REVISED WORK PLAN

Title
California spiny lobsters and South Coast MPAs: a partnership to quantify baseline levels of abundance, size structure, habitat use, and movement

Project leaders
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Project goals and objectives

The broad goal of our research partnership is to generate information on *baseline levels and short-term changes* in the abundance, size distribution, behavior, and consumptive use of a key South Coast fishery species inside and outside of existing and newly implemented MPAs along the San Diego and Orange County coastlines. Specifically, we will work within and outside of six South Coast MPAs to:

1. Map benthic substrata in order to link lobster abundance to benthic habitat composition and distribution across a range of spatial scales;
2. Establish baseline estimates of lobster density and shelter use through SCUBA-based surveys;
3. Implement a tag-recapture program to estimate spiny lobster abundance, size-frequency distribution, growth, spillover, and mortality;
4. Determine how CPUE and the amount and distribution of lobster fishing effort changes after MPA establishment.

We also will implement a fifth objective which will be to:

5. Establish a public outreach system to provide information on the purpose of our work with Monitoring Enterprise and the progress made toward project goals.

Plan of work

MPAs to be included

Our proposed work will take place within and outside of six MPAs within the South Coast region (Table 1, Figure 1).

Table 1. The six South Coast MPAs (in order from north to south) in which lobster monitoring will take place. The specific activities to be conducted within each MPA are listed.

MPA	Location	Objectives addressed
Point Vicente SMCA	Palos Verdes, CA	2, 3, 4
Laguna Beach SMR	Laguna Beach, CA	2, 3, 4
Swami's SMCA	Encinitas, CA	2, 3, 4
Matlahuayl SMR	La Jolla, CA	2, 4
South La Jolla SMR	La Jolla, CA	1, 2, 3, 4
Cabrillo SMR	Point Loma, CA	1, 2, 3, 4

- *Objective 1: Map benthic substrata in order to link lobster abundance to benthic habitat composition and distribution across a range of spatial scales*

For objective 1, in years 1 and 2 we will map benthic habitat within and outside of three MPAs along the San Diego County coastline. These data will be used to stratify SCUBA surveys (objective 2) and tag-recapture surveys (objective 3), and to objectively characterize how lobster distribution and abundance is linked to benthic habitat. Mapping will consist of boat-based sonar surveys and diver-based rugosity surveys. For boat-based surveys we will use a narrow beam (2 degree) 200kHz sonar coupled to an RTK differential GPS and an accelerometer/magnetometer sensor that senses heave, roll, and pitch. The system, owned by Parnell, is mounted on an 8 m vessel equipped with kelp cutting blades that enable sounding even through heavy kelp canopy. Mapping with this system is not subject to interference by giant kelp canopies that preclude large coverage of sidescan and multibeam transects. As part of Parnell's ongoing CASG sea urchin project (R/Fish – 209), mapping of benthic habitats at ten-meter horizontal scales is nearly complete for Pt. Loma using this system. This large-scale mapping effort has revealed a mosaic of complex habitat types at length scales ranging from dozens of meters to over a kilometer (Figure 2). Many represent potential movements corridors for lobsters (and sea urchins) both across and along the shelf.

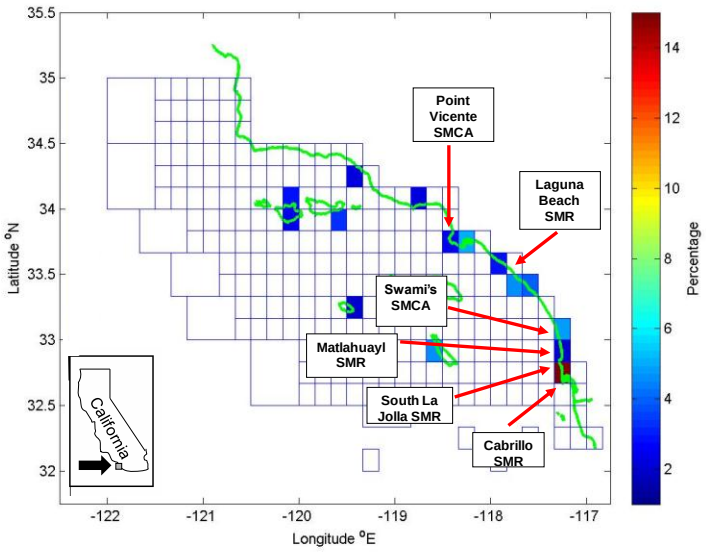

Figure 1. Location of the six MPAs to be monitored in the proposed research and statewide proportional lobster landings from adjacent 10 x 10 mile CDFG blocks. Note the high percentage of lobsters extracted from the block that includes La Jolla and Point Loma.

Our diver-based surveys will focus on a few areas identified in previous work (e.g. Parnell et al. 2006, Withy-Allen 2010) as being important habitats (i.e., combinations of rugosity, substrate type and depth variability). Our goal here is to map and parameterize discrete habitat types at higher resolution than can be achieved from the surface. Divers will swim transects and use an RDI Cobra-Tac Diver Navigation and Mapping System (owned by Parnell) to acquire high resolution, fine scale bathymetry at scales of ~100m at selected sites within and outside of MPAs in Point Loma and La Jolla. We will back-up digital data collection with randomized analog measures of rugosity using the chain method.

Data analysis. Habitat mapping data will be used to identify the most important diel lobster habitat scales to support stratification of abundance estimation based on transect sampling methodology (objective 2) and trap-based tag-recapture (objective 3). We will follow the protocols of Parnell et al. (2005, 2007, 2010), to select survey locations by reviewing habitat distribution from benthic maps, selecting a subset of habitat types to target, and stratifying sampling areas based on results from spatial decorrelation analysis (used to determine the

scale at which major habitat characterizing landscap e features are spatially unrelated; Parnell et al. 2005). Such stratification is vital to support the estimation of lobster abundance which can then be related to patterns of habitat use over time scales of days to seasons, and can be used to direct long-term monitoring for comparisons of baseline data on density and habitat association.

Deliverables. A GIS will be used to produce visualizations of bottom habitat which will be combined with data from objective 2 to result in data layers for habitat, lobster density, and predicted lobster abundance based on correlations between lobster density and habitat type.

- *Objective 2: Establish baseline estimates of lobster density through SCUBA-based surveys*

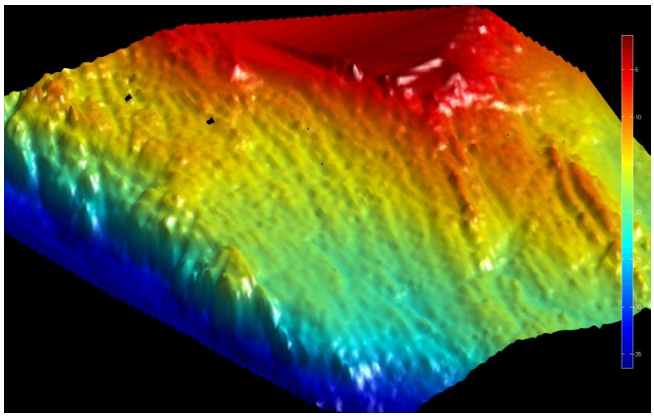

Figure 2. Preliminary visualization of the high resolution digital elevation model off South Pt. Loma. Data were gathered as part of an ongoing Sea Grant funded sea urchin collaborative fisheries research project. Ridge system is composed of uplifted and tilted Cretaceous sedimentary layers that structure the habitat influencing patterns of kelp distribution, foraging, migration, recruitment, etc. Depth units are meters.

In the summers of 2012, and 2013 we will conduct daytime transect surveys within and outside of each of all six MPAs to quantify lobster density and lobster shelter use. Initial dive surveys will be conducted in late summer and fall of 2011 in a subset of MPAs to help ground truth selection of specific sites based on bottom habitat information. Surveys will be conducted by divers swimming belt transects inside MPAs and outside MPAs at each site, with the final number and location of transects determined after review of benthic habitat maps and decorrelation analysis (but no less than n = 12 transects inside and outside of each MPA per year). Surveys outside of MPAs will take place at nearby reference sites that are no closer than 300 m away from the border of the MPA. Sampling for gregarious, patchily distributed spiny lobsters typically requires larger transects or sampling areas than often are used for smaller, less mobile invertebrates; therefore belt transects will be 8 m wide x 30 m long (MacDiarmid 1991, Kelly et al. 2000, Mai and Hovel 2007) and will be sampled by two divers each sampling over 4 m widths. The total number of lobsters contacted in transects will be counted. We also will count the number of purple urchins and red urchins encountered on the transects, and subsample transects for algal habitat cover. As the size of shelters used by lobsters and the number of lobsters per shelter may differ between MPA and non-MPA locations due to differences in predator abundance or habitat composition (Loflen and Hovel 2010), the type and dimensions of each shelter encountered will be quantified, as will the number of lobsters within each shelter. Assessing shelters for lobsters adds relatively little effort to surveys but will enable comparisons of shelter selection and potential shelter saturation between baseline surveys and surveys conducted after MPAs have been established and lobster density and size distribution may have changed (over both the short-term and long-term). Following Mai and Hovel (2007), shelter types in the kelp forest are categorized as (i) ledge shelters (cracks in the

substratum forming permanent crevices or overhangs), (ii) rock shelters (spaces between rocks or between rocks and the substratum), or (iii) holdfast shelters (large giant kelp holdfasts hollowed out by herbivores). Shelter dimensions are quantified by taking three haphazard measurements of shelter height, width, and depth with a meterstick, which when multiplied yield an estimate of shelter volume.

Data analysis. To link lobster density to habitat composition we will use the statistical model-building procedures that Parnell has developed to generate extensive fine scale habitat associations of all non-cryptic species across all the kelp forests off San Diego (these existing data will be integrated into our present analyses). Utilizing a general additive model (GAM) framework applied in stepwise multiple logistic regression fashion, we will build statistical models of lobster habitat utilization based on the larger scale acoustic mapping data for Pt. Loma and La Jolla. The result is a map of expected relative (relative to habitat composition) species distribution given acoustically based estimates of spatial modes representing characteristic length scales of rugosity and habitat variability.

We also will conduct analyses to determine if baseline estimates of lobster density and shelter use differ between MPA and non-MPA locations over the course of our project. Comparisons will be enhanced by incorporating existing data on abundance and shelter use from previous Sea Grant funded projects by Hovel's group at SDSU. Specifically, we will integrate abundance and shelter use data from the Pt. Loma kelp forest (collected in 2005, 2006, and 2009), and abundance and shelter use data from the La Jolla Ecological Reserve (collected in 2007 and 2009) into our data set to provide additional baseline information on lobster abundance and sheltering behavior before MPA network establishment. We will use a blocked analysis of variance (ANOVA) to test whether lobster density differs between MPA vs. non-MPA locations and among sites (blocks). Following analyses in Loflen and Hovel (2010), who found that solitary lobsters within an MPA used shelters more closely scaled to body size (presumably due to greater predatory threats within MPAs), we also will regress lobster carapace length (CL) on shelter height on for all solitary lobsters found within MPAs and compare the slope of the best-fit line to that of the best-fit line for solitary lobsters outside of MPAs using a *t*-test (Zar 1999). Additionally, as the formation of large aggregations also may protect lobsters from predators, we will use a Komolgorov-Smirnov test to determine whether the frequency distribution of lobster aggregation size differs between MPA and non-MPA locations (Loflen and Hovel 2010). Data on potential lobster predator (= large fishes) abundance from the companion project will aid in determining if any differences in shelter use behavior derive from perceived predatory threats vs. differences in substratum composition.

Deliverables. We will provide Monitoring Enterprise with our raw lobster survey data in spreadsheet form at the end of the 2012 and 2013 field seasons. We also will provide synthesis of the data in the form of graphs and tables portraying summaries of lobster density, behavior, and habitat use as determined visually and from benthic habitat mapping from objective 1. This will include GIS files as described under objective 1.

- *Objective 3: Implement a tag-recapture program to estimate spiny lobster abundance, size-frequency distribution, growth, spillover, and mortality*

Whereas sampling for objective 2 will yield information on spiny lobster density and shelter use, for objective 3 we will implement a tag-recapture program to obtain baseline

estimates for lobster abundance over larger spatial scales, lobster size distribution, movement across MPA boundaries, and lobster mortality rates. To implement this program, lobster fishermen will work with SDOF volunteers, PIs and students to capture and tag lobsters in baited traps inside and outside of five MPAs (see Table 1). In order to sample lobsters of a wide variety of sizes, traps will consist of 1 inch x 1 inch mesh with no escape ports, which have been approved for lobster sampling by the DFG (Hovel and Neilson 2011). For each daily trap haul, the size (carapace length), sex, reproductive condition (for females: no spermatophore, spermatophore present, or berried) and shell condition of all lobsters (new hard shell, old hard shell, or soft shell [newly molted]) will be recorded, and lobsters will be marked with individually numbered plastic t-bar tags inserted in the dorsal musculature, and then released (Goforth and U'Ren 1980, Goni et al. 2006, Hovel and Neilson 2011; Figure 3). The GPS position of all tagged lobsters will be noted upon release. For recaptured tagged lobsters we will note tag number and determine distance from last capture a nd whether lobsters crossed MPA borders.

Figure 3. A California spiny lobster tagged with a plastic, individually numbered t-bar tag. This lobster was tagged as part of a study on lobster abundance in San Diego Bay by Hovel and Neilson, 2009 – 2010.

We will begin the program in late summer 2011 by trapping and tagging in three MPAs (Cabrillo, South La Jolla, and Laguna Beach). This initial trapping and tagging will occur only within sites designated to become MPAs (i.e. not in adjacent reference sites) and will be performed to get a moderate number of lobsters tagged early on in the monitoring program (no less than 2000 per MPA). This allows us to test our technique, get initial estimates of trap efficiency and the number of days needed per site, and obtain longer-term estimates of lobster growth. Next, we will trap and tag for no less than a 4 month period beginning in April 2012 and continuing until shortly before lobster fishing season opens in early October. Following the recommendation of Dunnington et al. (2005), who used tag-recapture to estimate American lobster population size within heavily fished areas of the Gulf of Maine, at each site our trapping will consist of 4 discrete "sessions", one per month, with two consecutive trap hauls per 48 hr session. At each location, 12 baited traps will be set inside and outside of MPAs. Benthic habitat maps and habitat stratification generated from mapping (see objective 1) will be used to identify discrete areas for trap deployment for each MPA, in which traps will be set randomly. The same procedure will be applied to areas adjacent to MPAs, except that we will ensure to vary distance to the MPA border to quantify how spillover, catch, and mean lobster carapace length vary with distance from the MPA. We plan to repeat thisn program in 2013, but the protocol for 2013 trapping and tagging will be adjusted after an evaluation of the number of lobsters tagged and recaptured in 2012.

Data analysis. We will use modified Jolly-Seber methodology as described in Dunnington et al. (2005), as well as a mark-and-recapture parameter estimation software platform (program MARK v. 6.0, Gary C. White, Colorado State University, Fort Collins, CO) to obtain estimates of population size inside and outside of each MPA. These analyses allow

estimates of movement, immigration and emigration (including spillover from MPAs), as well as mortality. Growth data (change in carapace length in mm) will be obtained for lobsters captured one or more years after tagging. Frequency distributions for carapace length will be generated from each year's data to provide baseline data on lobster size distribution for each location and will provide an additional estimate of total mortality using kernel density estimation and goodness-of-fit tests.

Deliverables. We will provide Monitoring Enterprise with raw data on lobster size, sex, shell condition, capture location, and recapture location after the 2012 fishing season. This will allow us to include recaptures made by commercial fishing operations outside of MPA boundaries. In addition, we will provide a synthesis of the information which will include graphs and tables for: lobster size distribution, sex, and shell condition; estimated lobster population size in each location; and rates of spillover and "spill-in" in each location. The same information will be produced after the 2013 fishing season, but will include estimates of lobster mortality.

- *Objective 4*: *Determine how CPUE and the amount and distribution of lobster fishing effort changes after MPA establishment*

For objective 4 we will rely on data provided by Neilson as well as CLTFA partners and other participants to quantify aspects of consumptive use of lobsters. Neilson will use current and historical data, currently held by the DFG, to quantify the number of people or vessels engaged in lobster fishing, both commercially and recreationally. The datasets include commercial logbooks and landing receipts, and recreational lobster report cards and creel surveys. The level of activity will be determined by fishing location, vessel, port, and county relative to individual trips, weeks, months, seasons and years; related CPUEs will be calculated as well. In addition, the level of recreational activity will be determined by gear (hoopnet and diving types).

Economic value of the commercial fishery will also be calculated from landing receipts and, like the level of activity, the economics will be broken down by fishing location, port, and county, across a spectrum of time scales. A value will be calculated for the recreational fishery by using price per lobster derived from commercial landing receipts, for the same time period as each recreational lobster report card trip.

As part of the proposed study, CLTFA partners and other participants will collect data at a finer resolution than the current DFG 10 x10 minute block. Where needed, this higher resolution data will be used to equate commercial consumptive use to the higher resolution mapping data provided by Parnell. The higher resolution data collected will also be used to evaluate the accuracy of traditional DFG data parsed by nearest landmark and could lead to an historical baseline built on commercial data but at a resolution substantially higher than the present 10 x10 minute blocks. DFG does not currently use the landmark data in its analyses because this evaluation is missing.

Data analysis. We will extract data related to consumptive use from the 38 year commercial lobster logbook, 100 year commercial landings, and 2.5 year recreational lobster report card records. In addition we will have access to the 2007 DFG recreational bight-wide creel survey data. All data will be processed in the same fashion as currently performed by DFG for its normal reporting products. Length/weight conversions will rely on the relationship calculated from the bight-wide 2007 creel survey data. Weight per lobster, in the commercial

catch, will be calculated by equating the number of lobsters recorded on logbook receipts with the pounds recorded on associated landing receipts. The basic unit of effort for commercial data is the number of trap pulls, whereas it is fishing trips for recreational data. Because of this, the effort for the commercial and recreational fisheries cannot be combined into a total effort. Total catch, however, can be calculated by combining the number of individuals, or direct/converted weight, from each fishery.

Deliverables. After the 2011, 2012 and 2013 fishing seasons we will provide Monitoring Enterprise with records of landings, total catch, CPUE, catch per port, catch size frequency, and catch sex ratio. We also will produce syntheses of the information in the form of tables and graphs that portray how catch, fishing statistics, and the distribution of fishing effort change between 2011 and 2013. Note that records of individuals' catch are confidential and are not permitted to be disclosed by the DFG to outside parties; thus all data will be in summary form that does not allow identification of catch rate or catch location for specific individuals.

- *Objective 5*: *Establish a public outreach program to provide information on the purpose of our work with Monitoring Enterprise and the progress made toward project goals*

We will establish an outreach program through the San Diego Oceans Foundation (SDOF) and SDSU. The program will consist of press releases and web pages at each institution that list the basic reasoning for our partnership, the steps taken throughout the project, and summaries of the major results. We also will offer public seminars, organized by the SDOF, in which project PIs will field questions from the public and present information on lobster ecology, lobster fishing, and results of the monitoring. We also will be communicating with the lobster commercial fishing community via the members of the CLTFA who are helping to lead the project.

Deliverables. There are no direct deliverables to Monitoring Enterprise from this component, but we plan to communicate and coordinate with Monitoring Enterprise as we present information to the public.

- *Additional deliverables*

Pursuant to the guidelines set out by Monitoring Enterprise, we also will produce annual progress reports specifying progress towards our objectives and goals and timelines for progress in meeting milestones. Progress reports also will include updates on costs and actual expenditures for the project to date. Our final report will be submitted in 2014 and will include all sections outlined in the RFP.