Exploring the use of a towed video camera as a tool for assessing fish-habitat associations.

Introduction

Since the enactment of the Magnuson-Stevens Fishery Conservation and Management Act in 1996, marine managers have been faced with the responsibility to conserve and manage all fishery resources off United States coastal areas. In order to effectively manage fishery resources managers need information on the distribution, abundance, and habitat characteristics of the species in question (Iampietro 2008). Due to logistical constraints in many cases this information is difficult if not impossible to obtain using traditional stock assessment methods (i.e. extractive practices). For this reason marine managers are increasingly looking towards habitat-based assessments, which do not involve removing individuals from a population, but do give some estimate of abundance and distribution to make informed management decisions.

The most important assumption behind habitat-based assessment is that species are not randomly distributed in their environment and that distribution and abundance of a species or assemblage is highly correlated to assortment, quality, and extent of benthic habitats (Iampietro 2008). A brief review of fish-habitat association studies include those correlating satellite imagery with diver based surveys of fish and benthic populations to determine the most useful factors in defining essential fish habitat across shallow depths (Kuffner 2007; Pittman 2007; Wedding 2008; Pittman 2009; Kendall et al 2010). Others have focused on deeper habitats and aimed to assess both fish species distributions and benthic communities by correlating submersible, ROV, towed, or baited camera video footage with high resolution multibeam bathymetry grids (Iampietro et al 2008; Holmes et al 2008; Moore et al 2009; Chatfield et al 2010).

Data that proved useful in fish-habitat assessment vary greatly between studies, most likely, due to differences in equipment, data quality, analysis methods, and faunal assemblages. Additionally, Iampietro (2008) found that factors such as fishing pressure, recruitment success, and food availability also play a big role in fish distribution despite available habitat. For these reasons it is difficult to directly apply findings from one study to another.

The purpose of this report is to explore the use of the Coral Reef Ecosystem Division's (CRED) towed-camera sled (TOAD) as a tool for assessing fish-habitat relationships by determining which habitat factors (derived from acoustic data and classified video) best explain the variability in observed fish and benthic communities. This will be examined by focusing on one area that has been well-surveyed by CRED, that of French Frigate Shoals in the Northwestern Hawaiian Islands.

More specifically, research at CRED's Pacific Islands Benthic Habitat Mapping Center (PIBHMC) has focused on the following questions to better understand the relationships between fish and benthic assemblages and acoustically-derived seafloor data:

- Which continuous (raster based) environmental parameters are driving fish assemblage patterns?
- Which local habitat characteristics are driving fish assemblage patterns?

Methods

In 2008, NOAA-CRED-PIBHMC participated in a month long dedicated mapping cruise to French Frigate Shoals in the Papahanaumokuakea Marine National Monument (Northwestern Hawaiian Islands). 16 tows using the camera sled were conducted on the bank top at French Frigate Shoals in depths of 20 to 100+ m, with over 50km of seafloor surveyed. During this cruise acoustic multibeam survey was carried out to fill in gaps in multibeam coverage resulting in near 100% coverage of seafloor from 20-200+m. Due to the extensive coverage of both acoustic and optical data and the high quality of these data, French Frigate Shoals was chosen as the site at which data analyses would be conducted.

Video survey

The camera sled is composed of two Deep Sea Power and Light (DSP&L) Multi SeaCam 2050 color video cameras, two 500 W DSP&L Multi SeaLite underwater lights, one 400 W DSP&L HMI light, a depth sensor, a sonar altimeter, and a set of parallel lasers all enclosed in a stainless steel frame. A video feed from the sled was sent via an umbilical cable to a video monitor in a topside control unit where an operator watched a live feed and adjusted the altitude of the sled to roughly 1-3m above the seafloor.

After the videos were collected, trained seafloor video analysts classified benthic habitat at 30 second intervals using a stationary five point method. Points were classified using a hierarchical classification scheme which can be seen in Figure 1. A point was first classified at the substrate level, then the living cover on that substrate, and if applicable the scleractinian coral genera and morphology.

				** SCLERACTINIAN CORAL CLASSIFICATIONS			
Percentage of Substrate	**code**	**Living Cover**	**code**	**Coral Genera (Hawaii only)**	**code**	**Coral (Growth) Morphology**	**code**
UNCONSOLIDATED	u	seagrass	sg	*Pocillopora*	*pp*	Massive	m
mud	m	non-scleractinian coral	ns	*Porities* (massive & encrusting)	*pm*	Plate-like	p
sand	s	scleractinian coral**	sc	*Porities compressa*	*pc*	Encrusting	e
		coralline algae	ca	*Montipora*	*m*	Branching	b
		coral or coralline algae	cc	*Acropora*	*a*	Columnar	c
HARDBOTTOM	h	macroalgae	ma	*Leptoseris*	*l*	Free-living	f
rubble	rb	turf algae	ta	Other live coral	ol		
boulder	b	unclassified algae	ua	unencrusted coral	ue		
rock	rk	emergent vegetation	ev				
man-made structure	mm	Giant Clam	gc				
		Other non-mobile inverts	nm				
		None	no				
unclassified	uc	unclassified	uc	unclassified	uc	unclassified	uc

Figure 1: PIBHMC hierarchical benthic classification scheme

Following benthic habitat classification, analysts identified and counted all fish to the lowest taxonomic resolution possible for a 30-second period of video footage, starting 15 seconds before and ending 15 seconds after each central benthic point. If a fish could not be identified to the family level then it was called unidentified fish and was not included in subsequent analyses. This was done to reduce the chances of incorrectly increasing or decreasing similarity between benthic habitat points.

Finally, data from 10 consecutive 30-second sections were summed to give the total number of fish (by taxonomic group) and benthic cover (as percent cover) for each five minute interval. Fish families and benthic categories which were present in less than 5% of observations were considered rare and were excluded from analysis. The longitude and latitude of the mid-point of each 5-minute interval were imported into a GIS and 100-meter diameter buffers were drawn around the points. Buffers were used to derive an area from which acoustic habitat characteristics would be taken. A diameter of 100 meters was used since it was determined to be the average distance traveled by the towed-camera in a 5 minute interval.

Multibeam survey and habitat data

Data were collected during 2005 and 2008 from NOAA ship Hi'ialakai's EM300 and EM3002D sonars and from NOAA R/V AHI's Reson 8101ER sonar. Data from the different surveys were combined and 5-m resolution grids of the bathymetry and backscatter were produced.

ArcGIS spatial analyst tools were used to derive 5-m grids of slope and slope of slope. The benthic terrain modeler (BTM) was used to derive bathymetric position index (20m), BPI zones, BPI structures, and rugosity from the bathymetry grid (Wright et al 2005; Lundblad 2006). A classified layer predicting hard-soft substrate was also derived from bathymetry and backscatter grids (Weiss 2008). All of the bathymetry, backscatter and derived layers were imported into the same GIS. The derived layers used in these analyses were chosen due to previous studies demonstrating possible links to distinguishing fish and or benthic habitat (Guisan and Zimmerman 2000; Pittman et al 2007; Kuffner et al 2007; Holmes et al 2008; Moore et al 2009; Kendall and Miller 2010).

Mean values for each of the above layers within each 100m buffered polygon were extracted using the zonal polygon tool in ArcGIS v 9.3.1.

Statistical analysis

Multivariate statistical analyses were conducted using PRIMER v 6.1.12. Initially all benthic habitat and fish abundance data were square root transformed in separate tables to reduce the influence of common fauna. All acoustic data were log transformed and then normalized (Clarke & Gorley 2006). Two Bray-Curtis similarity matrices were calculated for fish and benthic habitat data. A Euclidean distance similarity matrix was calculated for acoustically-derived variables.

The first test (RELATE) was run in order to determine whether the pattern of similarity between points in two similarity matrices were due to chance alone. The strength of association between matrices is calculated using Spearman's rank correlation. Subsequent permutations are then run with sample labels randomly reassigned and correlation again calculated to determine whether the initial correlation value calculated arose by chance alone. In order to answer the two questions outlined in the introduction, this test was run between combinations of fish and acoustically-derived matrices and fish and benthic matrices.

Next a BIOENV routine in PRIMER was run to determine which acoustically-derived variables best explain the pattern in the fish similarity matrices. Additionally, a BIOENV test was run to determine which local habitat variables best explain the pattern in the fish similarity matrix. The BIOENV test conducts permutations wherein sample numbers are randomly rearranged and correlation is calculated (Spearman's). This is run using different combinations of variables from the environmental or habitat matrices and the top 10 correlations are listed.

Finally, a cluster analysis was performed in PRIMER in order to determine whether statistically significant groups could be defined and if so which families defined each group.

Results

There was a significant relationship between the fish assemblage and acoustically-derived variables ($\rho = 0.187$, $P < 0.001$). None of the 999 permutations were equal to or greater than the measured correlation value of 0.187. Additionally a BIOENV routine resulted in a three variable model consisting of hard-soft, depth, and slope of slope best explaining the similarity patterns between the two similarity matrices. Results from the top ten models can be seen in Figure 2.

There was also a significant relationship between the fish assemblage and benthic habitat data ($\rho=0.201$, $P< 0.001$). Again none of the 999 permutations calculated a correlation value equal to or greater than the measured correlation. Results from the subsequent BIOENV test showed a two variable model with scleractinian coral percent cover and *Porites* coral cover best explaining the patterns of similarity in the two similarity matrices. Results from the top 10 models can be seen in Figure 3.

Furthermore a cluster analysis on the fish abundance data showed 21 distinct clusters of fish family assemblages. Results from cluster analysis showed that although many fish families were similar between clusters the number of individuals was highly variable. Figure 4 shows the average number of individuals per family within each cluster.

	Acoustic Variable								
ρ	Hard-Soft	Zone	Structure	BPI 20	Backscatter	Depth	Slope of Slope	Slope	Rugosity
0.251	x					x	x		
0.248					x	x	x		
0.248	x	x			x	x	x		
0.246	x				x	x	x		
0.246	x	x				x	x		
0.244		x			x	x	x		
0.240	x				x	x	x	x	
0.240	x	x				x	x	x	

0.238	x	x			x	x		x	
0.238	x					x	x	x	
Total	8	5	0	0	6	10	9	4	0

Figure 2: Top 10 correlation values with acoustic variables included in each model derived from the BIOENV analysis. Total rows show the total number of times each variable was used in the top 10 model correlations.

	Benthic Habitat Variable									
ρ	Sand	Rubble	Rock	Scler Coral	Coralline Algae	Macroalgae	Unclass Algae	Uncolonized	*Porites* (m&e)	Massive
0.297				x					x	
0.295									x	
0.294				x		x			x	
0.293				x					x	x
0.293				x						
0.292		x		x					x	
0.292		x		x		x			x	
0.289		x		x					x	x
0.289				x		x			x	x
0.288		x		x		x			x	x
Total	0	4	0	9	0	4	0	0	9	4

Figure 3: Top 10 correlation values with benthic habitat variables included in each model derived from the BIOENV analysis.

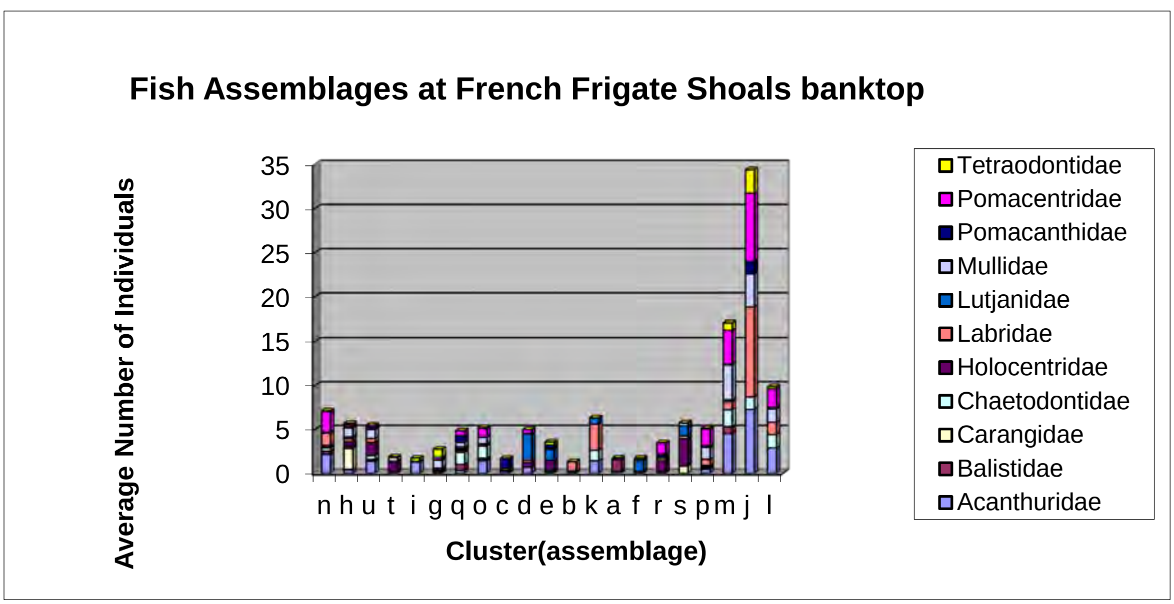

Figure 4: Average number of fish per fish family within each cluster

Discussion

The results from the above analyses suggest that the camera sled is a useful tool for assessing fish and benthic communities. Statistically significant correlations between discrete fish observations and continous acoustically derived data argue a case for further development of methods to model the distributions of key fish assemblages. Hard-soft, bathymetry, and slope of slope were the datasets generated by multibeamechosounder that were included in the model with the highest correlation value, as well as in the highest number of the top ten model combinations.

The use of a hard-soft substrate map to help explain similiarities in fish assemblages is not surprising. Most of the fish identified in camera sled video are site attached to either hard or soft substrate. The majority of fish that have large home ranges (i.e. are not site-attached), such as sharks, were removed before analysis as they were rarely seen. One interesting exception to this is that of the family Carangidae of which almost all observations were of the species *Caranx ignobilis* (giant trevally). This species was observed in a wide variety of habitats ranging from coral dominated reefs to sand flats. *C. Ignobilis* has also been observed hunting along with the camera sled snatching up prey which are startled by the lights of the sled. Further investigation may need to be conducted in order to determine whether roaming apex predators such as *C. ignobilis* which traverse a variety of habitats should be included in susequent analyses.

Depth was also found to be an important factor driving familial assemblages. Any diver who pays attention to fish assemblages will notice that certain species and families are observed more frequently in shallower environments than in deeper environments or vice versa. However, the relationship between depth and fish occurance should be interpreted with caution. In most cases depth derived presence is not really due to depth, but more due to some other depth correlated phenom such as temperature, salinity, wave energy, light penetration, or food availability.

Finally, slope of slope is an important factor driving the fish assemblages observed at French Frigate Shoals. Slope and rugosity, two other bathymetrically derived factors, were also included in the analyses, but were included in a small percentage of the top ten models. This was surprising given the importance of slope and rugosity in past studies (Kuffner 2007; Pittman 2007; Wedding 2008; Iampietro et al 2008, Holmes et al 2008, Moore et al 2009; Pittman 2009; Kendall et al 2010; Chatfield et al 2010). However, Pittman (2009) found that slope of slope was the single best predictor of fish distributions. Pittman suggests that in his study, this may have been because slope of slope revealed more cell to cell variability and intricacy than either slope or rugosity.

Statistically significant correlations between fish observations and benthic habitat observations were also found with scleractinian coral and *Porites* massive and encrusting corals as the factors most driving fish assemblages. Given that the majority of families observed in the camera-sled video are coral reef associated it's not surprising that coral cover is a driving force in fish assemblages. Further analyses which may prove useful may include defining broader habitats into categories such as reef and rubble flat.

The results from cluster analysis are less intuitive. Results showed 21 distinct clusters or fish assemblages. Differences between assemblages are mostly explained by differences in the abundance of only one or two fish families between clusters. For instance, cluster j had an average number of 7 individuals from the family Acanthuridae, whereas, the majority of clusters averaged numbers closer to 1. Differences in abundance should be further explored as these differences are probably less indicative of distinct assemblages than they are an indication that classification methods need to be further refined. For instance, video quality may need to be considered as differences in visibility, sled height, and equipment configurations could all result in the differential ability to identify and count fish. Time of day in which the observation occurred should also be taken in to account as fish are known to not only exhibit behavioral differences, but also utilize different habitats at different times of day. For instance, members of the family Pomacentridae (damselfishes) are commonly found in the water column during the day, however, they seek shelter in crevices during the night. Additionally, missidentification of fish may also be an issue and it is unknown to what extent incorrect identification is affecting in these results.

Overall, preliminary analyses were encouraging. Useful acoustic and benthic habitat factors have been identified as driving factors in fish assemblages and should be examined further. Future efforts may include first delineating more broad categories of benthic habitat such as reef, sand, rubble field, etc. Past studies by Pittman (2009) found classifying acoustic data in this manner, such as slope of slope into high, medium, and low intensity, also to be useful. Fish assemblage data should be reanalyzed and subsampled to include only data collected during the day and image quality should be examined to make sure that day to day variation in conditions and equipment are not causing significant differences in analysts ability to consistently analyze video.

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