Carr (UCSC): Baseline Monitoring of Ecosystem and Socioeconomic Indicators for MPAs along the North Central Coast of California: UCSC Kelp Forest Ecosystem Surveys

Project Goals and Objectives – The objective of the proposed surveys and analyses are to (1) produce a quantitative baseline characterization of the structure of kelp forest ecosystems in five of the marine protected areas (MPAs) recently established by the MLPA Initiative in the NCCSR, (2) provide a quantitative comparison between the kelp forest 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 kelp forest ecosystems (i.e. ecosystem indicators), and (4) integrate these assessments with other components of the baseline survey (e.g., rocky intertidal, ReefCheck, CDFG, collaborative fishing) to inform the role and design of those programs for a future monitoring and evaluation program.

Methodology – Our approach to conducting baseline characterizations involves a geographic extension of comparable design and sampling protocols that we have conducted to generate baseline characterizations of kelp forest ecosystems in the Central Coast Study Region (CCSR) and the network of marine reserves in the Northern Channel Islands (NCI). 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. Kelp forests will be surveyed for two consecutive years (2010 and 2011) in five MPAs including Salt Point SMP, Stewart's Point SMR, Del Mar Landing SMR, Saunders Reef SMCA and Point Arena SMR. Scuba diver surveys are conducted to estimate the density (individuals per unit area) and size distribution of conspicuous species of fish, the density of kelps and large benthic invertebrates, and the percent cover of other invertebrates and algae. Percent cover of substratum type (e.g., sand, cobble, bedrock, boulder) and vertical relief are quantified to compare habitats in MPAs and reference areas and to explore species-habitat relationships. Surveys are conducted at randomly selected kelp forests within each of the four MPAs and reference areas. Surveys haphazardly distributed within each of four depth strata from the inshore to offshore edge of the rocky reefs to characterize the entire forests.

Univariate and multivariate statistical analyses will be conducted to compare species abundances, guild abundances (e.g., trophic guilds) and community structure among MPAs and reference sites across the portion of the Study Region that encompasses the five MPAs. These analyses will be extended to explore species and species complexes as indicators of the state of separate and combined components of the ecosystems. 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.

Outcomes and Deliverables - Collaborations will be focused initially on the other survey programs identified in this proposal. Collaborations will consist of sampling designs and logistics to maximize comprehensiveness and cost-effectiveness (e.g., logistics: species and geographic complementarity) of the combined survey programs. As we have for the CCSR, we work with partner organizations (e.g., National marine Sanctuary foundations) 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. We will coordinate closely with ReefCheck and the collaborative fisheries programs to facilitate the development of these programs for future monitoring and evaluation studies.

Project Title: Baseline Monitoring of Ecosystem and Socioeconomic Indicators for MPAs along the North Central Coast of California: UCSC Kelp Forest Ecosystem Surveys

Project Leader(s) and Associated Staff

Dr. Mark H. Carr (PI): As the PI, Dr. Carr will oversee all aspects of the 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.

Mr. Dan Malone (Associate Specialist – Analyst): Mr. Malone will support Dr. Carr in all aspects of the project, with particular focus on design, analyses and report writing.

Dr. Jennifer Caselle (Associate Investigator): Dr. Caselle (UC Santa Barbara) will collaborate with Carr and Malone as she has on past kelp forest monitoring programs (PISCO, CRANE, Central Coast MLPA, Channel Islands MPAs) both for internal consistency with state-wide monitoring designs to date and in the development of ecosystem indicators.

Project Goals and Objectives

The objective of the proposed surveys and analyses are to (1) produce a quantitative baseline characterization of the structure of kelp forest ecosystems in five of the marine protected areas (MPAs) recently established by the MLPA Initiative in the NCCSR, (2) provide a quantitative comparison between the kelp forest 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 kelp forest ecosystems (i.e. ecosystem indicators), and (4) integrate these assessments with other components of the baseline survey (e.g., rocky intertidal, ReefCheck, CDFG, collaborative fishing) to inform the role and design of those programs for a future monitoring and evaluation program.

Rationale

Kelp forests are iconic ecosystem features along the coast of California with services that span commercial and recreational consumptive uses and a diversity of non-consumptive services (e.g., sea life viewing, diminishing coastal erosion). They support commercial and recreational fisheries that target a diversity of fishes (e.g., rockfishes, greenlings, cabezon) and shellfishes (e.g., abalone, sea urchins). How these ecosystems respond to the establishment of MPAs, relative to kelp forests outside MPAs, is critical to understanding how MPAs contribute to the protection of kelp forest biodiversity, structure, functions and the services they create.

Approach to be Used (Plan of Work)

Overview: Our approach to creating a baseline characterization of kelp forest ecosystems in the MLPA North Central Coast Study Region (NCCSR) involves surveys of targeted elements of kelp forest ecosystems using SCUBA: fishes, invertebrates, algae and habitat features. We propose to conduct surveys to characterize the relative abundance of these key species because existing data are very limited geographically and taxonomically for this region. Previous ecological surveys in this region have focused on subsets of the biological communities – fishes (Hobson et al. 2000, Laidig et al 2007) or abalone and sea urchins (Rogers-Benett 2007) – and have been restricted to a few sites, many of which are not located at or near the recently established MPAs. Similarly, the recent community-wide surveys conducted by ReefCheck are of limited geographic distribution.

Our proposed sampling design and protocols are a geographic extension of comparable design and protocols that we have used to generate baseline characterizations of kelp forest ecosystems in the Central Coast Study Region (CCSR) and the network of marine reserves in the Northern Channel Islands (NCI). We propose to maintain similarities in the design and protocols to maintain standardization across the Study Regions until necessary changes in design or sampling protocols are identified.

Spatial and temporal sampling design: Central to our overall sampling design is the underlying analytical model that defines all aspects of both the spatial and temporal components of the sampling approach. The sampling design involves a tradeoff in sample allocation between temporal and spatial samples. We believe, especially for a baseline characterization, that spatial coverage is far more informative in describing the distribution of key attributes of the ecosystem. While each location will be sampled once in each year, surveys will be conducted over the course of a two-month sampling period and therefore incorporate some degree of temporal variability. Individual MPAs and their associated reference sites will be sampled as closely as possible in time in order to avoid confounding these direct comparisons with temporal effects.

Large scale spatial sampling design - Our spatial sampling design is characterized as a *stratified random permanent* sampling design, in which randomly located transects are sampled within fixed sites ("cells") permanently located inside and outside of MPAs. These random transects are stratified within each site across fixed depth zones. We propose to sample five MPAs that include kelp forests (Salt Point SMP, Stewart's Point SMR, Del Mar Landing SMR, Saunders Reef SMCA and Point Arena SMR) and nearby forested reference[1] sites (Figure 2). We are not proposing to survey MPAs south of Salt Point because they support sparse kelp forests and because of their proximity to marine mammal rookeries and the higher occurrence of sharks. Three criteria are used in the selection of potential reference sites; (1) habitat characteristics at these sites is as comparable as possible to sites sampled within MPAs, including reef geomorphology (substratum type and relief and reef slope) and oceanic conditions (exposure to swell, upwelling conditions), (2) they are as close as possible to nearby MPAs, but outside of a 0.5 km buffer zone prevent the potential effects of regulatory treatments within the MPA from influencing density estimates at a nearby reference site (i.e., "spillover effects"), (3) the fundamental sampling unit ("cells") are distributed randomly among possible sample cells met by criteria 1 and 2.

We will use existing GIS layers of kelp canopy distribution (generated from CDFG aerial digital images of historic kelp canopy cover) to identify the distribution of kelp forests within each of the MPAs and corresponding reference areas that we propose to sample. Kelp forests identified by these images within and outside MPAs will be divided into sampling "cells" that extend 200 m along shore (i.e. along the outer edge of the kelp forest) and from the outer edge of the forest (not to exceed 20 m depth) inshore to a depth of 5 m (Figure 3 illustrates an example grid from the Central Coast Study Region). To reduce the likelihood of "edge effects" (i.e., "inside" samples collected near the boundary of an MPA being influenced by fishing effects in areas adjacent to the MPA), potential sampling cells will not lie within 100 m of an MPA boundary. To assure that selected cells are representative of the entire length of the MPA, the pool of potential sampling cells is divided into four equal sections along the length of the MPA. Within each of these four sections, a sampling cell will be selected randomly.

Within-cell spatial sampling design – Within each spatial "cell", all sampling of fishes, invertebrates and macroalgae is conducted along 30 m transects. Because the distribution and abundance of fish, invertebrate and algae species are known to vary with depth and the cross-shore location within the forest (i.e. offshore to onshore) , it is necessary to assure that samples

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[1] We use the term "reference sites" to refer to sites outside of NCCSR MPAs, used for comparison with MPAs.

are stratified across these gradients. This is achieved by distributing an equal number of transects (n= 3) for fish sampling at each of four depth strata (20 m, 15 m, 10 m, and 5 m depth) and for benthic invertebrates and algae (n= 2) at each of three depth strata (20 m, 12.5 m and 5 m depth) for forests that span these depth ranges (Figure 3). For forests that do not span these depths, the cross-shore distance is divided into four equal strata and fish transects are distributed equally among the strata. Thus, a total of twelve and six transects are sampled in each cell for fish and benthic organisms, respectively. Illustrations and further descriptions of these spatial sampling designs are available at: http://www.piscoweb.org/research/community/subtidal/protocols. Because fishes are also distributed throughout the water column (i.e. surface to bottom), each transect is sampled at two depth intervals: the bottom 2 m of the water column and at mid-depth between the surface and bottom. Although recorded and entered into the database separately, counts of fishes in these two portions of the water column are combined for each 30 m transect for analysis. A pair of divers samples each transect simultaneously, one on the bottom and one at mid-depth.

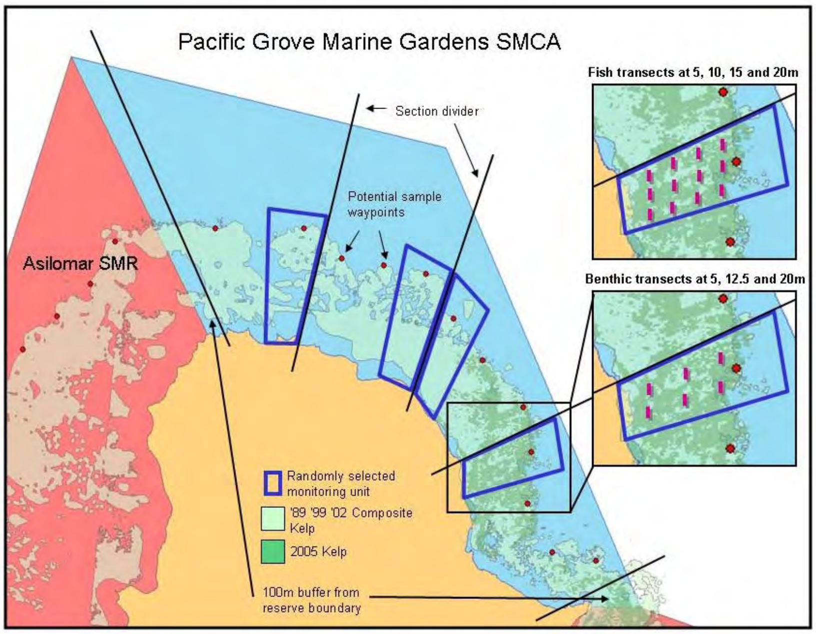

Figure 3. Schematic of the spatial array of samples in an MPA

Temporal sampling design – Kelp forests will be surveyed for two consecutive years (2010 and 2011). Within each randomly selected sampling cell, the stratified randomly located transect samples produce an estimate of the mean of the response variable (e.g., density of species X) at each sampling event and, over time, estimates the temporal trajectory of the mean of that response variable within each of the four sample cells in an MPA. Having initially selected each of the four sample cells randomly, we envision the four sample cells as permanent sample sites that would be repeatedly sampled over time. This random, permanent sampling design minimizes spatial variability as a source of variation in samples over time, yet generates independent estimates of the state of the response variables at each cell in each consecutive time interval (De Gruijter and Ter Braak 1990, van der Meer 1997). This sampling design produces an estimate of the mean temporal trajectory of cell means (of a response variable) within an MPA or reference area. Each of the stratified, randomly selected sample cells are sampled once (and could be sampled once each year in subsequent monitoring programs). The mean trajectory of response variables estimated from the four sample cells are assumed to be representative of all cells in the MPA because they were initially randomly selected. These trajectories can be compared directly or a change in the difference between treatment levels over time can be tested for. This analytical model is more clearly explained by example in the **Analyses** section below. Surveys are restricted to days that have not experienced recent (within 1-2 days) large swell events and with underwater horizontal visibility of no less than 3 m.

Sampling protocols:

Data collection -- All of the data used to estimate ecological elements (response variables) are collected visually by teams of SCUBA divers that access sample sites from vessels. The depth range of sampling (20 m depth), necessitates that divers use (and are trained to use) mixed gases (Nitrox). In general, fish surveys and benthic invertebrate and macroalgae surveys are conducted concurrently by different pairs of divers. Survey teams consist of a vessel driver, one pair of divers that sample fish and another pair that samples benthic invertebrates and algae (5 people total). Because of the geographic range of the study region and the time constraints imposed by seasonal variability (and access) among sample sites, we plan to deploy simultaneously two dive teams at two nearby sampling cells. With this approach, we predict that the field season required to complete the sampling will encompass 2 months (August, September). SCUBA surveys will be conducted using a chartered vessel based in Bodega Harbor when possible, and when necessary, particularly for sites at the northern end of the Study Region, surveys will be accomplished using UCSC's smaller 14 ft inflatables due to the limited availability of boat ramps in the area. Teams of divers will be housed during the two month field season at Bodega Marine Lab. Prior to each sample season, all divers participating in surveys are required to participate in a 2-week training program. Details on the scope of the training program are available at:
http://www.piscoweb.org/research/community/subtidal/protocols

Ecosystem elements (response variables) -- Elements of kelp forest ecosystems that will be targeted for sampling include (1) those species identified by the Monitoring Enterprise (ME) as potential kelp forest ecosystem focal species/indicators, (2) species that were identified as "likely to benefit" in the NCCSR MPA design process (these are primarily fished species), and (3) any other species and environmental variables that have been identified in the literature as indicators of ecosystem structure (e.g., collective abundances of grazers, planktivores, detritivores, primary and secondary carnivores) and functional processes (e.g, algal abundance as a reflection of primary production, drift kelp cover that fuels a key detritivore trophic pathway). Diver surveys estimate the density (individuals per unit area) and size distribution of all conspicuous species of fishes. Fish counts in 2m wide X 2m tall X 30m long transects along the bottom and mid-water are combined to generate density estimates per 240m^3 volumes. Counts of large benthic invertebrates and kelps generate density estimates per 60m^2 of reef area. Proportional cover of species for which individuals are not readily distinguishable (e.g., colonial invertebrate species, small macroalgae) is estimated by point contact estimates distributed along the length of each 30m-long transect (30 points per 30 m transect).

In conjunction with additional information (e.g., published size-fecundity relationships, habitat maps), these species-level metrics are then used to generate additional population metrics (e.g., size/age structure, larval production) and community-level metrics (e.g., species composition, relative abundance and richness, trophic guild abundance and biomass) and ecosystem-wide variables (abundance and spatial configuration of habitat-forming organisms, such as bull kelp and other algae).

Taxonomic resolution (i.e. species, genus, family, and higher) at which data are collected varies among taxa. For example, the red algae are difficult to identify and are therefore categorized into six morphological categories encrusting red, turf and four categories of foliose species (bushy, branching, leafy, lacy).

Abalone and sea urchin size frequency distributions – Size frequency distributions of red and purple sea urchins and red abalone will be sampled by an additional diver who will use the protocols identical to those used by the ReefCheck program. Size distributions will be sampled at a minimum of two cells within and two reference sites from each MPA. This sampling will be coordinated with and complemented by additional sampling of these species by the other two SCUBA programs (CDFG Abalone and Sea Urchins, ReefCheck).

Physical environmental variables -- Key environmental factors known to influence the distribution and abundance of fishes, invertebrates and macroalgae include geomorphological features of the rocky reef habitat and qualities of the seawater overlying the rocky reefs. Divers record percent cover of substratum type (sand, cobble, bedrock, boulder) and vertical relief in 4 categories (0 – 10 cm, 11 cm – 1m, 1 – 2 m, and > 2) along each benthic transect using the same unifom point contact method used to estimate cover of invertebrates and algae. These data allow quantitative comparison of habitats in MPAs to reference areas as well as examination species-habitat relationships. Larger scale features (e.g., rock type, reef slope, exposure to oceanic swells) are gleaned from geologic and bathymetric charts and models we have derived (based on regional swell buoys and CDIP models). Water temperature is one of the most important measures of the ocean environment that corresponds with a variety of ecological processes. For example, water temperature can reflect upwelling and relaxation events that in turn influence local delivery of larvae, planktonic prey and nutrients. We propose to deploy two submersible thermistors at one cell in each of the MPA and reference monitoring sites (one pair per MPA) in order to better track variation (spatially among MPAs and references sites, and temporal among years) in the ocean climate and use this to interpret differences in trends in ecological variables among monitoring sites and years.

Analyses and Data Management: Univariate and multivariate statistical analyses will be conducted to compare species abundances, guild abundances (e.g., trophic guilds) and community structure among MPAs and reference sites across the portion of the Study Region that encompasses the five MPAs. Estimates of the density of fish, invertebrate of algae species at an individual cell, an MPA, across an entire regulatory level (e.g., SMR, SMCA), or inside and outside of all MPAs within the network can be used to generate a multivariate description of species assemblages at each of these spatial scales. The same can be done for functional groups (e.g., detritivores, planktivores, primary producers) for description of the initial states of these community attributes among regulatory treatments and comparisons of how they change relative to one another over time. These analyses will be extended to explore how individual species or species complexes may function as indicators of composition, stability and functional processes within kelp forest ecosystems. The strength of potential system indicators (univariate or multivariate) will be explored by testing their correlation with various attributes of the system (e.g., the density of bull kelp vs. species diversity of detritivores). **Databases** (including meta-data catalogues) will be developed in accordance with the structure of the database developed for the integrated baseline study and will likely draw from previous structures we developed for the CCSR baseline surveys.

Outcomes and Deliverables

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. Databases and the results of analyses for baseline characterization and indicators will be incorporated into the final report. Collaborations will be focused initially on the other survey programs identified in this proposal (SCUBA, collaborative fishing, submersible and socioeconomic surveys). These collaborations will involve coordinating sampling designs and logistics to maximize comprehensiveness and cost-effectiveness (e.g., allocating sampling effort to achieve species and geographic complementarity) of the combined survey programs. As we have for the CCSR, we work with partner organizations (e.g., National Marine Sanctuary foundations) 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. We will coordinate closely with ReefCheck and the collaborative fisheries programs to facilitate the development of these programs for future monitoring and evaluation studies.

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																	
Field surveys								X	X											X	X															
Demobilization and data entry										X												X														
Data management											X												X													
Analyses																										X	X									
Syntheses / Ecological Indicators																												X								
Monitoring recommendations																													X							
Report writing											X												X							X						

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