Optical Analysis Overview

This document provides a brief summary of the rationale and approach used to classify optical data (video and still imagery) collected by PIBHMC. The specific methods described below relate to benthic habitat classification. In recent years classification of mobile fauna using the same imagery has begun, and this is described in more detail in the Mobile Fauna Analysis Overview document.

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, activities and species of coral reef ecosystem organisms.

To meet this need the PIBHMC produces a series of geographic information system (GIS) based maps that can be viewed together to provide information about the benthic habitat. 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 can be viewed together in a single GIS project enabling 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 constitute a flexible new kind of benthic habitat map.

Benthic classification of optical data

Many of the mapped layers described above are derived from multibeam sonar systems, which provide detailed and precise data on the depth of the seafloor, and some insight about its acoustic hardness. To 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.

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 video footage is reviewed and paused every 30-seconds[1]. 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, and any other biologically relevant observations are also recorded (e.g., presence of bleached coral). The classification scheme, while largely remaining constant, has undergone fine-tuning over time to reflect new insights and lessons learnt from previous work[2]. A more major revision was undergone in the early part of 2011 to

[1] Historically different intervals have been used, e.g., 20-seconds or 30-meters. Specific methodologies are described in associated metadata for each optical map product.
[2] The specific classification scheme used is detailed in the metadata record for each optical map product.

align the scheme more closely with similar schemes being used by other teams within the Coral Reef Ecosystem Division of NOAA's Pacific Islands Fisheries Science Center. The scheme now being used can be viewed on the Benthic Habitat Classification Scheme webpage.

Due to the limitations of classifying benthic fauna from video imagery alone, certain assumptions are made when conducting classification of the video footage. 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 obvious benthic fauna such as coral or macroalgae is most frequently colonized by turf algae. Accordingly, for situations in which it does not appear that anything is growing, the cover is classified as "turf algae." If it is obvious that there is some kind of cover, but it is not possible to distinguish the type of cover then the cover is classified as "unclassified."

Data are entered directly into a custom-built Access database, which includes metadata for each 30-second point (cruise, tow id, date, time, position, etc.) as well as the substrate and cover categories for each of the five points. Using the towsled track the results of the optical classification can then be mapped, using colors and symbols to highlight features of interest, such as areas of high coral cover (see below).

A similar method is used to classify still photographs. Due to the motion of the towsled it is difficult to obtain consistently focused images, and therefore still images are taken every 10-seconds to allow poor quality images to be rejected. Currently, Coral Point Count software is used to overlay random points on a digital image, and whatever lies underneath each point is classified using the same methods and assumptions as outlined for the video above. Data are directly entered into the same Access database that is used for the video classification. In general the higher quality of the images obtained from the digital still camera allows benthic fauna to be classified to a higher level of taxonomic detail. Still images can also be related to specific video footage using timestamps and this can aid in classification of the video imagery. Currently investigations are underway to determine the most analytically appropriate number of points to classify per photo.

Mapping the results

To be able to relate a section of video footage or still image to a specific location on the seafloor, the timestamp of the video is used to match the imagery to the position of the towsled at that same time using the towsled track.

As imagery has been collected on different ships and with the equipment set up in slightly different ways, the way in which the position of the towsled is determined can vary by cruise. Specific information on how the position of the towsled is determined is detailed in the metadata corresponding to each cruise on which optical metadata was collected. Importantly this can result in different levels of positional uncertainty, ranging from 20–100 m error. Currently, Hypack software is used to determine the position of the towsled, using the known position of the ship the amount of cable paid out, the horizontal and vertical offsets between the GPS antenna and the sheave over which the camera sled cable passes, and a built-in catenary function. The calculated position of the towsled at 30-second increments is exported as a text file, which is then imported into ArcGIS allowing the track of the towsled to be mapped. The time of these 30-second increments is then matched to the timestamp of the video footage or still photograph.

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 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. 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.