families have been secured in collaboration with Dr. Yehuda Benayahu of Tel Aviv University and Dr. Catherine McFadden of Harvey Mudd University. These samples will be used as outgroups to root the phylogenetic tree for *Carijoa* and provide a yard-stick against which to compare the degree of genetic difference seen in the Hawaiian population of *Carijoa*.

Preliminary results point to some very surprising conclusions regarding the dispersal history and biogeography of *Carijoa* in Hawai'i, the taxonomic status of the species in this group, and the biogeography of this soft coral in general.

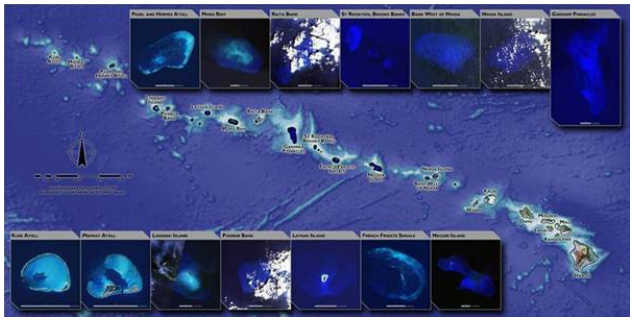
- *Carijoa* appears to be native to the Western Pacific with high and unique genetic diversity (i.e., the Indo-Pacific population of *Carijoa* is not a modern introduction from the Caribbean or Atlantic)
- The coral identified as *Carijoa riisei* in Hawai'i may not all be *C. riisei.* Preliminary data suggest that there may be multiple species of *Carijoa* in Hawai'i which are currently unidentified because of poor taxonomic resolution in the group worldwide. Further work is needed to resolve this issue in collaboration with Dr. Catherine McFadden and the Cnidarian Tree of Life consortium.
- Several specimens identified as *Carijoa riisei* by taxonomic experts are not closely related to any other samples in our soft corals database. The taxonomy of Carijoa appears to require major revision as a result of our research findings.
- *Carijoa* in Hawai'i almost certainly originated from a Pacific source, not the Caribbean or Atlantic, in contrast to previous reports.
- There appear to be multiple introductions of *Carijoa* into Hawai'i; sources of these introductions were likely locations throughout the Indo-Pacific, although based on the

current molecular data we cannot conclusively exclude the possibility that *Carijoa* invaded the Hawaiian Archipelago prior to human colonization.

Northwestern Hawaiian Islands Mapping

Project:

- ✓ **Mapping Support (P. Jokiel)**



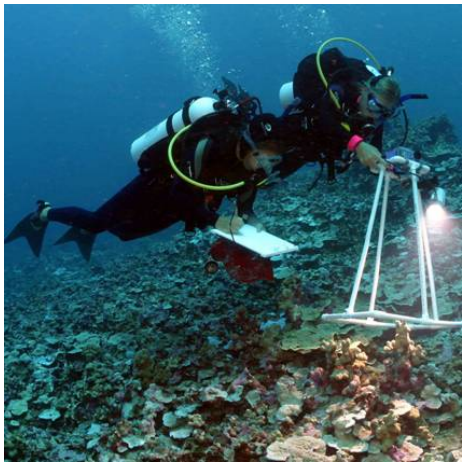
Data Base Component—We have purchased and installed a GIS Work Station; Characteristics: 64 bit, Xenon Dual Processor with 8 Gig RAM, 1.2 Terabytes. The work-station is a basic tool for all future work in mapping, ecosystem management and invasive species activities.

We are currently developing data layers with safeguards for proprietary data. The team includes:

Will Smith – shallow bathymetry, aerial photographs and habitat maps
Mike Wilton – Bathymetric data, political boundaries, analysis
Lisa Wedding – LIDAR, GAP, other fish and benthic survey data
Ku'ulei Rodgers/Paul Jokiel – benthic data, watersheds, environmental data, biological distributions
Ben Richards - fish data, bottom complexity
Collaboration with Bob Buddemeier (U Kans) – data for physical models, climate change
Daphne Fautin (U Kans) – distribution of biota, develop fine grid for future inclusion of data, aggregated for coarse data, develop single platform for all data

Mapping Support Component-The following products are under development:

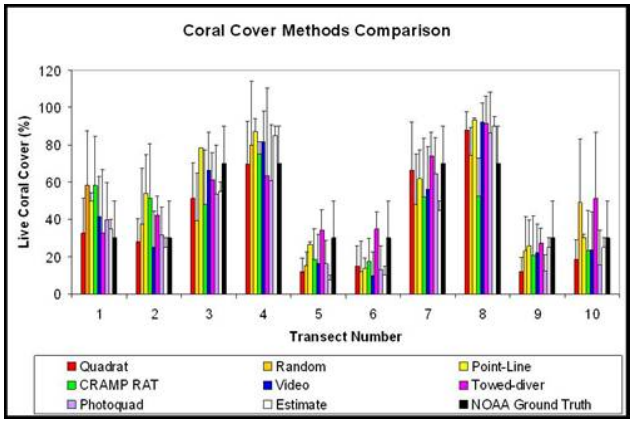
1. Integrated Bathymetric Layer
   - Regularly spaced (grid) surface for Archipelago
   - Create Base Map
   - Add detailed data as available
   - Interpolate (Kriging) depth values
   - Show confidence values in bathymetric data
   - Update
2. Hypsometric analysis based on best available data (plus rapid updates)
   - Within reserve boundary
   - Depths less than 30 m
   - Individual Islands less than 30 m
   - NWHI vs. MHI



3. Pseudo-bathymetry (Will Smith)
   - Identify and resolve problems, refine methodology, update
   - Future: Updates with additional field data, imagery
4. Benthic Habitat Maps (polygon shape files)
   - Main Hawaiian Islands (NOAA co-op) and NWHI
   - Future: Updates with additional field data, imagery, identify and resolve questions, refine analysis. Ability to update with additional field data, imagery.
5. Benthic Habitats – future update with additional field data, imagery as it becomes available (NWHI and MHI).

Communication-information exchange with other groups:

Rusty Brainard (NOAA Fisheries)
Joyce Miller (JIMAR, PMP)
Scott Ferguson (JIMAR, PMP)
Mike Parke (HIGICC)
Susan Vogt (NOAA/NOS)
Mark Monaco/Tim Battista (NOAA, MPA)
Jerry Ault/Steve Smith (RSMAS/NMSC)
Kris Holderdad/Rick Stumpf (NOAA/NOS)
Bob Buddemeier/Daphne Fautin (KGS/UK)
NWHICRER



Major results from the methods comparison study, in which we examined the estimates of coral cover obtained through a number of different methods over the last several decades, indicate that these varied data sets appear to be comparable and therefore *may* be combined for an overall larger mapping effort. The details of our findings are described in the following report:

*Report submitted: Jokiel, Paul L., Ku'ulei S. Rodgers, Erick K. Brown, Jean Kenyon, Greta Aeby, William R. Smith and Fred Farrell. 2005. Comparison of methods used to estimate coral cover in the Hawaiian Islands. Report to the Northwestern Hawaiian Islands Ecosystem Reserve, Honolulu. Dec. 2, 2005. 22 pp.

Ecosystems Management Studies

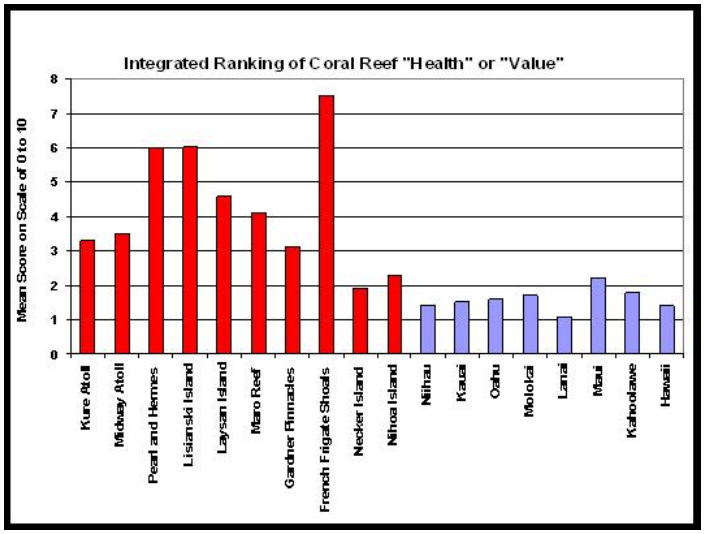
Project:

- ✓ **Evaluating ecosystem "health and value" (P. Jokiel & K. Rodgers)**

During the quarter we continued to gather and compile existing data and started synthesizing the information. An initial synthesis of some of this data was used to develop a preliminary ranking scheme that compares the health and value of islands in the NWHI with islands in the MHI. The analysis is presented in the following report:

*Jokiel, Paul L. and Ku'ulei Rodgers. 2005. Ranking coral ecosystem "health and value" for the islands of the Hawaiian Archipelago. Report to the Northwestern Hawaiian Islands Ecosystem Reserve. October 18, 2005. 15 pp.

This report evaluated relative biological "health" and "value" of the coral reefs of the Northwestern Hawaiian Islands (NWHI) in the context of the entire Hawaiian Archipelago. Sufficient data on five vitally important biological indicators have recently been developed for both the NWHI and the Main Hawaiian Islands (MHI). These include: reef fish biomass, reef fish endemicity, total living coral cover, population of the endangered Hawaiian monk seal (*Monachus schauinslandi*), and the number of female green sea turtles (*Chelonia mydas*) nesting annually on each island. These data were used to develop a simple integrated scoring and ranking scheme for all the islands of the archipelago. The composite scoring developed using these data shows that the ecological status of the MHI is poor compared to the NWHI. A growing body of information demonstrates that the reefs of the NWHI are an integral component of the Hawaiian Archipelago ecosystem and are an extremely valuable ecological resource. Thus the proper management of the NWHI is important to the ecology of the vitality of the Hawaiian Archipelago as a whole. The NWHI should not be viewed as a separate entity from the MHI because the two areas are clearly interdependent. The migration of turtles from feeding grounds in the MHI to nesting grounds in the NWHI provides an excellent example of the interdependence of the two areas. Movement of large fish and endangered Hawaiian monk seals provide other examples. The fact that the same species of fish, corals and other marine organisms occur along the entire Archipelago with high rates of endemism provides evidence that the NWHI and the MHI represent a single ecosystem with a long evolutionary history.



In summary, the major findings of this report are:

- The NWHI represent a valuable biological resource that is pristine in comparison to the MHI.
- The Hawaiian Archipelago must be viewed as a single ecosystem with the NWHI being an integral component.

Project:

- ✓ **Ecosystem management of the NWHI reserve**
  (R. Toonen, K. Selkoe & B. Halpern)

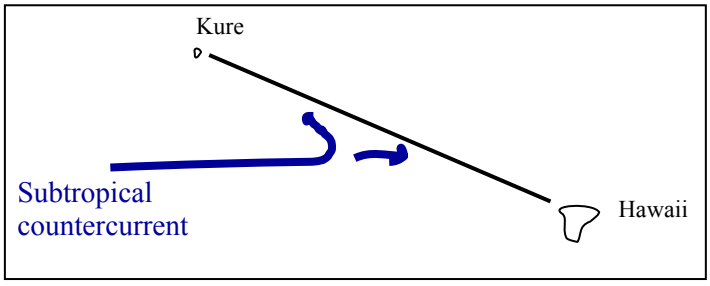
Effective ecosystem based management requires knowledge of the key biological and physical process controlling species and community distributions and functions as well as how human activities interact with and affect those dynamics (Grumbine 1994, 1997). Traditional approaches to fisheries and management for single species have been criticized for frequently resulting in unexpected regime shifts, and there is increased scientific and public support for ecosystem approaches to management on both theoretical and empirical grounds (reviewed by Bousquet &

Page 2004, Carignan & Villard 2002, Folke et al. 2004, Mayer & Rietkerk 2004). Even among fisheries that are not listed as overfished, data have shown an assortment of stock declines and fishery collapses as a result of serial depletion of local stocks (e.g., Orensanz et al. 1998). Thus, policies on marine exploitation are increasingly emphasizing ecosystems approaches to management rather than individually exploitable stocks (reviewed by Ormerod 2003). Along these lines we have made progress on two specific objectives identified as a high priority for the NWHICRER-HIMB partnership.

1. Identifying and assessing the vulnerability of the NWHI to threats

Through a working group funded by the National Center for Ecological Analysis and Synthesis (NCEAS), Kim and Ben recently created a new approach to using expert knowledge in assessing anthropogenic threats to ecosystems. Expert knowledge on the impact of threats is often an important criteria for managers to determine management priorities. The approach uses a transparent, rigorous, and repeatable method for scientifically evaluating the impacts of various threats, instead of the often undocumented and unclear way that expert opinion has been commonly used in the past. They have applied it to assessing all threats to marine ecosystems on a global scale (Halpern, Selkoe *et al.* Ecological Applications *in review*) and have now tailored it to NWHI ecosystems.. The method focuses on the distinct impacts of the threats to the ecological functioning of the communities in different habitats in the NWHI in order to compare the sensitivity of different habitats to each threat. So far over a dozen UH, NOAA and FWS scientists have participated and all have been enthusiastic about the project. The data provided by each scientist is combined to get a more rigorous assessment of threats than approaches that rely on just one or two experts. Moreover, each person's responses are weighted by an uncertainty factor that indicates the source of expertise that the answers are drawn from – personal observations, a single study or multiple published studies. The uncertainty data alone will provide valuable information on where knowledge is missing about how threats impact the NWHI. We have also begun to explore how we can partner with Erik Franklin to develop a spatially explicit map of the distribution of anthropogenic threats in the NWHI that incorporates the expert knowledge, to allow us to develop predictions about the effects of those threats.

2. Modeling patterns of connectivity within and among the main islands and NWHI



One of the greatest challenges to managing populations is to understand the spatial scales of population subdivision and larval dispersal that determine the source-sink dynamics of populations. Over the past year, we have worked to build a spatially-explicit, individual based model of population dynamics and genetics that is highly adaptable to a diversity of physical settings, dispersal parameters and life history types. Kim has worked with collaborator Brian Kinlan to parameterize the model using the physical relationships of the habitat areas of the NWHI based on the maps produced by NOS, oceanographic characteristics gathered from the literature, and any available demographic, life history and genetic data for a suite of model species. The model can be used to test hypotheses about the mechanisms generating observed patterns of genetics,

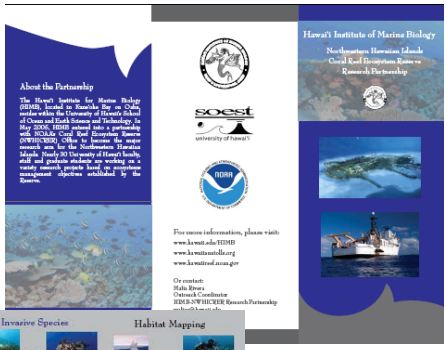
demographics and species diversity for existing empirical data, which will be tightly linked with on-going efforts in the genetic connectivity section. Even when there is little empirical data about particular species of NWHI, realistic ranges of parameter values can be inputted to the model and confidence intervals on the results can be used to rule out various scenarios of connectivity. These model results can be compared directly with those for larval dispersal patterns based on oceanographic currents in the NWHI (e.g., spiny lobster & grouper) in order to generate hypotheses to focus future studies of larval distribution and genetic connectivity.

The results of the model can also be used to generate predictions about spatial scales of connectivity and source-sink dynamics that can then inform the process of designing empirical studies. The model can also be used to examine reserve design or impacts of disturbance events such as storms or coral bleaching by spatially varying mortality parameters.

Outreach and Education

Dr. Malia Rivera was hired as the Outreach Coordinator position on August 11, 2005, close to the start of the second quarter of the HIMB-NWHICRER Research Partnership. During this reporting period, a number of outreach activities and programs involving the NWHI have been developed:

Development of tri-fold brochure and poster—As one of the first undertakings, the Outreach Coordinator developed a short brochure and poster for handing out at community events and to visitors at HIMB. This material was also displayed and distributed at the October 2005 University of Hawai'i SOEST Open House, at which there was participation by dozens of Hawai'i school groups and hundreds of students.



Integration of NWHI content into existing HIMB Community Education Program tours:-HIMB, largely through volunteer docents, runs an informal education program that serves visiting school groups, community groups and families by providing education tours of the facilities at Moku o Loʻe (Coconut Island). The Outreach Coordinator for the NWHI-CRER Research Project has successfully integrated NWHI research and education information into this tour. At the time of this report, approximately 300 students, teachers and community members have learned about the HIMB research program in the NWHI, have seen the NWHI video produced by NWHICRER (see www.hawaiireef.noaa.gov for download) and received the informational brochure on HIMB's NWHI research.

Visits from Agencies and Government—The Outreach Coordinator, at the request of the Director, has lead briefing tours of HIMB's research in the NWHI to visiting agency, congressional and state legislative members and staff. To date, visits have been lead for US Congressional staff, NOAA Coral Reef Research Program staff, NOAA Administration, State Legislator Senator Hee and his staff, the Hawaiian Islands Humpback Whale National Marine Sanctuary Advisory Council and the NWHICRER office.

Invited Presentations—As a result of a community tour group to HIMB, a request from the Rotary Club of Honolulu was made for a presentation to the West Hawaiʻi Chapter on HIMB's research on the NWHI. This was held on December 2nd, 2005, in which 40 audience members learned of the HIMB Research Program through a formal presentation. At the conclusion of the event, two other Rotary Club Chapters have requested this presentation as well.

Navigating Change Workshop—A workshop on the Hawaiʻi Standards aligned curriculum on the NWHI, *Navigating Change*, was hosted by HIMB on December 3rd, 2005. In attendance were representatives from the partner agencies (NWHICRER, USFWS, State of Hawaiʻi DLNR, UH and Bishop Museum) and 40 teachers from local schools. In addition to the curriculum materials, these teachers learned about the NWHI Research Program and were invited to establish ongoing communication with the Outreach Coordinator for help in integrating material on HIMB research into their classrooms.

HIMB Telepresence—In anticipation of funding for a telepresence initiative in Kāneʻohe Bay, the Outreach Coordinator has been working with NWHICRER and NMSP staff to place remote underwater cameras in the bay to stream live video of the coral reef habitat to classrooms. Ultimately the goal will be to establish lesson activities that will use live video to compare Kāneʻohe Bay to the Northwestern Hawaiian Islands. Pending funding, a preliminary test run will be established in the spring at sites already surveyed by the Outreach Coordinator earlier this year.