Project Title: Baseline Monitoring of Ecosystem and Socioeconomic Indicators for MPAs along the North Central Coast of California: Rocky Intertidal Ecosystems

Project Leader(s) and Associated Staff

Dr. Peter Raimondi, UCSC (PI): As the PI, Dr. Raimondi will oversee all aspects of the Rocky Intertidal kelp forest ecosystem baseline characterization as well as the development of an integrated data base, long-term monitoring recommendations, ecosystem indicators, synergies with other projects affiliated with this proposal, and report writing.

Project Goals and Objectives

The objective of the proposed surveys and analyses are to (1) produce a quantitative baseline characterization of the structure of rocky intertidal ecosystems **in all of the MPA's that have rocky intertidal habitats** recently established by the MLPA Initiative in the NCCSR, (2) provide a quantitative comparison between the rocky intertidal ecosystems in these MPAs and associated reference areas in the NCCSR, (3) analytically explore the baseline characterizations for potential indicators of the state of the rocky intertidal ecosystems using newly collected data along with our existing datasets from the region (13 sites where monitoring is ongoing), and (4) integrate these assessments with other components of the baseline survey (e.g., Kelp Forest, ReefCheck, UCD Abalone Urchin, Sandy Beach, collaborative fishing) to inform the role and design of those programs for a future monitoring and evaluation program.

Rationale

The north-central California mainland seacoasts possess an exceptional diversity of valuable rocky intertidal resources. Major factors contributing to the richness of coastal marine life in this region include their location along the boundary of two major biogeographic provinces (cold-temperate Oregonian and warm-temperate Californian), their high diversity of habitat types, and their exposure to varying local oceanographic conditions. In addition, these rocky intertidal resources are heavily utilized (Thompson et al. 1993), for recreation and harvesting. Recently, the extensive conversion of private to public access of many coastal areas has increased visitation and both legal and (especially) illegal harvest from these areas. Other threats are also present. Oil and gas activities, especially the tankering of oil along the California coast, raise the possibility of an oil spill or other impact to coastal resources. Because of the: (1) importance of these resources, (2) the recognition of real threats to such resources and (3) the recognition that the vast majority of all access and harvest (on a per area basis) is concentrated in rocky intertidal areas, establishment of baseline monitoring has been widely advocated. The basis of this reasoning is that monitoring of coastal biota in California would provide baseline information in case an event such as a spill damaged these resources. In addition, the monitoring studies have been thought to yield important data on population dynamics on a local and regional scale, which could be utilized for more effective resource management as well as provide fundamental ecological knowledge about the dynamics of the systems. As a result, a network of rocky intertidal sites along the coast of California have been established, where baseline information is currently available and data are still being collected. These sites were established before the MLPA process, and thus the current network does not provide adequate coverage to address questions regarding the status and baseline biodiversity within marine protected areas or information on the differences between marine protected areas and nearby reference sites. In this proposal we plan to fill critical gaps in our current north-central California rocky intertidal monitoring, which PI Raimondi oversees, to create a comprehensive baseline database **for all North-central California MPA sites (having rocky intertidal habitats) and reference areas.**

Approach to be Used (Plan of Work)

Our approach to conducting baseline characterizations involves a replicating our current intertidal sampling program that occurs throughout a network of 100 monitoring sites ranging from Alaska to Baja California (including sites in the NCCSR). This is the same approach we used to generate baseline characterizations of rocky intertidal ecosystems in the Central Coast Study Region (CCSR) and the network of marine reserves in the Northern Channel Islands (NCI).

Research described in this proposal will be closely coordinated with the two major existing regional monitoring programs for intertidal ecosystems. P. Raimondi is the PI on both these programs in the north-central California region. The first is MARINe (Multi Agency Rocky Intertidal Network, http://www.marine.gov/), which evolved from the monitoring program initiated by the Channel Islands National Park in the early 1980's (Davis 1985; Richards and Davis 1988). The MARINe monitoring was explicitly directed at detecting temporal changes in the intertidal communities. As part of the evolution of the program we assessed the ability to detect changes in communities, which led to the unified MARINe protocols (Engle et al. 2005)

While the unified MARINe protocols have proven to be extraordinarily powerful for detecting changes in communities (Minchinton and Raimondi 2005 and see figure 1 in this appendix) and particularly in separating anthropogenic from natural dynamics (Raimondi et al 1999), they were not designed to estimate biodiversity. Moreover, we found that geomorphology was tremendously important in determining communities and dynamics of communities. To address these concerns we designed a spatially explicit biodiversity monitoring program. This program has been variously called the SWAT or comprehensive surveys, but herein we will use the term biodiversity surveys (cbsurveys.ucsc.edu). Such surveys have been conducted at almost all of the MARINe sites and several non – MARINe sites. Finally, we initiated additional surveys at a number of our sites to track the catastrophic effects of withering disease and poaching on the black abalone (Raimondi et al 1999, Miner et al 2006) and harvest and poaching on the owl limpet (Sagarin et al, 2007).

We propose to maintain strong similarities in the design and protocols to maintain standardization across the Study Regions until changes in design or sampling protocols are identified. Rocky intertidal reefs will be surveyed for two consecutive years (2010 and 2011) in all 15 MPAs having rocky habitats (Figure 2) and associated reference sites. These sites include 10 locations where we have long-term sampling, which will provide a much longer times series for the baseline characterization. We use two separate survey types to characterize the ecosystem. (1) Community surveys are used to provide assessment of targeted species or communities (e.g. abalone, sea palm, mussel community, fucoid community, sea grass community). These protocols have been developed and validated by the MARINe consortium and are described in detail in the MARINe website (http://www.marine.gov/) (2) Biodiversity surveys are used to completely characterize the biodiversity of the site and are based on the PISCO biodiversity survey methods. Here we also map the distribution (in xyz space) for all species in the sampled area. These protocols are described in detail in the PISCO/UCSC website (http://cbsurveys.ucsc.edu/).

Community Structure Monitoring
To address issues of changes in community structure over time, we will set up monitoring plots at the new sites using MARINe protocols. As noted above our initial studies and review led to the unified MARINe protocols. We will monitor existing and new plots associated with target species at up to 30 rocky intertidal sites along the mainland coast of North Central California and on the Farallon Islands. Target species include all species indicated to be important to the MPA process, which are consistent with MARINe species guidelines. Target species include: mussels (*Mytilus californianus*), barnacles (*Chthamalus* spp., *Balanus glandula* and *Pollicipes polymerus*), anemones (*Anthopleura elegantissima*), algal species including *Endocladia muricata, Hesperophycus harveyanus, Silvetia compressa, Mazzaella* spp., *Mastocarpus*

papillatus, *Postelsia palmaeformis,* surfgrass (*Phyllospadix scouleri/torreyi*), motile invertebrates such as owl limpet *Lottia gigantea*, black and red abalone (*Haliotis cracherodii, rufescens*) and sea stars (*Pisaster ochraceus*). Analysis following the "Torch spill", an OCS pipeline spill from Platform Irene, showed that it was possible to detect change in percent cover as small as 8-15% using this fixed plot sampling protocol. Importantly, it was also possible to differentiate between natural changes such as the El Niño storms and the effects of the oil spill (Raimondi et. al, 1999). It is vital that the monitoring protocol is sufficient in detail to address low-level changes that may accompany MPA protection.

Mussels, barnacles, anemones and algal species will be photographed in fixed rectangular plots and scored in the lab by recording species under 100 points on each slide. Five replicate plots per assemblage will be photographed. Surfgrass cover will be estimated using a point contact method along 10 m transects. Owl limpets will be measured and counted in 5 replicate, 1-meter circular plots. Abalone and *Postelsia* surveys will record size and abundance of abalone in 3 replicate irregular plots. Sea stars will be counted, measured and classed by color in either 2 meter wide, 10 m long band transects or irregular plots, depending on the habitat.

Monitoring of the long-term sites are proposed for Fall and Spring. There can be considerable seasonal changes in the rocky intertidal community, especially after stormy winters and hot summers. Two samples per year will adequately track these communities (Raimondi et al 1999). October or November is usually the first period after summer with low tides during the daytime (which greatly improve efficiency of sampling and safety), and is appropriate for determining the post-summer community. March or April is an appropriate time to determine the post-winter community, and there are once again low tides during the daytime.

Protocols used to collect the data will be standardized, coordinated with other members of MARINe, and not altered without prior approval of all parties. A base protocol which is standardized across MARINe members shall be maintained at each site; additional protocols needed to address site specific problems or answer species-specific questions can be added as needed. Additional protocols which do not add field costs overall can be accommodated in order to address these important research questions, so long as this is coordinated properly with MARINe.

Biodiversity Monitoring

Our biodiversity monitoring at each site will be consistent with the approach and protocols of the Coastal Biodiversity Surveys (cbsurveys.ucsc.edu). Below we briefly describe this sampling approach.

Once an appropriate area of shoreline has been selected, the grid of the sampling area is defined by a series of parallel transect lines extending from the high zone to the low zone. To facilitate the setup of these lines, two permanent 30m horizontal baselines (parallel to the shoreline) are first established. The upper baseline is placed in the high zone above the upper limit of marine biota, such as barnacles, while the lower baseline is established farther down the shore within the low zone of biota at that site. The ends of these lines are permanently marked with either hex or carriage bolts.

Once these two baselines have been established, parallel transect lines are run perpendicular to the shoreline at 3-meter intervals crossing both the upper and lower baselines. In general the transect lines follow the contours of the site topography. When necessary, rocks are placed along the lines to prevent them from being shifted by heavy winds and a note is made of where each transect crosses the lower baseline.

Point-Contact Surveys

Each vertical transect is sampled using the point intercept method. Ideally 100 points are sampled at uniform intervals on each transect line. For each point two types of data are collected: data that are used to determine relative abundance (% cover), and data that are used to describe spatial distributions. The relative abundance data are collected by identifying all taxa that fall directly under each point, including rock, sand, and tar. If there is layering, the taxa occupying the different layers are identified and assigned a letter defining their vertical position within the canopy. Also recorded is whether the species under the point are found in pools, on cobble, or on boulders. A total of up to three taxa are identified under each point. If fewer than three taxa are recorded under a point, then data are collected on the identity of the next one or two species closest to that point. These data are used to describe the spatial distribution of species, and are not used when calculating relative abundances. These 'nearby' species must be different than those found under the point, and must fall within a circle centered over the point with a radius half the length of the sampling interval. When a species cannot be identified in the field, it is assigned an unknown number and a sample of it is collected.

Mobile Invertebrate Surveys, Sea Star and Abalone Swaths

Although point-contact surveys are good at determining the abundance of spatially common species, they do not sample rare or spatially uncommon species very well. Because most mobile species are not spatially common, their abundances are determined in 50 x 50 cm quadrats placed at three locations along each transect. Each transect is first divided into three zones; the low zone is the area below the mussels, the mid-zone includes the mussels and the rock weeds (e.g. *Silvetia, Pelvetiopsis*), and the high zone is the area dominated by barnacles and littorine snails. Within each zone a quadrat is randomly placed on the transect, and all mobile species found within the quadrat are identified and counted. Sub-sampling may be used when there are more than one hundred individuals of one species in a quadrat. If a quadrat lands in a deep pool or in an area dominated by sand, a new location is selected. The only mobile species not counted are worms, *Neomolgus littoralis*, and amphipods.

Seastars and abalone play an important role in the intertidal community, but often they are also not spatially common. As such, their abundances are measured along a two-meter swath centered over each vertical transect. Within this swath, the abundance and location along the transect (to the nearest 0.5m) of the following seastars and abalone are recorded: *Haliotis rufescens, Haliotis cracherodii and rufescnes, Asterina miniata, Dermasterius imbricata, Pisaster ochraceu*s, *Pisaster giganteus,* and *Pycnopodia helianthoides*.

Topography and environmental variables

Tidal elevations (relative to Mean Lower Low Water (MLLW)) of each point in the grid are measured using standard surveying equipment (a rotating laser leveler mounted on a tripod and a stadia rod). Elevation measurements are recorded along each transect wherever there is a change in topography. Thus, measurements are taken infrequently (every few meters) for gradual slopes, but more frequently (tens of centimeters) when necessary to capture the presence of smaller ridges and pools. These measurements are referenced to tidal elevations (meters above MLLW) by recording reference measurements of sea level at the time of low tide. The tidal elevation data within the grid are later spatially interpolated to create a three-dimensional topographic map of each site.

In addition to information on environmental variables collected by sampling teams, we will install tidbit thermistors (Onset Corp.) at all new sites to record local seawater temperatures. These will compliment the array of thermistors present at existing sites.

Analyses

While there will be a set of analyses that synthesize the program data sets (across all groups), we will also conduct analyses specific to the rocky intertidal ecosystem. Univariate and multivariate statistical analyses including geospatial modeling will be conducted to compare species abundances, patterns of diversity and community structure among MPAs and reference sites across the Study Region. In addition we will incorporate datasets from the rest of the state and west-coast (our surveys extend into Alaska) to obtain a broader spatial understanding of the NCCSR ecosystems and the performance of MPAs within the NCCSR. These analyses will be extended to explore species and species complexes as indicators of the state of separate and combined components of the ecosystems. As part of our overall collaboration (and the associated administrative component) data and associated metadata catalogues will be incorporated into databases (with associated metadata catalogues) with similar structure to those generated for the CCSR unless redesigned to conform to databases used across the various survey programs that constitute this and other proposals for the NCCSR. The third and final year of the project will not include field work and will focus on analyses and the generation of summary reports and outreach material.

This study will address the State's need to establish baseline information at MPA and reference sites in Central California. Analysis of more than 15 years of data at numerous locations along the Central California shoreline is now possible and can be brought to bear in determining baseline conditions and importantly, baseline dynamics (Raimondi et al, 2003). In many of our sites, which have been sampled for 15 years we are starting to see a decadal signal, where communities are returning to states that were characteristic of starting conditions (Miner et al 2005). The ongoing monitoring will be augmented by the establishment of new monitoring sites in areas where there are no ongoing efforts. The combined monitoring program will then provide baseline information for biodiversity and species of interest for all MPA areas and relevant reference areas for the entire central coast of California (as defined in the MPA documents and program objectives). Importantly, the data collected will be completely compatible with the two major intertidal monitoring programs along the west coast, MARINe and PISCO's Coastal Biodiversity Surveys. Hence the data collection and data products will be actively supported by local, state and federal agencies as well as academic institutions. This will ensure broad scale interpretation and utility as the MPA process expands both north and south in the State. Equally important is that the methodologies have all been tested and found to be powerful for the estimation of impacts (changes) and description of biodiversity (Blanchette et al, submitted, Minchinton and Raimondi 2004).

Outcomes and Deliverables(see milestone chart: figure 2 in this appendix)

In addition to the deliverables specific to this proposal (rocky intertidal), which include a complete characterization of the rocky intertidal resources of the central coast along with an initial assessment of the MPA network we will be focused on our collaboration with the other survey programs identified in this collaborative proposal. Collaborations will consist of sampling designs, analyses and logistics to maximize comprehensiveness and cost-effectiveness (e.g.,data, administration, logistics: species and geographic complementarity) of the combined survey programs. As we have for the CCSR, we work with partner to develop printed material summarizing the baseline surveys, and we will develop pages on the PISCO web site (http://www.piscoweb.org/topics/marine-protected-areas) that describe the surveys, their results and their role in informing decision makers.

Figure 1: "Reserves in reverse" Sea Lion Cove was opened to abalone extraction in 2004 after decades of protection (private property). Our monitoring detected a huge shift in size structure after 2 years characteristic of extraction. After 4 years we found a pronounced change in other components of the community that had responded to the loss of abalone. These results suggest that response to renewed protection at Sea Lion Cove and other intertidal areas may be rapid and across many species.

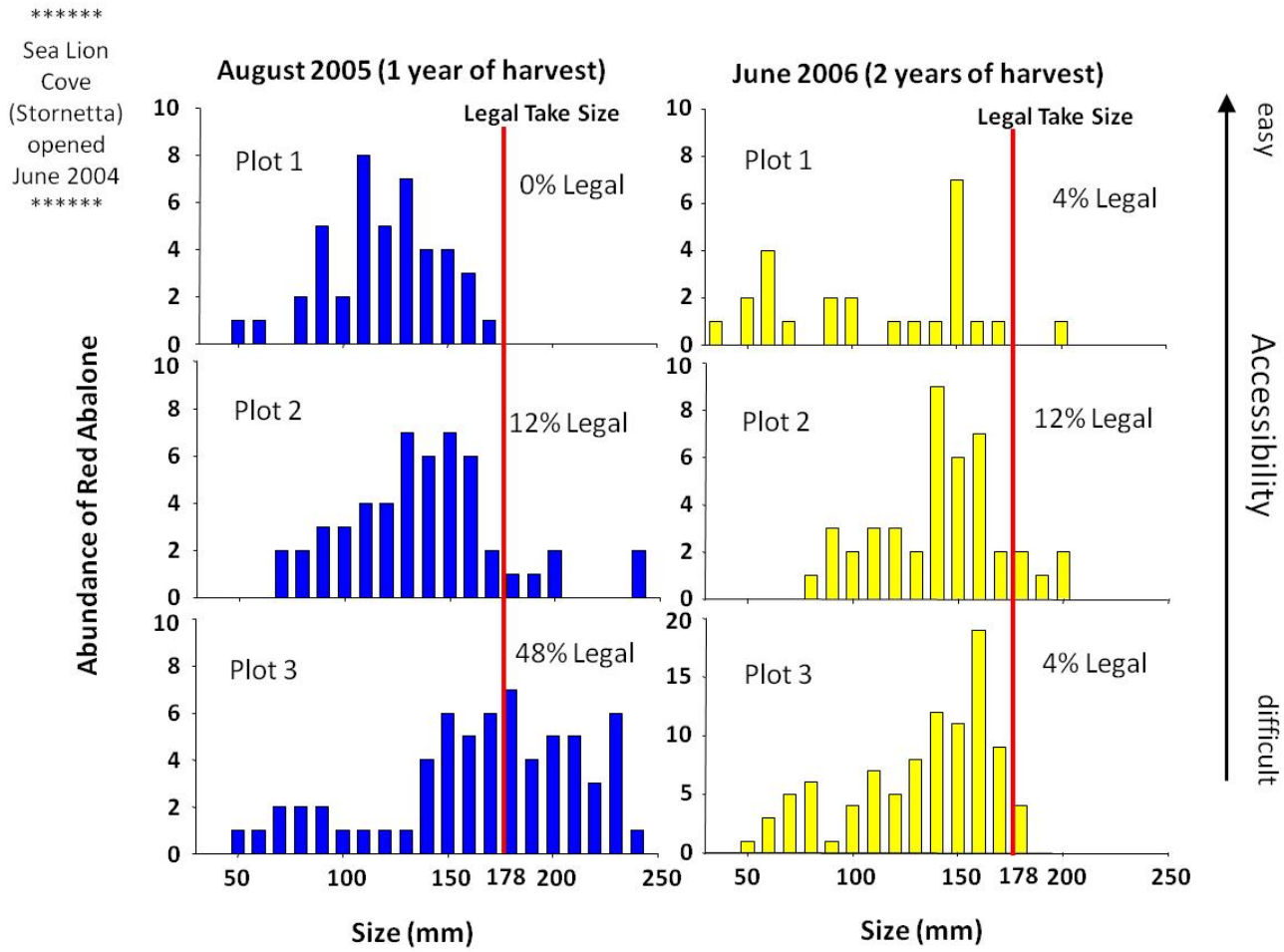

Figure 2: Milestones Chart

	2010												2011												2012											
TASKS AND MILESTONES	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Training and Preparation	X					X							X					X																		
Field surveys		X	X	X			X	X	X	X				X	X	X			X	X	X	X														
Demobilization and data entry					X						X						X						X													
Data management					X	X					X	X					X	X					X	X												
Analyses																										X	X									
Syntheses / Ecological Indicators																												X								
Monitoring recommendations																													X							
Report writing											X												X						X							