# EXECUTIVE SUMMARY

*Project Description and Background* - Kelp forest and nearshore rocky reef ecosystems are among the most productive in the world and provide numerous important services to humans. Because of their great productivity, biodiversity, and associated ecosystem services, they were targeted for protection by the MLPA planning process. A consortium of academic monitoring programs and a citizen science program was formed to conduct kelp forest monitoring across the network. The kelp forest monitoring datasets are among the longest time series in California for MPA evaluation and many were established at the time of MPA implementation. These surveys enumerate nearly all of the components of the ecosystem including fishes and invertebrates that are targeted by fishing and those that are not fished. These aspects allowed us to create a framework to test for MPA effects that takes into account the trajectories of species that are expected to be affected by cessation of fishing (Targeted species) and those that are not expected to be directly influenced (Non-targeted species). Using this framework, we can test the effects of cessation of fishing, while controlling for changing environmental conditions independent of MPA effects. The kelp forest monitoring is the only program that can utilize this accurate, albeit strict, test of MPA performance. In addition to the *in situ* ecological monitoring, this program also conducted a) *in situ* environmental monitoring (OAH and water temperature) at select sites throughout California and b) analysis of a long-term, large scale database of remotely-sensed kelp canopy cover.

*Methods* - To quantitatively characterize species size and abundances, the ecological community and geological features at each site, we conduct visual SCUBA diver surveys. From the data recorded by diver surveys, we calculated biomass, density and size frequencies of focal species and species groups, metrics of diversity, community composition, and response ratios (i.e., magnitude of the difference between MPAs and paired Ref sites). We focused this report on 20 MPAs across the state for which we had sufficient time series for analysis. We assessed changes in these metrics over time and across space in four bioregions, along with potential explanatory variables such as MPA attributes and seawater temperature.

*Key Findings*

- MPA effects vary across species, biogeographic regions, MPAs, and time periods. No statewide trends emerged. Analyses at and across regional scales proved more insightful than combined state-wide analyses.
- In general, of those sites with sufficient time series, the strongest population responses were in the Northern Channel Islands MPAs and South Coast MPAs and the weakest in Northern California MPAs (ES Figure 1). However, there was substantial variation in these responses among MPAs within each region (ES Figure 2). These same patterns were also reflected in mean biomass response ratios across years (ES Figure 3)
    - Strong positive responses in the Northern Channel Islands and South Coast MPAs are likely due to moderate to high fishing pressure outside the MPAs and high statistical power to detect responses (i.e., many MPA replicates with good time series).

    - Responses in the Central Coast MPAs were highly variable. Positive responses in this region were found largely in two southernmost MPAs (Pt. Sur and Pt. Buchon).
    - Because the North Coast MPAs are very difficult to access for SCUBA surveys and monitoring has been limited, we found no clear MPA effects in this region. However, environmental disturbance during the monitoring period caused dramatic changes to the kelp forest ecosystem in the region and these large-scale events likely swamped any MPA effects that might have occurred.
- Focal species that are heavily fished, particularly those in southern California, tended to show greater responses to protection. These include several species that have been previously documented as responding positively to MPAs (i.e. CA Sheephead, Kelp Bass, California spiny lobster).
- We did not detect any influence of MPA design attributes on the response of fishes targeted by fishing across the entire statewide network, whether categorical (e.g., SMR vs. SMCA, clustered or individual MPA) or continuous (e.g., MPA size, distance to port, habitat diversity). We detected large regional variation in species responses and tests of design attributes will best be made within regions. However, within each region, there is not sufficient replication of any categorical design attribute (e.g., SMR vs. SMCA) to statistically test for their effects.
- A key variable that should be further considered is fishing mortality at scales relevant to the MPAs. We found no relationship in MPA response with distance to nearest port across all regions, but when comparing MPA responses by the identity of the nearest port, we found that MPAs closest to the four southernmost ports (Morro Bay, Santa Barbara, Channel Islands and San Pedro) showed greater positive MPA responses than those nearest Ft. Bragg, Bodega Bay, and Monterey in northern and central California.
- Temporal patterns of diversity and richness differed among regions with the North coast showing declines, though non-significantly, for all four assemblage types (i.e., fish, algae, invertebrates and UPC organisms) and the Northern Channel Islands and South coast remaining more stable or increasing over time relative to the Central coast. These regional patterns of diversity trends across the four assemblages suggest community-wide responses to the 2014-2016 marine heatwave and geographic differences in trophic interactions enabled by the MPAs.
- We found a relationship between a simple measure of MPA response over time for species targeted by fisheries and annual patterns of sea surface temperature across the state. Within each region, the relationships, although not significant, were complex. Understanding the effects of both secular change in environmental conditions and extreme events such as heatwaves on MPA performance is a future research area.
- Environmental monitoring at select sites throughout California found high coherence in conditions across the North Coast and across the Central Coast but high variability in the South coast for temperature, pH and $O_2$.
- Environmental monitoring was able to measure exposure of MPA sites to potentially stressful pH and dissolved oxygen conditions. Exposure was highest in the North coast and lowest in the South coast with Central coast MPAs intermediate in exposure.

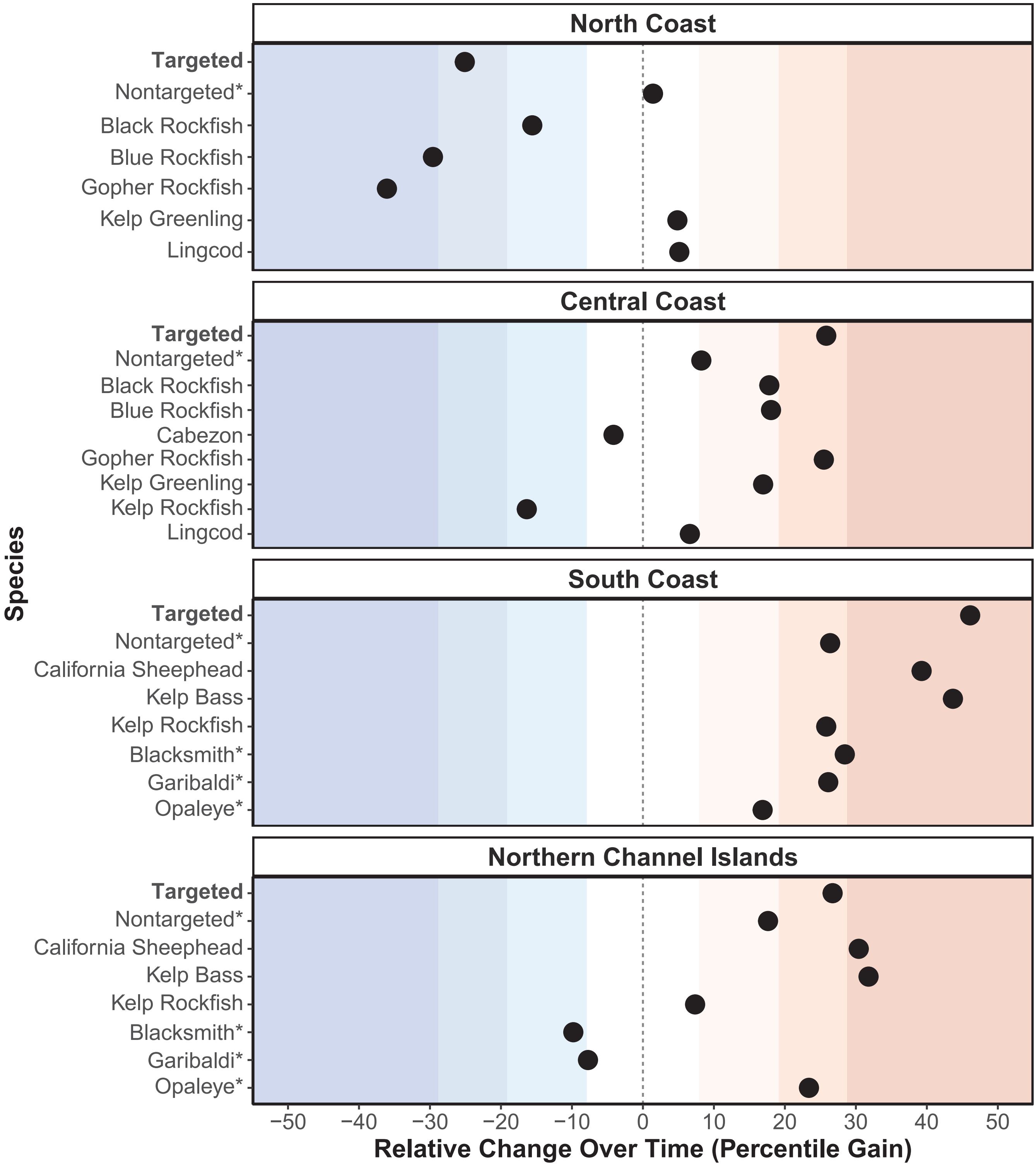
- Kelp canopy monitoring from Landsat remote sensing did not detect a strong effect of MPA protection on average kelp canopy area. However, kelp abundance did appear to exhibit higher resilience on average to the 2014-2016 marine heatwave inside MPAs as compared to reference areas.

*Key Recommendations*

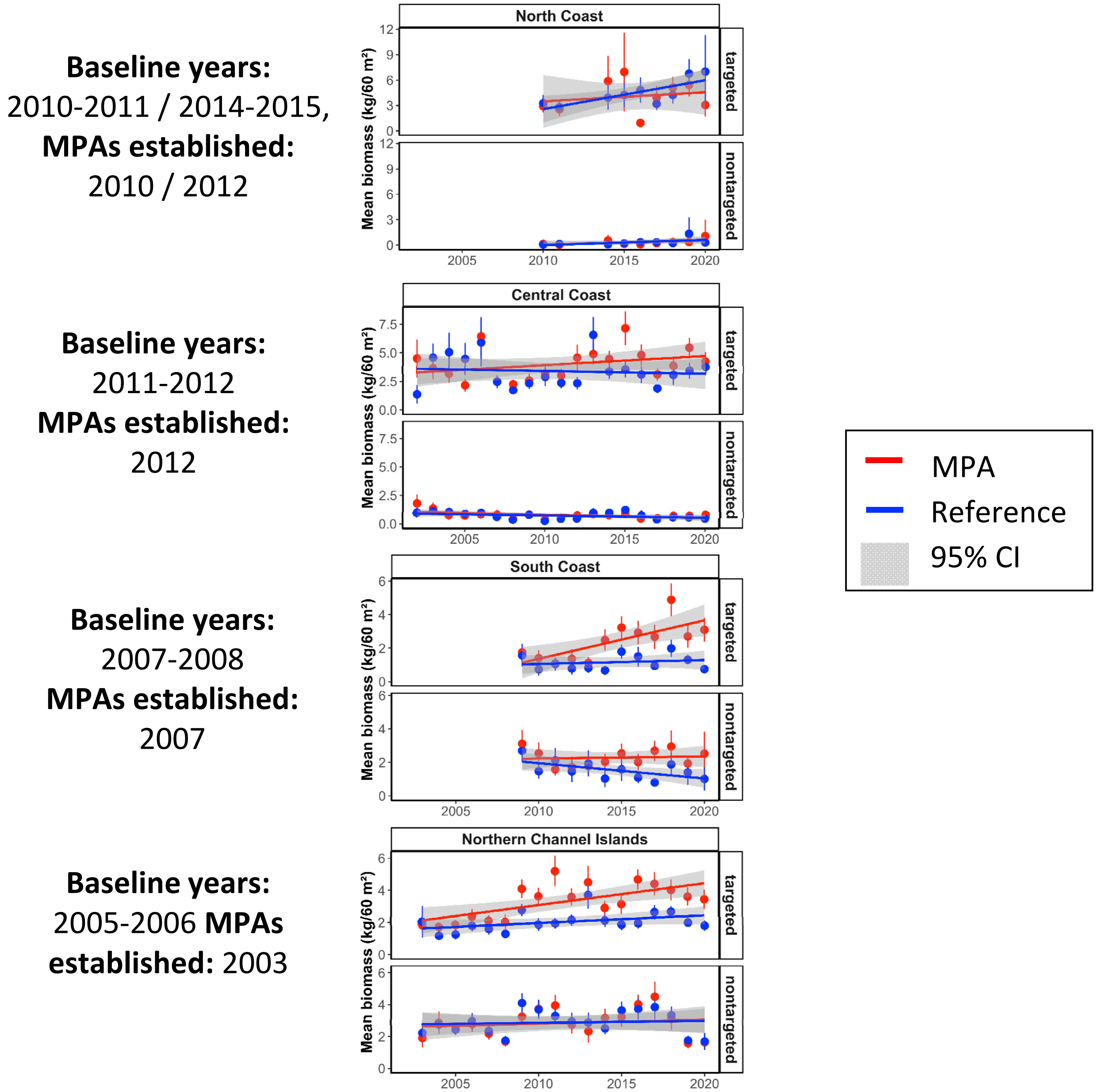
- **Consider regionally tailored network management.** Although one of the most important design attributes of the MLPA network is its integration across all of California's coastal waters, the results of this study strongly suggest a management program tailored to the regional ecological and human differences across the network may be more effective, efficient and potentially nimble. We found strong geographic differences in MPA responses as well as in data availability, mirroring geographic differences in the magnitude and types of fishing, fisheries management, human densities, stakeholder interests, among others. Potential regional MPA management decisions (e.g., relative levels of monitoring, enforcement, outreach, forms of partnerships between CDFW and types and amount of monitoring) parallel current, regionally-based management of many state fisheries and, as such, may facilitate the integration of MPA and fisheries management.
- **Continue robust long-term monitoring of kelp forest ecosystems and environmental conditions** but make realistic, science-informed decisions about the geographic scale of monitoring and the distribution of sites. Prioritize long-term series and minimize overlapping programs.As ecological and environmental disturbances are predicted to increase in the future with climate change, continued monitoring will become ever more important and serve multiple purposes across dimensions of fisheries management and biodiversity conservation.
- To better understand how fishing shapes populations relative to MPAs, **accurate, spatially explicit fishing data near MPAs** is needed. Consider providing more focused and dedicated resources to the sampling design and analysis of the state's fishing data.
- **Prioritize future research** that builds on the wealth of data from California's MPA network. In particular,
    - More detailed analyses building on the results from this report would be valuable.
    - Promoting research that favors aggregation of existing nearshore OAH observations and develops synergies with ongoing regional modeling efforts should be a high priority.
    - Incorporate LANDSAT and other remote sensing approaches into routine monitoring.
    - New research on seascape composition and spillover would help to contextualize observed MPA responses as CA MPAs mature.
    - New theoretical studies that leverage these empirical data and lay out realistic expectations for how populations should change in MPAs relative to disturbance, recruitment, and other factors known to influence the timing and detection of potential MPA effects.

  This body of research can guide monitoring decisions in the future and also **provide key information for communications to stakeholders as well as managers**.

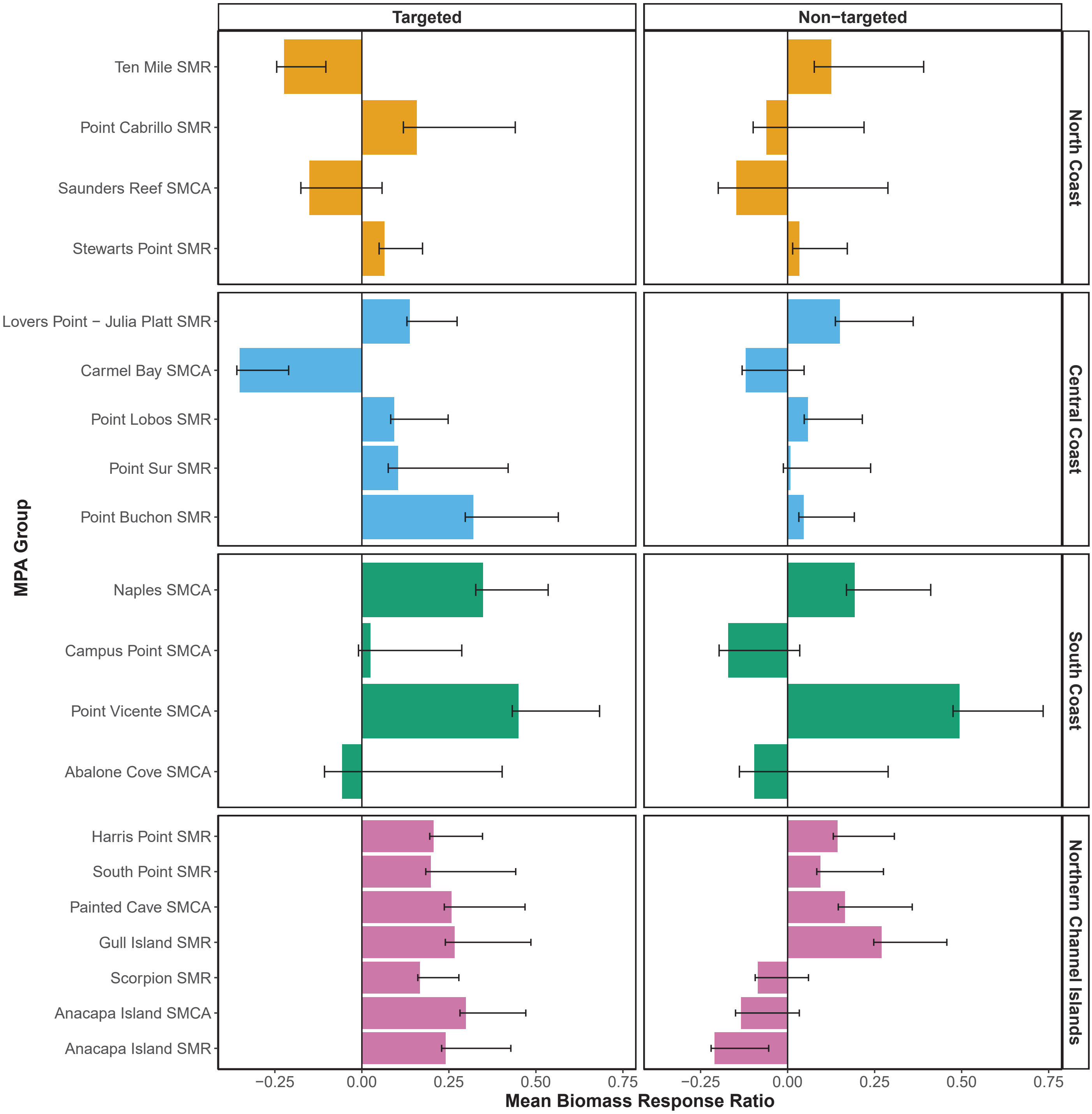
- **Continue and build on existing partnerships**. In particular, partnerships between CDFW and academic institutions could be strengthened and resource sharing improved towards more cost-effective long-term monitoring.




**ES Figure 1.** Relative change in fish biomass inside and outside of MPAs over time for each region. Relative change (slope) for MPAs and Refs were calculated using Hedges' g and expressed as percentile gain. Positive values mean average change in biomass over time (slope) for a group in MPA sites is higher than average slope in reference sites. Negative values mean the slope in reference sites is higher than average slope in MPA sites. An asterisk after the name or grouping indicates species which are not targeted by fishing. Shading indicates the magnitude of the effect size (or difference between MPA and Refs) with small, medium, and large effect represented by successively darker shading.




**ES Figure 2.** Trajectories of average biomass (kg/60m2) per region for Targeted and Non-targeted fish groups. Data for targeted and non-targeted are divided into two sub-figures with targeted on the top and non-targeted on the bottom. Legend key: Each data point represents average biomass across region within MPA or REF. Error bars on each data point are 95% confidence intervals (CIs) with sites as replicates. Data points are fitted with a regression line (red line = MPA and blue line = REF). Gray shading represents 95% CI for the slope of a regression line.




**ES Figure 3.** Mean biomass response ratio (log (Biomass $_{MPA}$/Biomass $_{Ref}$) with standard error over the time series for targeted (left) and non-targeted (right) fishes.