Evaluating the protection of diverse and representative coastal and marine habitats within California's Marine Protected Area (MPA) network

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Objective

This project evaluates the degree to which California's Marine Protected Area (MPA) network meets its primary goal of protecting diverse and representative coastal and marine habitats. By synthesizing newly available spatial datasets, this study will describe how habitat types are distributed among MPAs and across regions, and evaluate whether habitats are protected in proportion to their availability in the broader marine environment.

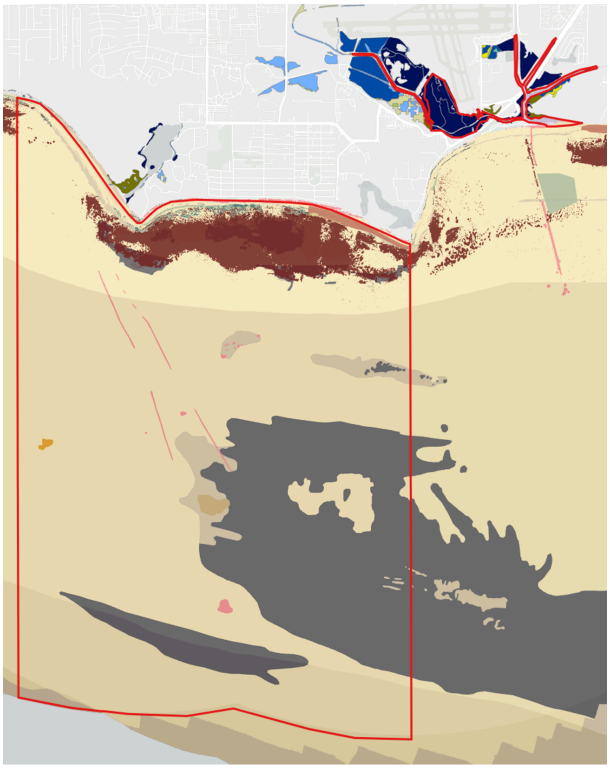

Fig 1. Newly available spatial data on nearshore habitats around the Campus Point No-Take State Marine Conservation Area (SMCA) and Goleta Slough SMCA in Isla Vista, CA. Red lines indicate MPA boundaries and other colors reflect different habitat types. For more information, see Supporting Materials.

Environmental Motivation

Marine protected areas (MPAs) are promoted as tools for protecting biodiversity and building resilience (Grorud-Colvert et al., 2021). California's MPA network was fully implemented in 2012, and one of its main goals is to protect key coastal and marine habitats (California Fish and Game Code §§ 2850-2863, 1999). This is also a fundamental scientific recommendation for designing MPA networks, as it ensures that the full range of species and processes that depend on those habitats are protected (Gaines et al., 2010). Protecting diverse and representative habitats is especially important given California's expansive coastline, which spans over 1500 km and crosses two major biogeographic boundaries, leading to a broad range of environmental conditions and diverse habitat types that support many coastal communities. While habitat was a focal element guiding the placement of California's MPAs (Gleason et al., 2013), habitat extent and distribution within the designated MPAs were never fully assessed due to insufficient data. However, newly available, public spatial datasets provide the first opportunity to evaluate how California's MPAs capture crucial habitats relative to the broader marine environment (**Figure 1**). As the State finalizes its 10-year review of the MPA network, this information will help assess whether the network is achieving one of its core legislative objectives and will inform ongoing monitoring, research, and adaptive management efforts.

From an environmental equity standpoint, understanding habitat representation provides insights into how the benefits of MPAs are distributed across regions and communities. Many coastal communities, particularly those that rely heavily on marine resources, depend on specific habitats for their livelihoods, cultural practices, and recreation. Many Indigenous communities have deep connections to specific habitats and species central to their heritage. With this in mind, this study aims to inform strategies for balancing habitat protection with equitable access by being the first to assess the abundance and geographic distribution of different habitat types among California's MPAs.

Data Science Need

Substantial advances in habitat mapping have occurred since the MPA planning process, including additional mapping efforts in areas with limited data, habitat extrapolations of shallow non-mapped portions of the coast, the inclusion of additional habitats (e.g., seagrass, wetlands), and more thorough satellite-derived estimates of kelp canopy cover. The Pacific Marine & Estuarine Fish Habitat Partnership (PMEP) recently synthesized 82 benthic habitat datasets, cross-walking each to a hierarchical framework aligned with the Coastal and Marine Ecological Classification Standards (Bizzarro et al., 2022). The NOAA Deep Sea Coral Initiative used a similar hierarchical process to combine multibeam bathymetry data into a single high-resolution continuous bathymetry layer. Finally, KelpWatch provides spatiotemporal data on kelp canopy cover spanning multiple decades, facilitating large-scale analyses of kelp forest dynamics and persistence (Bell et al., 2023). Each dataset spans the full extent of California state waters. The primary data science need involves two main steps: (1) integrating these spatial habitat datasets to generate layers for defined habitat types, and (2) using those layers to analyze the spatial protection of each habitat within the MPA network relative to its broader distribution.

1) *Data Selection:* Identify the key coastal and marine habitat types to use in the analyses, including identifying which data layers best represent regional or statewide coverage for each habitat type, how layers will be combined, and the metric(s) that will be used in statistical comparisons (e.g., area extent in km^2). Fundamental habitat types will be selected using discrete combinations of substrate, biotic cover, and depth, but additional specific focal habitats (e.g., kelp forests, wetlands) are flexible to student interests.
2) *Data Integration*: Examine the datasets and perform any cleaning needed to create the layers for each habitat type. Intersect the substrate and biotic components within each defined depth zone. Overlay with boundaries for MPAs and regions.
3) *Analysis:* Develop and execute statistical analyses to determine the following:
    a) The amount of habitat type within each MPA,
    b) How the amount of each habitat type varies among MPAs and regions,
    c) How the amount of each habitat type within MPAs compares to its relative distribution in the broader environment (e.g. statewide, within regions)
4) *Visualization:* Develop data visualizations to communicate key insights from the results. These could include: example maps of the distribution of habitat within and outside of MPAs, stacked bar charts displaying the relative proportion of each habitat type within MPAs, and bar charts or tables to describe differences in the amount protected within MPAs compared to the broader environment. Creativity is encouraged.

Deliverables

The deliverable for this project is a written report summarizing the data, methods, and results. While we do not have prescriptive requirements for the report, we expect it may include:

a) Background on the data sources used in the analyses and how they are combined to provide estimates for identified coastal and marine habitat types
b) Methods used to process and integrate the data layers
c) Overview of statistical approach and specific methods used to conduct analyses
d) Written details of the results from the statistical analyses
e) Effective visualization of key insights through tables, figures, and maps
f) Comprehensive discussion of the findings and any gaps or limitations

The audience for this report will be researchers involved in the decadal evaluation of California's MPA network. In addition to the collaborators listed on this proposal, this includes faculty and staff at UC Santa Barbara and other academic institutions and state partners at the California Department of Fish and Wildlife and California Ocean Protection Council. The report is not intended to be used by the public.

Data Access and Availability

A) The continuous spatial datasets provided below (via links) characterize substrate, vegetation, and bathymetry for the entirety of California's state waters. These datasets will be synthesized to create layers for the distinct habitat types that exist across CA and will be used to analyze variation in habitat type protection statewide. No NDAs required.

B) *Option 1:* The group members will have access to all datasets needed to complete the proposed research. Each dataset is publicly available online through the provided links, and the raw data and initial processed versions can also be accessed within the *ca-mpa* directory on *Aurora*. Simplified versions of several of the spatial habitat layers can be explored through the PMEP Estuary and Nearshore Habitat Viewer.

C) Links to data sets:

Variable	*Source*
California MPAs shapefiles	CA Department of Fish and Wildlife
Substrate (rock vs. sediment)	PMEP Nearshore Substrate Component
Nearshore biotic habitat (e.g. seagrass, kelp)	PMEP Nearshore Biotic Component
Bathymetry	NOAA West Coast Deep Sea Coral Initiative*
Kelp forest canopy cover	KelpWatch

*The bathymetry data is expected to be publicly available online soon, and is provided here via Google Drive.

D) The data described above are the only datasets necessary to complete the project. However, additional layers could be integrated if students are interested in certain habitats, including biotic cover within estuaries (PMEP Estuarine Biotic Component) or eelgrass extent (PMEP Eelgrass Habitat). These are also publicly available and integrate nicely with the layers described above since they were generated within the same framework as the other PMEP components. If there is additional time and interest, we also have clean, available datasets from our working group that describe human engagement in each MPA (e.g., via iNaturalist, eBird), which could be used to explore how MPAs with different habitat types support different anthropogenic activities.

Project Requirements

The initial steps provided in the *Data Science Need* section propose one option for conducting the analyses for this study and are meant to help the group get started with the data and generate initial insights. Specifically, defining fundamental habitat types based on substrate, biotic cover, and depth is a straightforward approach that aligns with the methods used during the CA MPA planning process. There are opportunities for students to adapt or redesign the approach, or extend it to explore additional statistical comparisons or applications. We are supportive of creative opportunities for them to follow interesting questions and insights and employ the statistical and modeling approaches they are learning in the program.

Project members will need to conduct geospatial analysis in either R or Python. The data are currently stored on *Aurora* at NCEAS, which has been sufficient for most basic tasks. Given the computational needs of conducting spatial analyses over large areas, it is possible that the group will need access to additional computing resources to reduce computation time.

Supporting Materials

References

Bell, T. W., et al. (2023). Kelpwatch: A new visualization and analysis tool to explore kelp canopy dynamics reveals variable response to and recovery from marine heatwaves. *PLOS ONE*, 18(3), e0271477. https://doi.org/10.1371/journal.pone.0271477

Bizzarro, J.J., et al. 2022. State of the knowledge: U.S. West Coast nearshore habitat use by fish assemblages and select invertebrates. Portland, OR: *Pacific Marine & Estuarine Fish Habitat Partnership.* https://www.pacificfishhabitat.org/assessment-reports/

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Gaines, S. D., et al. (2010). Designing marine reserve networks for both conservation and fisheries management. *Proceedings of the National Academy of Sciences*, *107*(43), 18286–18293. https://doi.org/10.1073/pnas.0906473107

Gleason, M., et al. (2013). Designing a network of marine protected areas in California: Achievements, costs, lessons learned, and challenges ahead. *Ocean & Coastal Management*, *74*, 90–101. https://doi.org/10.1016/j.ocecoaman.2012.08.013

Grorud-Colvert, K., et al. (2021). The MPA Guide: A framework to achieve global goals for the ocean. *Science.* https://doi.org/10.1126/science.abf0861

Letters of support

Attached.

Budget and justification

The proposed project is not anticipated to require additional funding beyond the standard project support made available to all MEDS capstone projects.

Additional background resources for students

Figure 1, Detailed Caption: The data displayed here are from the Pacific Marine and Estuarine Fish Habitat Partnership. This map shows an overlay of the Nearshore Substrate Component, Nearshore Biotic Component, and Estuary Biotic Component. The substrate data are classified as rock (shades of gray), unconsolidated mineral (shades of tan), or anthropogenic (e.g., pipes or structures, pink), and darker shades indicate deeper depth zones. The biotic cover types shown here include canopy-forming kelp (dark brown), other aquatic vegetation beds (light green), and inshore wetland and marsh habitats (greens and blues).

Webpage for the decadal review of California's MPA network

Pacific Marine and Estuarine Fish Habitat Partnership's Estuary and Nearshore Habitat Viewer