CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE REPORT ON OFF-YEAR SCIENCE AND STOCK ASSESSMENT METHODOLOGY REVIEW TOPIC SELECTION

Title: Methods for using remotely operated vehicle (ROV) survey data in assessment of nearshore groundfish stocks along the California coast.

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Overview: Nearshore groundfish stock assessments have identified the lack of fishery-independent data sources as a research and data need (Agenda Item E.2, Attachment 1, September 2017). In addition, methods currently utilized in stock assessments do not explicitly account for biomass inside of no-take Marine Protected Areas (MPAs). Remotely operated vehicles (ROVs) provide a non-lethal sampling method in areas where harvest is prohibited. They also allow collection of data on overfished species and nearshore species which constrain take of healthy stocks. Because ROVs employ only non-lethal data collection methods, they avoid need for research set-asides or other allocative considerations that may arise between fisheries and research sectors.

The CDFW in collaboration with Marine Applied Research and Exploration (MARE) conducted ROV surveys to measure differences in density (fish/km^2) and size of fish inside MPAs and at reference locations open to fishing. These data can be applied in stock assessments as indices of relative abundance or expanded using habitat area estimates to provide estimates of biomass.

The California Seafloor Mapping Program (CSMP) is a collaborative effort that has performed high resolution bathymetry mapping allowing the categorization of seafloor for the vast majority of California's State Waters out to three nautical miles encompassing most of the habitat of nearshore groundfish species. In combination, estimates of rocky reef habitat area, density estimates for nearshore groundfish species and average lengths converted to weights can be used to estimate biomass given appropriate distribution and life history characteristics. Analogous methods were used to assess cowcod in the Southern California Bight (Dick and MacCall 2013), lingcod and shelf rockfish stocks in Alaska (NPFMC 2013) and groundfish stocks in Puget Sound (Pacunsky et al. 2016).

The CDFW proposes a methodology review be conducted for the use of the density estimates and expanded estimates of biomass generated using data from this ROV study in nearshore stock assessments.

Outline of Methods

Field Methods: The statewide ROV survey conducted between January 2014 and December 2016, visited 148 sites providing observational data for density estimates from MPAs and associated reference locations (Appendix 1). Survey transect lines within sites were positioned based on the location of rocky habitat and distributed across the entire depth range of rocky reef where possible. At each site, four to ten transect lines started at a random point were surveyed to achieve four kilometers of transects within rocky habitat at each site. The ROV positioning system calculated the longitude, latitude and depth every two seconds allowing observations to be georeferenced. Ranging sonars were used to estimate transect width allowing calculation of the observed swath width along the course of each transect at one second intervals. The ROV was outfitted with stereo cameras and paired lasers allowing estimates of lengths of encountered fish.

Post Processing: Substrate type was categorized by video observers as mud, sand, cobble, boulder, and rock for each one second interval of the video transect allowing post-stratification of transect segments into multiple combinations of bottom type. For analysis of fish density, substrate categories were combined to generate habitat classifications of hard (rock and/or boulder), mixed (sand/mud and rock or boulder) and soft (sand and/or mud). Subunits of 25 m^2 segments of transect with greater than 50% hard or mixed habitat were concatenated into 100 m^2 base sampling units. A spacer subunit was discarded between each transects in the interest of creating independent sampling units to minimize effects of spatial autocorrelation on estimates. Fish species were identified to the lowest possible taxon and only those occurring within the established field of view and at a distance of less than four meters in front of the ROV were included in the counts.

Density Estimates: Density estimates will be stratified regionally, defined by boundaries at Cape Mendocino, Pigeon Point and Point Conception, with the northern Channel Islands evaluated separately from the mainland. Further stratification by MPA vs. reference site and rocky habitat vs. mixed habitat will be evaluated. Estimates of density and variance will be generated using bootstrap analyses of randomly selected segments of transects in each stratum. Coefficients of variation (CVs) will be compared between alternative stratification schemes to best account for sample variability. Tests for significant differences between density estimates from rocky reef and mixed habitat will determine whether stratification between habitat types is necessary. A generalized linear model (GLM) will be used to test for correlation with depth, region, MPA designation and bottom type to identify key predictors to inform development of a relative index of abundance from the density estimates.

As time allows, model based approaches will be explored to provide improved error estimates, and account for key covariates such as depth and better address spatial autocorrelation. Point process models implemented using the igcp and geostatsp packages in R (Chakraborty et al. 2011, Hedley and Buckland 2004) as well as maximum entropy models in the program Maxtent

(Philips and Dudik 2008) relying on presence data will be considered for use in estimation of density and expansion across strata. The results of design and model based estimates will be compared in terms of the resulting CV and other statistical properties.

At the September Council meeting the SSC expressed concerns regarding variable detection probability and the potential implications for density estimates. A preliminary review of considerations relative to the proposed methodology is provided in Appendix 2. Further analysis of the research informing the presence and degree of variable detection probability and the appropriateness of application of ROV based survey methods to nearshore species will be provided for the review.

Expansion of estimates using habitat mapping: Categorization of bottom habitat identifying rocky and mixed habitat are available in the form of GIS layers from the CSMP, allowing estimation of total area under each proposed stratification. The density estimates for each stratum under a given stratification scheme will be multiplied by the respective estimates of habitat area for each species given its depth distribution. The product of the density and area for each stratum will be summed to generate estimates of total biomass for comparison. For model based methods, the expansion will proceed on the basis of covariates and their distribution over the respective area of estimation. The percent total habitat area sampled within the depth range of each species analyzed will then be estimated for each stratum used to generate the total biomass estimate, to provide an indication of the spatial coverage of each contributing stratum.

Use of results in stock assessments: The results can be used in stock assessments as: 1) density estimates as an index of relative abundance methods, 2) estimates of abundance from habitat area expansions as an index of absolute abundance, 3) absolute estimates of abundance used to scale integrated assessments, and 4) independent estimates of absolute abundance multiplied by current F_{MSY} proxies to derive overfishing limits.

Funding, logistics or other factors that would indicate the likelihood of success of the proposed methodology: Continued sampling of MPAs and reference sites is expected as part of a long-term monitoring plan to meet the mandates of the Marine Life Protection Act. However, future sampling intensity, periodicity, and spatial coverage will be dependent on available funding.

References:

Chakraborty A., A.E. Gelfand, A.M. Wilson, A.M. Latimer and J. A. Silander. 2011. Point pattern modelling for degraded presence-only data over large regions. Journal of the Royal Statistical Society. Appl. Statist. 60, Part 5, pp. 757-776.

Dick E.J. and A. MacCall. 2014. Status and Productivity of Cowcod, *Sebastes levis*, in the Southern California Bight. Pacific Fishery Management Council. Portland, OR.

Green K., J. Stahl, and M. Kallenberger 2013. 2013 Demersal shelf rockfish remotely operated vehicle survey. Alaska Department of Fish and Game, Regional Operational Plan ROP.CF.1J.2013.09, Anchorage.

Hedley S.L. and S.T. Buckland. 2004. Spatial models for line transect sampling. Journal of Agricultural, Biological and Environmental Statistics, 9, 181–199.

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Olson A., J. Stahl, K. Van Kirk, M. Jenicke and S. Meyer. 2013. Assessment of the Demersal Shelf Rockfish Stock Complexes in the Southeast Outside District of the Gulf of Alaska. In: Stock assessment and fishery evaluation report for the groundfish resources for the Gulf of Alaska, North Pacific Fishery Management Council, Anchorage, Alaska pp. 555-608.

Pacunski R., D. Lowry, L. Hillier and J. Blaine. 2016. A comparison of groundfish species composition, abundance and density estimates derived from a scientific bottom-trawl and a small remotely-operated vehicle for trawl habitats. Washing Department of Fish and Wildlife Fish Program Science Division FPT 16-03. http://wdfw.wa.gov/publications/01824/wdfw01824.pdf.

Phillips S.J. and M. Dudik. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31: 161 – 175.

Appendices:

Appendix 1. Transect summary and site locations.

Table 1. Summaries from each cruise for number of fish transects, total fish count, and number of observed taxa. *Total number of taxa is a cumulative summary of each taxa observed from all cruises.

	Total no. of survey lines completed	No. of Transect cts 100m (Fish)	Fish counted	No. of Fish Taxa (Approx.)	Fish per km	% of total fish
Cruise A (South Coast)	99	141	18,812	41	300	2
Cruise B (South Coast)	155	384	403,459	51	4,768	51
Cruise C (North Coast)	115	552	34,203	39	472	4
Cruise D (North Central)	146	810	20,717	42	270	3
Cruise E (Central)	183	1,023	320,152	44	1,749	40
Totals:	**698**	**2,910**	**797,343**	**101***		

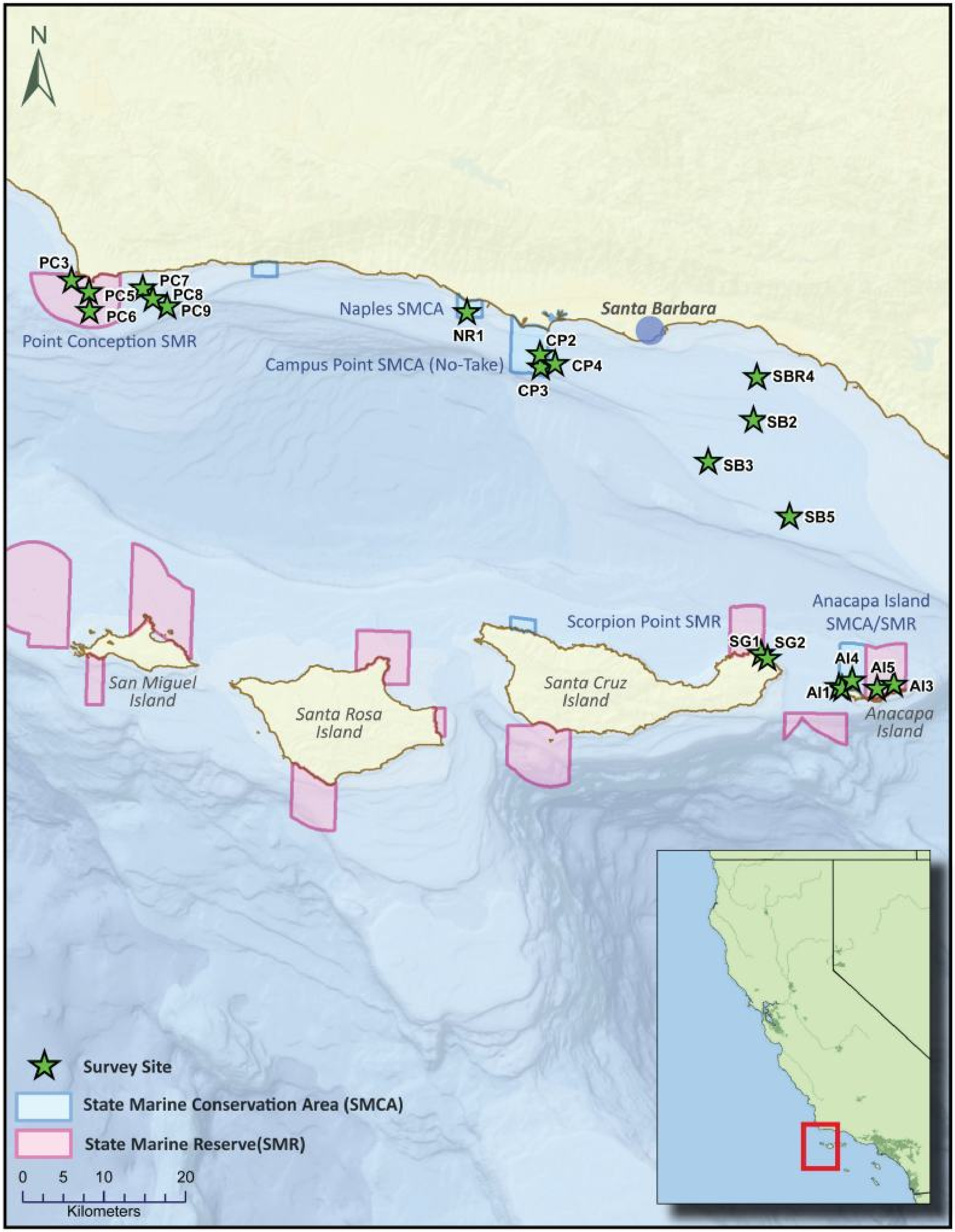

Figure 1. Site locations for CIAP cruise A in southern California, January 2014. Note that ten additional sites were sampled in the vicinity of the Channel Islands by MARE that are not represented here.

Figure 2. Site locations for CIAP cruise B in southern California, July 2014.

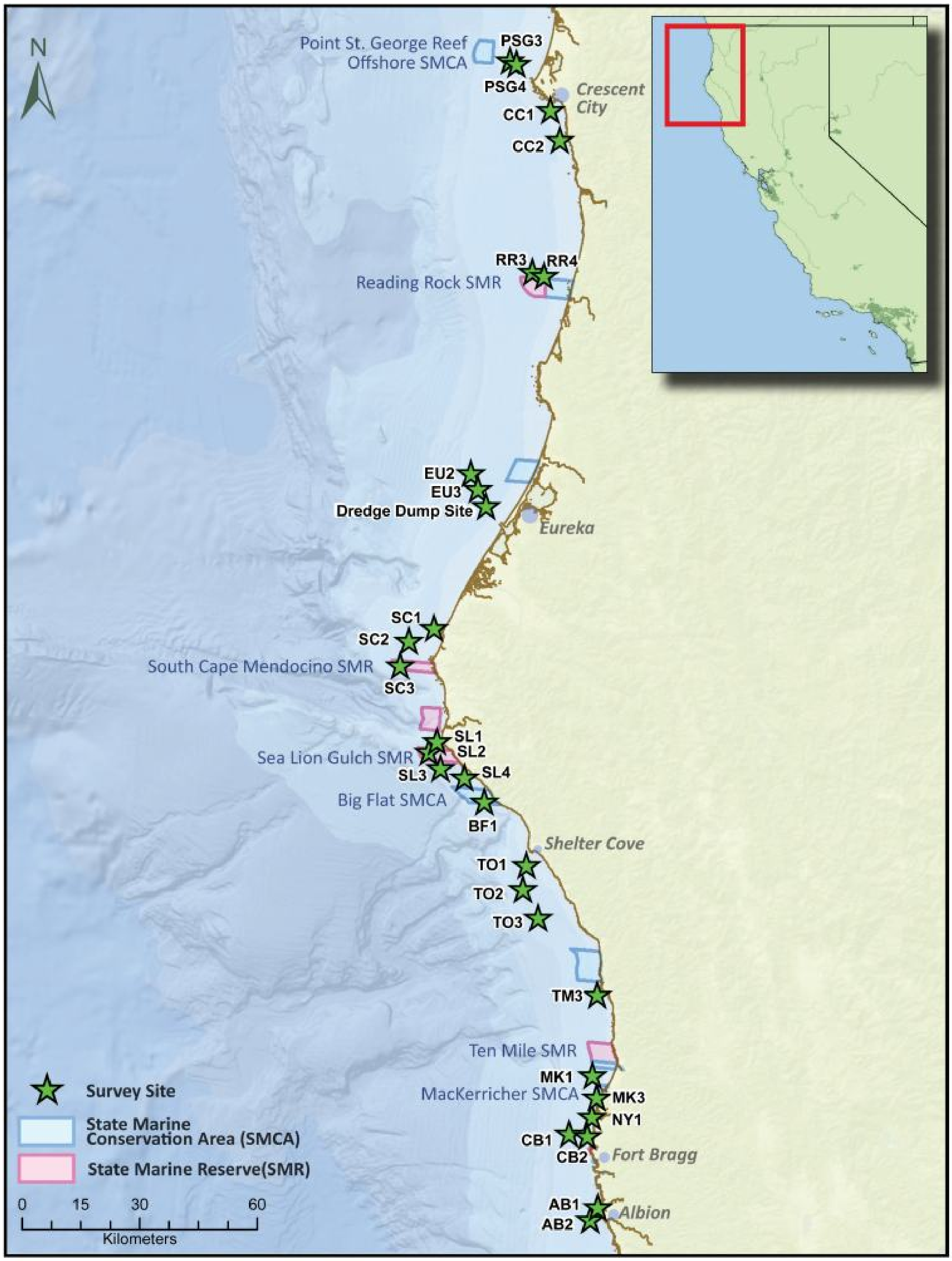

Figure 3. Site locations for CIAP cruise C in northern California, September-October 2014.

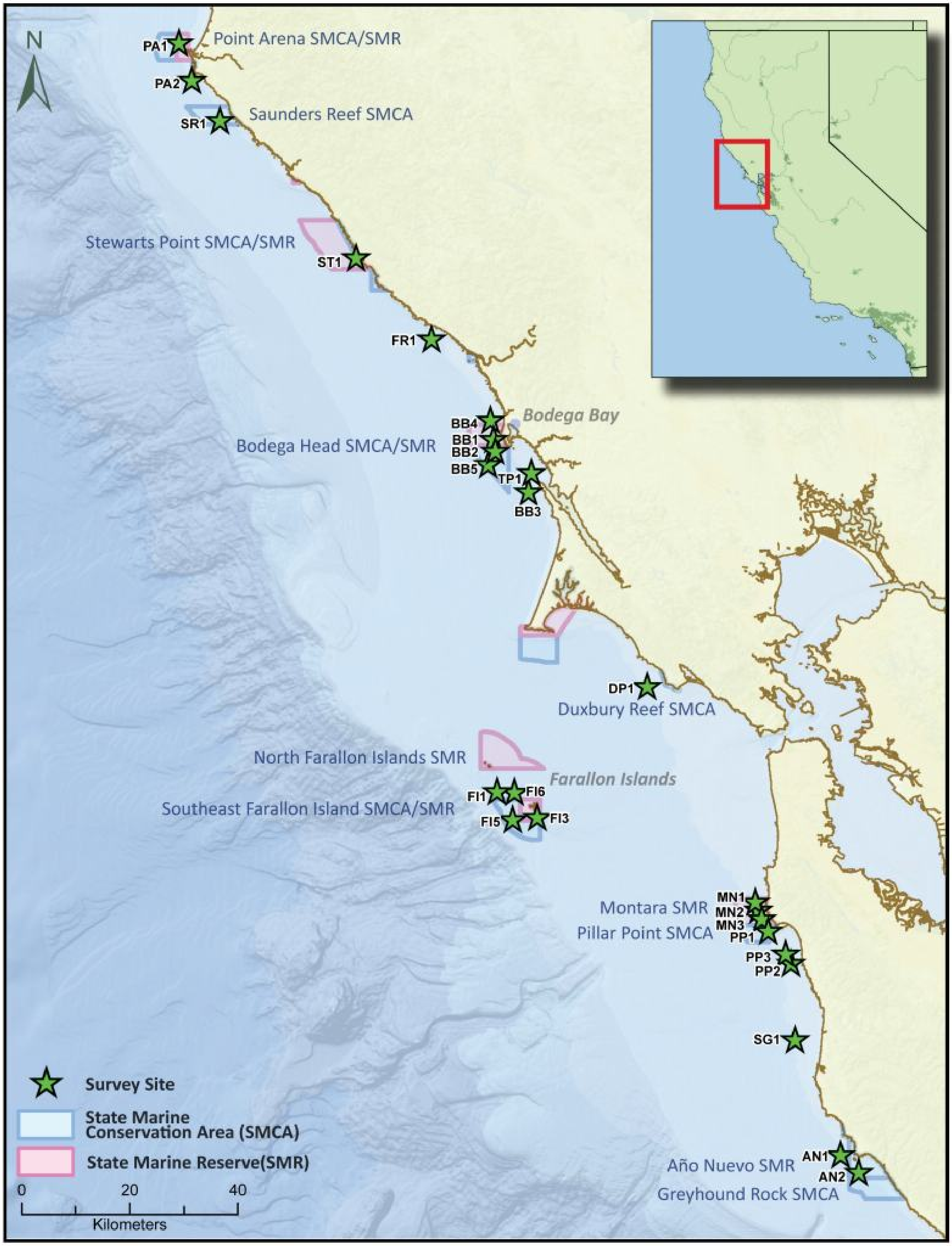

Figure 4. Site locations for CIAP cruise D in north central California, September-October 2015.

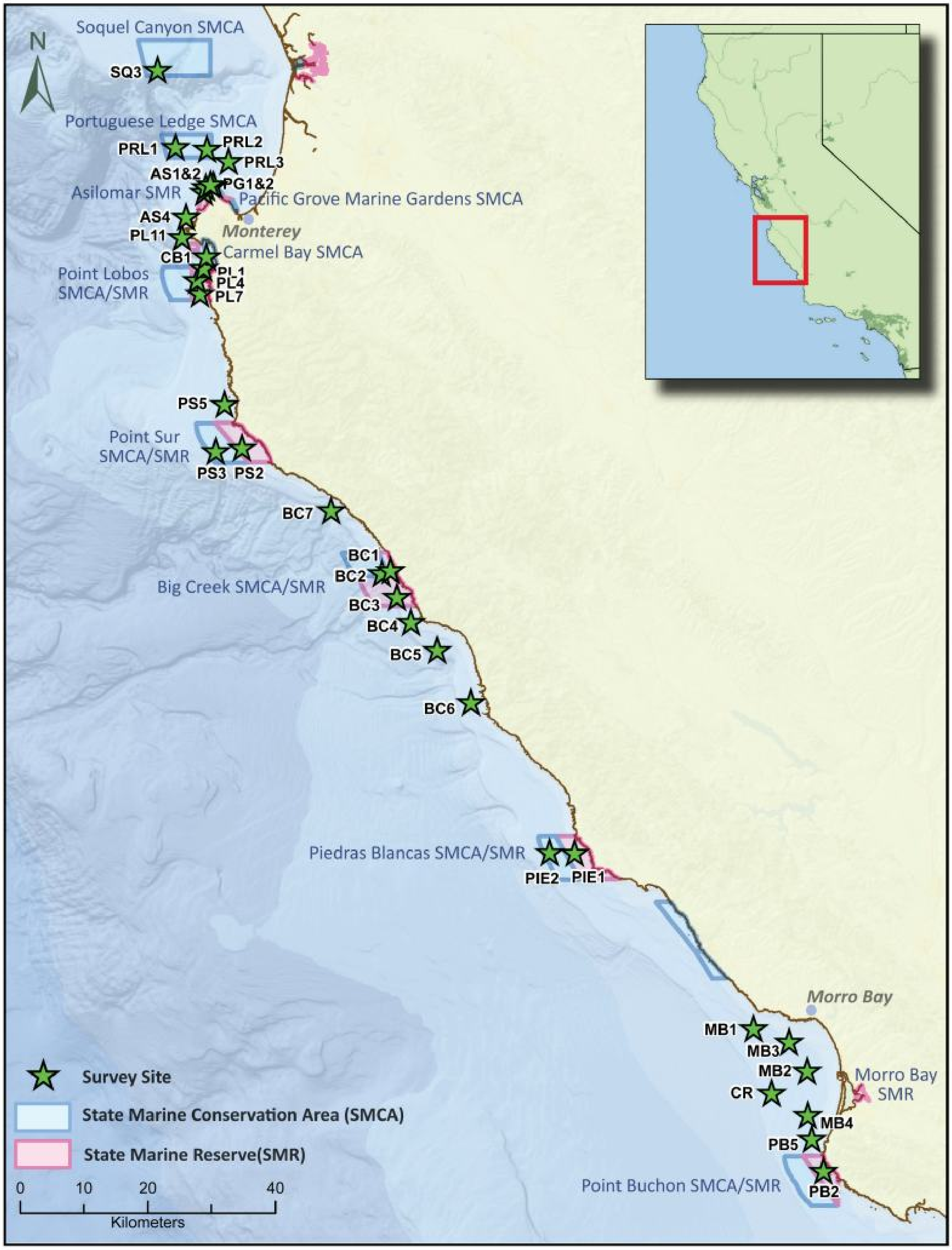

Figure 5. Site locations for CIAP cruise E in central California, September-October 2016.

Appendix 2. Considerations regarding variable detection probability.

Concerns regarding the implications of variable detection probability for density estimates between sites or transects raised by the SSC (Agenda Item E.3, SSC Report, September 2017) have been addressed in part through criteria for adequate sampling conditions, the sampling methodology itself and post processing methods. Video data collected was only used for density calculations when visibility was sufficient to view the entire video field of view out to at least 2 meters in front of the ROV. During the course of a transect, the angle of the ROV camera relative to the substrate was adjusted by the pilot to maintain an oblique field of view with the horizon slightly below the top of the viewing area thereby insuring that fish behaving evasively in front of the ROV could be detected.

The behavior of observed fish and the distribution of distance of observations from centerline of the field of view can be examined to examine whether the behavioral response of a given species may have implications for detectability, though this would require a rescoring of the recordings for this specific purpose, which is time and cost prohibitive. In review of the recordings from our study, the overall behavior of encountered fish provided some indication of notable weariness or attraction to the ROV of a given species. The vast majority of demersal rockfish were found to be relatively unresponsive (MARE personal communication). Cabezon, treefish and California scorpionfish were relatively cryptic potentially affecting detectability. Schooling rockfish species such as blue, black or yellowtail rockfish were unavailable to the ROV in mid-water making the ROV based methods poorly suited to estimating their absolute abundance without supplemental acoustic data and potential changes to the sampling methodology.

While the methods and selection of appropriate subject species address some of the potential issues relative to variable detection probability, the response of fish beyond the view of the ROV is unknown. Other studies conducted by the Alaska Department of Fish and Wildlife (Green et al. 2013) and National Marine Fisheries Service (Laidig and Yoklavich 2013) provide some insight on the degree species respond to ROVs in way that may affect detectability. Our analysis will provide a review on a species by species basis taking into account the distribution and behavior of each species as well as results of other research conducted to date.