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

Quarterly Progress Reports V-VI
July 2006 – January 2007

Cover photos:
Front cover – ***Paracirrhites forsteri***; *hilu piliko'a*; Blackside Hawkfish at Johnston Atoll (Luiz Rocha)
Back cover – ***Heniochus diphreutes***; Schooling Banner Fish at French Frigate Shoals (Jill Zamzow)
Front cover, upper left – reef at Pearl and Hermes (James Watt)

Hawai‘i Institute of Marine Biology
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Coral Reef Research Partnership

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Report submitted by Jo-Ann Leong and Danielle Carter

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Photos provided by NOAA PMNM and HIMB.
This page: Aerial photo of Moku o Lo‘e (Coconut Island) by B. Daniel.

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Background

The Hawai‘i Institute of Marine Biology (HIMB) signed a memorandum of agreement with the National Marine Sanctuary Program (NOS, NOAA) on March 28, 2005, to assist the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve 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 for the biogeographic characterization of NWHI habitats.
4. Identify the pool of invasive species in the Main Hawaiian Islands and develop measures to prevent the spread of these species to the NWHI.
5. Support sound ecosystem-based 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 eight Main Hawaiian Islands (MHI) 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) which 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 (NWHI CRER), the largest marine protected area in the United States.

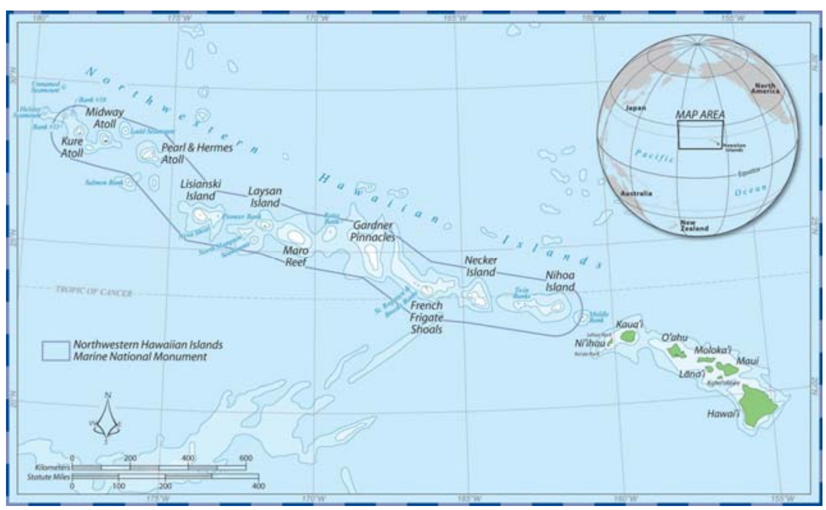

Fig. 1. Map produced by NOAA - Northwestern Hawaiian Islands Marine National Monument

On June 15, 2006, President George W. Bush signed a proclamation creating the Northwestern Hawaiian Islands Marine National Monument (NWHI MNM), the world’s largest marine protected area. The official name for the monument, Papahanaumokuakea Marine National Monument, was announced on March 2, 2007. This proclamation designation overlays the NWHI CRER and affords the NWHI the greatest possible marine environmental protections. It also increases immediacy of the need for an ecosystem management plan. The monument spans nearly 140,000 square miles and is home to an estimated 7,000 species including fishes, invertebrates, marine mammals, and birds. However, many biologists believe that this is a huge underestimate of the actual number of species in the region. While the full extent of its biodiversity is largely unknown, approximately one quarter of these species are likely found nowhere else on Earth.

Hawaiʻi is one of the most isolated yet populated areas on Earth and this site provides a unique opportunity to compare relatively pristine coral reefs in the northern end of the Hawaiian 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.

Summary of Activities and Results

The Hawai‘i Institute of Marine Biology has completed two sampling cruises to the Northwestern Hawaiian Islands (NWHI) since the research partnership was initiated in the spring of 2005. The most recent cruise aboard NOAA Ship Hi‘ialakai occurred during May-June 2006.

- Preliminary results of the fifth and sixth quarters of research are presented here, as well as other accomplishments associated with work being done in the monument.
- Tagging data indicate a broad dichotomy of top predator movements in the monument, with some very wide-ranging species and others that appear to be resident at individual atolls.
- Tiger sharks captured in monument waters are extremely wide-ranging, traveling thousands of kilometers along the Hawaiian Archipelago and up to 840 km into open-ocean beyond monument boundaries.
- Uku (*Aprion virescens*) are atoll residents that ‘ride the tide’ along atoll barrier reefs, and travel back and forth up to 24 km daily.
- The first data to compare population genetic structure for a species found at both Johnston Atoll and the Hawaiian Archipelago (the sea cucumber *Holothuria atra*) supports a connection between Johnston and the NWHI.
- *Acropora* growth anomalies were found to reduce the reproductive output of *A. cytherea* colonies.
- *Acropora* populations at French Frigate Shoals may be at risk for decline from the combined effects of increased mortality from *Acropora* white syndrome and reduced reproduction from *Acropora* growth anomalies.
- Fish have similar diseases in the NWHI as compared to the Main Hawaiian Islands but at lower prevalence.
- Although ta’ape from French Frigate Shoals had a high prevalence of the nematode infection, ta’ape at Midway lacked the disease presenting the possibility that disease transmission between islands is lagging temporally behind the spread of ta’ape.
- Health compromised *Acropora cytherea* harbor *Symbiodinium* clade A which appears to be an invasive species.
- The population of *Symbiodinium* in the corals *Acropora cytherea* and *Acropora nasuta* are different between French Frigate Shoals and Johnston Atoll.

- A survey highlights that the worst threats to the NWHI are global climate change effects and marine debris, while local activities have comparatively less impact, implying that the greatest challenge to managers of the monument will be mitigating these extra-boundary threats to the NWHI.

- HIMB established a GIS workstation for the management and analysis of datasets related to the research activities, marine habitats, bathymetry, regulatory boundaries, and other vital information of the Hawaiian Archipelago.

- HIMB developed and completed of the "Northwestern Hawaiian Islands Coral Reef Research Partnership" website accessible at the following web address: http://www.hawaii.edu/HIMB/nwhi_crrp/index.htm.

- HIMB completed an assessment of vessel traffic patterns in the Northwestern Hawaiian Islands which demonstrated two main corridors of traffic across and along the archipelago. The results were used for a review of the NWHI Area-to-be-Avoided designation by the International Maritime Organization.

- HIMB initiated data collection and production of an NWHI Threat Assessment Map Atlas.

- HIMB collaborated with the NWHI Marine National Monument and the University of Miami for a spatial data evaluation of NOAA NWHI coral reef monitoring programs.

- HIMB recruited a team of three graduate students who serve as scientific advisors for the Hawaiian Islands Humpback Whales National Marine Sanctuary (HIHWNMS) Marine Science Curriculum project for grades 3-8. .

- HIMB graduate students served as on-board educators on the PNMS annual education cruise on NOAA Ship Hiʻialakai.

- Studies conducted under the NWHI partnership resulted in 15 publications. See List of Project Publications and Presentations on page 26.

The following pages provide detailed descriptions of the research progress.

Northwestern Hawaiian Islands Connectivity Studies

Project:

- ✓ **Connectivity among coral reef invertebrates and fishes across the Hawaiian Archipelago**
  (R. Toonen, B. Bowen et al.)

The survey continues of fish and invertebrate species across the Northwestern Hawaiian Islands (NWHI) to assess the level of connectivity between the isolated reef habitats of the NWHI and the Main Hawaiian Islands (MHI). Our research seeks to answer the question of how connected are populations of invertebrates and fish among islands and atolls within the NWHI and between the Main and NWHI. A long-term debate exists as to whether the division between the Main and NWHI is a biological or socio-political one. This debate has become particularly relevant since the establishment of Papahanaumokuakea Marine National Monument, because people want to know whether the largest marine protected area in the world will provide recruits to seed the depleted resources of Main Hawaiian Islands fisheries. A similar discussion is ongoing about whether the NWHI are a series of relatively fragile (isolated) ecosystems that must be managed atoll-by-atoll, or whether the archipelago is a single large and robust ecosystem that can withstand anthropogenic influences such as debris accumulation, pollution and global climate change (see Environmental Management report by Selkoe et al.). By using genetic assays of population connectivity across a broad range of coral reef invertebrates and fishes with widely varying life history characteristics, we hope to settle this issue in a format that has both statistical power and scientific credibility.

We have assembled an outstanding team of scientists, including faculty, post-doctoral fellow, graduate student and undergraduate researchers to address these questions. Current collaborators on this project include Iliana Baums (faculty, Penn. State Univ.); Chris Bird, Kim Selkoe, Luiz Rocha and Matt Craig (post-docs, UH Mānoa); Scott Godwin, Jennifer Schultz, Michelle Gaither, Tonatiuh Trejo, Jeff Eble, Toby Daley-Engel, Kim Weersing, Greg Concepcion, Joe O'Malley, Matt Iacchei, Derek Skillings (graduate students, UH Mānoa); and several undergraduate research assistants including Van Nicholas Valesco & Carly Allen (UH Mānoa), Nichole Edelman (Hawai'i Pacific University) and Ashlee Albright (Simon Fraser University). Some of these researchers have participated in research cruises to the NWHI, using the newly-outfitted NOAA Ship Hi'ialakai, to visit eight locations (Nihoa, Necker, FFS, Gardner, Maro, Pearl & Hermes, Midway and Kure) throughout the NWHI over the past year. Over the past three years of research cruises we have collected non-lethal tissue samples from nearly 30 different species of invertebrates and fin clips from nearly 30 species of common reef fish from throughout the Hawaiian Archipelago that together comprise a tissue sample "museum" of nearly 4000 specimens. The multi-species approach to assess population connectivity in the Hawaiian Archipelago is also incorporated into a broader framework (funded by the National Science Foundation) to put population structure within the Hawaiian Archipelago into context using samples from elsewhere throughout the Indo-Pacific.

To date, our preliminary results suggest that there can be large differences among taxa in their degree of connectivity throughout the archipelago. Some species appear to move around the archipelago with relative ease and show no significant population structure between the NWHI and MHI (e.g., some reef fish – Schultz et al., 2007; Craig et al., 2007). In contrast, other species (e.g., ‘opihi - the Hawaiian endemic limpets *Cellana exarata*, *C. sandwicensis*, and *C. talcosa*) do not and can show striking population differentiation between the Main and Northwestern Hawaiian Islands (Bird et al., 2007). For all three species of ‘opihi, significant differentiation of populations occurs across the Hawaiian Archipelago, but the spatial scales, patterns and magnitudes of partitioning differ by almost an order of magnitude among species (Bird et al., 2007). Preliminary data from hermit crabs (Baums et al., in prep) suggests similar variability among closely related species in this group as well. In terms of the management implications of our work, there is significant population differentiation between the Main and Northwestern Hawaiian Islands for all three species of ‘opihi, and estimates of dispersal (migrants per generation ≤ 3) are far too low to augment depleted MHI populations (Figure 2). Even within the Main Hawaiian Islands, one of these species (the ko‘ele, *C. talcosa*) shows such strong population differentiation that if the Kaua‘i population were depleted, this species could not recover within our lifetime without human intervention (Bird et al., 2007). Finally, this work shows that despite similar life histories and ecology, these closely-related limpets have highly contrasting patterns of connectivity, highlighting the dangers of relying on exemplar species in management initiatives or to predict population structure and dispersal in the context of marine protected area delineation.

This past year, we also managed to visit Johnston Atoll for the first time and were able to collect samples for many of the same species there. The first genetic data to come out from that sampling is a comparison of population structure for the sea cucumber *Holothuria atra* (Skillings et al. in prep). A recent publication from Kobayashi (2006) used a Lagrangian individual-based computer simulation to infer patterns of larval dispersal between Johnston Atoll and the Hawaiian Archipelago. In his simulations, Kobayashi found a “northern corridor” which connects Johnston Atoll (JA) and the central portion of the NWHI MNM and a “southern corridor” which connects JA to the MHI. We compared genetic structure of sea cucumbers between O‘ahu, French Frigate Shoals (FFS) and JA to show that connectivity is very low between O‘ahu and FFS and between O‘ahu and JA. In contrast, there was no significant difference between samples from FFS and JA suggesting that connectivity is extremely high, and supporting the northern corridor for dispersal between JA and the Hawaiian Archipelago. This result adds to the data accumulating to support the hypothesis first advanced by Maragos & Jokiel (1986) that JA is a potential gateway for Hawaiian reef diversity to enter the chain.

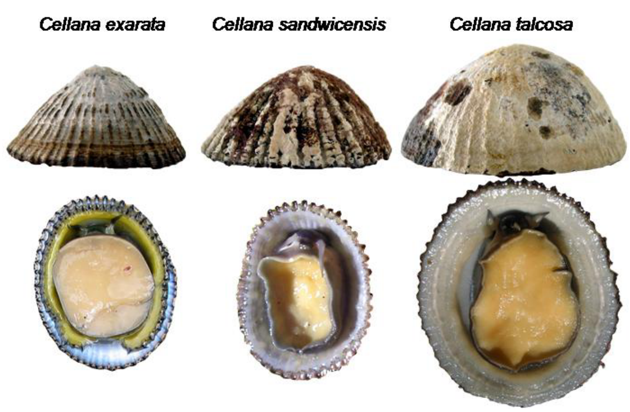

Figure 2. ‘Opihi are Hawaiian endemic limpets that are important as both cultural and commercial species. Researchers have shown that despite their similar life history and ecology, these three species have markedly different patterns of connectivity across the Hawaiian Archipelago, and that the populations present in the protected NWHI are incapable of supplying the Main Hawaiian Islands.

Our results thus far suggest that population structure across the Hawaiian Archipelago does not fit a simple isolation-by-distance model, and broad-scale generalizations based on previous dispersal models driven by average (geostrophic) oceanographic currents are poorly supported. Also, closely-related species with similar ecology and reproductive biology (such as ‘opihi & hermit crabs) can have dramatically different patterns of connectivity. Together, these results suggest that species-specific differences in reproductive biology or larval behavior may dominate patterns of connectivity throughout Hawai‘i and need to be considered in the management of the Northwestern Hawaiian Islands Marine National Monument.

Project:

- ✓ **Microspatial scale genetic differentiation on a coral reef (S. Karl)**

A critical management question is whether all members of a coral species in a reef are genetically related and whether the genetic heterogeneity of corals confers greater resilience of

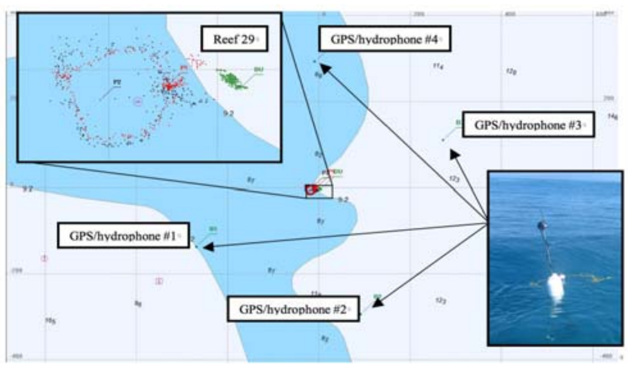

Figure 3. Map of GPS / hydrophone array positioned around Reef 29, a patch reef in French Frigate Shoals.

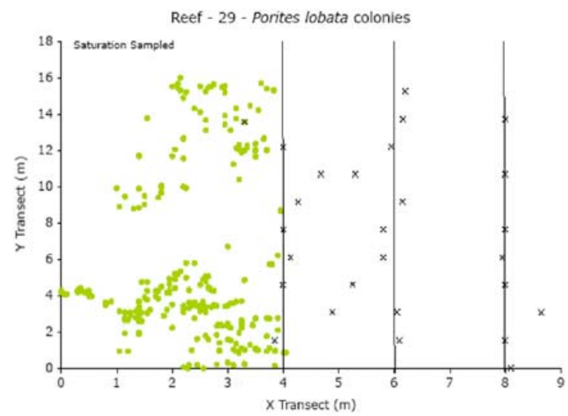

Figure 4. Spatial distribution of 264 coral colonies sampled at Reef 29.

the reef to disease and bleaching events. To this end, a nearly complete census of *Porites lobata* colonies on a single reef at French Frigate Shoals was done. Initial surveys identified two reefs as potential candidates for the census. The basic characteristics of an acceptable reef were less than 100% coral cover, a relatively shallow depth (to allow enough bottom time to survey efficiently), and a small enough area to not exceed the number of colonies allowed in the collection permits. Reef 29, a 0.025 hectare patch reef in the northwest of the atoll (166° 15.7825W, 23° 49.9316N) fit these criteria fairly well.

To place both the reef and the colonies on the reef in a global position context, an underwater GPS system was used. This system included four buoys each mounted with an above water GPS unit and a below water hydrophone (Figure 3). Divers carried two acoustic transmitters (32 KHz and 39 KHz) that the buoyed hydrophones used to triangulate the underwater position. These signals were then relayed via radio from each of the buoys to a receiver connected to a computer on a nearby boat where the data were processed and converted into position (Figure 4). Measuring tapes were set in a grid on the reef and the acoustic transmitters were placed at the beginning and end of one of the tapes. The grid headings were 310° for the Y transect and 220°

for the X transect. The exact location of every colony within the transect grid was determined based on the distance from the measuring tape. These locations will be converted into a global position in relation to the underwater acoustic transmitters. Genetic analysis has begun in the lab.

Project:

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

Top predators play an important role in ecosystems by shaping communities through trophic cascades (Pace et al., 1999; Stevens et al., 2000). In the Northwestern Hawaiian Islands Marine National Monument (NWHI MNM), this role is filled by sharks (primarily *Galeocerdo cuvier* [Tiger Shark], *Carcharhinus galapagensis* [Galapagos Shark], *C. amblyrhynchos* [Grey Reef Shark] and *Triaenodon obsesus* [White tip Reef Shark]) and large teleost fishes (primarily *Caranx ignobilis* [Giant Trevally]) (Sudekum et al., 91; Friedlander and DeMartini, 2002; DeMartini et al., 2005). Science-based management of the fish resources of the Hawaiian Archipelago requires that we know whether key species are site attached to specific areas and, if not, how frequent and extensive are their movements. If the populations of key species are "tied" to individual atolls or islands, different management options may be available than if significant numbers of individuals move between atolls or, indeed, move throughout the Hawaiian Archipelago. We are using acoustic and satellite telemetry to quantify the movements of top predators in the monument in order to address three questions relevant to management zoning:

(1) Do top predators move across open-ocean between atolls?
(2) How extensive are their intra-atoll movements?
(3) Do top predators exhibit predictable patterns of movement and habitat use?

<u>Recent fieldwork activities</u>

In September 2006, we participated in a 35 day research cruise that visited nine atolls, islands and pinnacles in the monument. Our primary goals during this cruise were to service and augment an array of underwater receivers that listen for predators equipped with acoustic transmitters. Seventeen receivers were successfully recovered, downloaded and redeployed, and five additional receivers were deployed at previously non-arrayed locations (Gardner Pinnacles, Lisianski/Neva Shoals and Laysan). As a result of these activities we now have a total of 23 receivers stationed at nine

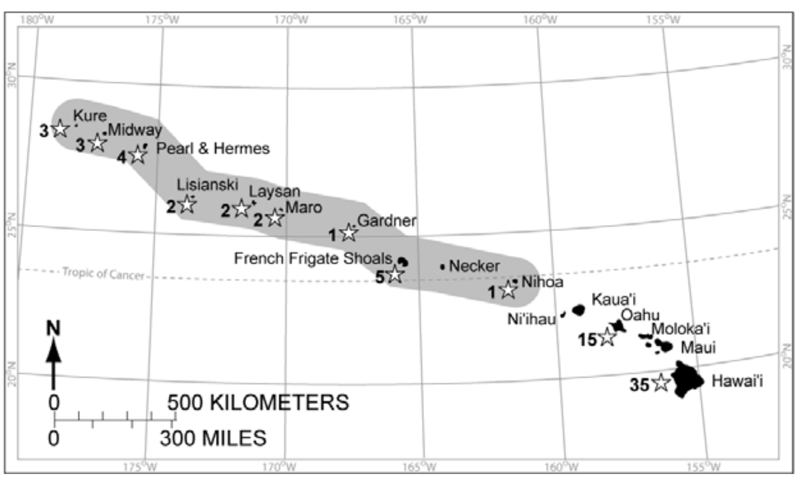

Figure 5. Hawaiian Archipelago showing locations (asterices) and numbers (bold) of VR2 receiver deployments. Light shaded area indicates boundaries of the Northwestern Hawaiian Islands Marine National Monument.

monument locations, contributing to an archipelago-wide listening array of over 70 receivers (Figure 5).

Results

To date, the listening array has recorded 372,577 detections of 98 top predators that were equipped with acoustic transmitters in monument waters in 2005 and 2006 (Table 1).

Table 1. Summary of monitoring data for 121 acoustic transmitter-equipped predators captured at five NWHI MNM atolls.

Species Name	Hawaiian Name	Common Name	N tagged	N (%) detected	Max Detection Span (days)	Inter-Atoll Movements Detected?
Carcharhinus amblyrhyncos	manō	Grey Reef Shark	6	4 (67)	500	Y
Galeocerdo cuvier	manō	Tiger Shark	15	11 (73)	388	Y
Aprion virescens	uku	Green Jobfish	28	27 (96)	472	N
Caranx ignobilis	ulua aukea	Giant Trevally	32	29 (91)	474	N
Carcharhinus galapagensis	manō	Galapagos Shark	40	27 (68)	474	N
TOTAL			**121**	**98 (81)**	**500**	

Between May 2006 and January 2007, 2,301 transmissions were received from nine sharks (five tiger sharks and four Galapagos sharks) equipped with dorsal fin-mounted satellite (SPOT) tags, yielding 341 positional fixes. Analyses of these data indicate a broad dichotomy of top predator movements in the monument, with some very wide-ranging species and others that appear to be resident at individual atolls (Table 1). For example, tiger sharks captured in monument waters were extremely wide-ranging, traveling thousands of kilometers along the Hawaiian Archipelago and up to 840 km into open-ocean beyond monument boundaries (Figure 6). These extensive open-ocean movements might help to explain why tiger sharks are taken as a bycatch in pelagic longline fisheries conducted in oceanic waters surrounding Hawaiʻi (Polovina & Lau, 1993).

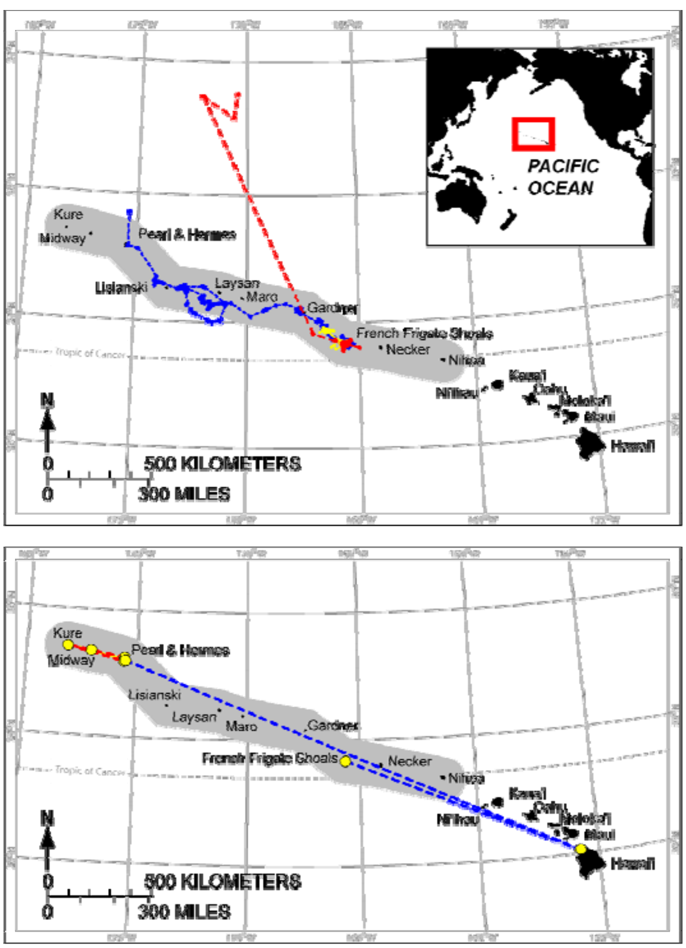

Figure 6. Long distance movements by tiger sharks captured in the Northwestern Hawaiian Islands Marine National Monument (grey shaded area) in May 2006. Top Panel: Tracks of three tiger sharks (yellow, red and blue lines) captured at French Frigate Shoals and equipped with dorsal fin mounted satellite transmitters (Smart Position Only Tags). Bottom Panel: Most direct paths between underwater acoustic receivers (solid yellow circles) by three tiger sharks captured at Pearl & Hermes Reef (blue line) and Kure Atoll (red & yellow lines), and implanted with acoustic transmitters.

Other monument predator species, such as ulua and uku (Figure 7), were resident at individual atolls where they exhibited well-defined diel and seasonal patterns of movement. Ulua at French Frigate Shoals atoll participated in summer lunar spawning migrations, with individuals utilizing the same spawning aggregation site in successive years. Uku also showed tidal rhythmicity in their movements resulting in migrations back and forth along 10 km of reef during one tidal cycle. The management implications of ulua and uku movement patterns are discussed in detail in forthcoming, peer-reviewed publications.

Figure 7. Releasing an uku (*Aprion virescens*) equipped with an implanted acoustic transmitter.

Acknowledgements
We thank Rusty Brainard, Peter Vroom (NOAA Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division) for providing us with berths on the September 2006 NWHI Marine National Monument research and monitoring cruise.

Project Publications

Meyer CG, Papastamatiou YP, Holland KN. (In Press) Seasonal, diel and tidal movements of green jobfish (*Aprion virescens*, Lutjanidae) at remote Hawaiian atolls: Implications for Marine Protected Area design. Marine Biology.

Meyer CG, Holland KN, Papastamatiou YP. (In Press) Seasonal and diel movements of giant trevally (*Caranx ignobilis*) at remote Hawaiian atolls: implications for the design of Marine Protected Areas. Marine Ecology Progress Series.

Papastamatiou YP, CG Meyer, JE Maragos. (In Press) Sharks as cleaners for reef fish. Coral Reefs.

Project:

- ✓ **Acoustic monitoring for biological and anthropogenic sounds in the Northwestern Hawaiian Islands Marine National Monument**
  (M. Lammers & W. Au)

Two significant challenges facing federal and state agencies responsible for managing the Northwestern Hawaiian Islands Marine National Monument include assessing the long-term stability of the monument's remote marine ecosystems and monitoring anthropogenic encroachment in the monument's isolated atolls and shallow banks. Acoustic-based methods can help meet these challenges by providing important indicators of both biological and anthropogenic activity. The sounds in many marine habitats are effective indicators of a number of biological processes, such as spawning events (Lobel, 1992; Hawkins & Amorim, 2000), courtship behaviors (Mann and Lobel, 1997), feeding (Versluis et al., 2000), competition (Johnston and Vives, 2003) and social communication among many species of fish, invertebrates, and aquatic mammals. In addition, sound can be an effective indicator of human presence, which in marine habitats is typically accompanied by the noise of vessel engines. Monitoring sounds is therefore a very promising means of establishing long-term trends in both biological activity and human presence at a site.

The Ecological Acoustic Recorder (EAR) is a tool that was recently developed to record the ambient sounds in marine habitats (Lammers et al., in review). The EAR is a digital, low power system based on a Persistor CF2 microprocessor and a 16-bit analog to digital converter that records the ambient sound field for periods of up to one year (Figure 8). Recording is initiated in one of three ways: on a software-regulated schedule; on a start trigger tuned to vessel-generated acoustic energy; and/or on a trigger tuned to sounds produced by cetaceans.

Figure 8. The EAR attached to a concrete anchor

Last September, four EAR units were placed in the monument. Two were deployed at French Frigate Shoals, one at Pearl and Hermes Atoll, and one at Kure Atoll. These units were programmed to record ambient sounds up to 25 kHz for 30 seconds every 15 minutes and were also set to trigger on vessel generated sounds. To date, no data exist to report from these deployments, as the units are not scheduled to be recovered until July of this year. However, it is expected that the resulting recordings will yield revealing insights into (1) patterns of natural fluctuation in the ambient sounds produced by fish and invertebrates, (2) the incidence of vessel traffic near the deployment sites and (3) the occurrence of cetaceans in the areas of deployment.

Coral Health Assessment Program Studies

Project:

- ✓ **Investigation of diseases of corals and fish within the Northwestern Hawaiian Islands and Johnston Atoll**
  (G. Aeby & T. Work)

<u>Coral disease</u>

Disease can affect coral communities directly through mortality or indirectly through sub-lethal events such as reduced growth, resilience or reproduction. *Acropora* growth anomalies (Figure 9) potentially result in an energy drain on colonies that could affect reproductive output. *A. cytherea* is known to reproduce during May/June in the Northwestern Hawaiian Islands (NWHI) (Kenyon, 1992) so tumored and non-tumored *A. cytherea*

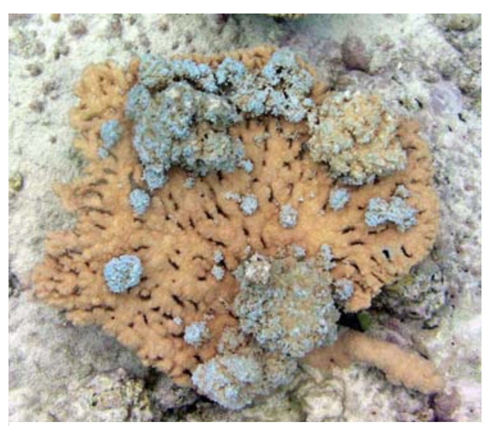

Figure 9. *Acropora cytherea* with growth anomalies at French Frigate Shoals.

colonies were sampled in June 2006 and coral polyps examined for presence of reproductive structures. All polyps examined from healthy colonies were gravid and contained eggs and sperm bundles. In contrast, no polyps from growth anomalies were gravid (Figure 10). Polyps from growth anomalies had abnormal development with increased polyp length and an absence of visible mesenteries. In healthy tissue from colonies with growth anomalies, only one sample had gravid polyps. One objective of disease studies is to determine the virulence of particular diseases, giving managers the information needed to decide if management options need to be developed. From our studies, we now know that *Acropora* growth anomalies is a progressive disease that results in reduced reproduction of colonies and can lead to partial colony mortality.

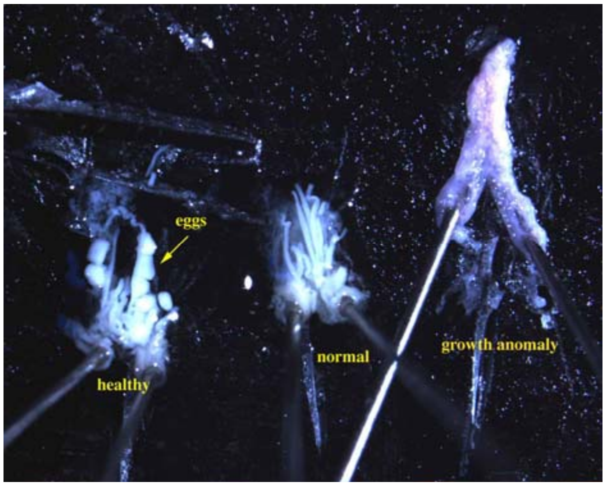

Figure 10. Polyps from healthy *Acropora* compared to polyps from a growth anomaly and a normal area from the affected colony. Notice eggs are only found in healthy polyps, whereas polyps from growth anomlies are larger and lack eggs and mesentaries.

Acropora white syndrome was also found to be a highly virulent disease with 97.6% of individually marked colonies suffering moderate to total tissue mortality. French Frigate Shoals (FFS) has the highest diversity and abundance of acroporid corals within the NWHI (Maragos et al. 2004). *Acropora* at FFS are affected by *Acropora* white syndrome (AWS) and *Acropora* growth anomalies (AGA), both of which have now been shown to be detrimental to colonies. *Acropora* populations at French Frigate Shoals may be at risk for decline through time from the combined effects of increased mortality from *Acropora* white syndrome and reduced reproduction from *Acropora* growth anomalies. As such, it is recommended that strategies be development to manage these diseases. Pilot studies to test potential methods of treatment for both diseases are planned.

<u>Fish disease</u>

Introduced species can be problematic not only in terms of out competing native species but also in the possible introduction of novel diseases. In Hawaiian terrestrial ecosystems, introduced pathogens have had a major impact on endangered species. For example, avian malaria was introduced into the islands with released imported cage birds. This disease has spread to native bird species and has seriously affected native forest birds (Atkinson et al., 2000). In the marine environment, *Lutjanus kasmira* (ta'ape) (Figure 11) were introduced into Hawai‘i in the 1950s (Randall, 1987) and have spread all the way to Midway Atoll. Ta'ape share habitat and are closely associated with certain

Figure 11. Ta'ape populations at French Frigate Shoals.

native fish such as goatfish (Freidlander et al., 2002) and there is the concern that any diseases brought in by ta'ape may have spread to native fish populations. Work et al. (2003) screened ta'ape for disease and found bacterial and protozoal diseases in their spleens and kidneys. Aeby et al. (unpub. data) found them to harbor nematode infections (*Spirocamallanus istiblenni)* in their guts. Studies in the Main Hawaiian Islands (MHI) found native goatfishes to have the kidney, spleen and nematode infections. In May 2006, ta'ape and goatfish from the NWHI were examined to determine whether these diseases were present in the NWHI fish populations. Disease in the spleen and kidney were found in the NWHI ta'ape and goatfish populations but at a lower level than found in the MHI. In a separate study, goatfish from Kure, where ta'ape are not yet found, were screened and also found to have the kidney and spleen disease (Work et al. unpub. data). This suggests that these diseases were not brought into the ecosystem by ta'ape but instead may have been already established in the native fish populations.

Ta'ape and goatfish examined from FFS were also found to harbor the nematode infection at levels as high or higher than fish from the MHI. Goatfish were not examined from Midway, but ta'ape were examined and found to lack nematode infections. Presence of this disease in fish populations at FFS but not at Midway suggests that the spread of the disease between islands is lagging temporally behind the spread of its fish host. Annual screening of ta'ape from Midway for the nematode infection may ultimately give information on rate of spread of fish disease between islands within the Hawaiian Archipelago. Goatfish from Midway and Kure need to be examined to verify this hypothesis.

It has been suggested that the nematode infection was brought into Hawai'i with the introduction of ta'ape (Font & Rigby, 2000). If the disease was introduced, then goatfish from areas lacking ta'ape should not be infected. To examine this, nineteen goatfish from Johnston Atoll, which has not yet been invaded by ta'ape, were examined for disease. Although other types of gut parasites were found in goatfish (*Mulloides flavolineatus*), no nematode infections were documented. This is consistent with the hypothesis that the nematode disease was introduced into Hawai'i by ta'ape.

Project:

- ✓ **Assessing the diversity of bacteria associated with healthy and health-compromised corals across the Hawaiian Archipelago (J. Salerno, E. Hambleton & M. Rappé)**

<u>Investigating bacterial communities associated with the coral *Porites lobata* in Kāne'ohe Bay and French Frigate Shoals</u>

Bacterial communities associated with *Porites lobata* colonies sampled from French Frigate Shoals during the September 2005 cruise were examined using terminal restriction fragment length polymorphism (T-RFLP) analysis to quantitatively and qualitatively assess the resident microbial community structure. Resulting microbial community structure data were compared with those of *Porites lobata* colonies sampled from Kāne'ohe Bay, O'ahu to examine overall similarities and/or differences in bacterial community composition associated with this species of coral at the two locales. A statistical ordination method (PC-ORD multivariate analysis of ecological data) was used to compare T-RFLP data for each *Porites lobata* colony sampled at each site (*Porites lobata* colonies sampled in Kāne'ohe Bay came from a single patch reef site and those sampled at French Frigate Shoals came from four different sites; Figure 12). Preliminary results from a non-metric multi-dimensional scaling ordination indicated that bacterial communities associated with *Porites lobata* from Kāneʻohe Bay are different in composition (diversity and abundance) than those associated with *Porites lobata* colonies from French Frigate Shoals (a general rule of thumb for interpreting NMDS graphs is that points that are closer together have a higher percent similarity and those that are farther apart are less similar). There appeared to be marked inter-colony variation in bacterial community composition at French Frigate Shoals, with no structure or grouping based on habitat type. Bacterial communities associated with *Porites lobata* samples collected from other atolls within the Northwestern Hawaiian Island Marine National Monument will be analyzed and compared with those from French Frigate Shoals to determine if coral-associated bacterial communities are conserved across the archipelago or if they vary based on geographical location, habitat type, and/or season. Possible relationships between bacterial community composition and environmental variables such as sea surface temperature, salinity, nutrient concentrations, phytoplankton biomass, and anthropogenic impacts will also be explored.

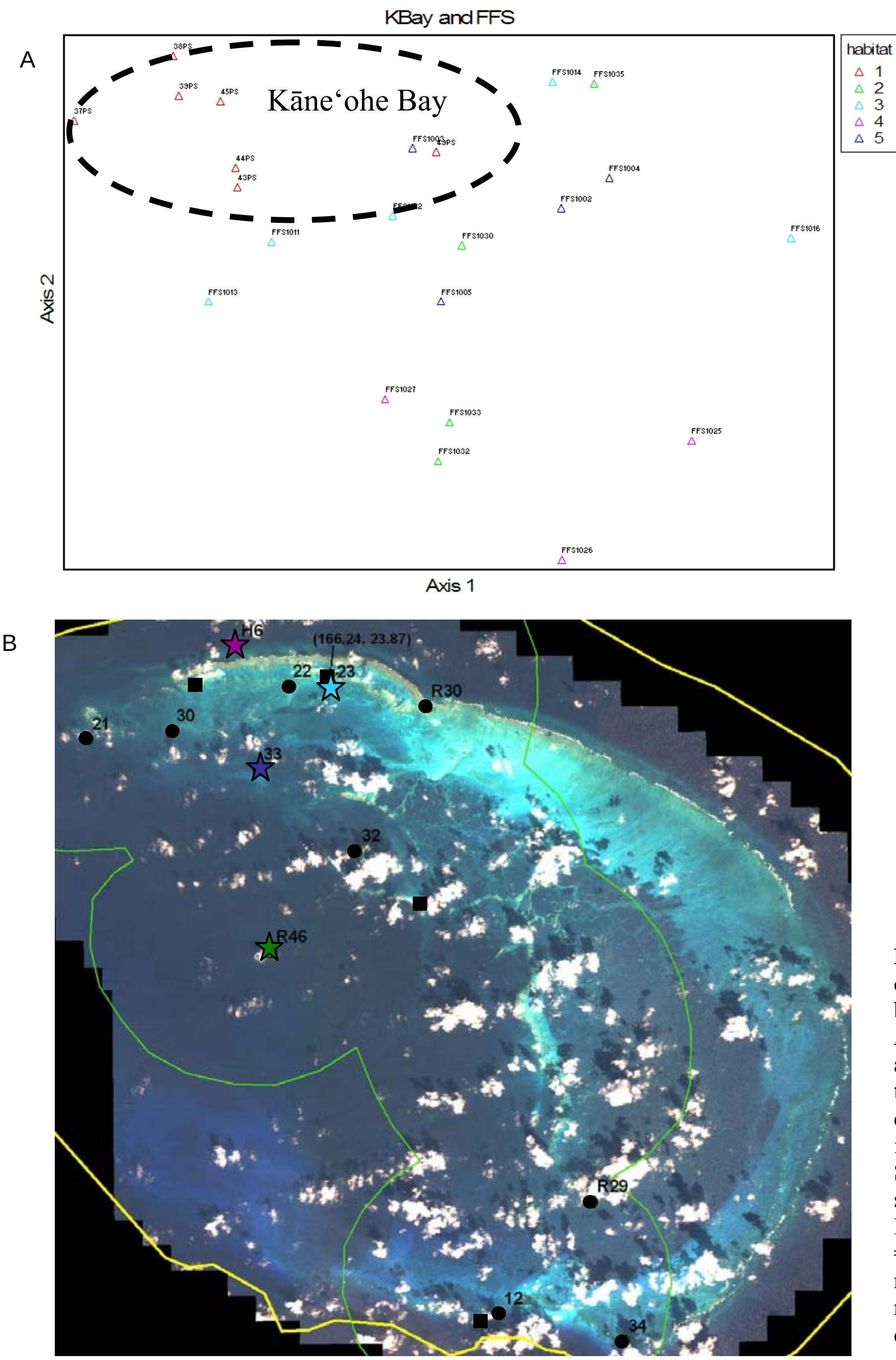

Figure 12. A, Non-metric multi-dimensional scaling ordination of bacterial communities associated with *Porites lobata* colonies in Kāneʻohe Bay and French Frigate Shoals. Each triangle represents the bacterial community associated with an indiviudal *Porites lobata* colony. Symbol colors correspond to the starred sites shown on the NOAA aerial map of French Frigate Shoals (B). H6 (purple) = fore reef site, 23 (light blue) = back reef site, 33 (dark blue) = lagoon/patch reef site, and R46 pinnacles (green) = coastal reef site.

Assessment of reef water bacterioplankton and phytoplankton communities
Seawater samples were taken adjacent to sampled coral heads to compare microbial community composition (including bacterioplankton and phytoplankton) between corals and the surrounding seawater environment. To obtain bacterial and phytoplankton cells for DNA extraction, 100 ml to 1 L of seawater was filtered through 0.8-μm-pore-size GFA filters and 0.2-μm-pore-size Supor-200 filters. Filters were stored in DNA lysis buffer at -40° C at sea and then transported to a -80° C freezer at the Hawai'i Institute of Marine Biology. Thus far, 47 seawater samples have been collected from two cruises to the Northwestern Hawaiian Island Marine National Monument. These samples were taken from back reef, fore reef, lagoon, and coastal reef habitats from nine islands and atolls within the monument. Seawater samples were also collected from nine sites at Johnston Atoll and 17 sites at American Samoa (Tutuila and Ofu Islands) and will be compared to those collected from reef waters within the monument. Genomic DNA has been extracted from all samples using the DNeasy Tissue Kit (Qiagen). Bacterial community profiles will be produced using the same T-RFLP methods described above and will be compared with those of seawater- and coral-associated bacterial communities from other locales.

Additional seawater samples were collected at each site to measure temperature, salinity, nutrients, the abundance of heterotrophic bacteria and autoflourescent phytoplankton, and chlorophyll *a* concentrations. The concentration of chlorophyll *a* photosynthetic pigment in the seawater serves as a proxy for phytoplankton community biomass, which, in turn, provides information on how productive the area is. To date, we have processed and extracted chlorophyll *a* from 32 seawater samples taken from French Frigate Shoals, Gardner Pinnacles, Johnston Atoll, and American Samoa. Sampling of chlorophyll *a* and the aforementioned environmental variables will be continued on subsequent cruises to the monument. These measurements will provide valuable information about the environmental conditions that seawater- and coral-associated bacterial communities are exposed to during the course of the HIMB research cruises which can subsequently be used to link our research with that of the Coral Reef Ecosystem Division of The Pacific Islands Fisheries Science Center (NMFS, NOAA) directed by Dr. Rusty Brainard.

Project:

- ✓ **The diversity of the coral endosymbiont *Symbiodinium* and their role in disease susceptibility**
  (M. Stat & R. Gates)

Dinoflagellates from the genus *Symbiodinium* form mutualistic associations with coral (Muscatine and Porter, 1977). This symbiosis allows for the growth and development of coral reefs, which is an ecologically important habitat for marine invertebrates and fish. The genus *Symbiodinium* contain a diverse number of genetic varieties which have been shown to affect the biology of the coral host, including growth rate and tolerance to elevated sea surface temperatures (Little et al., 2004; Rowan, 2004). The genus has been grouped into eight clades (A-H; Fig. 13a), which in turn contain multiple sub-clade types based on rDNA (reviewed in Stat et al., 2006). The diversity of *Symbiodinium* harbored by corals in the Northwestern Hawaiian Island Marine National Monument (NWHI MNM) and Johnston Atoll (JA) remains unexplored.

This research aims to 1) investigate whether the genotype of *Symbiodinium* affects the health status of coral, and 2) describe the diversity of *Symbiodinium* from corals in the NWHI and JA and in the surrounding reef waters.

<u>Investigating whether the genotype of *Symbiodinium* affects the health status of coral</u>

We collected samples from colonies of *A. cytherea* that appeared healthy (Figure 13b), displayed an abnormal phenotype containing blue pigmentation (Figure 13c), and showed evidence of active tissue loss (Figure 13d). Restriction fragment length polymorphism (RFLP) of ssu rDNA was used to determine the clade of *Symbiodinium* present in coral hosts. At French Frigate Shoals, we found a significant association between the clade of *Symbiodinium* and the health state of coral, with corals harboring clade A showing a higher incidence of disease. Clade C was primarily found in healthy *A. cytherea* colonies. Furthermore, we cloned and sequenced the ITS2 region from *Symbiodinium* and found that *A. cytherea* harbors *Symbiodinium* sub-clade A1. This is the first report of A1 being found within coral from the Pacific. Interestingly, the upside down jellyfish, *Cassiopeia* sp., which is an introduced species to Hawai'i from the Atlantic Caribbean (Holland et al., 2004) also harbors A1. It is likely that the clade A *Symbiodinium* found in health compromised *A. cytherea* in the NWHI MNM is an introduced species vectored by *Cassiopeia* sp.

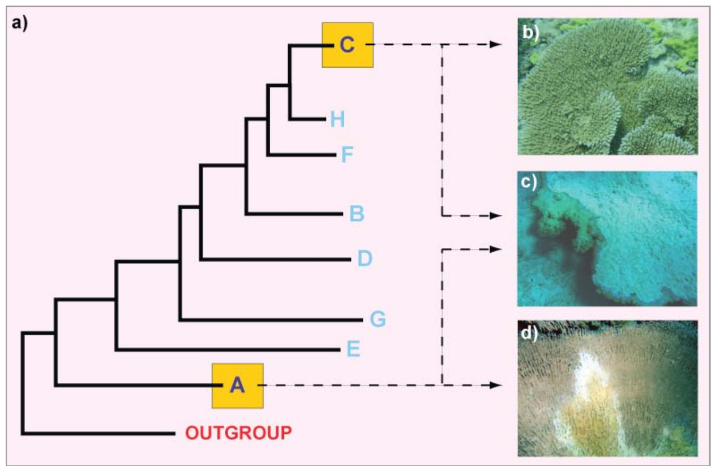

Figure 13. a) phylogeny of *Symbiodinium*, b) healthy *A. cytherea*, c) *A. cytherea* with abnormal phenotype and blue pigmentation, and d) *A. cytherea* with active tissue loss.

<u>Exploring the diversity of *Symbiodinium* from corals in the NWHI and JA and the surrounding reef waters</u>

RFLP of *Symbiodinium* ssu rDNA from corals collected in the NWHI MNM show that corals predominantly harbor clade C *Symbiodinium*. To obtain greater genetic resolution, the nuclear ribosomal ITS2 gene and the chloroplast 23S gene will be amplified from DNA extracted from *Symbiodinium* in all the coral hosts sampled. We have obtained sequences for both markers from *A. cytherea* and *A. nasuta* from French Frigate Shoals and Johnston Atoll. The symbiont population in these two coral species partitions according to geographic location, with only the global symbiont generalist, C3, found at both locations.

<u>Global mapping of *Symbiodinium* ITS2 types</u>

A GIS database on *Symbiodinium* ITS2 types, hosts they are found in, and their geographic location is in development in collaboration with HIMB GIS specialist Erik Franklin. This tool will be helpful in identifying endemic Hawaiian *Symbiodinium* types and their distribution throughout the archipelago and on a global scale.

Ecosystem Management Studies

Project:

- ✓ **Life history of coral reef fishes of the Northwestern Hawaiian Islands (M. Craig & E. Franklin)**

The primary goal of this research is to compile life history data for a suite of reef fishes within the Northwestern Hawaiian Islands Marine National Monument (NWHI MNM). We aim to determine the relationship between age and growth, the age/size at first sexual maturity, and the relationships among morphological measurements such as standard length to total length and length to weight for each species (Figure 14). This project provides critical biological information that, in conjunction with reef fish community monitoring data collected by NOAA and other collaborators, can be used to perform population assessments and ecosystem modeling exercises fundamental to the effective management of these species in the NWHI marine ecosystem. An important aspect of this work is that we utilize species already sampled for genetic analysis by B. Bowen and colleagues, thus, we will make maximal use of specimens that unavoidably have been sacrificed for other studies.

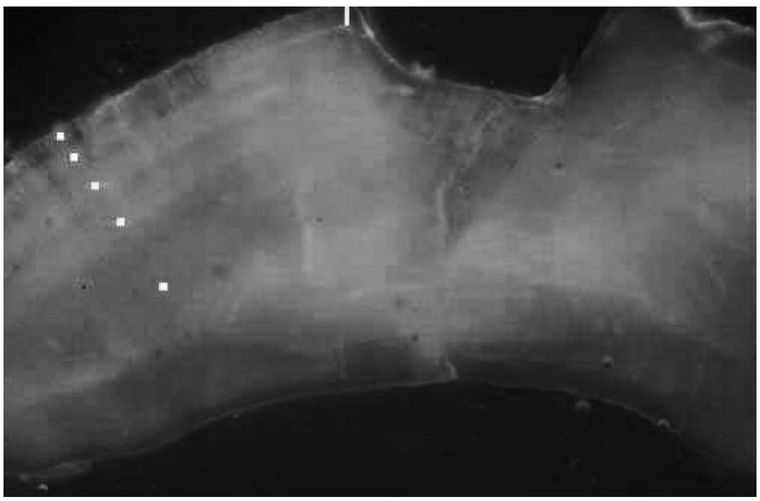

Figure 14. The annual growth increments (identified with white dots) in a fish ear bone called an otolith that are read to determine the age of a fish. (image: Robertson MEPS 2005)

The reef fish were collected during research trips to the Northwestern Hawaiian Islands on the NOAA Ship Hiʻialakai. Specimens were collected from French Frigate Shoals, Nihoa Island, and Gardner Pinnacle in 2006. Additional collections from Kure Atoll, Midway Atoll, Pearl and Hermes Atoll, Laysan Island, Lisianski Island, Gardner Pinnacle and Nihoa Island are planned during the upcoming 2007 research cruises (Figure 15). The fish sampled include several species of butterfly fish, surgeon fish, wrasse, parrotfish and several others. The sample size target is 25-30 specimens per species per atoll/island for a total of 250-300 for the entire NWHI. These are the same individuals used for genetic studies, not in addition to their project.

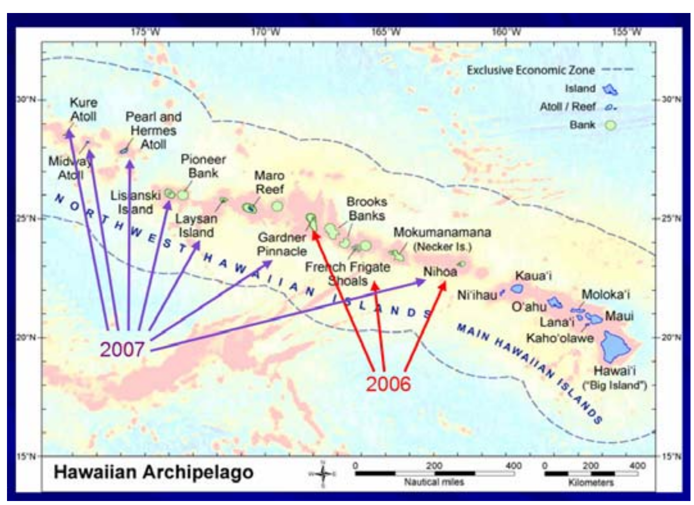

Figure 15. 2006 and 2007 collection sites

The characterization of reef fish life history parameters from this study will provide a foundation for a comparative study between impacted reef fish populations in the Main Hawaiian Islands (MHI) and non-impacted populations of reef fishes in the monument. We have begun a collaborative effort with researchers at the University of Hawai‘i’s Hawai‘i Cooperative Fishery Research Unit to commence a comparative study on populations of kole (*Ctenochaetus strigosus*), brown surgeonfish (*Acanthurus nigrofuscus*), and yellow tang *Zebrasoma flavescens*) between the NWHI and MHI. This collaboration seeks to examine the geographic variation in life history parameters and the impact that fishing and collection have on the growth and maturation dynamics of reef fishes.

Project:

- ✓ **Ecosystem management**
  (P. Jokiel & K. Rodgers)

Assessment of future habitat changes under projected climate change scenarios is being conducted using mesocosms and computer modeling (Figure 16). A long term mesocosms experiment comparing growth of crustose coralline algae and reef corals under present day conditions versus the expected future carbonate saturation state due to ocean acidification was completed. Extreme reduction in crustose coralline algae (CCA) recruitment and growth was measured (Figure 17). The CCA is the cement that holds the reef together, so this is an ominous sign for future change. Reduction in coral growth and production of number of eggs by corals was also observed under conditions of ocean acidification. Modeling of changes in coral cover under projected changes in ocean temperature and carbonate saturation state continue in collaboration with Dr. Robert W. Buddemeier (U Kansas) and others with a prototype model presently under testing.

An ecological gradient model (EGM) that can compare sites and describe reef condition using biological criteria is under revision. We are exploring over 40 biological, physical and environmental factors in the model to select those which can best describe the ecological status of the reefs. In this way we can describe the condition and compare reefs throughout the archipelago. A manuscript entitled “Modeling Hawaiian Coral Reef Ecological Status” has been prepared for submission to a peer reviewed journal.

Figure 16. Ocean acidification experiments being conducted in mesocosm facility at Coconut Island. Projected future levels of acidification were produced by pumping dilute acid into the intake.

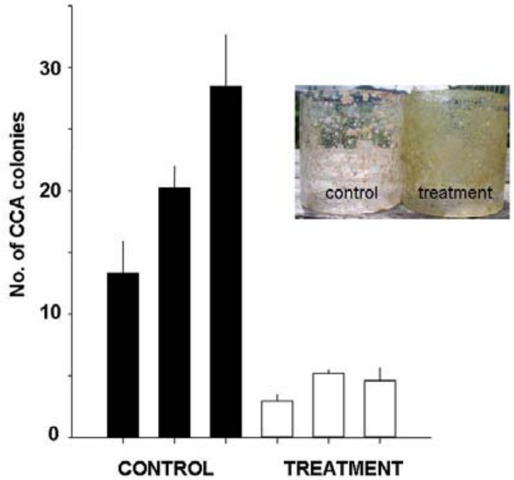

Figure 17. Recruitment and growth of crustose coralline algae (CCA) on plastic cylinders in mesocosms (3 replicate mesocosms for control and treatment with 3 cylinders per mesocosms). Treatment showed extreme decline in CCA and increase in green algae.

Project:

- ✓ **Northwestern Hawaiian Islands ecosystem management studies (K. Selkoe, B. Halpern, E. Franklin & R. Toonen)**

Expert survey of threats

While exhaustive lists of anthropogenic threats to the Northwestern Hawaiian Islands (NWHI) have been generated in the past (e.g., Maragos & Gulko, 2002, Friedlander et al., 2005), understanding how and why those anthropogenic activities threaten the ecosystem has not been systematically addressed. The goals of this project are: (1) to understand which anthropogenic threats have had the worst and least impact on the NWHI ecosystem, (2) to systematically compare the way in which each threat impacts the NWHI with five metrics, (3) to understand how different habitats in the NWHI (e.g., lagoon, intertidal or deep banks) have different vulnerabilities to each threat, and (4) identify which threats and habitats are not well understood and should be targeted for further study. Our approach has proven to be of high interest for managers and conservationists in many regions (e.g., the Monterey Bay National Marine Sanctuary, The Nature Conservancy offices in the Pacific Northwest, the Moore Foundation's California Current project). Interest in understanding the affects of human activities on the Northwestern Hawaiian Islands Marine National Monument is particularly high right now as regulations and management plans are in the process of being re-written.

This last quarter we continued to refine our social science survey of threats to the NWHI after solicitation of critical review by several colleagues and peer review. The foundational methods paper for this study has now been accepted for publication at Conservation Biology (Halpern et al., in press). Our improved manuscript on the NWHI-specific study is under review at Biological Conservation (Selkoe et al., in review). We are now working with managers on ways to integrate the study's findings into management practices. Translating science into policy is always a difficult final step of conservation research. In order to advance the effectiveness of this process, we spent time this past quarter designing a workshop to convene decision theory experts and social scientists, with the specific goals of improving/vetting our survey technique, creating a protocol for making management decisions based on our expert survey data, and exploring methods for incorporating the analysis of future threats into the survey. We secured $12,000 from the Moore Foundation to run this workshop in April 2007. This workshop will vastly improve the power of our survey and mapping projects to contribute to ecosystem based management of the Northwestern Hawaiian Islands Marine National Monument.

<u>Mapping the impacts of threats</u>

During the last quarter we focused on gathering data for our project to map threats to the NWHI. The aims of this project are to provide the NWHI user groups, including managers, scientists and citizens, with an easy to use, coherent framework for viewing all types of spatial data of the NWHI marine ecosystem, and to provide useful analyses on the current impacts of anthropogenic threats to various aspects of the ecosystem. In addition to some general work to develop and refine the details of our spatial data analysis approaches, relevant GIS data layers on various threats have now been either created or collected. These include high resolution spatial data on: thermal anomalies which can be used to identify the areas most vulnerable to coral bleaching and coral disease (Figure 18), seawater acidification due to climate change, areas most vulnerable to sea level rise, areas affected by shipwrecks, areas of high scientific use, past fisheries data, ship traffic data, distributions of exotic species, areas of hardened shoreline, and the distribution of marine debris and sites of debris removal. These data will be combined with newly available habitat maps (see Figure 19) and biodiversity maps to allow analyses of which areas of the NWHI have the most threats, which are least vulnerable to threats, and which habitat types are most threatened. These analyses should be of great use to the scientific and management communities for many purposes. The data will also be made available for all uses via a website.

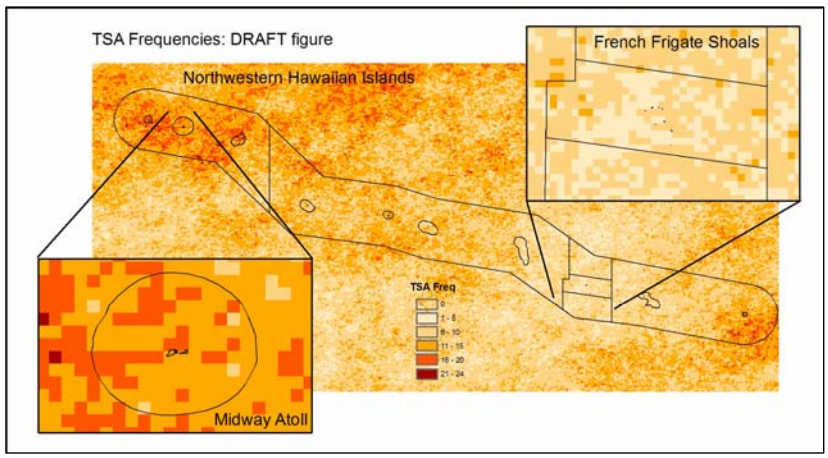

Figure 18. Thermal Stress Anomaly (TSA) map of the NWHI. Values represent the frequency of events of elevated seawater temperature associated with coral bleaching (i.e., degree heating weeks). Data are 4 sq. km resolution satellite data spanning 1985-2005.

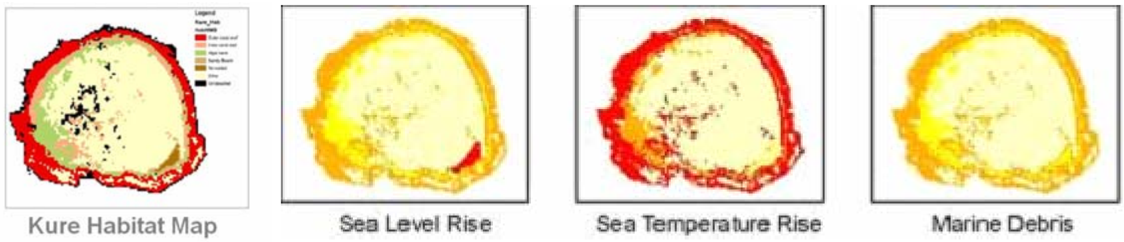

Figure 19. Example of how threat impacts are mapped onto habitat data. Kure Atoll habitat map in rightmost panel shows designations of distinct ecozones used in the expert opinion survey. In other panels, colors code differing levels of impacts by ecozone. We have similar threat maps for 13 distinct threats in total.

Northwestern Hawaiian Islands Mapping

Project:

- ✓ **Mapping support**
  (P. Jokiel)

A database of all available bathymetry data in the Hawaiian Archipelago is being compiled, synthesized and integrated in a manner that is readily available and useful to scientists and managers. The data are from several sources and in many formats ranging from raw XYZ data to processed raster imagery. Work is being facilitated through the efforts of Ben Richards (CRED), Lisa Wedding (NOAA Biogeography Program), Will Smith (CRAMP-NOAA habitat mapping), as well as Joyce Miller and her team at Pacific Islands Benthic Habitat Mapping Center. We are currently defining a procedure that will be used for processing the entire SHOALS LIDAR dataset using the 4 meter raster grids employed for the habitat classification being completed for the Main Hawaiian Islands in relation to bathymetric data and habitat data from the Northwestern Hawaiian Islands. One aspect of this work is to optimize information on bottom complexity in a manner relevant to investigations concerning essential fish habitat and other ecological questions. The LIDAR investigation has entailed processing the data using a variety of different parameters within two standard interpolation methods, inversed distance weighting and kriging (see definition of term in references). The goal of the processing is to identify which combination of parameters and interpolation method produce the best results in relation to known bathymetric features and landscapes. The results are being overlaid on raster grids created from multi-beam data as well as Smith and Sandwell (1994). The areas of overlap are analyzed for consistency between the two datasets as a means of validation. This aspect of the bathymetric work is in the final phases of analysis. The complete data set will then be processed and made available to the users. A GIS layer consisting of all known coral cover data in the archipelago is being compiled.

Geospatial Technologies and Data Analysis
(E. Franklin)

Hawai‘i Institute of Marine Biology- Northwestern Hawaiian Islands CRRP GIS Workstation

Projects for the HIMB-NWHI Coral Reef Research Partnership that utilize GIS were made possible through the establishment of a GIS workstation at HIMB. The workstation provides a repository for digital datasets that include satellite imagery, benthic habitat maps, research locations, bathymetry, and regulatory boundaries. Software on the workstation enables geospatial analyses, data management, and map production for the projects described in this section and other collaborations.

<u>HIMB NWHI Coral Reef Research Partnership website</u>

To communicate and share information about the scientific activities of the HIMB-NWHI Coral Reef Research Partnership, the development of an online website (Figure 20) was initiated and completed. HIMB partnered with the UH-School of Oceanography and Earth Science and Technology Publication Services who designed the layout and populated the site with content created by HIMB. The Web site serves as a focal point for public outreach and the dissemination of scientific results to managers and colleagues. The site will be updated as exciting, new discoveries are made in the lab and at sea and can be accessed at http://www.hawaii.edu/HIMB/nwhi_crrp/index.htm

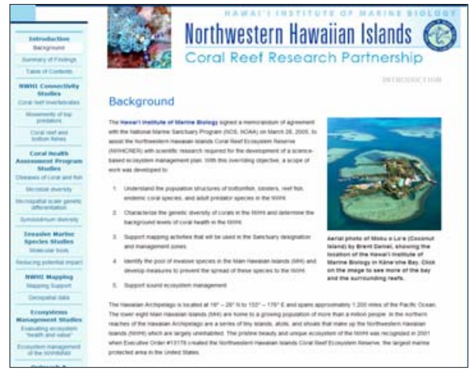

Figure 20. HIMB-NWHI Coral Reef Research Partnership Web site

<u>Northwestern Hawaiian Islands Threat Assessment Map Atlas</u>

The NWHI Threat Assessment Map Atlas provides a visual representation of the results from the ecosystem-based management approach to the threat evaluation of the resources of the Northwestern Hawaiian Islands (by Selkoe, Halpern, and Toonen). During the evaluation process, various threats were identified and ranked by scientific experts for their potential impact on the different habitats of the NWHI. The survey results were combined with digital habitat maps to create a map series of the severity and location of threats for each island or atoll (Figure 21). The identification and collection of spatial data sets to represent the threats at both the atoll scale and the NWHI regional scale were initiated during this period but are not yet completed. Next steps include a raster-based modeling exercise to create composite layers of all the threats by island/atoll and region. The final analysis and map products will be made available as a report, through the website, and as digital files.

<u>Northwestern Hawaiian Islands Vessel Traffic Patterns</u>

The first quantitative assessment of vessel traffic patterns of the Northwestern Hawaiian Islands was performed to identify hot spots of coral reef areas at risk. The preliminary analysis of twenty months of data was expanded to a ten year period from 1994 to 2004. Vessel location data was provided by the NOAA International Comprehensive Ocean-Atmosphere Data Set (ICOADS) program, and the US Coast Guard provided descriptive information about the size, tonnage, and country of the vessels. Vessel traffic operated primarily through two corridors, one along the NWHI island chain that consisted of vessels that mainly originated from the Main Hawaiian Islands (MHI) and another across the NWHI of vessels that transited between Pearl and Hermes Atoll and Lisianski Island. This information was used for a review of the NWHI Area-to-be-Avoided designation by the International Maritime Organization.

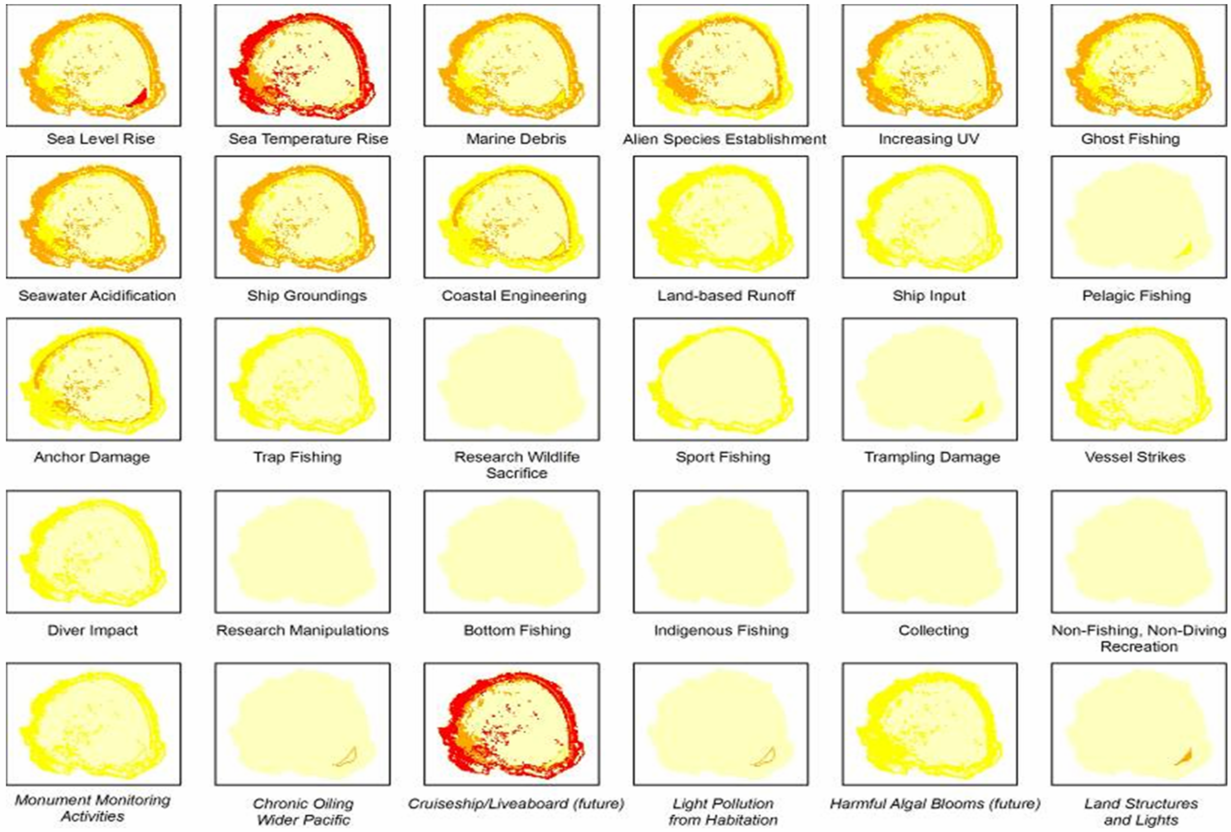

Figure 21. An example of threat mapping for Kure Atoll. Red represents areas of highest vulnerability, followed by orange, yellow, and off-white.

Outreach & Education
(M. Rivera)

Outreach and Education for the NOAA Memorandum of Agreement includes efforts for the HIMB-NWHI Coral Reef Research Partnership (MOA 2005-008/6882), the Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS) Marine Science Curriculum project (MOA 2005-008/6944), and the Bay-Watershed Education and Training Strategy Development project (MOA 2005-008/7189). This report also contains progress on projects related to the NOAA MOA efforts that are funded through other sponsors. HIMB has continued to develop and expand on already existing outreach and education programs during the reporting period:

Northwestern Hawaiian Islands Continuing Education Program

HIMB’s School and Community Education Program has been working with NWHI researchers at HIMB to establish a community focused Continuing Education Program at the University of Hawai‘i Windward Community College (WCC). Launched in February 2007, registered participants attend an evening lecture series on the WCC campus followed by a weekend field activity at HIMB. Topics for this semester will include an overview of HIMB research and tour of the institute, as well as shark migration research, coral reef health, and alien species in the Northwestern Hawaiian Islands.

Hawaiian Islands Humpback Whale NMS Marine Science Curriculum project for grades 3-8

Collaborative efforts between the HIHWNMS and HIMB during this reporting period have resulted in a number of positive developments concerning the marine education curriculum project. The HIMB-NWHI Research and Outreach Coordinator has recruited three graduate students who are actively engaged in marine science research at HIMB to assist on the project. HIMB also successfully executed the subcontract to Capital City Technical Consulting, Inc., who will provide education consultancy services and workshop design throughout the project duration.

In partnership with HIHWNMS and Capital City Technical Consulting, HIMB hosted the first advisory workshop for the marine education curriculum project. The workshop brought together over twenty teachers, education specialists, and curriculum developers in an effort to establish connections and collaborative relationships during the process of curriculum development. Detailed discussions and brainstorming sessions brought to light ideas and potential obstacles to creating practical, usable curriculum within the framework of the Hawaiʻi State Department of Education guidelines. Although primarily hired to provide accurate scientific content, the graduate assistants were active participants in many of these discussion sessions. In addition, the graduate assistants took extensive notes during the workshop which were incorporated into a comprehensive summary and distributed to the main coordinators of the project.

Shortly after the first advisory meeting, curriculum writers began receiving extensive scientific content researched and organized by the three HIMB graduate students. Completed topics include: coral biology, coral reef ecosystems, food chains, predator/prey interactions, and invasive species. The purpose of the scientific content is to provide a background of information that is easily accessible and usable for the writers during the curriculum development process. In this capacity, the HIMB Research and Outreach Coordinator and assistant graduate students have become science content advisors as well as reviewers of completed lessons to check for accurate and appropriate science content. Units and lesson plans that are somewhat formalized are subsequently returned to the reviewers at HIMB for further accuracy and content assessment.

Figure 22. Zoology graduate student Mackenzie Manning shows Kanu o Ka ʻĀina students, from right, Kamalani Pahukoa, Kapua Perry, Stanya Laa and Dale Bates how to check dissolved oxygen levels in seawater during their visit.

During the week of October 30 – November 4, 2006, two of the graduate assistants represented HIMB on the yearly HIHWNMS sponsored education cruise on the NOAA Ship Hiʻialakai. These HIMB graduate students served as on-board educators, leading hands-on labs that taught selected high school kids from Hilo and Kona to Moloka‘i about water quality, invertebrate zoology, plankton dynamics in the water column and GPS navigation skills (Figure 22).

Whenever possible, the graduate students also participate in leading educational tours of HIMB facilities in order to enhance the interest of K-12 students in the field of marine science. During this reporting, the MEC graduate assistants led 15 separate tours totaling 365 students.

HIMB School and Community Education Program (CEP)
Information about the HIMB-NWHI research program is disseminated through the ongoing HIMB CEP. A cadre of volunteer docents and a newly hired University of Hawai‘i funded coordinator hosts between 7-10,000 visitors annually, introducing students, community groups, families and others to the wide array of marine research programs conducted at HIMB. Faculty and staff of the HIMB-NWHI program hosts a large proportion of these visitors, each of which receive a brief oral introduction to HIMB’s NWHI research program either through a presentation or walking tour, the tri-fold informational brochure (see quarterly report II-III), and views the NWHI video *Islands in the Sea—the Northwestern Hawaiian Islands* (available at www.hawaiireef.noaa.gov). Groups and media staff that have been hosted during this reporting period include German Public Radio, OC-16 TV show “Living Local”, Western Association of Marine Labs, Hanuama Bay Education Program volunteers, and the Kohala Center.

Reef Missions: Exploring Underwater Habitats Using Autonomous Underwater Vehicles
Dr. Malia Rivera is the Principal Investigator of a grant from NOAA’s Office of Education that utilized capabilities of an Autonomous Underwater Vehicle (AUV) to collect reef and water quality data. The project centers on middle and high school level marine science education and will include a series of lessons based on the capabilities of the AUV that address topics such as species diversity, reef health, alien species, animal behavior and water quality. Presently the AUV is under fabrication with partners at MIT’s AUV Laboratory (Figure 23). We anticipate completion and field testing of the unit in July 2007. HIMB has recruited doctoral student Nicholas Whitney to write the accompanying science class lessons for the AUV technology.

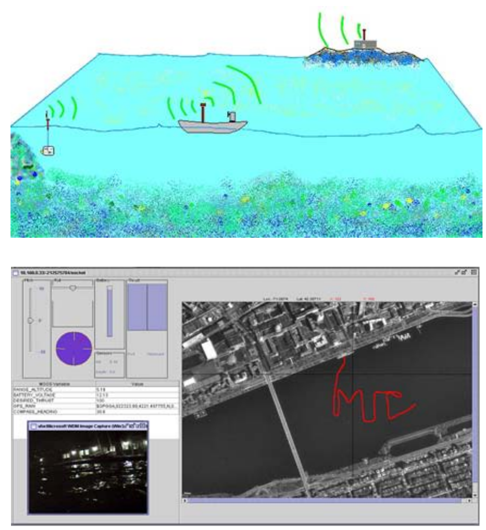

Figure 23. Schematic of the wireless AUV concept and interactive web-based interface (by Victor Polidoro, MIT AUV Lab).

Bay-Watershed Education and Training
A contract to the educational consultant for the strategy development was just finalized in late January, 2007. No significant progress has yet been made on B-WET.

Agency and government visitors
Briefing tours and events for agency and government at the state, federal, and international levels is a regular part of the NWHI outreach efforts at HIMB. In the last six months, HIMB has hosted visitors and held briefings and/or tours to disseminate information on the NWHI research project to NOAA General Counsel, NOS Leadership, Senator Daniel K. Inouye’s Office and the White House Council on Environmental Quality.

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