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).