OCEANOGRAPHIC PROCESSES AFFECTING CORAL REEFS

Background

Information pertaining to the structure and dynamics of the ocean is essential to understand marine ecosystem dynamics and to interpret the dynamics of coral reef and fishery resources within the context of the ecosystem, habitat, and large-scale environmental patterns. Oceanographic data have potential application to marine resource management including the establishment and evaluation of the effectiveness of MPAs and predictions of the effects of seasonal, interannual and decadal variability on the reef health, productivity, recruitment, and population assessment. Global scale coral bleaching events associated with climate fluctuations, such as the 1998 El Nino-Southern Oscillation (ENSO) warm episode, have been shown to have devastating effects on coral reef ecosystems. Similarly, large-scale changes in the productivity of the North Pacific have had profound effects on coral reef ecosystem dynamics of the NWHI, where populations of monk seals, lobsters, and sea birds have fluctuated in response to large-scale oceanographic changes.

In order to effectively manage the coral reef ecosystems of the U.S. Pacific Islands, it is essential to understand and monitor the fundamental oceanographic processes that support and maintain these ecosystems. Many oceanographic properties such as temperature, wave energy, currents, salinity, nutrients, and ultra-violet radiation (UV-B) are known to significantly influence the growth, health, and distribution of corals, algae, and other reef organisms. Physical processes control both the functioning and the biogeography of reef ecosystems (e.g., areas exposed to high wave energy are fundamentally different from sheltered low energy areas; areas exposed to wide temperature ranges generally differ from those with narrow temperature ranges; and areas with high nutrient supply differ greatly from areas with low nutrient supply). Ocean currents generally determine larval distribution as well as influence recruitment patterns and nutrient supply. These are only a few of the many parameters affecting reef ecosystem health. Oceanographic processes are not static, but vary spatially and temporally over a wide range of scales. In many of the U.S. Pacific Islands areas, the natural variability of the physical system may be the dominant cause of changes to the ecosystem health. In order to distinguish between anthropogenic and natural changes, a critical requirement for resource management decision-making, it is essential to know both the natural variability of the physical and biological components of the ecosystem and an estimate of the human–induced stresses to the ecosystem.

Goals and Objectives

One of the most significant challenges facing CREI and our partners is to develop an ocean observing system that can effectively address the most salient issues affecting coral reef ecosystem health. In order to accomplishment this, it is critical to determine the appropriate parameters to measure, as well as the necessary time and space scales. More specifically, the goals of the CREI oceanography program are to:

- Develop a multi-platform ocean observing system capable of monitoring the key physical and biological parameters likely to affect coral reef ecosystem health.
- Examine the role of ocean circulation on larval transport and recruitment of fish, corals, algae, and crustaceans with the goal of improved understanding of ecosystem dynamics and an ability to evaluate the effectiveness of no-take MPAs as refugia and replenishment areas.
- Examine the role of ocean circulation on transport, distribution, and accumulation of marine debris with the goal of significantly improving debris removal efficiency and source identification.
- Test and identify a reliable and maintainable suite of instruments to be deployed on remote platforms for long-term monitoring and provide near real-time data telemetry to alert researchers and resource managers of imminent or occurring coral reef bleaching or other natural events.

Methods

Oceanographic Moorings

In order to better understand the influences of oceanographic processes on the health of coral reef ecosystems, the development and deployment of an array of surface and subsurface oceanographic moorings have been initiated over the past year to provide high-resolution time series observations of ocean conditions. To date, 21 moored ocean observing systems of 4 different types have been deployed in the NWHI, U.S. Line and Phoenix Islands, and American Samoa. Nine Coral Reef Early Warning System (CREWS) oceanographic data buoys, of two types, have been deployed in sheltered lagoon habitats at FFS, Maro Reef, Lisianski Island /Neva Shoals, Pearl and Hermes Atoll, Midway, and Kure in the NWHI; Rose Atoll in American Samoa; and at Palmyra and Kingman Atolls in the U.S. Line Islands. Six standard CREWS buoys collect data on sea surface temperature (SST), air temperature, barometric pressure, and wind speed and direction. Three enhanced CREWS buoys additionally collect data on surface and subsurface UV-B and Photosynthetically Available Radiation (PAR) levels, and salinity. Subsets of the data are transmitted to the HL via the Service Argos satellite telemetry system. On-board data storage allows the full data sets (typically 10-30 minute resolution) to be archived for later retrieval.

Six SST moorings have been deployed in Emanate and Fagasa Bays in Tutuila Island, Aunuu Island, and Ta'u Island in American Samoa; at Howland Island in the U.S. Phoenix Islands; and at Jarvis Island in the U.S. Line Islands in relatively shallow water of the forereef slopes or near reef flats. These systems are designed to withstand high energy wave environments at these exposed locations. SST is sampled every 10 minutes by a high accuracy temperature sensor and hourly averages are transmitted using the Argos system.

Subsurface current meter moorings that were deployed in 2002 at Kingman and Rose Atolls and off Tutuila Island are collecting high resolution time series of currents and temperature in high velocity channel passes or prominent points that are hypothesized to play a significant role in controlling the dynamics and circulation of these atolls/islands. Subsurface moorings with Acoustic Doppler Current Profilers (ADCP) and Conductivity (salinity), Temperature, and Depth (CTD) recorders were deployed in the shallow waters surrounding Swains, Baker, and Jarvis Islands. These ocean data platforms observe waves, currents, temperature, and salinity and provide investigators insight into the dominant processes controlling these remote ecosystems (Fig. 24).

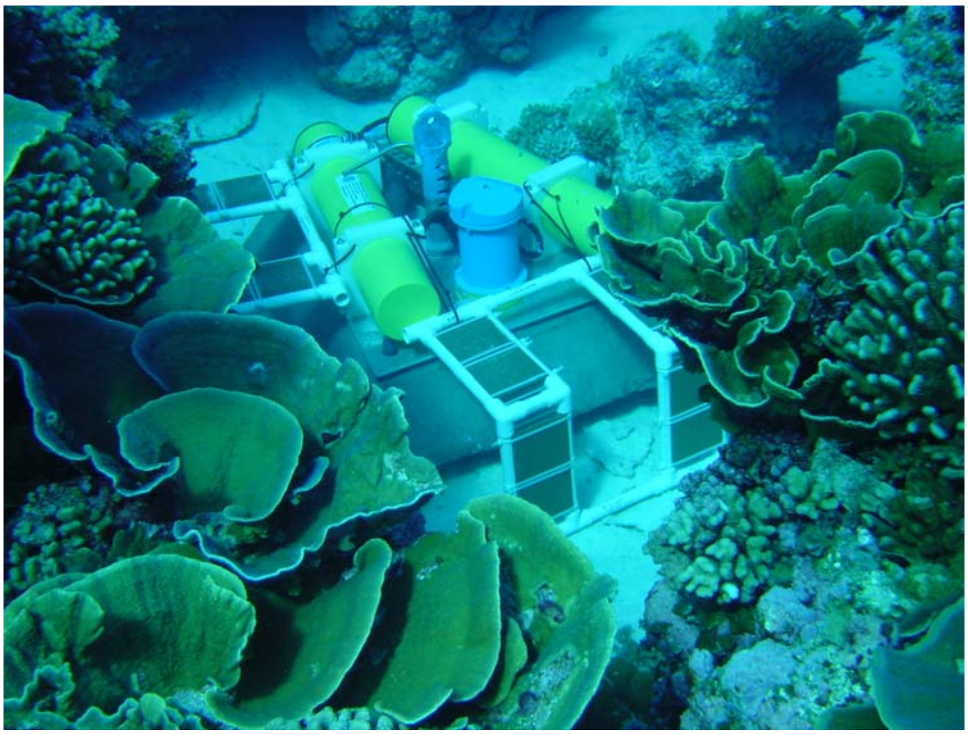

Fig. 24. Subsurface Ocean Data Platform – Subsurface moorings that provide high resolution, current profiles, directional wave spectra, and temperature and salinity.

All satellite telemetered data from the nine CREWS buoys (Fig. 25) and six SST buoys are received daily via the Argos system, parsed, quality controlled, plotted, and posted on the prototype CREI web site (http://crei.nmfs.hawaii.edu/). While still under development, this prototype web site is being made available to allow fisheries managers and scientists immediate access to CREI data products. (Fig. 26). The site currently contains an inventory of CREI oceanographic instrumentation and allows near-real-time access to a number of automated telemetered oceanographic data products including satellite drifter plots and both raw ASCII data and plots from the SST buoys. Site navigation is both spatial (map-based) and textual. The telemetered *in-situ* SST measurements will be linked to the CREWS expert system at NOAA's Atlantic Oceanographic and Meteorological Laboratory to provide early warnings and to ground-truth satellite measurements of SST in these regions. Other CREI data products developed by the benthic habitat mapping and characterization team and ecological assessment team will be added to the web site as they become available.

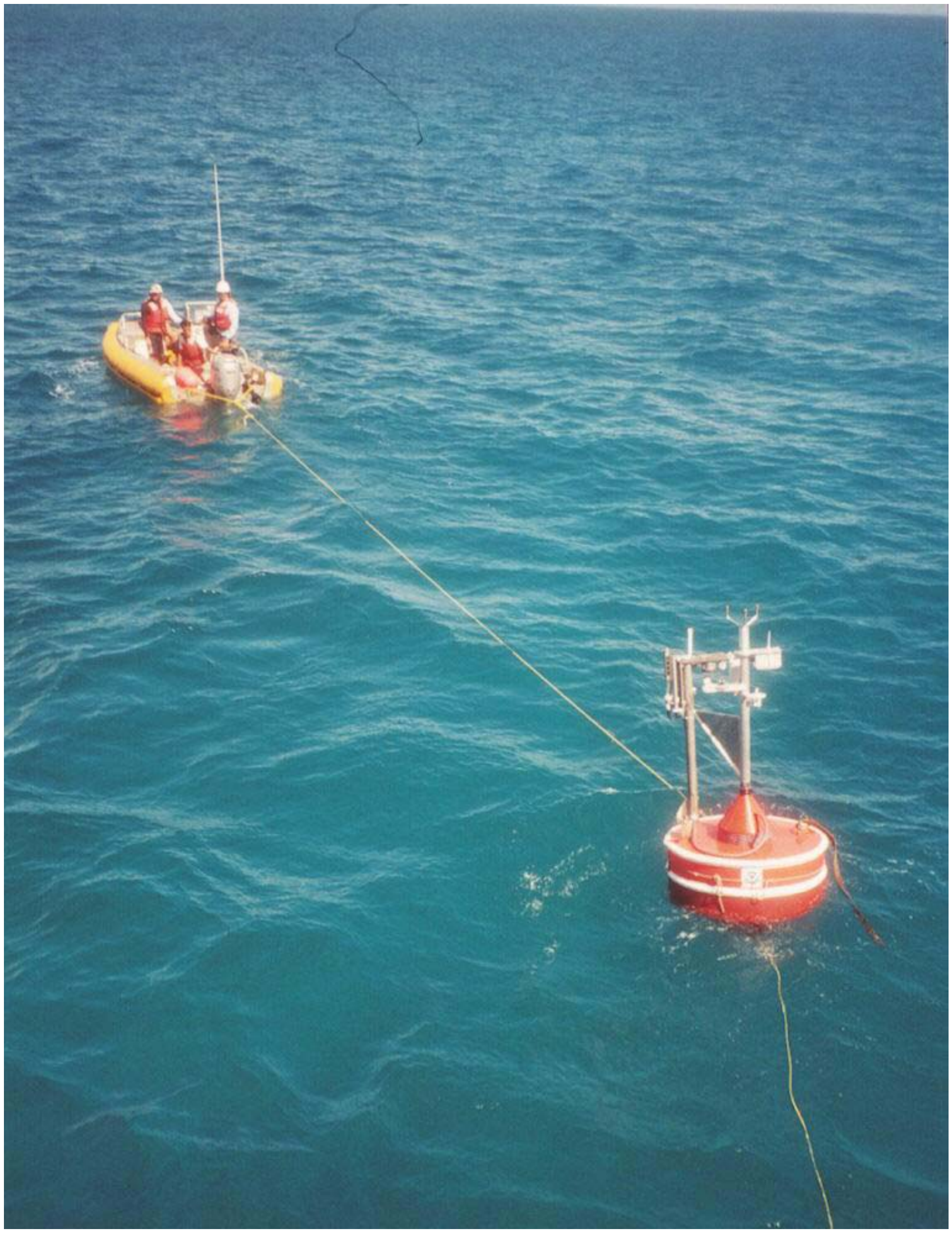

Fig. 25. Installation of CREWS buoy which provides high resolution SST, barometric pressure, wind speed, and wind direction. Enhanced versions additionally provide salinity, UV-B, and PAR. Subsets of these data are transmitted daily via satellite telemetry.

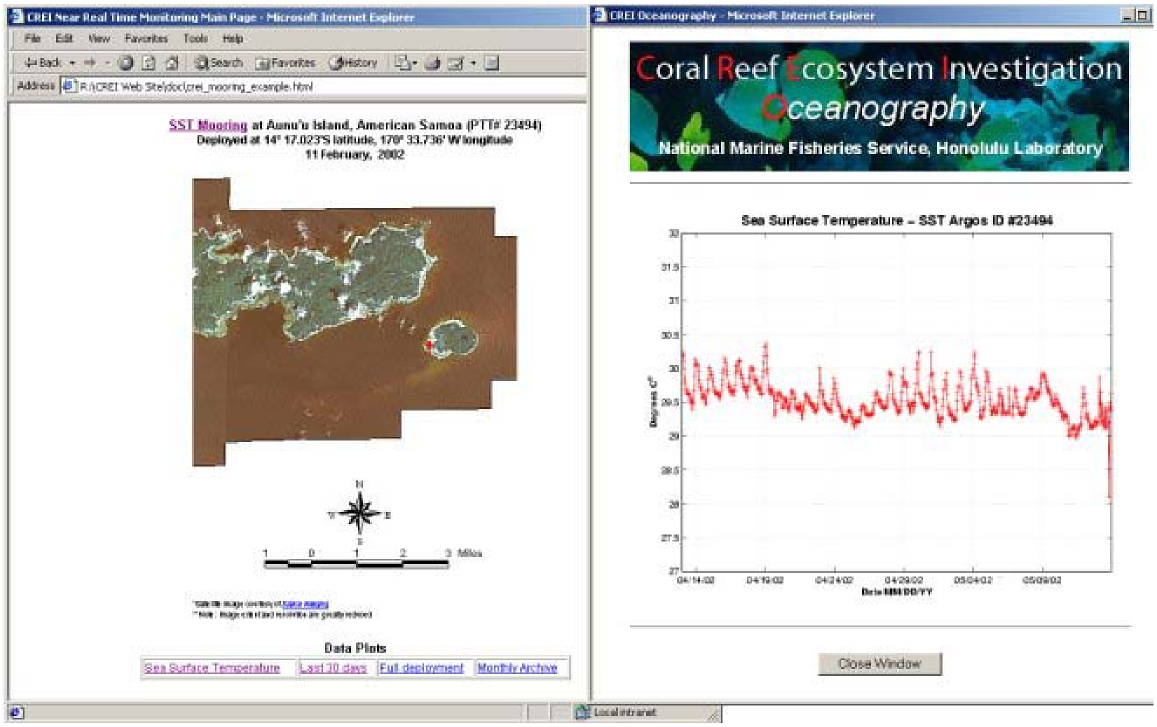

Fig. 26. The prototype CREI website allows scientists access to real-time oceanographic data.

Shipboard Ocean Observations

While the oceanographic moorings provide valuable high-resolution time series at representative sites, it is likewise important to understand the processes within each ecosystem that cause observed spatial differences in species composition and reef health. In order to assess these processes, it is standard during CREI research cruises to conduct as many oceanographic observations as time and conditions permit. These include: 1) repeated shipboard CTDs (with chlorophyll and dissolved oxygen) to a depth of 500-m on representative sides of each island/atoll, 2) closely-spaced shallow water CTDs (with chlorophyll) to a depth of about 30-m around the forereef and inside atoll lagoons, and 3) repeated ADCP transects around each island/atoll to observe the vertical and spatial structure of ocean currents.

In addition to these *in-situ* ocean observations conducted during CREI cruises, in 1999 a long-term opportunistic oceanographic monitoring program was initiated to establish a time series of the vertical structure of the upper ocean properties in the NWHI. This program consists of ten permanent stations off Nihoa, Necker, FFS, Gardner Pinnacles, Maro Reef, Laysan, Lisianski, Pearl and Hermes Atoll, Midway, and Kure, where CTDs (with chlorophyll and dissolved oxygen) are conducted to a depth of 500-m each time a HL cruise transits to the NWHI. This program also includes processing and analyses of a rich time series of shipboard ADCP observations of currents in the upper 250-m along the NWHI since 1988. To date, the ADCP data set includes about 120 cruise transects along the NWHI.

Satellite Remote Sensing

CREI oceanographers work closely with the Hawaii CoastWatch coordinator to utilize remotely-sensed observations of SST (AVHRR, GOES), sea surface height (altimeter), surface winds (scatterometer), ocean color (SeaWiFS, MODIS), and planned follow-on satellite sensors to examine the large scale oceanographic and atmospheric processes effecting the coral reef ecosystems of the U.S. Pacific Islands and elsewhere. While the *in-situ* moorings and shipboard observations are critical, it is likewise important to understand the larger scale environmental context within which these ecosystems function. The larger scale processes generally drive the local processes. Without an understanding of large-scale oceanographic conditions, such as ENSO or the North Pacific decadal oscillation, it is difficult to understand the local processes influencing reef health. One of the principal remote sensing activities of CREI and CoastWatch oceanographers has been the development of a set of oceanographic atlases of the U.S. EEZs. These activities are discussed in the Applied Research Activities section of this report.

Data Analysis and Results

The data from these various ocean-observing platforms provide valuable tools for better understanding the dynamics supporting and maintaining reef ecosystems of the Pacific islands. While most of the effort to date has focused on design, development, and deployment of a multi-platform ocean observing system to monitor and understand coral reef ecosystems, the following preliminary results demonstrate some of the potential benefits that lie ahead. Recent observations from the near-real-time SST and CREWS buoys in American Samoa alerted researchers and resource managers about high water temperatures and the potential for coral bleaching events. Colleagues at the National Park of American Samoa have since reported bleaching activity at many sites there.

CREI *in-situ* oceanographic observations at Howland, Baker, and Jarvis Islands demonstrate that large-scale ocean processes can have profound influence on local processes. In this case, the interaction of the strong westward-flowing Equatorial Undercurrent with the steep topography of these islands is observed to drive strong topographically-induced equatorial upwelling, which in turn provides nutrient enrichment, high productivity, and localized high biomass of these reef ecosystems. The closely spaced, shallow water CTD observations in 2000 at each of these islands revealed very strong surface temperature gradients. In one area at Howland Island, a surface water temperature difference of 2.8° C was observed over a distance of several hundred meters between the west and southwest sides of the island (Fig. 27). These localized areas of upwelling influence the small-scale biogeography of these ecosystems.

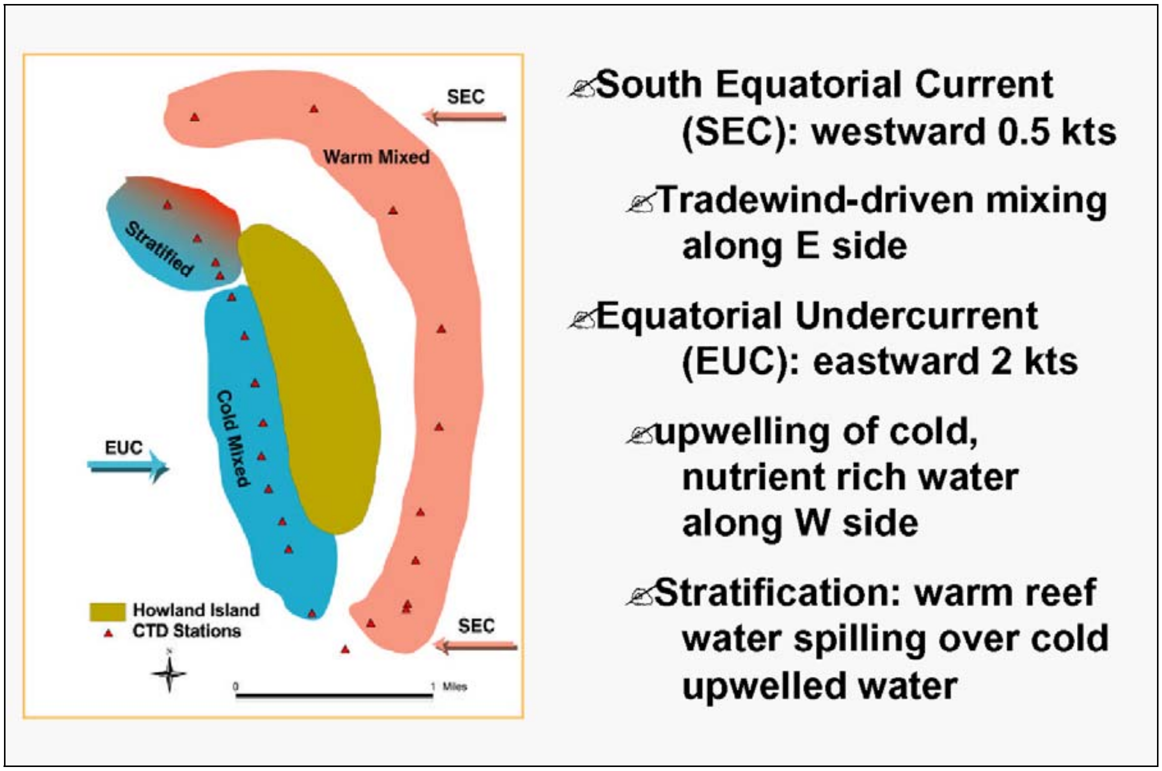

Fig. 27. Strong surface temperature gradients and localized areas of upwelling near Howland Island influence the small scale biogeography of the ecosystems.

Satellite and *in-situ* observations of large-scale ocean circulation patterns can also be used to explain observed differences in species richness. For instance, the number of coral species observed at the equatorial islands of Jarvis, Howland, and Baker are significantly less than the number observed farther north at Palmyra and Kingman Atolls. While habitat diversity explains part of this difference, it is also important to note that the equatorial islands are located in the westward flowing South Equatorial Current, which means that larvae must come from the low biodiversity regions of the eastern tropical Pacific. There are few coral reef ecosystems located upstream of Jarvis. This is contrasted at Palmyra and Kingman Atolls, where the surface currents come from the high biodiversity regions of the western Pacific (Fig. 28).

CREI oceanographers are nearing the completion of the processing and analysis of over 10 years of shipboard ADCP observations in the NWHI. This analysis, from which a manuscript is presently being prepared, represents the first long-term observational study of ocean currents in the NWHI and will be useful for determining likely larval transport and recruitment dynamics. Long-term means show westward flow in the region immediately south of Kauai to south of Nihoa; elsewhere the mean flow is weak, dominated by variability (Fig. 29). This information will assist scientists and resource managers in establishing and evaluating the effectiveness of MPAs in the NWHI.

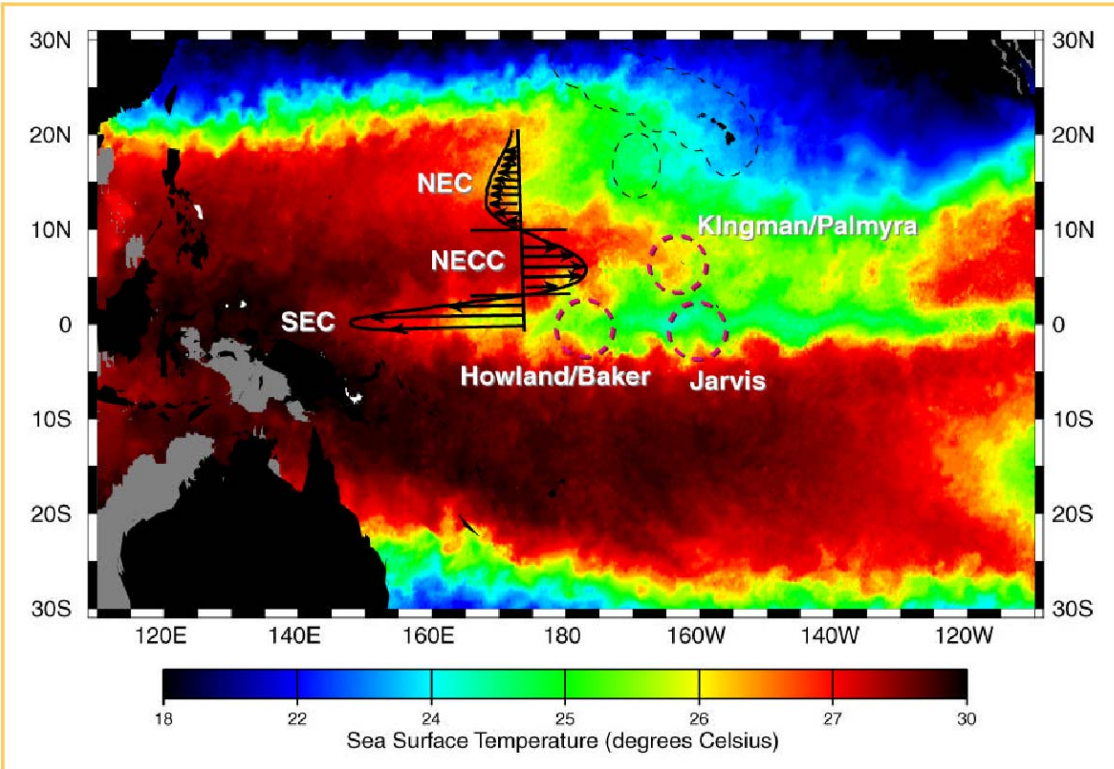

Fig. 28. Satellite observations of SST across the tropical Pacific Ocean with generalized mean current structure showing the North Equatorial Current, the North Equatorial Countercurrent, and the South Equatorial Current.

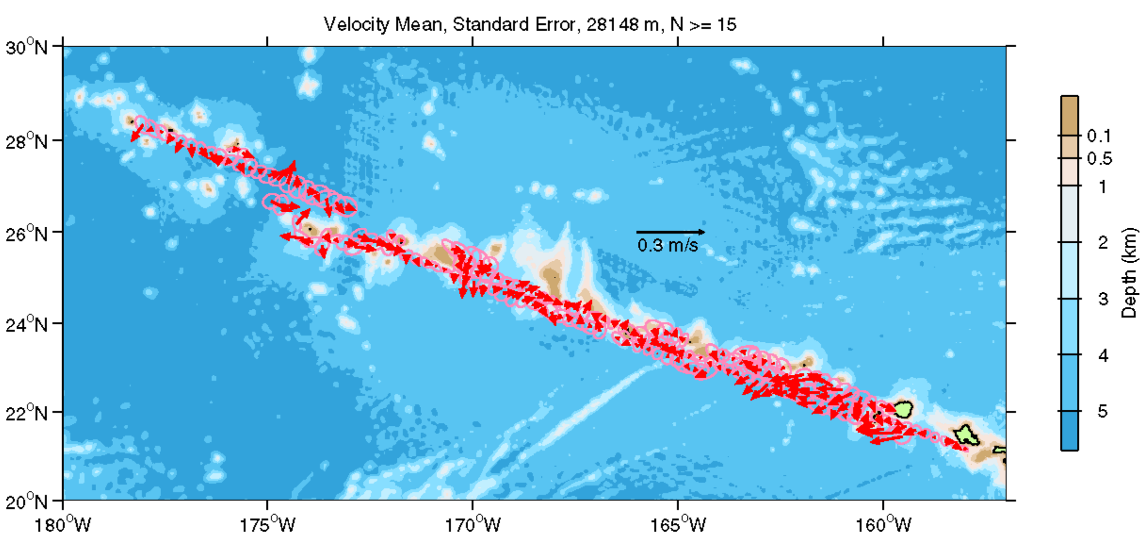

Fig. 29. Long-term mean currents in the NWHI, which are calculated from 10 years of shipboard ADCP observations, show westward flow in the region immediately south of Kauai to south of Nihoa; elsewhere the mean flow is weak and dominated by variability.

CREI and CoastWatch oceanographers are developing products to allow visualization of the multi-platform oceanographic observations as different layers in a GIS, which can be toggled on or off, to allow researchers to view oceanographic and biological information from multiple perspectives. As an example of merging complementary data sets, Figure 30 shows chlorophyll estimates from the SeaWiFS Ocean Color satellite, SST from the AVHRR satellite, geostrophic currents computed from sea surface height observations from the TOPEX satellite, and *in-situ* observations of ocean currents from the shipboard ADCP aboard the NOAA ship *Townsend Cromwell*. Other layers can be easily added (such as wind speed and direction vectors from satellite scatterometers or satellite-tracked drifter tracks) to provide investigators a more comprehensive understanding of the relevant processes.

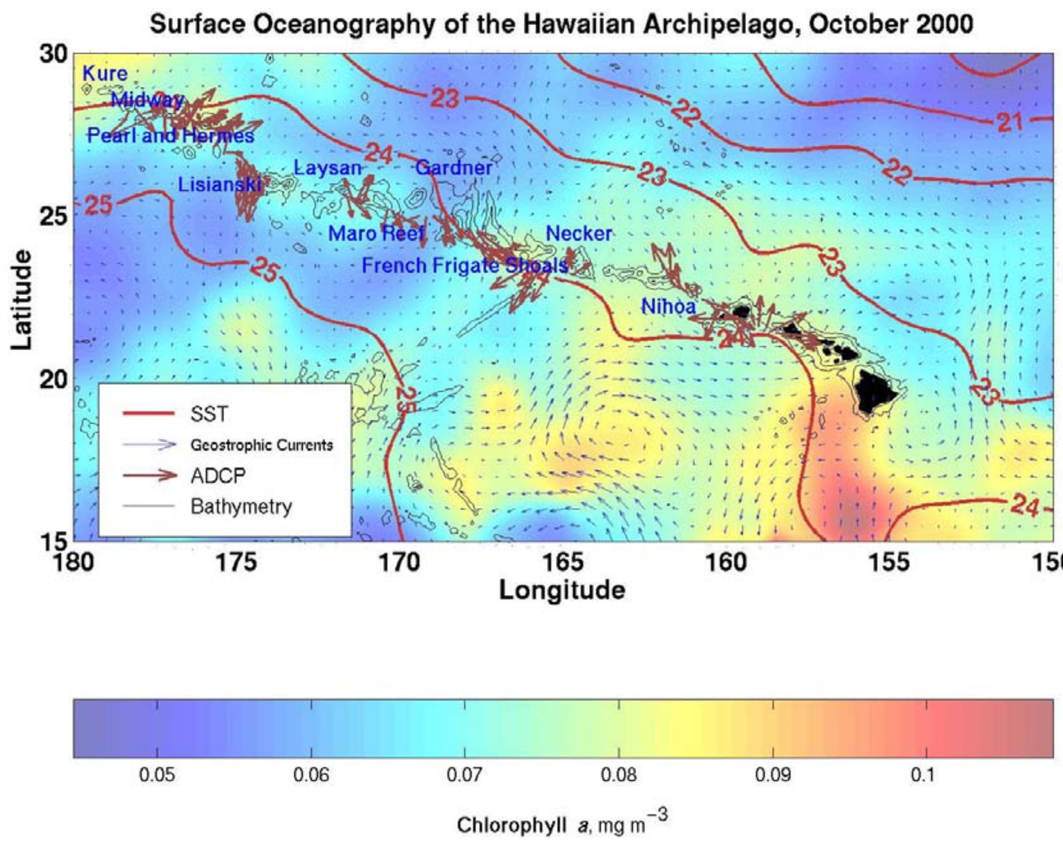

Fig. 30. Chlorophyll estimates from the SeaWiFS Ocean Color Satellite, SST from AVHRR satellite, geostrophic currents computed from sea surface height observations from the TOPEX satellite, and *in-situ* observations of ocean currents from the shipboard ADCP aboard the NOAA ship *Townsend Cromwell*.

Future Plans

The CREI oceanography program plans to continue developing and deploying a multi-platform ocean observing system to monitor ocean conditions and processes influencing the health of the coral reef ecosystems of the U.S. Pacific Islands. In the fall of 2002, CREI will expand the monitoring capabilities in the

NWHI by establishing two additional SST buoys at Necker and Laysan Islands, two subsurface Ocean Data Platforms at Necker and Pearl and Hermes Atoll, and ten subsurface temperature recorders on shallow reef flats at Kure, Midway, Pearl and Hermes Atoll, Lisianski, Maro Reef and FFS. These additional sensors will greatly enhance our ability to monitor and understand the oceanographic processes in the NWHI coral reef ecosystem. In 2003, CREI plans to expand the multi-platform ocean observing system to include the coral reef areas of CNMI and Guam, and to perform extensive analyses of existing data sets.

APPLIED RESEARCH ACTIVITIES

Background

In addition to the on-going ecological and oceanographic assessment and monitoring and benthic habitat mapping and characterization activities, CREI receives input from fishery and resource management agencies such as the Office of Habitat Conservation at NMFS Headquarters, NMFS SWR, and PIAO, WPRFMC, NOAA National Marine Sanctuary Program, USFWS, National Park Service, State of Hawaii, Territories of American Samoa and Guam, and the CNMI on additional focused research activities that are needed to better manage and protect the coral reef ecosystems of the U. S. Pacific Islands. Based on these inputs, the CREI has initiated the following focused research activities.

Larval Transport and Recruitment

Critical to the establishment and monitoring of effective MPAs is an understanding of the ocean circulation patterns affecting the transport and eventual settlement and recruitment of larvae. CREI oceanographers are using satellite-tracked drifters to complement shipboard ADCP and satellite remote sensing observations to examine the ocean circulation patterns in the NWHI and other U.S. Pacific Islands areas. Two types of satellite-tracked drifting buoys have been deployed to examine upper ocean currents and their role in the dispersal and recruitment of some larval, as well as the transport and accumulation of marine debris. Six Surface Velocity Program (SVP) drifters were deployed in the NWHI in fall 2001, along with six Autonomous Profiling Explorer (APEX) floats, which track surface flow for 11 hours at night, then descend to 100 m to track the water flow for 13 hours, giving a crude approximation of the currents' effects on diurnally migrating larvae with limited horizontal swimming ability. In 2002, eight SVP drifters were deployed in the waters of American Samoa.

Analyses of the SVP and APEX data are providing a test of larval dispersal models and provide insight into potential larval recruitment. These early drifter deployments have already improved our understanding of ocean currents in both the NWHI and American Samoa. Interestingly, ten of the twelve APEX and SVP drifters deployed in the NWHI have drifted predominantly to the west or southwest while only two have drifted north of the archipelago. Only the SVP drifter deployed at Nihoa approached the MHI before turning back to the west. In

American Samoa, most of the drifters initially drifted to the east, opposite conventional wisdom, before turning and drifting to the west. A drifter deployed at Swains Island confirmed that larvae could be transported to the Manu'a Islands. Collaboration with researchers of the National Park of American Samoa and HL's Marine Turtle Research Program on the correlation of drifter tracks and the paths of turtles equipped with satellite transmitters are being used to examine the effect of surface currents on turtle movement. A manuscript of this turtle work is presently being prepared.

Observations of sea surface height (from the TOPEX altimeter satellite) and scatterometer surface winds are being used to force a simple upper ocean circulation model. Combining the analyses of the drifter observations, ADCP time series, and model calculations will greatly improve our understanding of ocean circulation and larval transport and potential recruitment in the NWHI. This information, essential for determining potential sites for no-take MPAs and for evaluating the effectiveness of existing no-take or low-take MPAs, is also being used to improve spatially population-modeling activities (see below).

Development of Ocean Atlases for the U.S. Pacific Island Regions

As an additional step in developing an understanding of the marine ecosystem dynamics of different regions of the Pacific basin, CREI staff are collaborating in a program funded by the UH JIMAR PFRP to compile available oceanographic and environmental data and develop a set of oceanographic atlases for each of the U.S. EEZs in the central and western Pacific. The leadership and primary work on this project is provided by the NOAA Hawaii CoastWatch site located at the HL. These atlases will provide a compendium of oceanographic data in CD electronic format that may be used to examine relationships between coral reef resources and environmental changes. A very limited number of atlases may also be made available in graphical format.

The compiled data sets include both satellite-based and *in-situ* measurements. Due to a general scarcity of oceanographic surveys in many of these regions, the primary *in-situ* data sets are subsurface temperature and salinity observations from NOAA's National Oceanographic Data Center and the Navy's Master Oceanographic Observations Data Set. In regions with particularly scarce subsurface observations, dynamical oceanographic model output from the International Pacific Research Center at the UH SOEST are used to supplement the observations. These data complement the satellite observations of SST; sea surface height and computed geostrophic velocities; surface wind velocities, wind stress curl, and wind divergence; and ocean color available through the NOAA CoastWatch site. Extensive data quality control and processing are being conducted prior to producing the final atlas products. Specific databases are being developed for use in modeling, assessment, and management of coral reef resources.

The oceanographic atlases are climatological in nature and will include maps of statistical means and standard deviations for each of the fields for each quarter of the year. Time series plots and tables of each of the fields are being included at monthly or higher temporal resolution. Each of the published atlases will be posted on the web at the NOAA CoastWatch Hawaii Regional Node. These climatologies and time series will provide essential references with which coral reef researchers and resource managers will more effectively place the near real-time data sets within the context of the environmental and ecological dynamics specific to a given region. These near-real-time data sets are currently available from NOAA CoastWatch and other NOAA|NESDIS programs; the addition of the oceanographic atlases in similar units, resolution, coverage, and data format will greatly enhance these operational data sets.

Evaluating the Potential Impact of Lobster Trapping on Habitat

Habitat destruction due to fishing is recognized as a potential threat to coral reef ecosystems. One of the major management goals with the establishment of the NWHI Coral Reef Ecosystem Reserve is to minimize potential human impacts to the NWHI coral reefs. In recent years, there has been considerable debate about the potential impact of traps from NWHI lobster fisheries on coral reef habitats. Arguments on both sides were generally based on limited actual data and mainly anecdotal evidence or assumptions. To address these concerns, CREI plans to: 1) develop camera systems and methodologies to record the habitat types and condition in NWHI lobster trapping grounds and 2) to conduct field experiments to evaluate the direct impacts of the traps on the benthic habitats where the lobster fisheries operate. These field experiments will include video and/or still camera observations of trap strings being set and hauled from chartered commercial fishing or research vessels. Some of the data will be acquired by placing the cameras onto the traps while others will be obtained by diver surveys, towed diver surveys, and towed camera surveys. These experiments will be conducted in the areas commonly visited by the fishery and using similar gear and methods. Experiments are proposed for similar habitats of both seldom-fished areas and heavily fished areas to better assess the impacts of heavy trapping activity. If possible, commercial vessels will be utilized to simulate more closely the potential impacts of the commercial fishery.

Development of Bottomfish Stock Assessment Methodologies

While most CREI reef fish surveys are conducted in shallow reef areas (0-20-m), it is recognized that many of the exploited fish stocks of reef ecosystems are commercial bottomfish species which generally occupy deeper reef habitats (50-400-m). Traditional fishery-dependent sampling methods (e.g., hook-and-line or capture CPUE) cannot be used in many areas of the NWHI Coral Reef Ecosystem Reserve as they are now no-take MPAs. The ability to assess and monitor the resources most likely to be exploited is important for ecosystem management as well as to determine the effectiveness of MPAs. To address these needs, fisheries biologists and engineers from CREI and the UH Hawaii

Undersea Research Laboratory (HURL) are collaborating to augment remote camera systems employed by HURL and others to assess the spatial distribution and relative abundance of bottomfish species.

Ecosystem Modeling of Trophic Linkages and Interactions

As set forth in the *National Action Plan to Conserve Coral Reefs*, one of the two fundamental themes is to reduce adverse human impacts to coral reef ecosystems. Most studies and surveys clearly indicate that globally and nationally, fisheries and over-exploitation represent one of the largest and most difficult to address potential threats to coral reef ecosystems. The potential threats of fishing include: 1) direct taking or removal of resources (fish, crustaceans, coral, algae), 2) physical impacts to the reef habitats, such as coral and algal substrates, and 3) the many complex and difficult-to-observe interactions occurring over a wide range of trophic levels (e.g. when one species or group of species is taken, it often has a widespread impact on other far-removed species).

HL investigators in the Ecosystem and Environment Investigation are conducting a series of modeling experiments to examine trophic interactions of the coral reef ecosystems of the NWHI using the ECOSIM model, an updated and widely used food web and fishery interaction model. Using the ECOSIM model, researchers are examining simulated fishery and environmental impacts on coral reef ecosystems over many trophic levels. ECOSIM provides a capability to examine the dynamics of physical and biological interactions over a range of temporal and spatial scales. Investigators can simulate varying levels of exploitation of individual families and/or species and examine the impacts throughout the food web. These surveys are based on known or assumed diets of many families of fishes, mammals, and invertebrates. To complement the modeling experiments, targeted fieldwork is being conducted to continue refining our knowledge of individual species and diets through their life histories. The role of fluctuations of benthic habitats, such as changes over time of coral or algae cover in response to chronic or acute stressors on other trophic levels will be examined with the models. As an example, the existing model appears to be highly sensitive to fluctuations in abundances and distributions of benthic algae. Although many of the simulations result in more questions than answers, the simulation runs provide investigators reasonable hypotheses that can be further tested during field studies. In the case of benthic algae, for instance, the high sensitivity of the model to fluctuations of benthic algae have led to improved efforts to monitor temporal and spatial variability of benthic algae using towed diver habitat surveys, towed camera surveys, and acoustic surveys. The model is being used to improve sampling designs and strategies. These simulations allow resource managers and scientists to ask very specific and targeted questions about impacts of exploitation, coastal development or other potential anthropogenic interactions.

Development of Spatially Structured Population Models for NWHI Resources

Recent advances in our understanding of the spatial structure of NWHI marine resources and their population dynamics indicate that many of these resources are metapopulations – a group of populations inhabiting discrete patches of suitable habitat that are connected by the dispersal of individuals between habitat patches. For NWHI resources, the various “banks” constitute discrete patches and connectivity between patches occurs during the larval transport phase. This results in individual banks of either recruitment sources, recruitment sinks, or both. Thus, the dynamics at a particular bank are not only dependent on the dynamics at that bank, but also at surrounding banks.

Prior NWHI resource modeling efforts have largely ignored spatial structure, relying solely on simple discrete population models applied at the individual bank level. Recent research on NWHI lobster populations by HL’s stock assessment scientists identified the shortfalls of ignoring spatial structure, particularly as it relates to population forecasting and fishery management (DiNardo and Marshall, 2001). To advance our understanding of the dynamics of NWHI resources, and provide sound scientific advice to decision makers, spatial structure will need to be incorporated in subsequent population models.

As a first step toward model advancement, the HL stock assessment scientists convened a workshop at the NMFS HL December 4-6, 2001 to develop a blueprint for improving population models for NWHI lobster resources. Scientists with expertise in crustacean biology and population modeling participated. Alternative approaches to modeling were discussed and a course of action to advance population modeling and data collection was recommended (Botsford et al., 2002). The underlying conceptual model adopted by the workshop participants for lobster populations in the NWHI entails consideration of dispersal processes affecting recruitment during the larval stages at each location and losses to mortality. The relative importance of recruitment derived from local sources, recruitment subsidies derived from other locations, and dispersal of larvae from the natal location to other areas are critical in understanding the metapopulation structure of lobsters, as well as other NWHI resources in this region. While this coupled physical-biological model provides the methodology for incorporating varying sources of recruitment, it also gives decision makers a mechanism to assess the efficacy of using marine reserves as a management tool for NWHI resources. Stock assessment scientists and NOAA CoastWatch node are presently engaged in the development of the coupled physical-biological model. Data to facilitate development of the physical portion of the model will be provided by the Oceans Atlas project (funded by the NOAA PFRP).