Optical Analysis Overview

To analyze seafloor videography collected by the TOAD camera sled deployments, a series of five small circles extending in a straight horizontal line are marked on a video monitor screen. The type of substrate (sand, rock, etc.) and living cover (macroalgae, scleractinian coral, hydrocorals or other benthic fauna, etc) falling within these circles are identified at 20 m or 30 second increments along the camera's trackline. Other biologically relevant observations are made as well. The full listing of benthic habitat classifications made can be seen below. Classification codes for each increment are entered into spreadsheets for each tow.

Analysis of particularly close and clear TOAD video data, in conjunction with diver observations, suggest that hard substrate (rock, rubble, etc) that is not obviously colonized by distinct coral colonies is usually colonized by macroalgae, turf algae or coralline algae. In fact, hard substrate in coral reef ecosystems that is not otherwise colonized is almost always covered by a thin community of algal turf. Accordingly, for situations in which it is not possible to directly distinguish the type of living cover on hard substrate, the cover is classified as "Unclassified algae," which includes macro, turf, and coralline algae. This assumption was tested using a series of short seafloor video segments taken by scuba divers, over six areas that had been covered by camera tows. Holding a video camera one meter above the seafloor, divers slowly moved along a transect line aiming the camera straight down. Using a high-resolution camera held at an ideal altitude and angle, and by allowing more time for it to focus, these video segments show detail that is usually not discernible in the towed videos. Although the videos collected by hand reveal an occasional sponge, coral, or other encrusting organism that is unlikely to be discernible in the towed videography, they suggest that that living cover identified as unclassified algae is correct for more than 90% of the instances in which it is applied.

For videography collected prior to 2004, ship's position and time data recorded to data files by the In-Tow software are converted to ArcView shapefiles using ArcView extensions specifically written for that purpose. The actual position of the TOAD is estimated to be not more than 50 m from the reported position. Estimates of camera sled position for the 2004 and later videos are recorded in Hypack software and exported as text files, which are imported into ArcGIS and coverted to shapefiles. The Hypack software currently used for data collection includes a window for manual entry of the length of camera sled cable paid out, a utility to enter horizontal and vertical offsets between the GPS antenna and sheave over which the camera sled cable passes, and a built-in catenary function. Using these additional data, the Hypack software automatically adjusts the position of the GPS antenna to generate and record an estimate of camera sled position. Analysis of tow data indicate that horizontal positional uncertainty associated with the location of the camera sled recorded in Hypack is ± 13 m. ***Insert sentence about integration of TPII to reduce positional uncertainty.***

Classification of Benthic Habitats in Coral Reef Ecosystems

Maps delineating the spatial extent of benthic habitats have often been identified as a key tools required for effective management of coral reef ecosystems. Mapping of benthic habitats is also mandated by requirements of the Magnuson-Stevens Fishery Management and Conservation Act to determine and characterize essential fish habitats and habitat areas of particular concern. However, marine resource managers, scientists and other stakeholders have yet to arrive at consensus regarding the optimal scheme to use for classifying benthic habitats, and many different approaches are currently utilized.

The term "habitat" is defined as "the area or environment where an organism or ecological community normally lives or occurs" (http://dictionary.reference.com, 2005). However, characteristics that define habitat boundaries for one species may be different from those relevant to another. Complicating matters further, a single species may require very different benthic characteristics for different life stages, or even for different activities occurring over the course of s single day, such as resting versus foraging. Even a very cursory review of scientific literature that details habitat requirements for different coral reef ecosystem organisms, life stages and activities reveals a diverse range of very specific benthic and water column characteristics.

The following examples illustrate a few of the specific habitat requirements for different coral reef organisms in the Hawaiian Archipelago.

- A study of endangered Hawaiian monk seals identified transitional regions of low relief where consolidated substrate, rubble, and talus bordered areas of sand at depths between 50 and 80 m as their preferred foraging habitat (Parrish et al., 2000).

- The spiny lobster *Panulirus marginatus* on banks in the Northwestern Hawaiian Islands are found to be limited to those with summits shallower than 30 m, and to be most commonly associated with in areas of intermediate (5 – 30 cm) relief. Results suggest that the availability of intermediate relief habitat limits the size of the adult lobster population (Parrish and Polovina, 1994).

- Friedlander and Parrish (1998) report that Hawaiian reef fish strongly associate with areas that provide shelter, particularly those in which there are numerous holes in the substrate. They find a strong linear relationship between fish length and hole volume. Reef fish are also affiliated with seafloor that is more structurally or topographically complex, and is closer to the reef edge. Deeper reef areas tend to host greater numbers of fish species, although the distribution of different trophic and mobility guilds shows some dependence on depth.

- The ideal nursery habitat preferred by the commercially important juvenile pink snapper *Pristipomoides filamentosus* is a sediment-covered seafloor free of relief, near focused sources of terrestrial drainage (Parrish et al., 1997). Areas with silt-clay size sediments tend to have larger populations also, but that appears to be more a function of current speed, which also affects the size of sediments which can accumulate in an area.

From the above examples it is clear that maps delineating habitat boundaries of juvenile pink snappers will be of little use in the management of spiny lobsters, and that boundaries of monk seal foraging habitat may be different from those of shelter habitat for reef fish. Given the widely varying needs of different organisms it is not possible to portray the full range of substrate variables that affect their distribution in a single conventional paper map. Accordingly, a different type of map is required to effectively delineate habitat boundaries for different life stages, activites and species of coral reef ecosystem organisms. To meet this need the PIBHMC is developing a geographic information system (GIS) based benthic habitat maps. The maps consist of a series of primary layers of directly mapped or measured data, including high-resolution bathymetric grids, acoustic backscatter imagery grids, geo-registered optical transects. Secondary layers will be derived from analyses of the primary data and will include metrics such as seabed texture (e.g., Local Fourier Histogram analysis), Topographic (or Bathymetric) Position Analysis, and geological interpretations of the video data and photographs. All these data layers are packaged together in a single GIS project that enables the user to combine and query different layers to delineate regions of distinct benthic habitats for different species. Collectively the data layers and GIS framework consititute a flexible new kind of benthic habitat map.

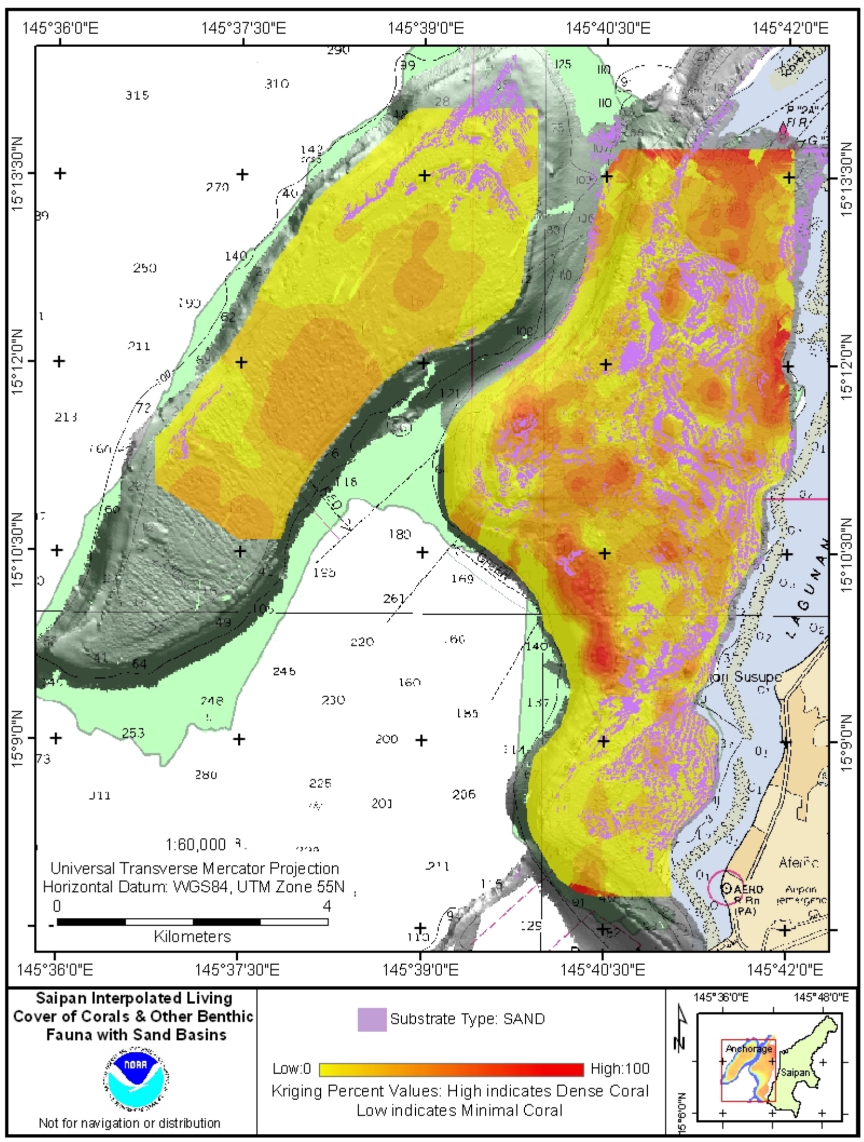
Although multibeam sonar systems do provide detailed and precise data on the depth of the seafloor, and some insight about its acoustic hardness, they alone do not provide all the information necessary for benthic habitat mapping. Optical data are also required to identify types of coral, algae, shellfish etc. that may be colonizing the seafloor, and to classify the nature of the substrate itself, as rubble, sand, solid rock, etc. To extract information about the seafloor contained in optical imagery, PIBHMC staff classifies individual still photographs or specific frames from a video. For each image an entry is made for each column of data from the classification scheme below. For the percentages of living cover and substrate categories, the cover and substrate is identified at 5 points on each video frame or 10 points per still photograph. The timestamp from each image is then linked to the timestamp from the track of the towsled during the data collection so that the benthic classifications can be precisely linked to the spot where the imagery was collected. Spreadsheets with benthic classification data from video analysis are attributed to the appropriate tow track shapefile and along-track location. Color coding is then applied to highlight features of interest, such as the percentage of the seafloor covered by living corals or other benthic fauna found at each.

Although our basic approach has remained constant, details of the classification scheme have been adjusted numerous times to reflect new insights and lessons learned from previous work. We anticipate that this evolution will continue for the foreseeable future, but version in current use is shown below and is available for download.
***Clean up Benth-Habitat-Class-Codes.xls & include table ***

Filling In The Blank Spaces…

It isn't practical to get complete optical coverage of the seafloor useful for benthic habitat classification purposes, for other than extremely small areas, using any technology available today. However, the distribution of benthic communities in coral reef ecosystems will be controlled, to some degree at least, by the availability of suitable substrate at appropriate depths, the level of disturbance from natural and anthropogenic causes such as storms and anchor chains, and oceanographic conditions including the current regime and water quality. Thus it seems reasonable to assume that broad areas of coral reef ecosystems subject to generally similar environmental conditions, leading to coextensive biological communities. The distribution of living coral and other benthic fauna seen around some Pacific Islands indicated that this is often a valid assumption, and suggest that the type and density of biological communities between areas that have been optically sampled can be interpolated. However, the character of the substrate can vary due to reasons that have nothing to do with current environmental conditions and result in habitat that may or may not be suitable for the recruitment and growth of coral reef ecosystem species. For example, sandy areas can not generally sustain growth of hermatypic (reef forming) corals or other sessile benthic fauna, so a simple interpolation of the percentages they cover is likely to over estimate populations on these substrates. PIBHMC researchers have invested considerable effort in looking for ways to reliably correlate seafloor texture, slope, depth, and acoustic hardness to delineate the extents of different benthic communities and substrate types. CRED personnel hope to eventually develop derivatives of multibeam bathymetric and backscatter data to generate gridded surfaces of numerical values to use in conjunction with an interpolation method to characterize benthic communities between optical sampling locations.

A number of automated characterization techniques approaches have been tested to date, with varying degrees of success. No method utilized to date produces results that are free of obvious defects but research in this area is continuing. As an interim approach, PIBHMC researchers have generated interpolated maps of living cover of corals and substrate types. Interpolation methodologies (such as regression or splining) can reliably capture simple trend surfaces if all data



measurements are independent. Data from benthic communities do not support such an assumption of independence because they are autocorrelated and patchy in distribution. Therefore, interpolated maps of benthic fauna are derived using a geostatistical method of interpolation called Kriging. The Kriging method takes into account spatial autocorrelation, the statistical relationship among the measured points based on proximity. Kriging is a robust interpolation method that accounts for spatially correlated distance or directional bias in the data. It assumes that the distance and/or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. Kriging fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. There are multiple types of Kriging, each of which is most appropriate for a particular data set. Universal Kriging has been used for these analyses because this method takes into account certain discernable trends in the data, such as directionality and non-random patchiness. For surface maps of coral and other benthic faunal cover, a first-order polynomial is used to de-trend the data (identify the degree of patchiness).

Using the resulting variogram, a search radius containing of the most appropriate number of classified sample points is identified to best fit the mathematical function, with a minimum of 5 classified neighbors used to determine the output value for the surrounding surface. Maps generated in this way are prediction surfaces, and have a prediction accuracy associated with each interpolated area. This approach was utilized for the Garapan anchorage area outside of Saipan Harbor in the Commonwealth of the Northern Mariana Islands to map the distribution of coral communities there, as shown below.