Persistence and Change of Geomorp
Rippled Scour Depressions and Ro
Continental Shelf of Monterey

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INTRODUCTION

"Rippled Scour Depressions" (RSDs) also known as sorted bedforms are assiduous patches of prominently coarse sediment and shell hash inset into soft sediment sand plains (Green et al, 2003). These features are commonly located from average depths of 10-70m, up to 160m from shore and run perpendicular to the coastline (Bellec,2009). Studies using sidescan sonar, sediment analysis and backscatter data have identified these features in the continental US, Norway, France, the Mediterranean, New Zealand, Puerto Rico and various other locations globally (Murray and Theiler, 2003). Most of these studies have proposed that alongshore currents are the dominant factor in their formation and persistence, but large storm waves and wind swells also have an impact. No studies to date have done an accurate long term comparison of the RSDs change or movement. Iacona and Guillen's study of the Mediterranean over a 13 year period showed that the RSDs can form and move in the absence of large storms; however, their positioning system had an error of >100m. Now, recent data collected as part of the California Seafloor Mapping Project (CSMP) reveal RSD's to be the most ubiquitous features of sedimentary habitats across the State's continental shelf (R. Kvitek pers com).

The purpose of this study is to precisely quantify change in RSD and adjacent rocky habitat features over a decade. A time series comparison was performed on high resolution multibeam bathymetry data sets collected by the CSUMB Seafloor Mapping Lab (SFML) in summer 2000 and the CSUMB ENVS 433-533 Sea Floor Mapping Class in February 2010 at a RSD site in Pacific Grove adjacent to the Hopkins Marine Lab.

While the distribution of these features can be clearly seen in the CSMP data, it is not known how frequently or under what circumstances they form and change. Our general question is has the spatial distribution and relative abundance of soft-sediment and rocky habitat types changed over time? And if so, are changes correlated with depth?
Here we present spatial analysis of repeat mapping results to address the following specific questions:
1. Did the amount or spatial distribution of exposed rock reef change between 2000 and 2010?
2. Is there a significant shift or contraction of the entire RSD feature field?
3. Did the percent cover or spatial distribution of discrete RSDs change between 2000 and 2010?
4. Has the base elevation of persistent RSDs changed since 2000?
5. Is the sediment grain size coarser in RSDs than on plateaus?

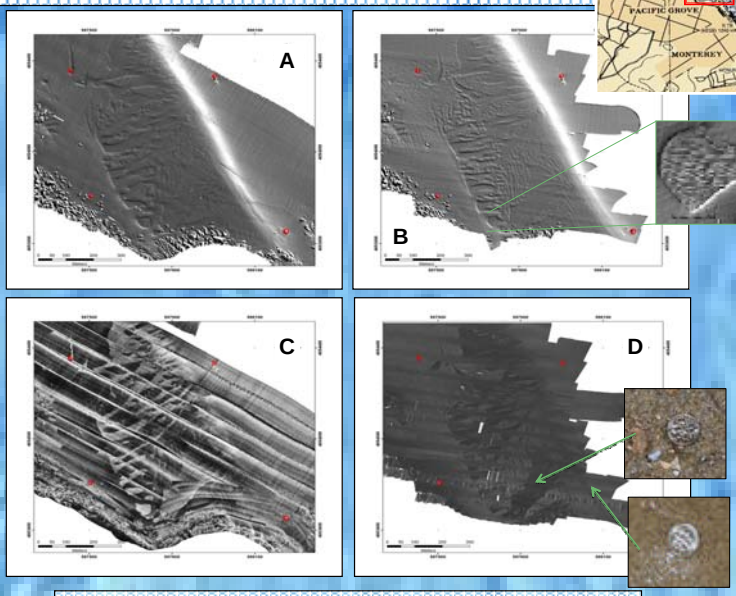

Figure 1. **A)** Hillshade raster displays surface illumination of surveyed area in 2000 values at 45 degrees. **B)** Hillshade raster displays surface illumination of surveyed area in 2010 values at 45 degrees. **C)** The sidescan backscatter shows sediment and feature variation in 2000. **D)** The sidescan backscatter shows sediment and feature variation in 2010, fine sediment collected from highs of RSD in 2010 (bottom inset image), coarse sediment collected from depressions of RSD in 2010 (top inset image).

METHODS

To assess the stability and persistence of seafloor features within the RSD study area, CSUMB Seafloor Mapping class collected bathymetry and backscatter data on February 12, 2010. The class analyzed the collected data for precision, and changes in rocky outcroppings and RSD features between 2000 and 2010 data sets. In order to accurately compare the data sets from 2000 and 2010, four rock features visible in the 1 meter Digital Elevation Models (DEM) created from the bathymetry data for both dates were identified and tested for significant difference via paired t-test (Tab.1). The extent of rocky habitat was quantified from the DEM raster data for both years using the rugosity builder tool in the NOAA Benthic Terrain Modeler (BTM) extension for ArcMap (Fig. 2). A paired two-tailed T-test was conducted on a 50 m sampling grid created in Hawth's Tools to assess change in percent cover of exposed rocky reef between 2000 and 2010 (Fig. 3). In order to assess changes in the RSD cover and distribution, DEMs were first classified into depressions and plateaus using BTM Bathymetric Position Index tool, and the raster results were used to calculate the percent cover of and change in each using ArcGIS Spatial Analyst. The study area was further classified as depressions or plateaus binned in 2.5 meter depth intervals. Percent change within each depth zone was calculated after analyzing the pixel counts of depressions and plateaus within the various depth gradients to determine the total areas of each feature type. The areas of each depression were also calculated and subtracted to find the change in percent cover. The centroids of the entire RSD field for each year were found and their difference was used to test for any shift in the overall location of the field over time. Divers collected sediment samples on plateaus and in RSDs to compare grain size to backscatter intensity data.

2010-2000 Control Point Position Difference (meters)			
Control Points	Easting	Northing	Depth
A	-1	0	0.04
B	-1	0	-0.14
C	0	0	0.00
D	0	0	0.00
Mean	-0.5	0.0	-0.02
STDEV	0.5	0.0	0.07

Table 1. The easting and northing position in UTM and depth in mean sea level of four control points were compared using a paired t-test.

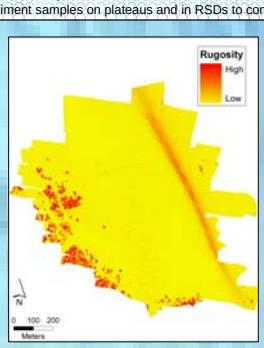

Figure 2. Rocky habitat was classified using the Rugosity Builder Tool in NOAA's Benthic Terrain Modeler on the bathymetry data for both datasets. Rocky habitat is more rugose (more rough) and therefore has higher rugosity values and shows as red shades; areas covered by soft sediment are less rugose and show as yellow shades.

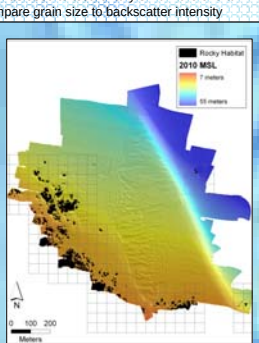

Figure 3. Rocky habitat (black polygons) was determined by reclassifying the rugosity maps for both datasets . A 50 meter grid (grey gridlines) was created using Hawth's Tools. The area of exposed rocky habitat within each grid cell was determined for both 2000 and 2010 data. The difference in rocky habitat exposure between the two data sets was found not to be significant (p=0.844).

RESULTS

The data collected in 2000 compared to the data collected in 2010 showed no significant net change in percent cover of rocky habitats (Fig. 3). The size and shape of these habitats also showed no significant changes; therefore the null hypothesis was supported. Analysis showed minimal RSD percent cover change across all depth ranges between 2000 and 2010 (Fig. 4). Total RSD percent cover remained consistent with a 1% difference between 2000 and 2010. The total area of the RSD field changed by <3% (6250 m²) during the same time period (Table 2 and Fig. 7). The overall position of the RSD field shifted by < 2 m to the west and 22 m to the north as measured by the centroid (Fig. 5). Vertically, there was a statistically significant difference in the base elevation of persistent depressions between 2000 and 2010 ($p<0.000$). Points in the 2010 depressions were 0.40 ± 0.12 m (mean ± SD, n = 10) deeper than the same depression points in 2000 (Fig. 6). The visual analysis of the sediment samples validated that areas of high intensity backscatter return was due to coarse sediment grain size (Fig. 1D).

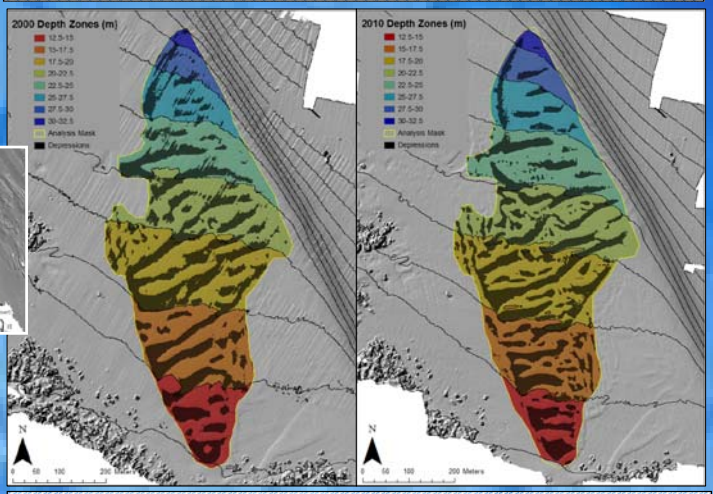

Figure 4. BPI classification with rippled scour depressions depicted in black. The red to blue color gradient represents 2.5 meter interval depth zones with red representing shallow areas and blue representing deeper areas.

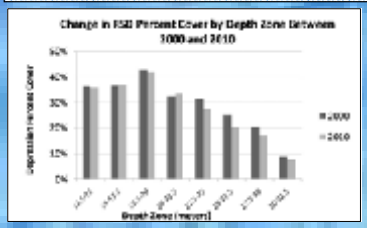

Figure 5. 2000 and 2010 RSD percent cover vs. depth zone. The comparison results between 2000 and 2010 data yield minimal RSD extent movement from both shallow and deep areas to mid depth ranges. Total RSD percent cover remains consistent with a 1 percent difference between 2000 and 2010.

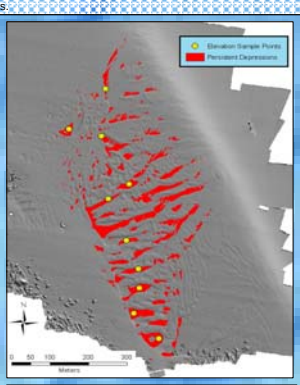

Figure 6. Location of persistent depressions derived from the 2000 and 2010 Benthic Terrain Modeler (BTM) after raster calculations were conducted to visualize no change areas that remain persistent for both years. Sample points were chosen across the depth range of the area of interest to test elevation change in depressions that existed in both 2000 and 2010.

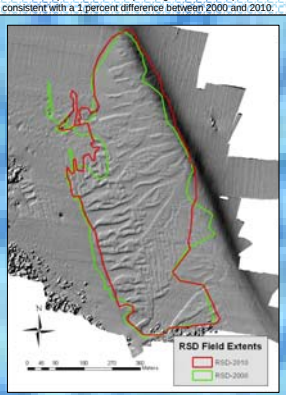

Figure 7. The observed extents of the overall RSD field in 2000 and 2010 overlapping the 2010 bathymetric data hillshade. Each respective color represents a different year's extent.

Data Year	Area (m²)	Centroid Easting	Centroid Northing
2000	254291	597722	4054082
2010	260541	597720	4054104
Total Change	6250	-2	22

Table 2. Change in overall RSD field area and position as measured by the centroid in UTM, calculated in ArcGIS.

DISCUSSION

Although there was no significant change in overall area or position of the RSD field, there was internal rearrangement of the RSDs, but no significant change in their relative percent cover between these two dates separated by10 years. This internal rearrangement of the RSDs did not result in any significant change in the percent cover of the adjacent rocky habitat i.e. rocky habitat did not appear to be buried or uncovered.

Future research in this area will focus on the ecological and biological aspects of these RSDs, particularly as they relate to California's newly designated MPA network. Furthermore, with the completion of the California Seafloor Mapping Project, it will now be possible to quantify the distribution, abundance, and dynamics of RSDs as well as ephemeral rocky habitat along the entire California coast using the analytical tools applied here.

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