Using MPA Watch Data to Analyze Human Activities Along the California Coast

M.V. Eitzel, Ryan Meyer, Nick Ulle, Eliza Oldach, Mark Lubell, and Michael Dobbins

CENTER FOR COMMUNITY AND CITIZEN SCIENCE

CEPB

UCDAVIS DataLab
Data Science and Informatics

About this report

This report was prepared for the California Department of Fish and Wildlife (CDFW) to inform the Marine Protected Area (MPA) Decadal Management Review (DMR). It is one of two projects at the Center for Community and Citizen Science aimed at supporting this important milestone for the MPA Network in California:

- Examining the Role of Community and Citizen Science in Marine Protected Area Implementation; and
- Using MPA Watch Data to Analyze Human Activities Along the California Coast (this report).

Each of these projects directly addresses goals of the Marine Life Protection Act and the four pillars of MPA Management: Research and Monitoring; Outreach and Education; Enforcement and Compliance; and Policy and Permitting. They also help to develop and expand a human dimensions research agenda for MPAs in California and beyond.

Acknowledgments

This project was supported by the Resources Legacy Fund, through a grant from the Once Through Cooling fund, administered by the California Ocean Protection Council. We received valuable guidance from both of those organizations, as well as the California Department of Fish and Wildlife. Two expert reviewers, Matt Williamson (Boise State University) and Ben Goldstein (UC Berkeley), were extremely generous with their time and expertise. We thank Mark Briggs for visual design and formatting of the report. Finally, the many different organizations that make MPA Watch possible have also been crucial to this project; we thank them for their time, energy, and feedback throughout the process.

Cover Photography
(Clockwise from left) Orange County Coastkeeper; Santa Barbara Channelkeeper; Orange County Coastkeeper

Design
Mark Briggs

Highlights

Information about human activities along the coast can help us understand human impacts on natural resources and the benefits people derive from marine protected areas (MPAs). In this project we examined human activities along the California coast from 2012 to 2020 using data from the MPA Watch community science network, gathered by more than 1,900 volunteer participants, and a handful of program staff.

Key messages and findings

MPA Watch is gathering useful data at a statewide scale, and has successfully grown its network of volunteer monitoring programs over the last decade to include 12 local programs, 104 monitoring sites, and hundreds of volunteer surveyors each year (page 3).

Among the observations recorded by MPA Watch surveyors, **non-consumptive activities vastly outnumber consumptive activities**, both inside and outside of MPAs (Figure 4, page 5). This highlights the value of MPA Watch data for understanding human coastal use, underscores the importance of recreational activities in California's coastal economy, and reinforces the need to monitor and understand non-consumptive uses in and around MPAs.

Our analysis confirms that **MPA Watch data can detect broad, statistically robust patterns** in human activities along the coast (page 6), including among recreational activities that relate to Goal 3 of the Marine Life Protection Act, but have not been the focus of other socioeconomic monitoring projects.

MPA Watch data can be used to detect statistically significant differences between activities inside and outside of MPAs (Table 1, page 6). Our analysis used occupancy modeling to investigate occurrence probabilities for seven categories of human activity. Our statistical results focus on an activity's likelihood of occurrence, rather than the total number of occurrences. From 2012 to 2020 at the statewide level:

Onshore fishing was **less likely** inside of MPAs.

Tidepooling was **more likely** inside of MPAs.

Recreational boating was **more likely** inside of MPAs.

Recommendations

- Continued and expanded monitoring could reveal statewide temporal trends that may be occurring, but are not yet statistically detectable with only nine years of data.
- MPA Watch can make improvements to its program without sacrificing the utility of past data through:
  - Consistent implementation of the surveyor ID system.
  - Updating protocols for recording potential violations.
- MPA managers can improve their ability to use MPA Watch data through:
  - Coordination between law enforcement data collection and MPA Watch.
  - Identifying specific questions about human uses to guide future analyses.
- There are many ways to improve and build upon the analysis presented here, including:
  - Investigating spatial patterns by leveraging data about covariates such as public access, and other site-specific attributes, and investigating seasonal within-year patterns in activities.
  - Developing models that examine the count of activities at a given site, in addition to this report's examination of presence/absence of activities.

Introduction

This report presents an analysis of human activities along the California coast from 2012 through 2020. Data for the analysis were collected by surveyors in a community science[1] monitoring network known as MPA Watch.

Goal of analysis

The primary goal of this project was to investigate human activities along the coast, looking for patterns, trends and shifts in consumptive and non-consumptive uses of marine ecosystems following implementation of MPAs. Of particular interest within this broad goal was:

- Differences in activities between MPA and non-MPA sites; and
- Patterns in activities that represent potential violations of MPA regulations.

Why does this matter?

Analysis of MPA Watch data contributes to a broader understanding of human impacts on marine ecosystems, and of the benefits that marine ecosystems provide to humans. Analysis of MPA Watch data can inform efforts toward goals 1, 2, and 4 of the Marine Life Protection Act (MLPA)[2], which guided the development of California's network of MPAs, by shedding light on human activities that could impact marine ecosystems. Goal 3 of the MLPA also calls out the role of MPAs in improving recreational, educational, and study opportunities in ecosystems subject to minimal human disturbance. Analysis of human activities inside and outside of MPAs can help us to understand progress toward that goal, as well as large-scale patterns in human recreation throughout the coast.

What is MPA Watch?[3]

MPA Watch is a network of programs that collect observations of human activities inside and outside of MPAs in California. Data are gathered by MPA Watch surveyors (mostly volunteers and a small number of paid staff) who travel to a predefined location and record observations on a data sheet that is later digitized in an online database. Most MPA Watch observations occur as a surveyor walks along the coast (beach or bluffs), though some programs also collect observations from a single vantage point, or by boat.

To date, 12 programs have been involved in the MPA Watch network. The observation protocol has been designed for consistency in data collection in which all programs use the same data sheet and manual,[4] and for flexibility of implementation due to significant variation in human and environmental geography along the coast.

[1] There are multiple terms for research and monitoring that involves people who do not self-identify as professional scientists (and are often volunteers). The MPA Watch network uses the term "community science," and so we will use that term throughout this report, except when discussing the broader field of practice, for which we use the term "community and citizen science." See more in a separate DMR report: "Examining the Role of Community and Citizen Science in Marine Protected Area Implementation."

[2] *Marine Life Protection Act.* 1999. Vol. Ch. 1015, Sec. 1. https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?lawCode=FGC&division=3.&title=&part=&chapter=10.5.&article=

[3] See also the DMR report: "MPA Watch: Community Science for Stewardship of Ocean Resources"

[4] Data sheet, manual, and other program resources available at https://mpawatch.org/resources. See also the report submitted by the MPA Watch network for the DMR: "MPA Watch: Community Science for Stewardship of Ocean Resources"

Box 1. MPA Watch at a glance

Key terms and concepts

- *MPA Watch:* The statewide network of monitoring programs that contribute data using aligned methods and protocols.
- *MPA Watch program or "program" for short:* A local chapter of MPA Watch, run by one or more local organizations. Each program monitors a distinct set of sites.
- *Site:* An area targeted for data collection by MPA Watch (can be an MPA or a non-MPA reference site).
- *Non-MPA Site:* An area targeted for data collection that is not within an MPA. Because there is not a standard state-wide approach for identifying such sites, we use the term "non-MPA" rather than "control" or "reference" in this report.[5]
- *Transect:* Area covered by a single survey, conducted by an MPA Watch volunteer. On land, a transect is usually designed to take an hour or less on foot. Many sites contain multiple transects.
- *MPA Watch surveyor or "surveyor" for short:* A person who has received training from an MPA Watch program, and has approval to travel to collect and contribute data for the network.

Key facts and figures (2012–2020)

- Number of chapters: 12
- Number of survey sites: 104 (44 MPA sites, and 60 non-MPA sites)
- Number of individual volunteers since 2012 (estimated): 19186
- Surveys conducted 2012 through 2020: 31,702
- Activities observed 2012 through 2020: > 1.2 million

While there are multiple ways to monitor human activity along the coast (e.g., lifeguard beach counts, parking lot counts, phone surveys), MPA Watch has a significant advantage in providing monitoring that is detailed (surveyors identify specific activities, not just counts of people), repeated (surveys are collected at the same site at many points of time, over multiple years), and standard (surveys across the state follow the same format)[7].

The MPA Watch network grew rapidly between 2011 and 2015, both in its geographic coverage (Figure 1) and in the number of people participating as surveyors (Figure 2; see also Appendix A), which includes breakdowns by site and bioregion). Some growth in coverage continued through 2020, even while there was a slight drop-off in overall participation. MPA Watch surveyors collect data throughout the year, with slightly more activity in summer months (Figure 3). Surveyor activity dropped briefly in March–June 2020, coincident with California's COVID-19 shelter-in-place orders, but quickly returned to pre-2020 levels (Figure 3).

[5] For example, some non-MPA sites are chosen for similar habitat (e.g., rocky intertidal, kelp forest), while others may be chosen to examine potential "edge effects" on either side of an MPA.

[6] This underestimate is based on data from the MPA Watch database. Programs have different data entry practices: in some cases program staff enter data for their surveyors and in others, individuals enter their own data. This leads to undercounting. As detailed in the separate DMR submission from the MPA Watch network, more than 4,000 surveyors have participated since the start of the program. This number was generated after our own analysis was completed and cannot be broken down by year.

[7] We also note that MPA monitoring in California has included in-depth, multi-method investigations of consumptive uses, both commercial and recreational, including the long-term monitoring project focused on commercial fishing and commercial passenger fishing vessels (CPFVs).

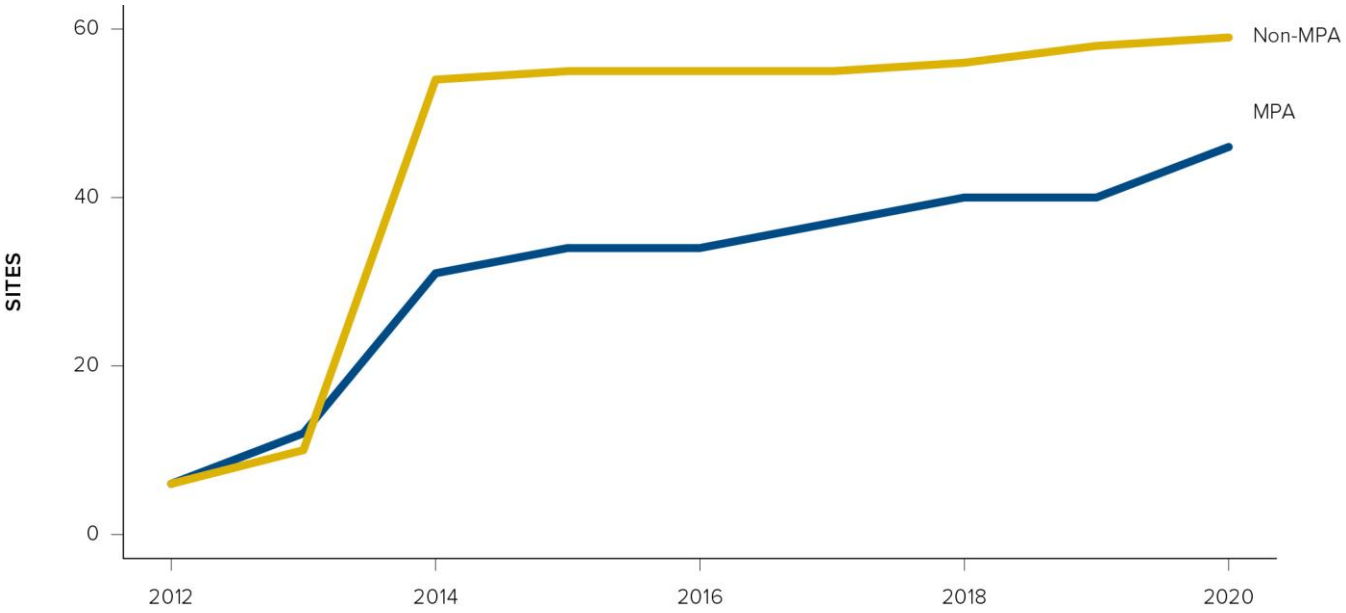


Figure 1. Cumulative sites in the MPA Watch Network over time. Count is based on the "first survey date" of each site (i.e., data do not reflect possible later elimination of sites from the sampling regime). Note the sharp increase in non-MPA sites around 2013, when the Beach Watch program joined the network. Beach Watch began operating in 1993, before MPA implementation, and many of its sites do not happen to be located in MPAs.

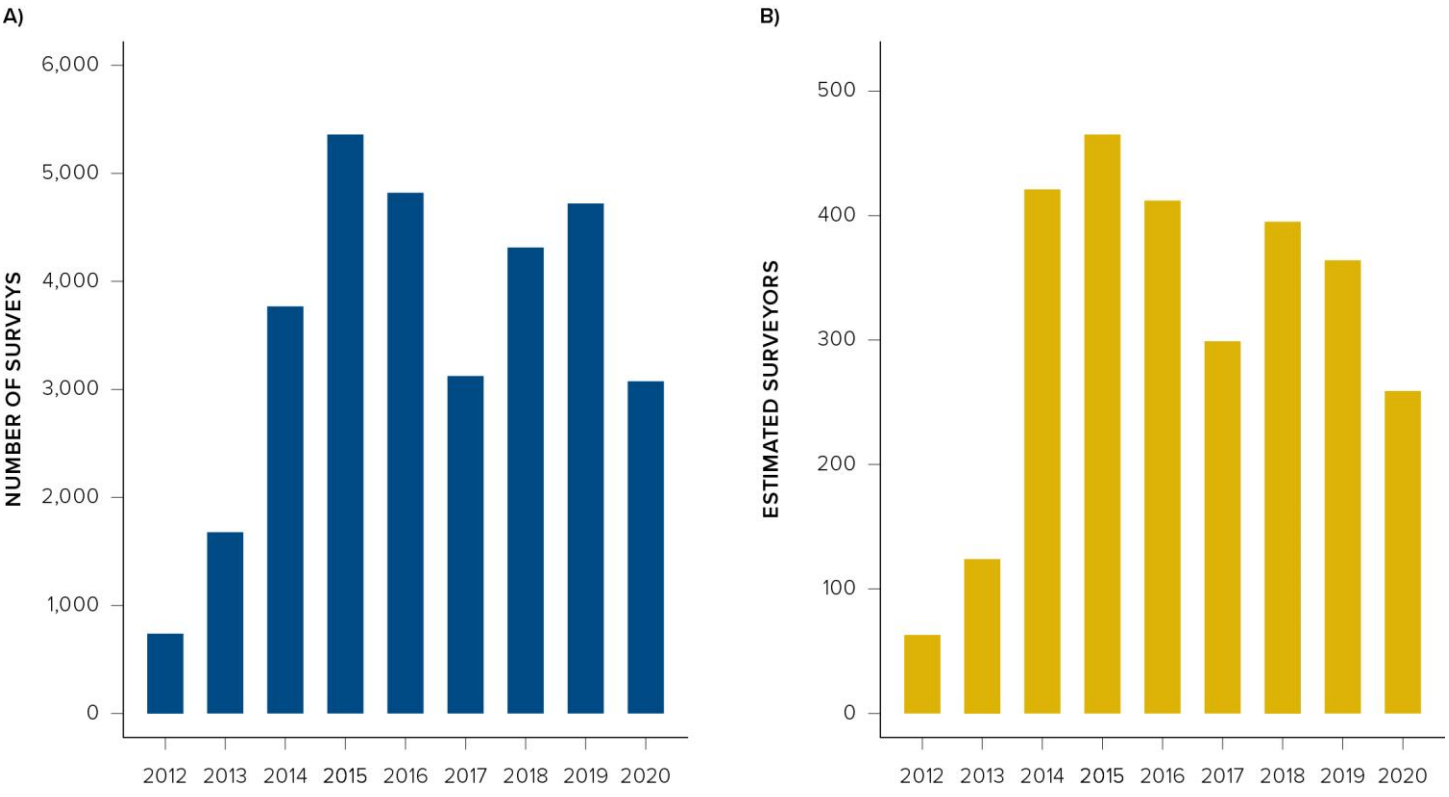


Figure 2. Number of surveys (Panel A) and estimated surveyors (Panel B) per year in the MPA Watch network. Undercounting of surveyors stems from cases of data entry by program staff, rather than surveyors.

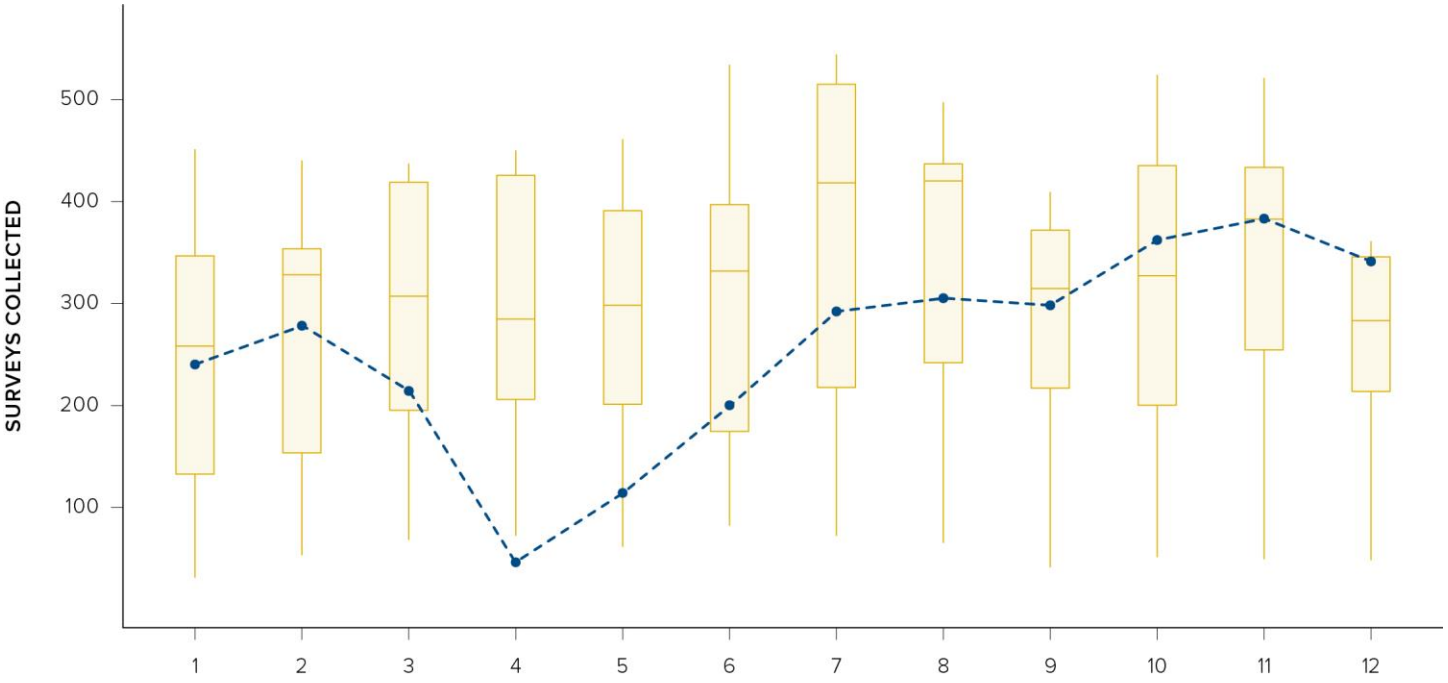


Figure 3. Surveys conducted by month across all MPA Watch sites. Boxplots show survey collection from 2012–2019; blue points show survey collection in 2020. Note weak seasonality in survey collection, with a slightly greater number of surveys collected in summer on average, and short-term decline in survey activity during the initial COVID shut-down.

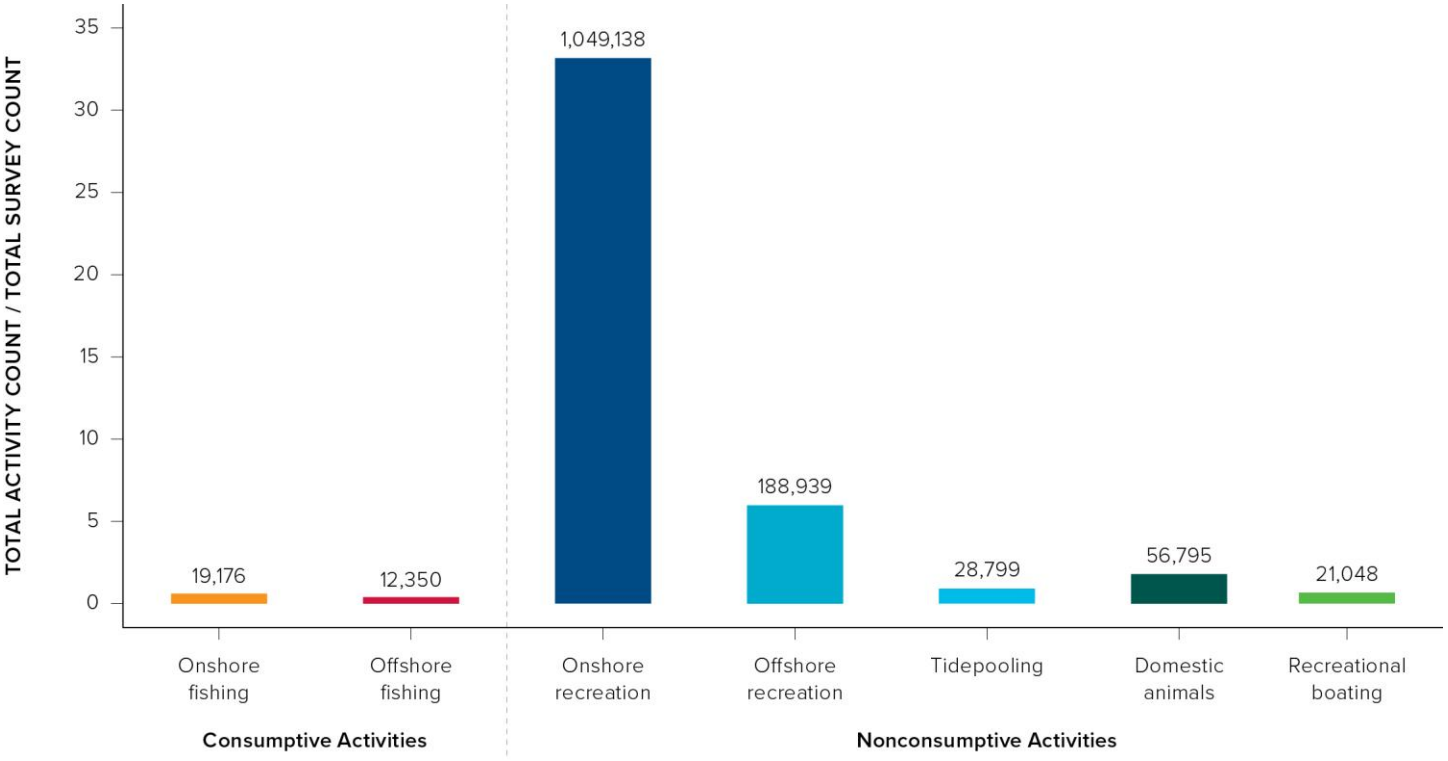


Figure 4. Counts of activities observed by MPA Watch surveyors from 2012 through 2020 in the seven categories of activity created for our analysis. Consumptive activities are onshore and offshore fishing; nonconsumptive activities include all remaining activity categories.

What does MPA Watch monitor?

The data sheet used by MPA Watch surveyors includes 66 types of human activity. For this analysis, we have grouped many of those activities into seven broad categories. We used two categories of consumptive activity: onshore fishing, and offshore fishing. We used five categories of non-consumptive activity: onshore recreation; domestic animals; tidepooling; offshore recreation; and recreational boating.[8] **The vast majority of activities observed by MPA Watch are in the onshore recreation category, with a very small percentage associated with consumptive activity** (Figure 4).

Statistical Modeling of MPA Watch Data

As with many community and citizen science programs, the data from MPA Watch are rich, but can be challenging to evaluate at a statewide level over the entire timeframe of data collection. This stems from the program's gradual growth in spatial coverage over time from south to north, and the fact that sampling by surveyors is voluntary and can be sporadic, with some sites sampled more consistently than others. We used a method called "Occupancy Modeling" to account for this uneven sampling in order to answer key questions about coastal use in a statistically robust way. Occupancy modeling addresses the "yes-no" question of *whether or not* an activity occurred, either statewide or at a given site or in a given year. Therefore our results do not directly address the question of *how many times* an activity occurred in a given year. For more details on the occupancy model, see Appendix B.

Can we detect patterns in human activities using MPA Watch data?

Yes. A key insight from this first effort to statistically model MPA Watch data is that the dataset is a rich resource, with the potential to address important questions about consumptive and non-consumptive uses of coastal natural resources. Importantly, we can also analyze differences between activities occurring inside and outside of MPAs.

Are activity patterns different inside of MPAs?

Yes, for some activities (for example, see results for Onshore Fishing, Figure 5A). A key question for this project was whether there are statistically significant differences between human activities taking place inside of, and outside of, MPAs. As shown in Table 1, three of our activity categories – Onshore Fishing; Tidepooling; and Recreational Boating – showed a statistically significant MPA effect. This means that there was a higher (or lower) probability that at least one person was engaging in that activity in an average year inside an MPA as opposed to outside an MPA. The remaining categories did not show a significant link between MPA status and activity.

Table 1. Modeled effect of MPAs on human activities.

Category	MPA Effect*
Onshore Fishing	**Less** likely inside MPAs
Tidepooling	**More** likely inside MPAs
Recreational Boating[9]	**More** likely inside MPAs

* No significant effect for Offshore Fishing, Onshore Recreation, Offshore Recreation, or Domestic Animals

[8] See appendix A to review the MPA Watch data sheet, and an account of which activities are lumped into the seven categories. Note that we did not include all activity types, because some contain extremely small numbers of observations, and cannot be lumped easily into larger categories.
[9] This category includes: Paddle Operated Boat; Kayak; Power boat; Sail boat; Jet ski; Dive boat; Whale Watching Boat.

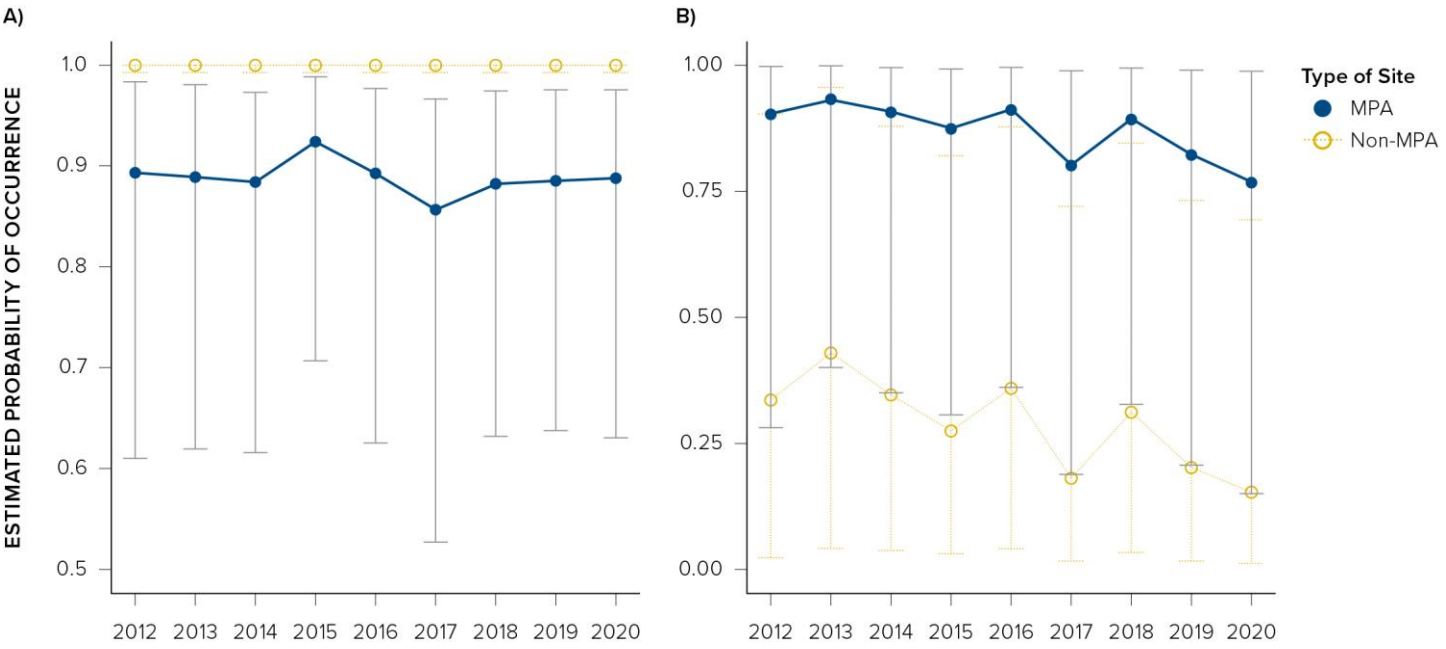


Figure 5. The statistical models show significantly **lower occurrence of onshore fishing in MPA sites** versus non-MPA sites, and little variation from year to year (Panel A). The model shows a **potential trend toward declining tidepooling** in later years, though this pattern is not yet statistically significant (Panel B). (Note that the probability in Panel A ranges from 0.5 to 1, and from 0 to 1 in Panel B.)

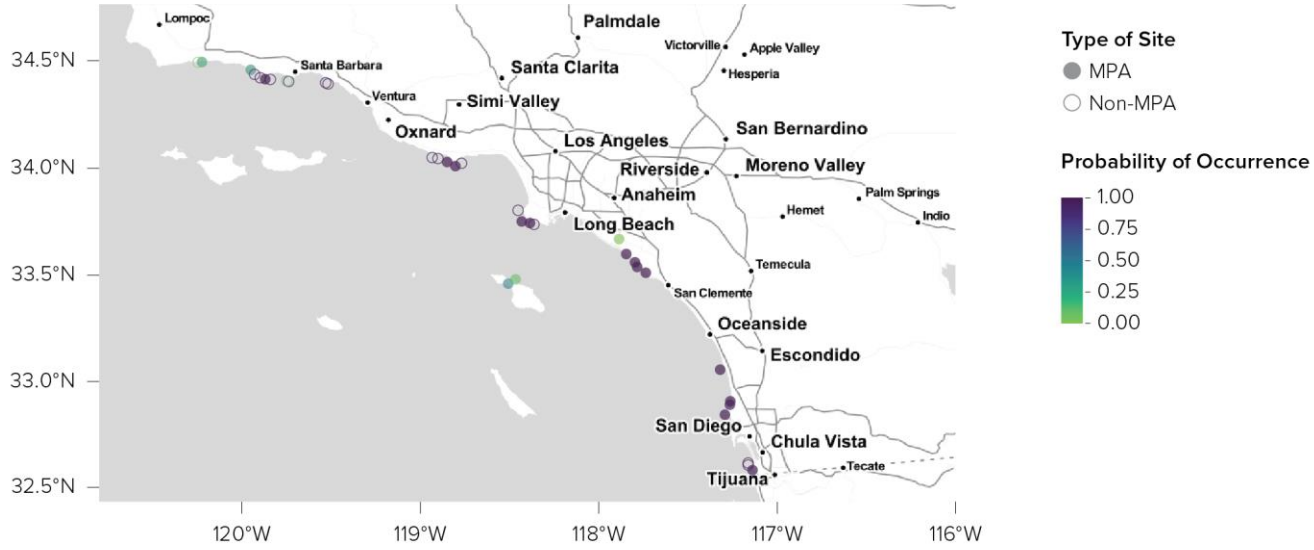


Figure 6. Occupancy model output showing site-level probability of tidepooling occurrence in the South Coast bioregion for MPA (filled circles) and non-MPA (outlined circles) sites. Lighter greens indicate lower probabilities of the activity occurring in an average year, and darker blues indicate higher probabilities.

Do activity patterns change over time?

Yes. There is some variation from year to year in the probability of activities occurring at the statewide level for 2012–2020, but no clear trends. Some activities show the possible beginnings of trends: for example, tidepooling seems to be gradually declining over the past nine years (Figure 5B). However, the existing time series is not long enough to disentangle trends from typical yearly variation.

Do different sites experience more or less human activity?

Yes. In our analysis, activities vary across different sites based on unmodeled attributes beyond MPA or non-MPA status. Some activities, like onshore recreation, occur consistently across all sites. Other activities, such as tidepooling, are more likely to occur at some sites than others (Figure 6) The model does not tell us anything about the numbers of people at different sites, but just the probability of at least one person tidepooling in an average year at that site. The variation in site-level effects uncovered in this phase of analysis highlights a promising area for further work to understand how different specific site attributes beyond MPA status influence activity patterns. These attributes could include factors like parking, site amenities, and natural attributes of the site like coastline type (e.g. beach versus bluff). Future models can explicitly include and test for the impacts of these factors.

Does population density explain human activity patterns across sites?

Not in this analysis. California's coast encompasses a wide range of population densities, from dense metropolitan areas to less populated rural sites, and these differences in population may impact coastal activity. We tested the influence of nearby population density (from U.S. Census data, see Appendix B for more details) on activity occurrence at each site. However, model results showed that **this measure of population density had no influence on the probability of an activity occurring**; this means that all recorded activities were equally likely to occur in an average year along all of California's MPAs, regardless of population density differences. Future work could also test different measures of population density to assess effects on human activity occurrence, in addition to testing the influence of additional site-specific attributes.

What are the patterns of "potential violations" in MPA sites?

In this project, we assessed patterns of *potential* violations of MPA regulations. MPA Watch surveyors do not directly report potential violations. Instead MPA Watch used lists of prohibited activities at each MPA site to retroactively identify observations that constitute a potential violation, based on those site-specific regulations. This method may overcount violations due to challenges in differentiating between permitted and prohibited activities that are visually similar (e.g., certain types of onshore fishing may be permitted, but they may resemble prohibited types of onshore fishing). Furthermore, the overcounting issue is likely uneven across sites: data for so-called "no-take" MPAs may be much more accurate than for those MPAs that allow various kinds of consumptive activities.

At most sites, our model estimates a high probability of at least one potential violation occurring in an average year.

It is important to remember that a high probability of occurrence does not mean that potential violations occur in large numbers; rather, it means that most sites have at least one potential violation in an average year. The actual number of violations at a given site may still be quite low. Activity frequency – or the total number of potential violations in a given year, at a given site – is not addressed by the occupancy modeling approach.

To illustrate, drawing on raw data from MPA Watch: there are 2,925 surveys with at least one possible violation, amounting to around 13 percent of all surveys conducted in MPAs from 2012 through 2020. Though year-to-year variation was not statistically significant, the raw data suggest a decreasing trend (Figure 7). More years of data and a more consistent method of identifying potential violations would help to definitively answer whether there is a decrease. The model indicated that it is 96% likely that sites had at least one violation in an average year, though a few sites had significantly lower probabilities: Sea Lion Cove; Kashtayit; and Dana Point.

We urge caution in interpreting model results for potential violations, but nevertheless report them here. We believe that, with some adjustments and coordination with CDFW, there is strong potential for MPA Watch to generate useful data about potential violations at a scale that complements the data gathered by law enforcement.

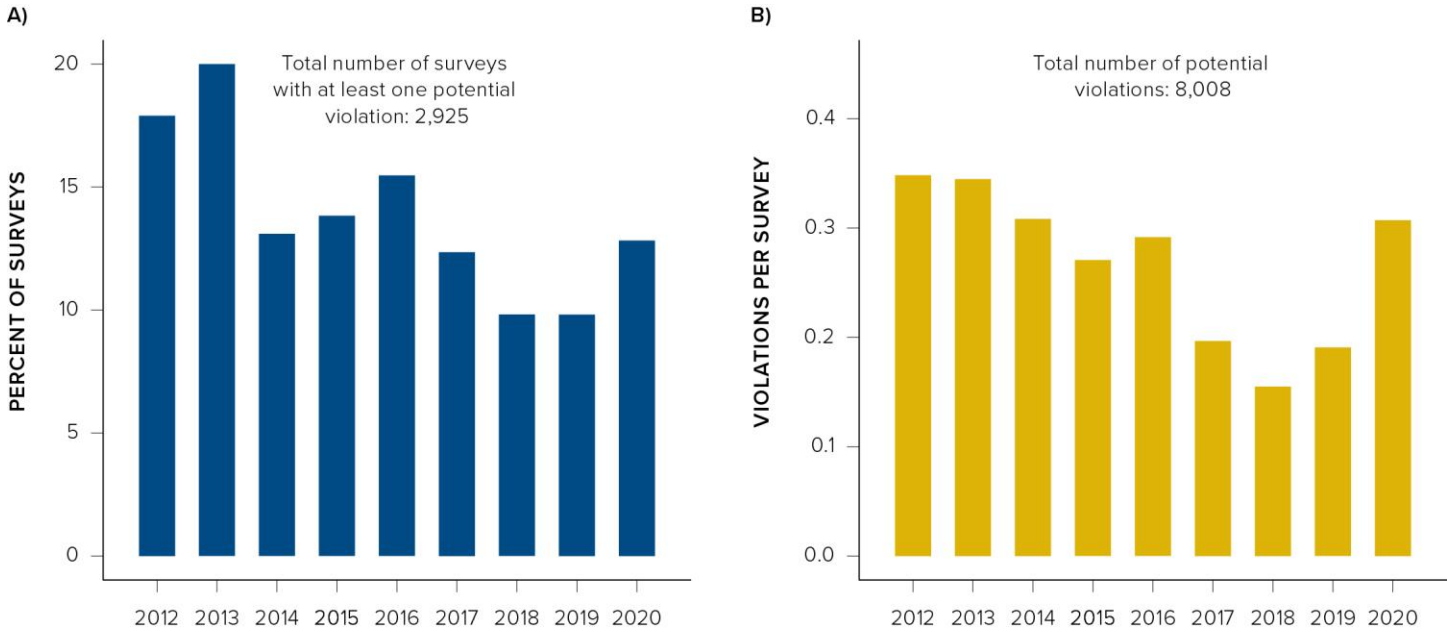


Figure 7. Panel A: Annual percentage of surveys conducted at MPA sites with at least one potential violation observed, from 2012 through 2020 (these are the data used in the model). Panel B: Number of potential violations per survey from 2012 through 2020.

Challenges and Recommendations

This project provides the first formal statistical analysis of MPA Watch data. We find that MPA Watch is generating a valuable dataset that can be used to robustly assess human activities along California's coast, both within and beyond MPAs. This analysis uncovered particular challenges in navigating the rich but complex nature of community science data, and suggests ways to build the contributions of MPA Watch to MPA and coastal management in California, through further analysis.

Challenges

Modeling limitations

This round of modeling simplified MPA Watch data to focus on the presence or absence of activities at MPA and non-MPA sites, and to examine patterns at the annual, statewide scale. Richer insights might be found by addressing activity counts at finer spatial and temporal scales, instead of presence or absence, although this will come with its own statistical challenges.

Relatively short time series

Our analysis did not reveal robust time trends in human activities from 2012–2020 at the statewide level. It is possible that some trends are underway, but that nine years is too short a timeframe for long-term change to be distinct from year-to-year variation.

Analyzing potential violations

As described above, the potential violations data used for this analysis have some flaws that could be addressed through a statewide protocol for direct observations (rather than retroactively processing the data, as was done for this analysis).

Recommendations

For future analyses

There is strong potential to gain more insights at finer spatial scales, and for specific activities of interest (as opposed to large groupings of diverse activities such as “onshore recreation’’). We recommend that future modeling efforts experiment with:

- Testing the impact of site-specific attributes on activities;
- Modeling activity counts, rather than presence or absence;
- Studying within-year patterns of use; and
- Repeating analysis as the time series extends.

For the MPA Watch network

MPA Watch can make improvements to its program without sacrificing the utility of past data through:

- Consistently applying the existing surveyor unique ID, to help account for differences between surveyors.
- Updating protocols for recording potential violations, in collaboration with CDFW.

We also note two other more significant potential changes, which likely would require more data analysis and strategic planning before moving forward:

- We recommend that program managers and state partners develop a strategy and experimental design framework for designating future reference (non-MPA) sites.
- Survey effort could be balanced more evenly across sites and times of year. This likely cannot be done on a statewide basis, given the realities of travel times and distinct local programs in the network. But individual programs could develop incentives and targets to address local imbalances.

For MPA management

Sustain and expand the MPA Watch network. With continued support by the State and other funders, the value of MPA Watch data will grow over time. Continued monitoring could reveal statewide temporal trends that may be occurring, but are not yet detectable with only nine years of data. This could be enhanced still further if MPA Watch received support to expand monitoring to more MPA sites.

Leverage MPA Watch as part of a broader strategy for human dimensions research and monitoring. To help focus further analyses, MPA managers should identify specific questions (e.g., about specific activities, covariates, and/or focal areas) that fit into a broader human dimensions research agenda for MPAs, which has been called out as an important knowledge gap by the California Ocean Protection Council’s Science Advisory Team.[10] We note also the MPA Watch network represents significant statewide capacity that could be leveraged for other data collection activities focused on human dimensions (e.g., on-site surveys of MPA users).

Align approaches to monitoring of potential violations. There is an opportunity to coordinate and develop shared expectations between MPA Watch and CDFW, and improve the role of MPA Watch data in enforcement and compliance.

[10] Hall-Arber, M., Murray, S., Aylesworth, L., Carr, M., Field, J., Grorud-Colvert, K., Martone, R., Nickols, K., Saarman, E., Wertz, S. Scientific Guidance for California’s MPA Decadal Reviews: A Report by the Ocean Protection Council Science Advisory Team Working Group and California Ocean Science Trust, June 2021. https://www.oceansciencetrust.org/wp-content/uploads/2021/06/Evaluating-California%E2%80%99s-Marine-Protected-Area-Network-2021.pdf

The **Center for Community and Citizen Science**, based at the UC Davis School of Education, helps scientists, communities, and citizens collaborate on science to address environmental problems as a part of civic life. The Center was founded in 2016 and engages a wide array of on and off-campus partners to advance research, practice, and dialog on community and citizen science.

The mission of the **Center for Environmental Policy and Behavior (CEPB)** is scientific analysis of the interactions among policy institutions, human behavior, and political decisions in the context of environmental and natural resource conflicts. Through developing and testing theoretical models from social science, CEPB seeks to derive practical lessons that can be used to improve environmental policy.

The **UC Davis DataLab** seeks to promote academic and research excellence through quality programs, engaged researchers, and an innovative research and learning environment and to meet growing industry and academic need for graduates with data science skills.

CENTER FOR
COMMUNITY
AND CITIZEN SCIENCE

UC Davis School of Education
1 Shields Avenue
Davis, CA 95616

ccs@ucdavis.edu

Appendix A: Further details on the MPA Watch dataset

This appendix contains the following additional details regarding the MPA Watch network and its associated dataset:

MPA Watch core data sheet

Name(s):		Date: ___/___/_____	Transect ID:
Start Time:	End Time:	Clouds: clear (0%)/ partly cloudy (1-50%)/ cloudy (>50%cover)	Precipitation: yes / no
Air Temperature: cold / cool / mild / warm / hot		Wind: calm / breezy / windy	Tide Level: low / med / high
Visibility: perfect / limited / shore only		Beach Status: open / posted / closed / unknown	

On-Shore Activities	Rocky	Sandy
Recreation (walking, resting, playing, etc. NOT tidepooling)		
Wildlife Watching		
Domestic animals on-leash		
Domestic animals off-leash		
Driving on the Beach		
Tide-pooling (not collecting)		
Hand collection of biota		
Shore-based hook and line fishing		
Shore-based trap fishing		
Shore-based net fishing		
Shore-based spear fishing		

Off-Shore Activities (Non-Boating)	
Offshore Recreation (e.g., swimming, bodysurfing)	
Board Sports (e.g., boogie boarding, surfing)	
Stand-Up Paddle Boarding (alternatively can tally in paddle operated boat below)	
Non-Consumptive SCUBA and snorkeling	
Spear Fishing (free diving or SCUBA)	
Other Consumptive Diving (e.g., nets, poles, traps)	

Boating	Recreational		Commercial		Unknown	
	Inactive	Active	Inactive	Active	Inactive	Active
Boat Fishing - Traps						
Boat Fishing - Line						
Boat Fishing - Nets						
Boat Fishing - Dive						
Boat Fishing - Spear						
Boat Kelp Harvesting						
Unknown Fishing Boat						
Paddle Operated Boat (can separately tally stand-up paddle boarding above under board sports)						
Dive Boat (stationary – flag up)						
Whale Watching Boat						
Work Boat (e.g., life-guard, DFW, research, coast guard)						
Commercial Passenger Fishing Vessel (5+ people)						
Other Boating (e.g., powerboat, sail boat, jet ski)						

Comments

Did you observe: ☐ scientific research; ☐ education; ☐ beach closure; ☐ large gatherings (e.g., beach cleanup); ☐ enforcement activity

Describe below and provide counts of individuals involved where possible, and whether it took place on rocky or sandy or sandy substrate.

Did you report a violation: ☐ yes ☐ no If yes, how many violations did you report _____

Who did you report the violation to (mark all that apply): ☐ DFW ☐ State Parks ☐ other entity (e.g., lifeguard, harbor patrol)

Which method did you use to report your violation (mark all that apply): ☐ phone call ☐ text ☐ mobile app ☐ website ☐ email ☐ in person

Guide to the seven categories of human activity used in our analysis

To facilitate data modeling and interpretation, we grouped MPA Watch Core Tally Sheet activities into larger activity categories. Certain activities on the MPA Watch Core Tally Sheet were excluded from analysis on the basis of very low occurrence over 10 years (e.g. Kelp Harvesting, Driving). Activities with a * are on the Tally Sheet, but as presence checkboxes, not counts. Activities with a ^ are present in a combined category on the Tally Sheet, and are differentiated here.

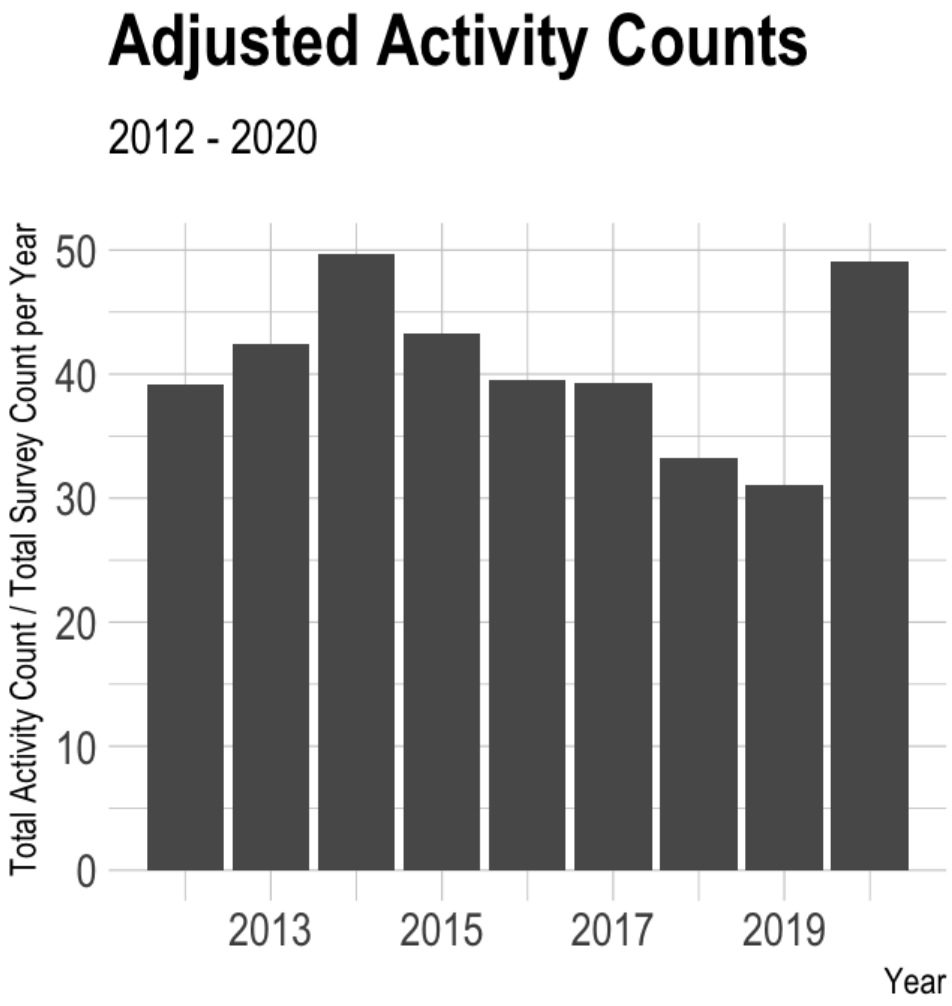
1. Onshore recreation
    a. Shore-based recreation (sandy) (NOT tidepooling)
    b. Shore-based recreation (rocky) (NOT tidepooling)
2. Domestic animals
    a. Domestic animals on-leash (sandy)
    b. Domestic animals on-leash (rocky)
    c. Domestic animals off-leash (sandy)
    d. Domestic animals off-leash (rocky)
3. Tidepooling
    a. Tidepooling
4. Onshore fishing
    a. Shore-based hook fishing (sandy)
    b. Shore-based hook fishing (rocky)
    c. Shore-based trap fishing (sandy)
    d. Shore-based trap fishing (rocky)
    e. Shore-based net fishing (sandy)
    f. Shore-based net fishing (rocky)
    g. Shore-based spear fishing (sandy)
    h. Shore-based spear fishing (rocky)
5. Offshore recreation
    a. Offshore recreation
    b. Board sports
    c. Surfing/boogie boarding ^
    d. Kitesurfing/windsurfing ^
    e. Stand-up paddle boarding (alternatively can tally in paddle operated boat)
    f. Non-consumptive scuba/snorkeling
6. Offshore fishing
    a. Boat fishing, traps, recreational (inactive)
    b. Boat fishing, traps, recreational (active)
    c. Boat fishing, traps, commercial (inactive)
    d. Boat fishing, traps, commercial (active)

   e. Boat fishing, traps, unknown (inactive)
   f. Boat fishing, traps, unknown (active)
   g. Boat fishing, line, recreational (inactive)
   h. Boat fishing, line, recreational (active)
   i. Boat fishing, line, commercial (inactive)
   j. Boat fishing, line, commercial (active)
   k. Boat fishing, line, unknown (inactive)
   l. Boat fishing, line, unknown (active)
   m. Boat fishing, nets, recreational (inactive)
   n. Boat fishing, nets, recreational (active)
   o. Boat fishing, nets, commercial (inactive)
   p. Boat fishing, nets, commercial (active)
   q. Boat fishing, nets, unknown (inactive)
   r. Boat fishing, nets, unknown (active)
   s. Boat fishing, dive, recreational (inactive)
   t. Boat fishing, dive, recreational (active)
   u. Boat fishing, dive, commercial (inactive)
   v. Boat fishing, dive, commercial (active)
   w. Boat fishing, dive, unknown (inactive)
   x. Boat fishing, dive, unknown (active)
   y. Boat fishing, spear, recreational (inactive)
   z. Boat fishing, spear, recreational (active)
   aa. Boat fishing, spear, commercial (inactive)
   bb. Boat fishing, spear, commercial (active)
   cc. Boat fishing, spear, unknown (inactive)
   dd. Boat fishing, spear, unknown (active)
7. Recreational boating
   a. Paddle Operated Boat
   b. Kayak
   c. Power boat^
   d. Sail boat^
   e. Jet ski^
   f. Dive boat
   g. Whale Watching Boat
8. Excluded activities from MPA Watch Core Tally Sheet
   a. Wildlife watching (sandy)
   b. Wildlife watching (rocky)
   c. Driving on the Beach
   d. Hand collection of biota (sandy)
   e. Hand collection of biota (rocky)
   f. Spear fishing (free diving or SCUBA)
   g. Other consumptive diving
   h. Kelp harvest (commercial, active)

i. Kelp harvest (commercial, inactive)
j. Kelp harvest (unknown, active)
k. Kelp harvest (unknown, inactive)
l. Work boat
m. Commercial passenger fishing vessel
n. Other boating
o. Onshore enforcement*^
p. Boat-based enforcement*^
q. Onshore border patrol*^

Adjusted counts of activities over time

Typical numbers of people observed using coastal areas ranged from 30-50 per survey. The increase until 2014 and subsequent decline until 2019 could be due to the expansion of the MPA Watch network first in the south, with greater numbers of people using beaches and other areas, and then into more northern sites with fewer numbers of people engaging in the activities. This uneven distribution of sites over time is one reason for using the statistical models detailed in Appendix B, which account for such biases. The peak in 2020 could be due to the COVID-19 pandemic causing more people to choose to recreate outside, but further study as the pandemic evolves over time will allow a more careful analysis.



Number of surveys conducted at each site

Table A1: All sites, ordered North to South, and the number of surveys in each year. Note that these are the surveys used in the occupancy model; there may be more surveys in the larger dataset.

Site Name	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Pyramid Point SMCA	0	0	0	0	0	0	27	12	81
False Klamath Rock Special Closure	0	0	0	0	0	0	79	66	13
Samoa SMCA	0	0	0	0	0	0	0	0	4
CONTROL Manila Dunes	0	0	0	0	0	0	1	0	4
Sea Lion Gulch SMR	0	0	0	0	0	1	0	0	0
MacKerricher SMCA	0	0	0	0	0	0	0	0	13
Point Cabrillo SMR	0	0	0	0	0	0	0	0	4
Russian Gulch SMCA	0	0	0	0	0	0	0	0	4
CONTROL Big River Estuary	0	0	0	0	0	0	0	0	4
Big River Estuary SMCA	0	0	0	0	0	0	0	0	4
Van Damme SMCA	0	0	0	0	0	0	0	0	4
CONTROL South Manchester Beach	0	0	2	13	12	25	22	20	7
Sea Lion Cove SMCA	0	0	0	12	12	17	26	21	16

Site Name	2012	2013	2014	2015	2016	2017	2018	2019	2020
Del Mar Landing SMR	0	0	0	13	13	16	25	23	9
CONTROL Walk On Beach	0	0	3	23	14	14	24	25	16
CONTROL Black Point Beach	0	0	5	25	26	19	22	24	15
Stewarts Point SMR	0	0	2	12	2	11	15	14	2
Russian River SMRMA	0	0	3	18	14	26	17	21	15
Russian River SMCA	0	0	5	32	24	34	34	38	18
CONTROL Miwok Beach	0	0	2	21	22	25	27	22	15
CONTROL Salmon Creek Beach	0	0	3	12	19	23	25	23	12
CONTROL Doran Beach	0	0	5	27	25	26	25	23	14
Bodega Head SMR	0	0	4	42	38	39	48	40	11
CONTROL Pinnacle Gulch	0	0	3	15	12	13	18	10	5
CONTROL Dillon Beach	0	0	5	26	21	21	25	19	15
CONTROL Brazil Beach	0	0	5	24	25	22	21	22	14
CONTROL Point Reyes Beach A	0	0	4	27	26	24	25	24	8
CONTROL Tomasini Creek Ranch	0	0	4	23	23	25	21	12	13
CONTROL Point Reyes Beach B	0	0	5	23	23	21	20	19	9

Site Name	2012	2013	2014	2015	2016	2017	2018	2019	2020
CONTROL Point Reyes Beach C	0	0	4	25	25	25	22	22	8
Point Reyes SMR	0	1	34	100	63	79	133	100	45
Estero de Limantour SMR	0	0	13	59	34	49	83	67	28
Control PRSOUTH	0	0	9	22	4	12	44	23	11
CONTROL Limantour Beach East	0	0	4	25	18	21	23	18	5
Corte Madera Marsh SMP	0	0	0	16	37	31	16	16	14
CONTROL Bolinas Lagoon, Dipsea Road	0	0	4	23	25	26	24	21	9
CONTROL Seadrift	0	0	4	20	14	16	25	18	9
Duxbury Reef SMCA	0	0	3	33	91	74	48	62	88
CONTROL Muir Beach	0	0	5	19	13	8	19	9	13
CONTROL Rodeo Beach	0	0	4	25	26	25	25	21	19
CONTROL Kirby Cove	0	0	4	17	21	10	24	11	5
CONTROL Baker Beach	0	0	4	12	5	9	3	2	17
CONTROL China Beach	0	0	0	24	15	11	14	2	14
CONTROL Land's End	0	0	2	10	11	12	11	13	10

Site Name	2012	2013	2014	2015	2016	2017	2018	2019	2020
CONTROL Ocean Beach North	0	0	5	24	26	25	23	17	9
CONTROL Ocean Beach Central	0	0	4	15	13	14	19	23	13
CONTROL Thornton Beach North	0	0	4	18	12	15	11	8	5
CONTROL Sharp Park	0	0	5	24	25	24	21	22	12
CONTROL South Montara Beach	0	0	4	25	25	23	24	23	14
Montara SMR	0	0	16	100	97	89	82	72	29
CONTROL Pillar Point, Mavericks	0	0	5	27	24	20	26	24	13
CONTROL Half Moon Bay, Naples Beach	0	0	4	26	27	26	26	22	15
CONTROL Half Moon Bay, Frances Beach	0	0	4	25	23	14	10	12	0
CONTROL Pomponio Headlands	0	0	2	12	13	23	16	21	5
CONTROL Pescadero Beach	0	0	4	24	25	25	23	23	11
CONTROL Pebble Beach	0	0	4	24	24	21	24	19	10
Control Bean Hollow	0	0	40	58	16	0	0	0	0
Ano Nuevo SMCA	0	0	34	96	70	65	71	57	25

Site Name	2012	2013	2014	2015	2016	2017	2018	2019	2020
Control Coastal Bluffs	0	0	39	45	84	31	0	0	0
CONTROL Seacliff State Beach	0	0	0	0	0	0	0	29	208
Natural Bridges SMR	0	0	34	55	107	11	0	0	0
CONTROL Natural Bridges State Park	0	0	0	0	0	0	0	19	6
Asilomar SMR	0	0	61	163	131	25	21	33	22
Lovers Point SMR	0	0	102	135	161	27	14	36	23
Control 17 Mile Drive	0	0	28	77	72	27	23	13	3
Point Lobos SMR	0	0	49	88	72	11	12	11	8
Control Malpaso	0	0	18	63	46	11	9	1	0
Cambria SMCA	0	0	51	54	177	26	3	2	0
Control Montana de Oro	0	0	50	113	97	40	33	10	0
Point Buchon SMR	0	0	12	27	32	8	0	0	0
Kashtayit SMCA	0	36	74	90	78	71	83	100	76
Control KWEST	0	18	38	44	39	35	42	51	37
Naples SMCA	4	31	60	77	51	34	41	70	34
Control NPEAST	0	18	35	39	22	17	42	53	25

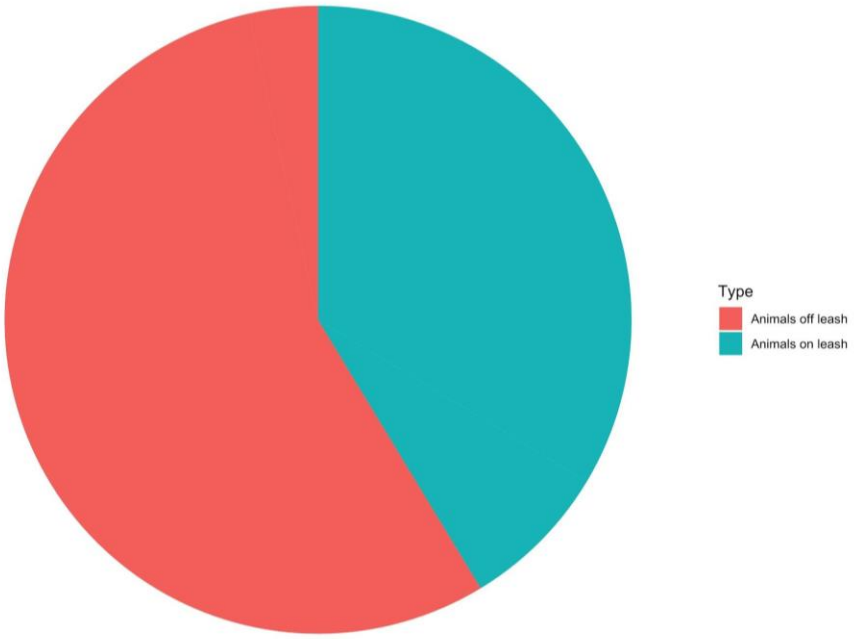
Site Name	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Control CPWEST	1	19	49	61	41	29	24	54	43
Control CPEAST	20	33	81	83	53	37	55	60	32
Control ABWEST	0	0	5	0	0	0	0	0	0
Control ABEAST	0	0	6	0	0	0	0	0	0
Campus Point SMCA	49	117	329	334	237	172	286	340	309
Control CARPW	0	0	2	0	33	14	9	0	0
Control CARPE	0	0	2	0	30	14	9	0	0
Control LEO	0	4	13	9	0	0	0	0	0
Control OW	12	66	27	12	11	4	3	4	2
Point Dume SMCA	108	206	169	144	123	51	70	93	65
Control OE	27	86	41	36	21	11	13	9	5
Point Dume SMR	207	224	191	262	168	79	118	86	58
Control PVON1	49	88	84	88	73	58	51	89	78
Point Vicente SMCA	116	177	193	176	115	123	121	188	164
Abalone Cove SMCA	62	113	94	90	65	68	76	99	110
Control PVOS1	27	61	36	36	35	41	35	46	64

Site Name	2012	2013	2014	2015	2016	2017	2018	2019	2020
Upper Newport Bay SMCA	0	0	77	90	100	84	82	128	81
Crystal Cove SMCA	0	0	56	87	93	109	70	156	156
Laguna Beach SMR	0	0	175	186	175	147	101	252	231
Laguna Beach SMCA	0	0	28	22	39	42	34	84	68
Dana Point SMCA	0	0	68	62	38	53	64	48	58
Blue Cavern (Catalina Island) SMCA	0	0	0	0	0	11	4	0	0
Cat Harbor (Catalina Island) SMCA	0	0	0	0	0	4	2	0	0
Swami's SMCA	0	6	47	28	0	2	30	100	130
San Diego-Scripps Coastal SMCA	0	8	25	7	0	5	16	8	10
Matlahuayl SMR	0	10	12	7	2	15	20	27	13
South La Jolla SMR	0	0	0	0	0	0	16	26	35
Control Outside Boundary 1 (TRM)	0	8	0	0	1	2	7	43	3
Control Outside Boundary 2 (TRM)	0	0	1	0	6	0	4	16	2
Tijuana River Mouth SMCA	0	55	136	45	25	12	3	9	1

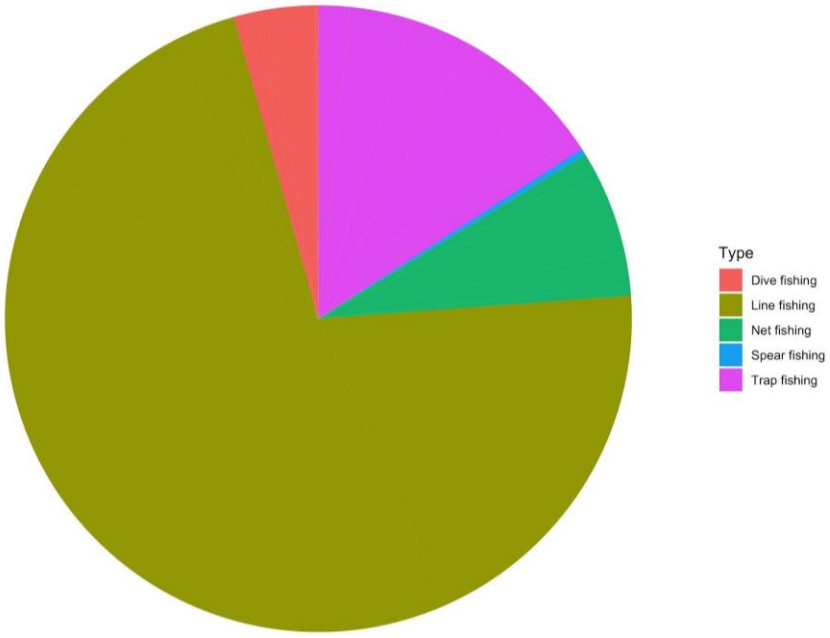
Breakdowns of Activity Categories

The following charts show the relative proportions of specific activities in each of the seven large categories used in our analysis.

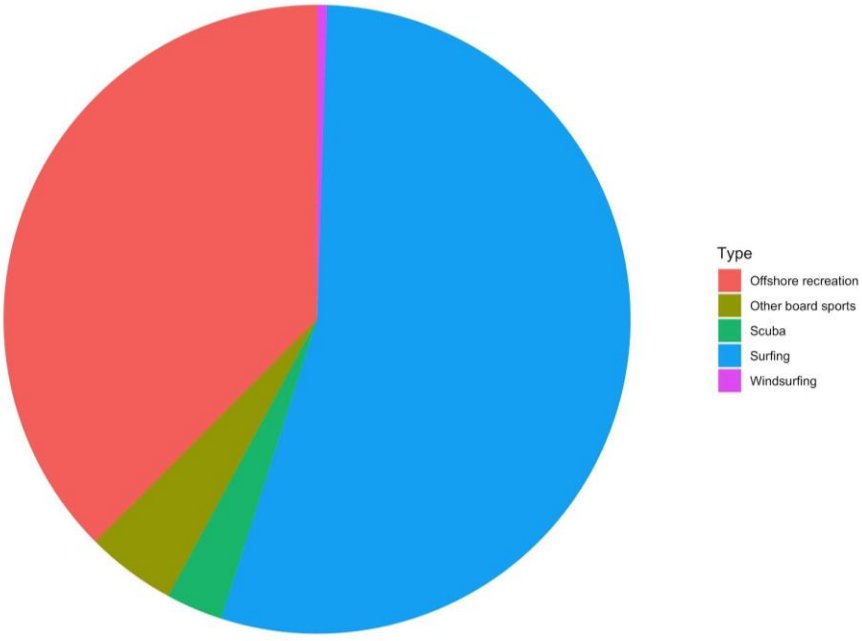
Domestic animals



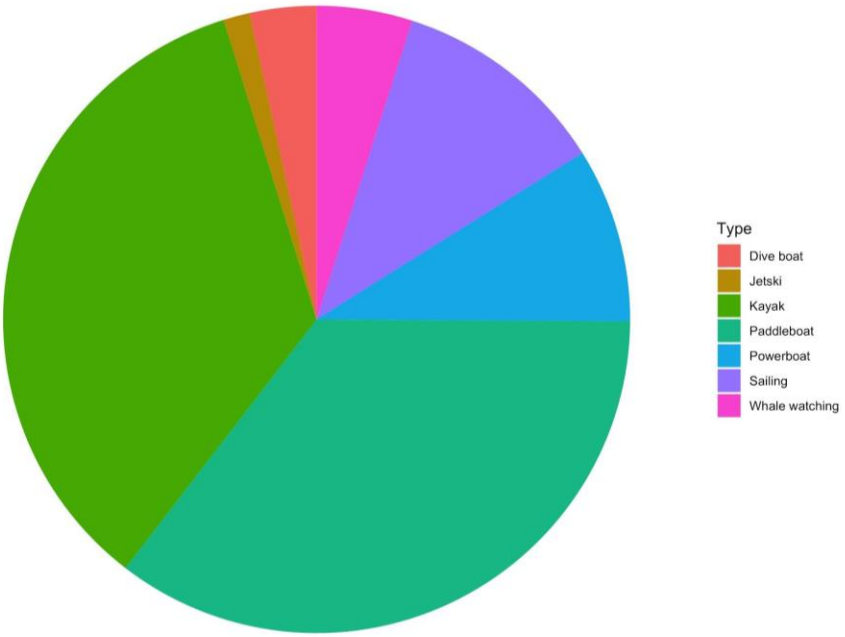
Offshore fishing



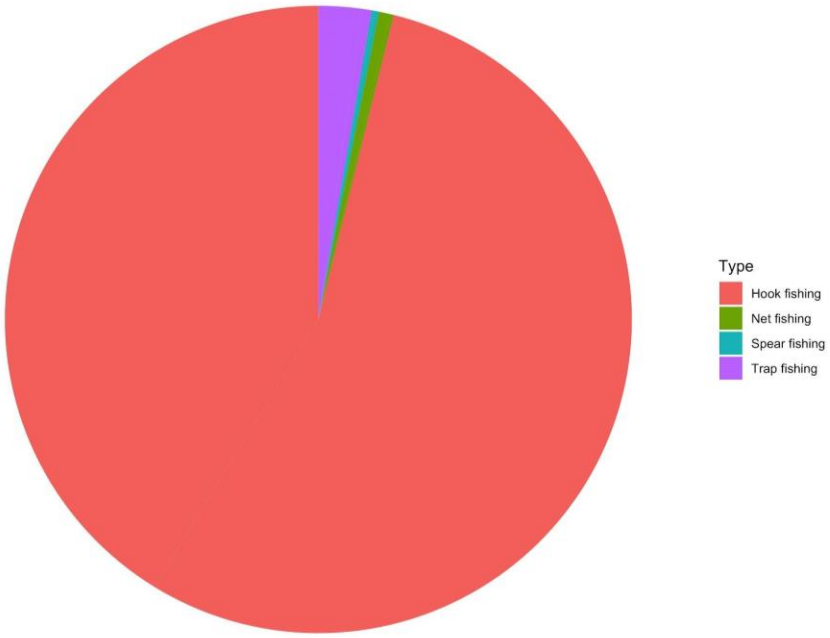
Offshore recreation



Recreational Boating



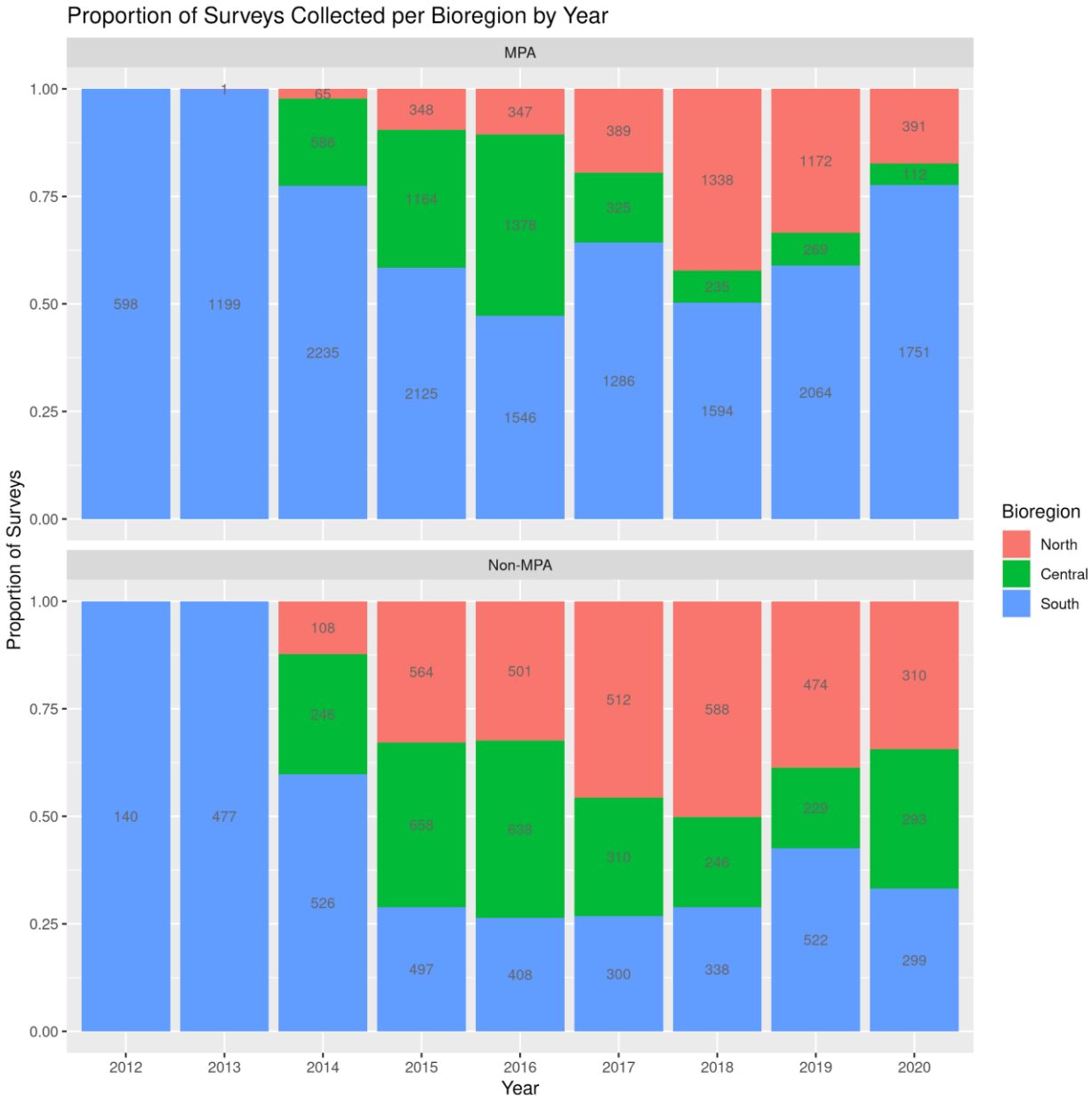
Onshore fishing



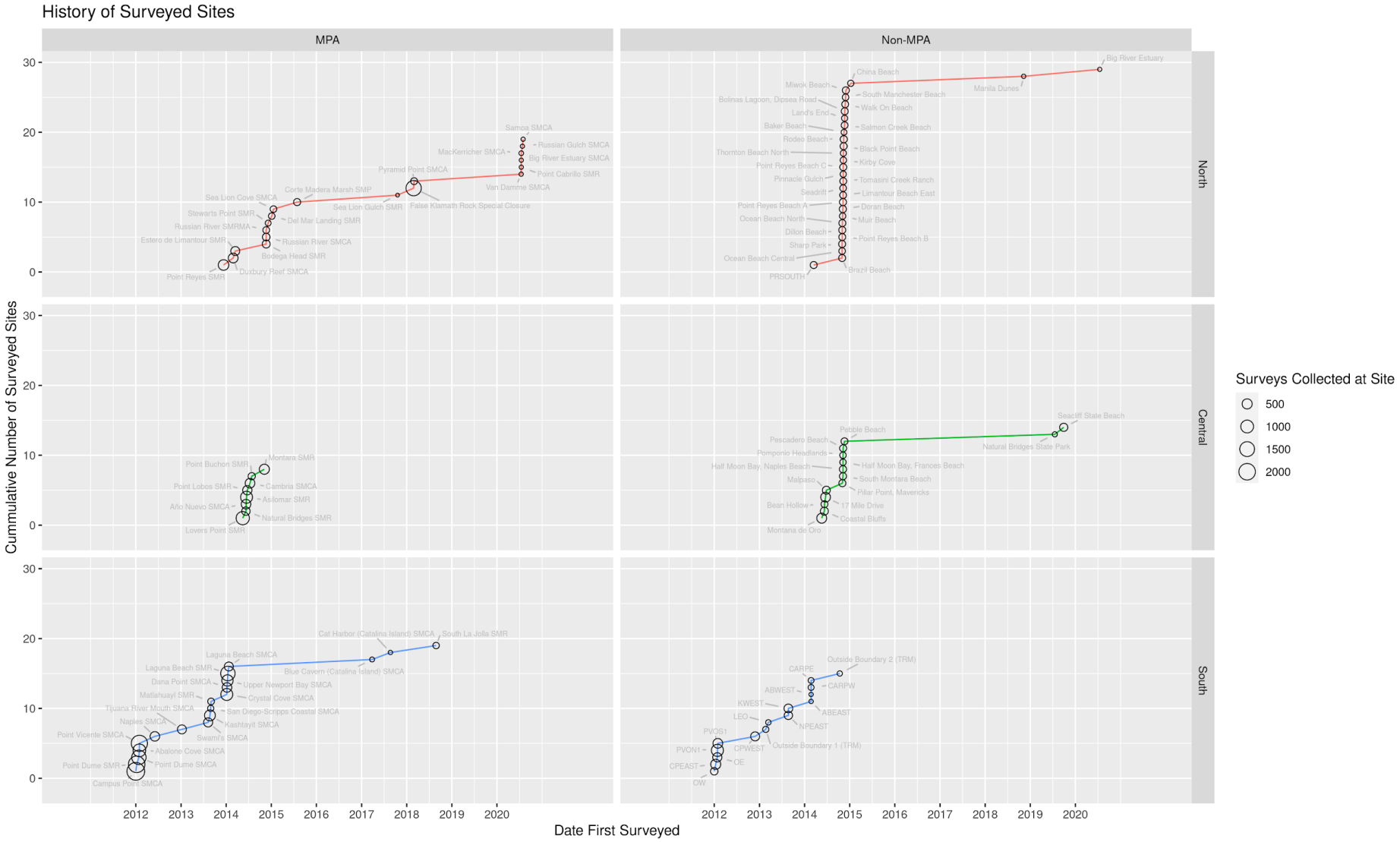
Data summaries by bioregion

Figures in this section summarize MPA Watch data in a variety of ways through the lens of MPA bioregions.

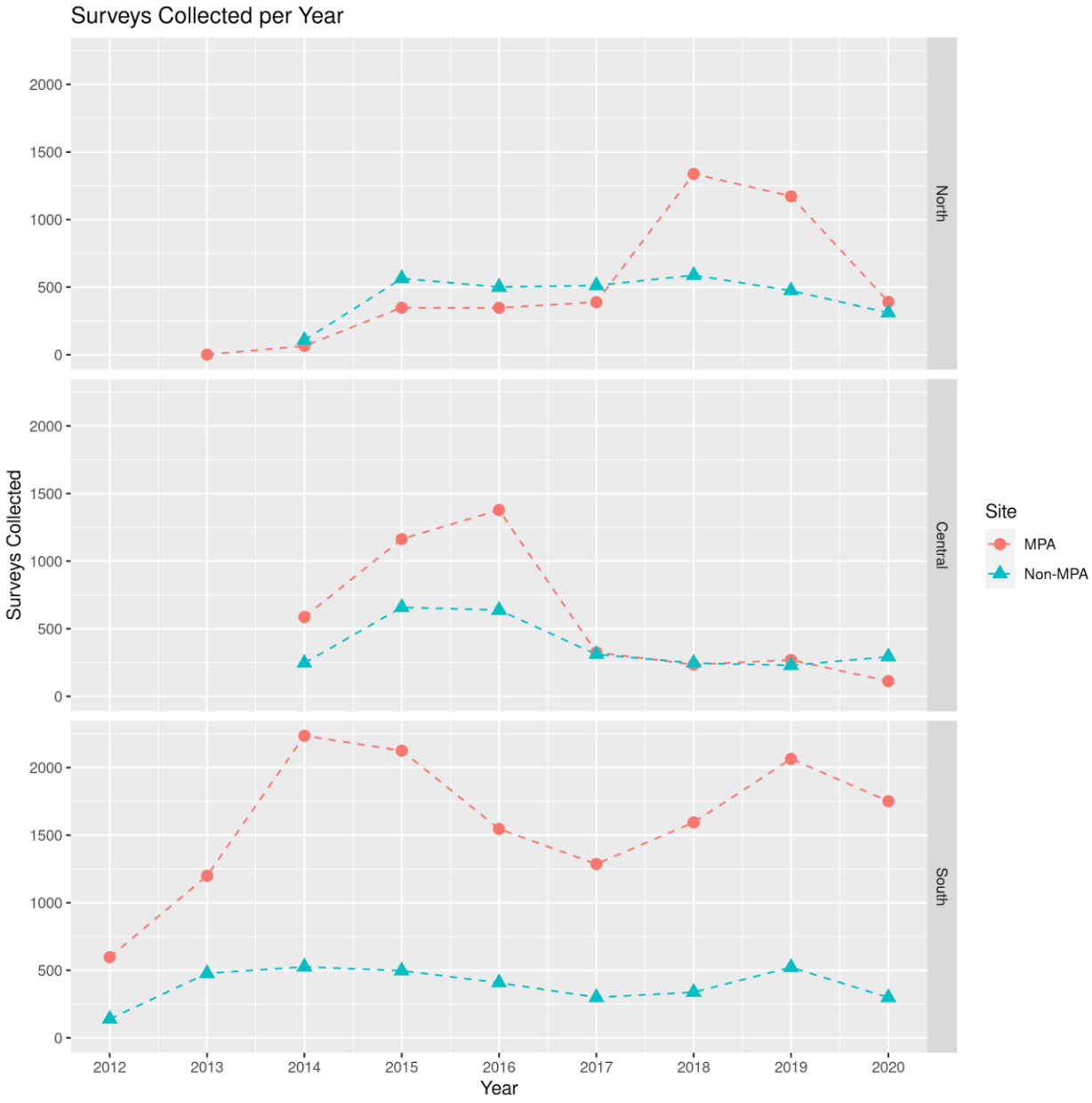
Proportion of surveys collected per bioregion by year



History of surveyed sites in each bioregion

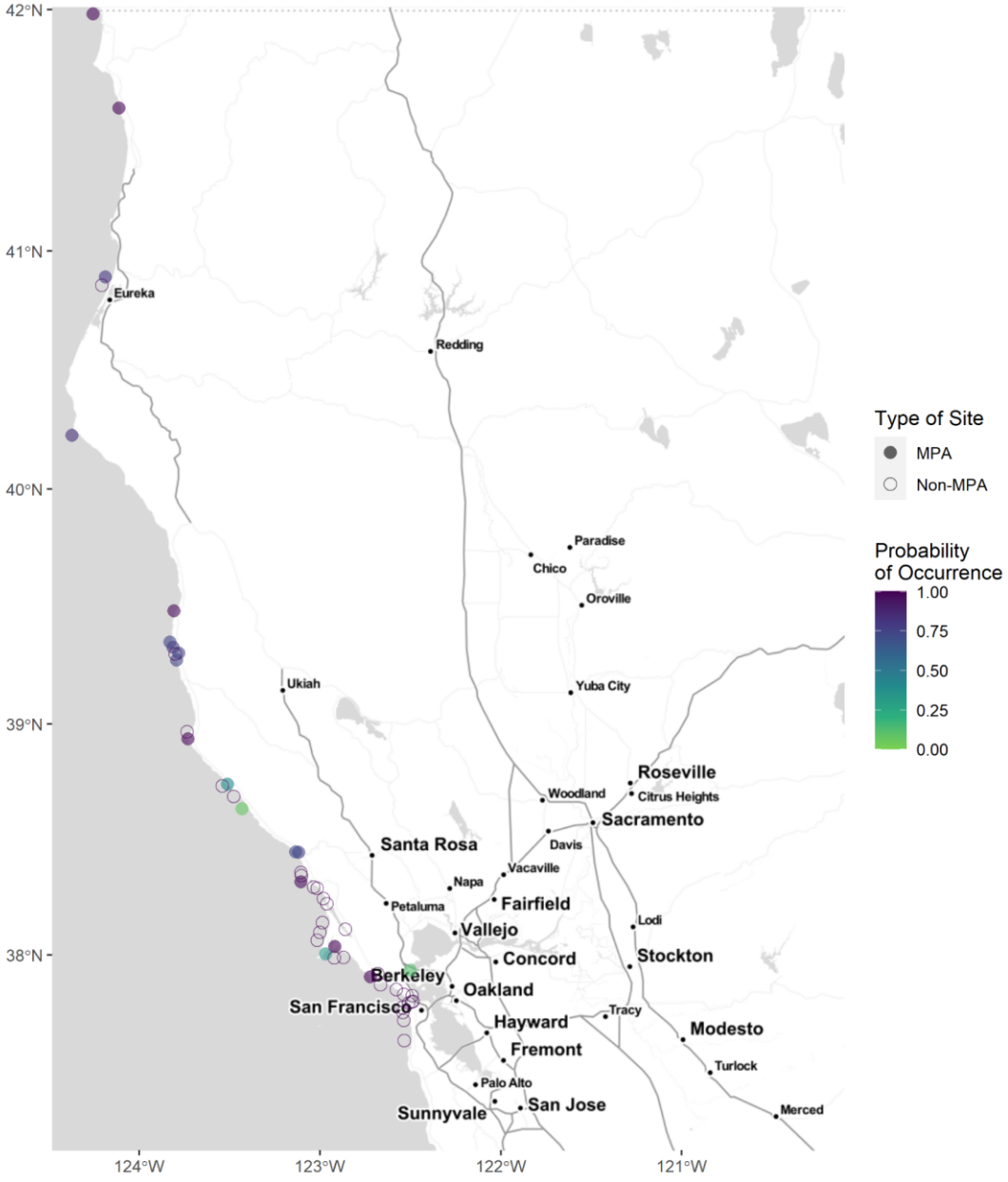


Surveys collected per year in each bioregion

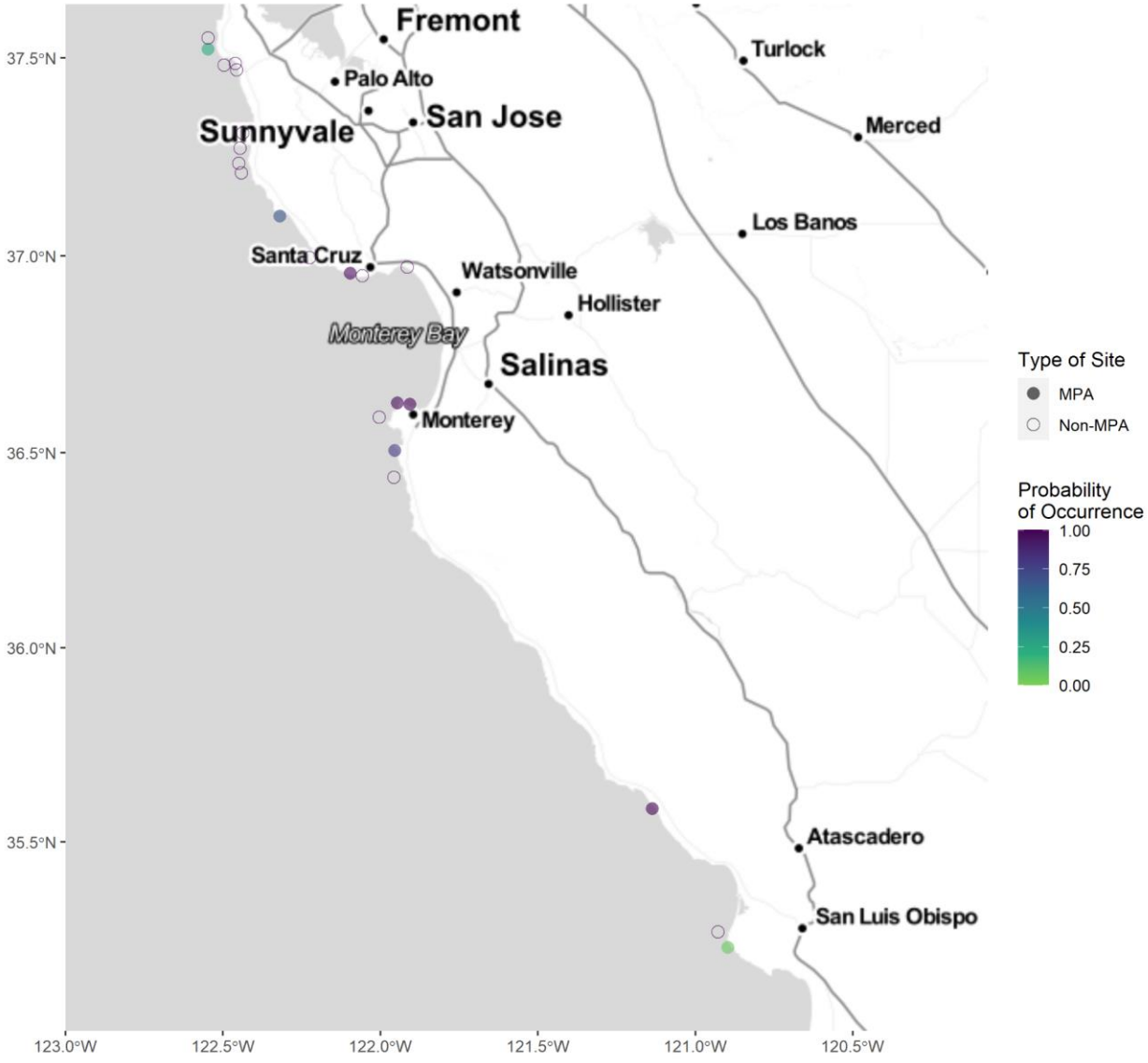


Occurrence probability for each site, broken down by bioregion

Onshore fishing - North Coast

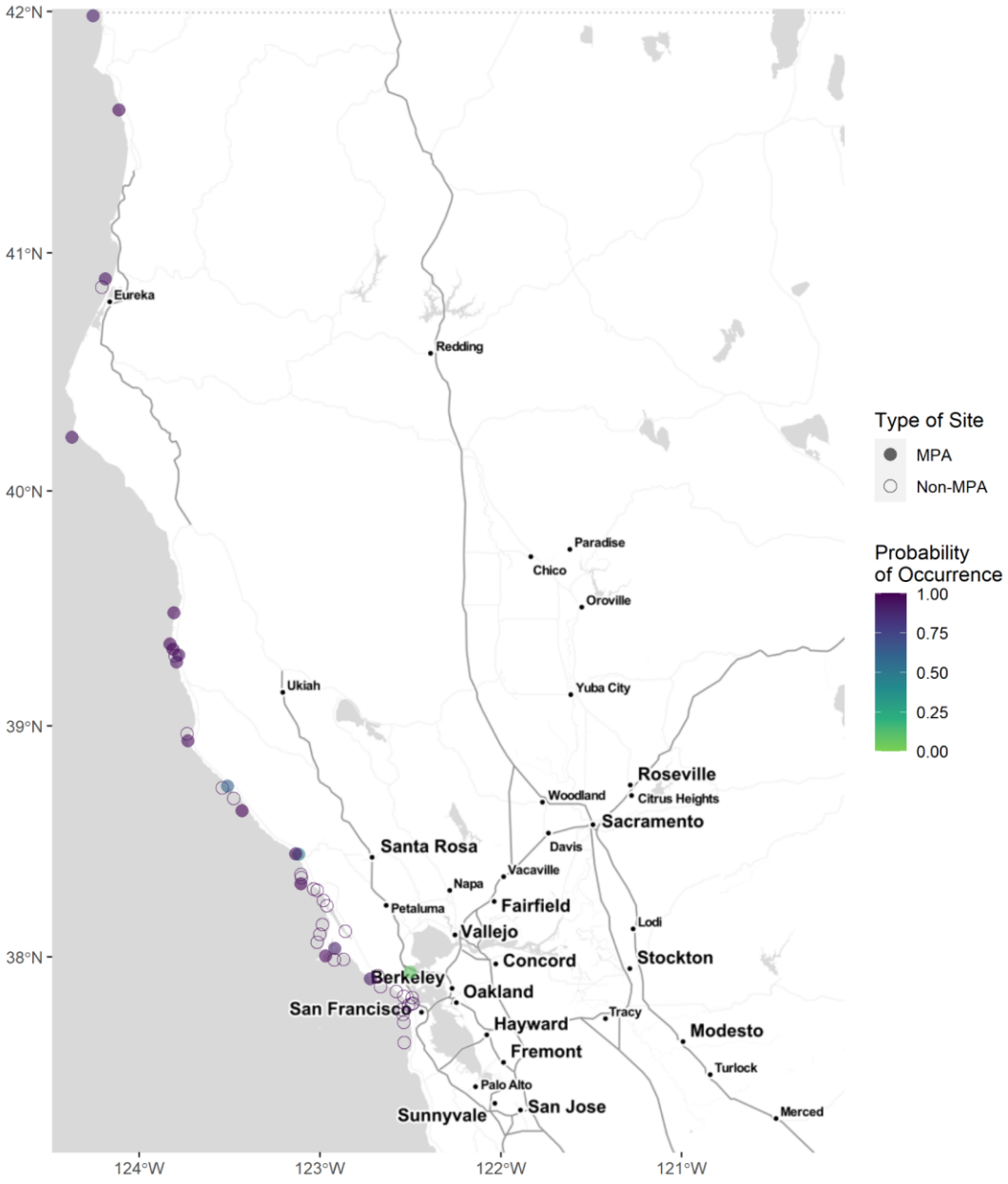


Onshore Fishing - Central Coast

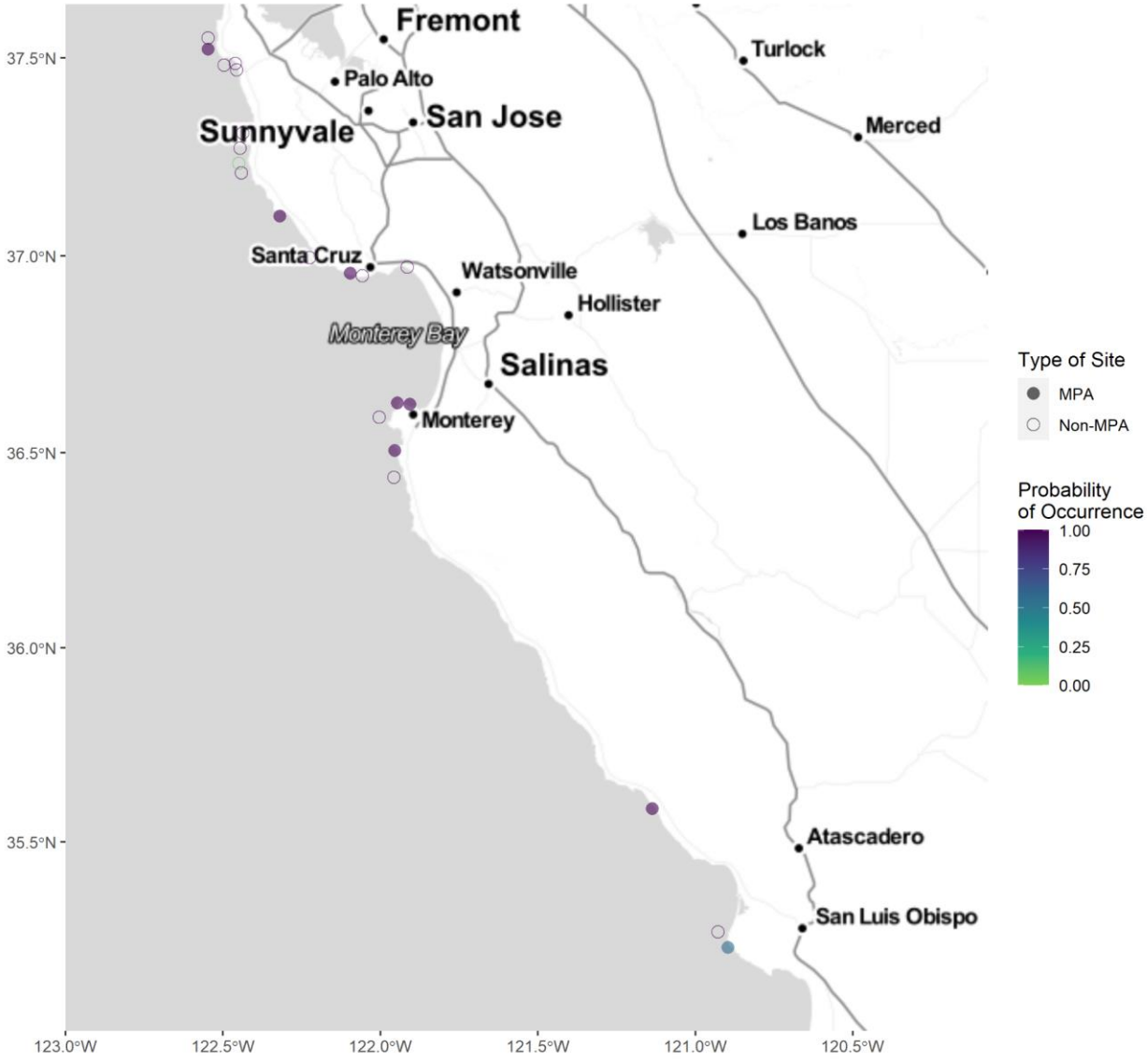


Onshore Fishing - South Coast

Offshore fishing - North Coast

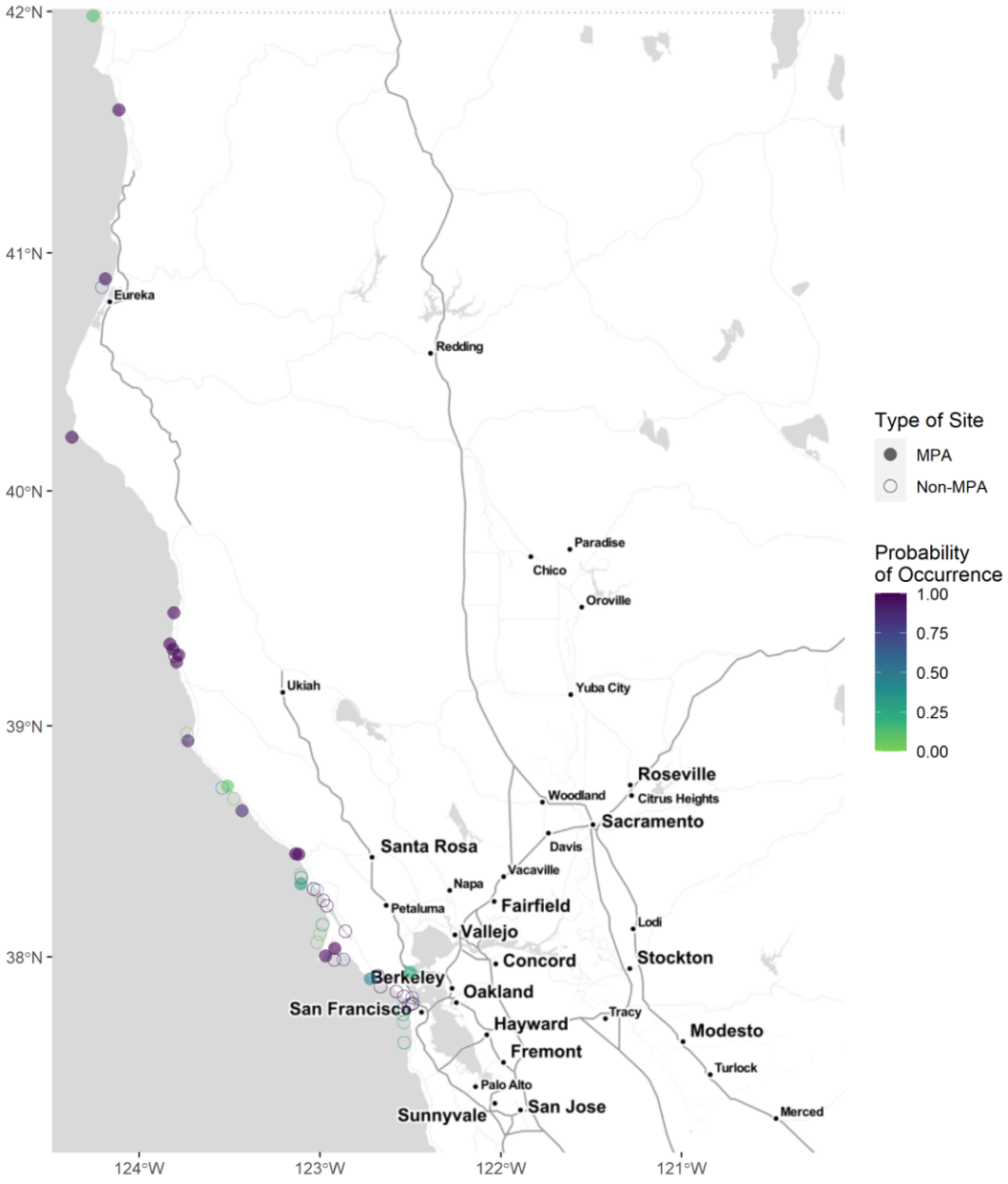


Offshore fishing - Central Coast

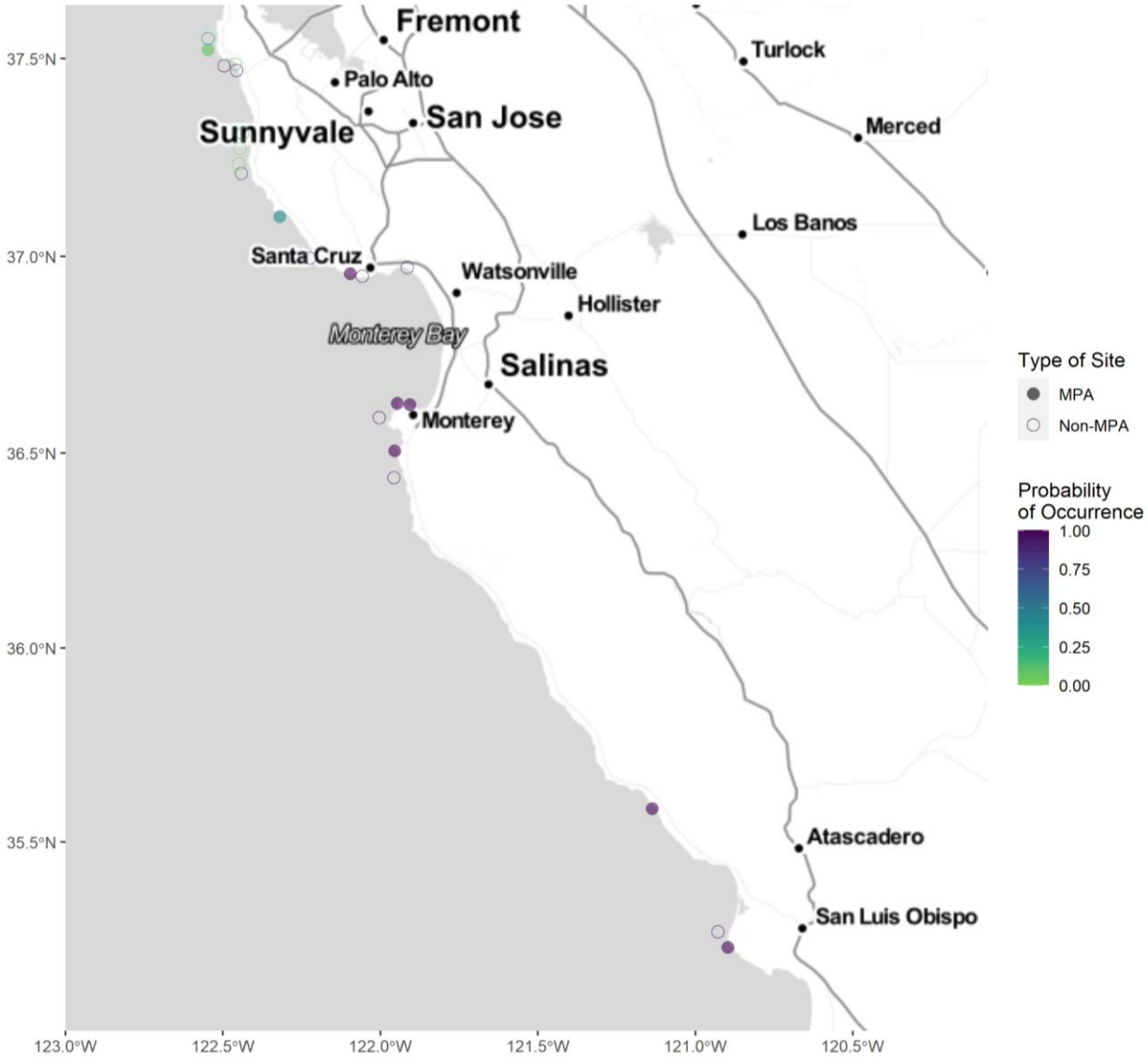


Offshore fishing - South Coast

Recreational boating - North Coast

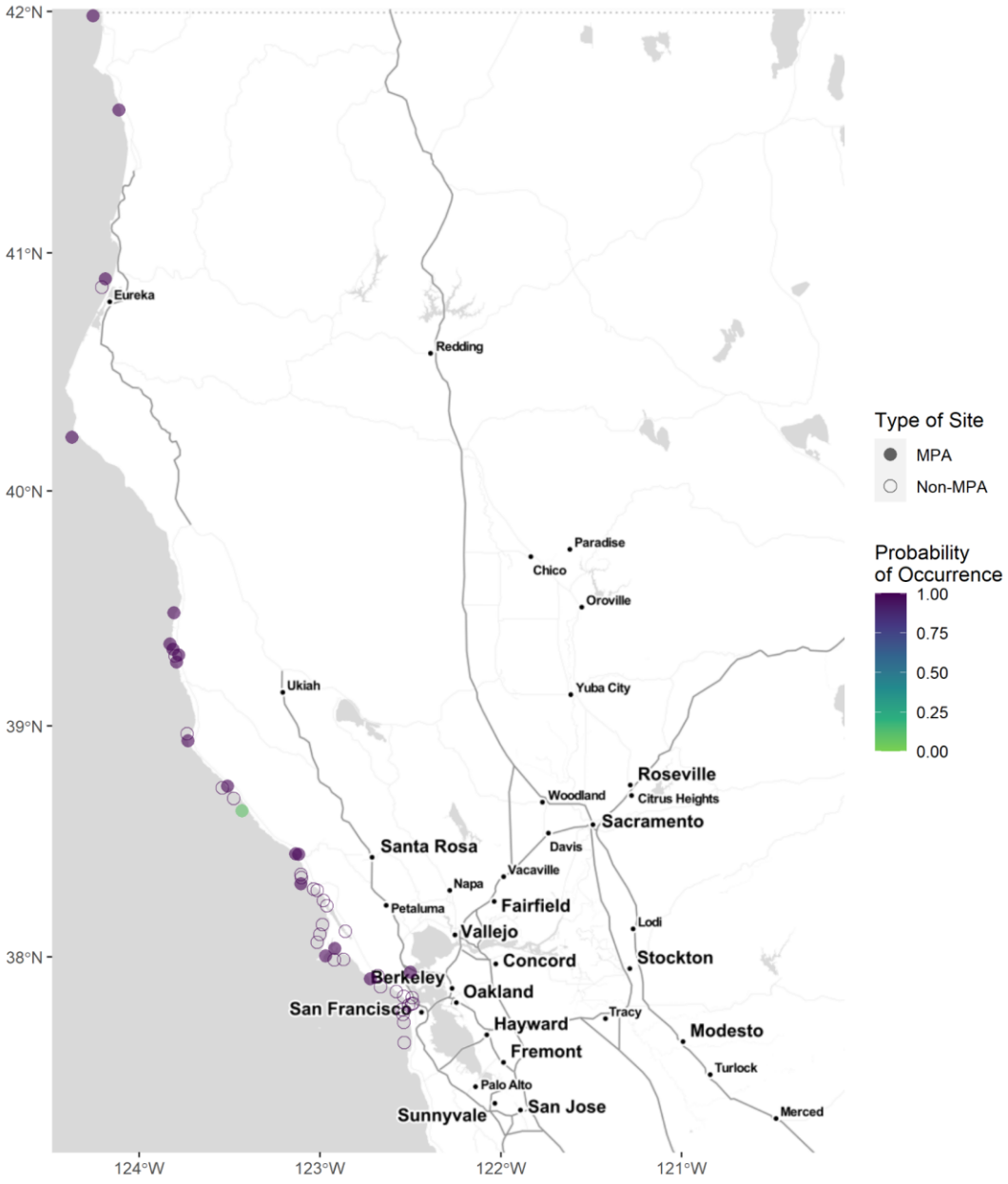


Recreational boating - Central Coast

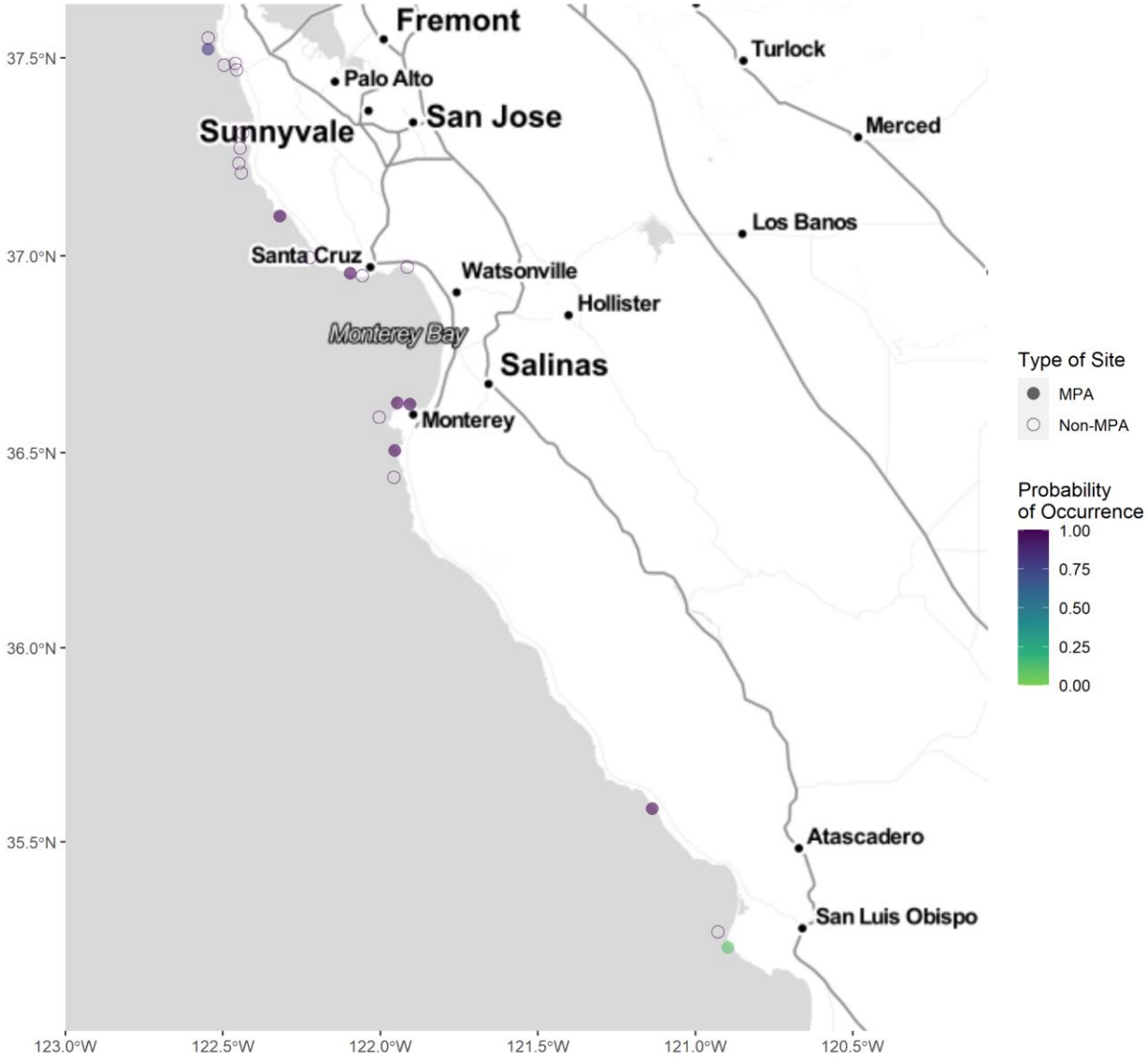


Recreational boating - South Coast

Domestic Animals - North Coast

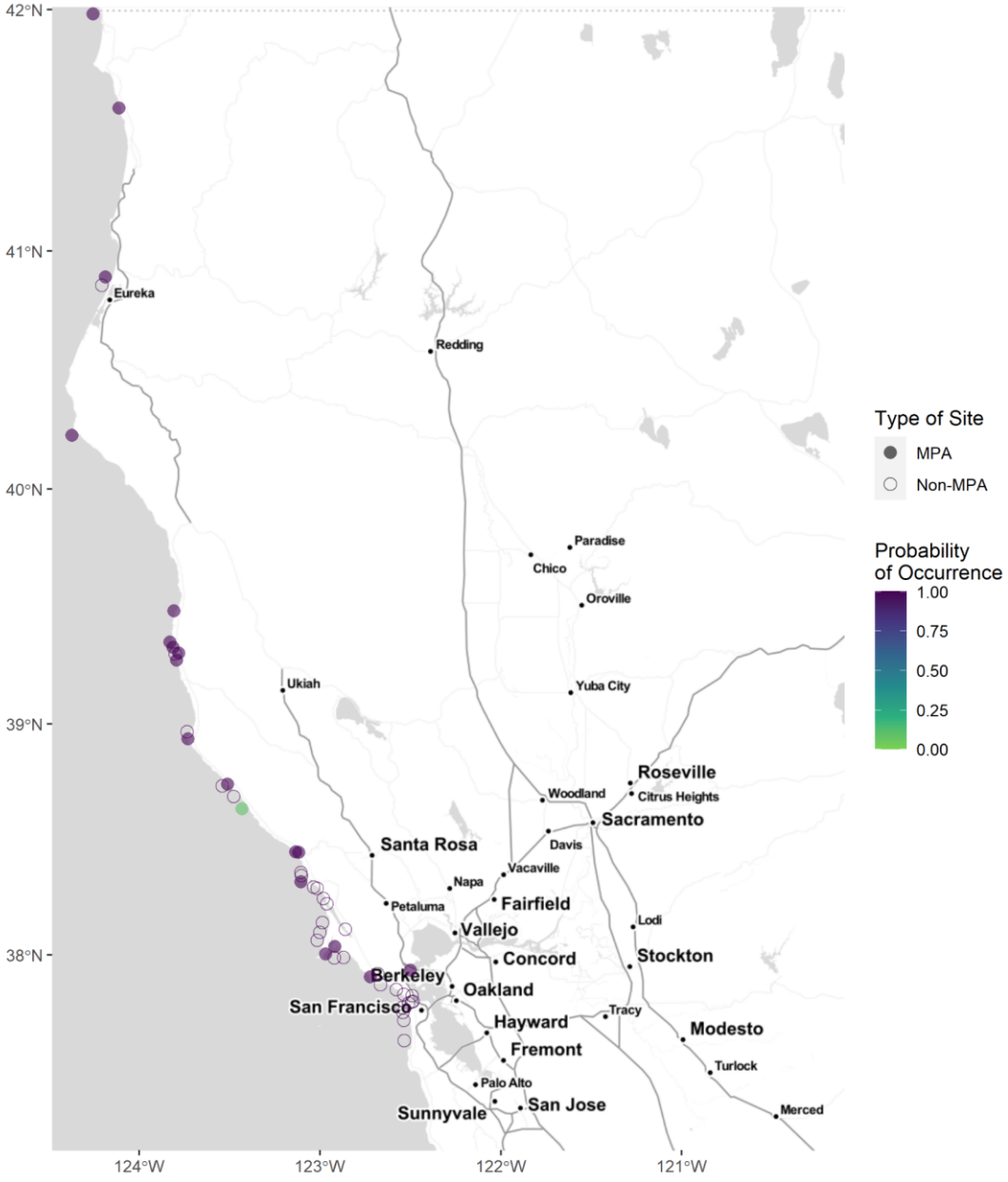


Domestic Animals - Central Coast

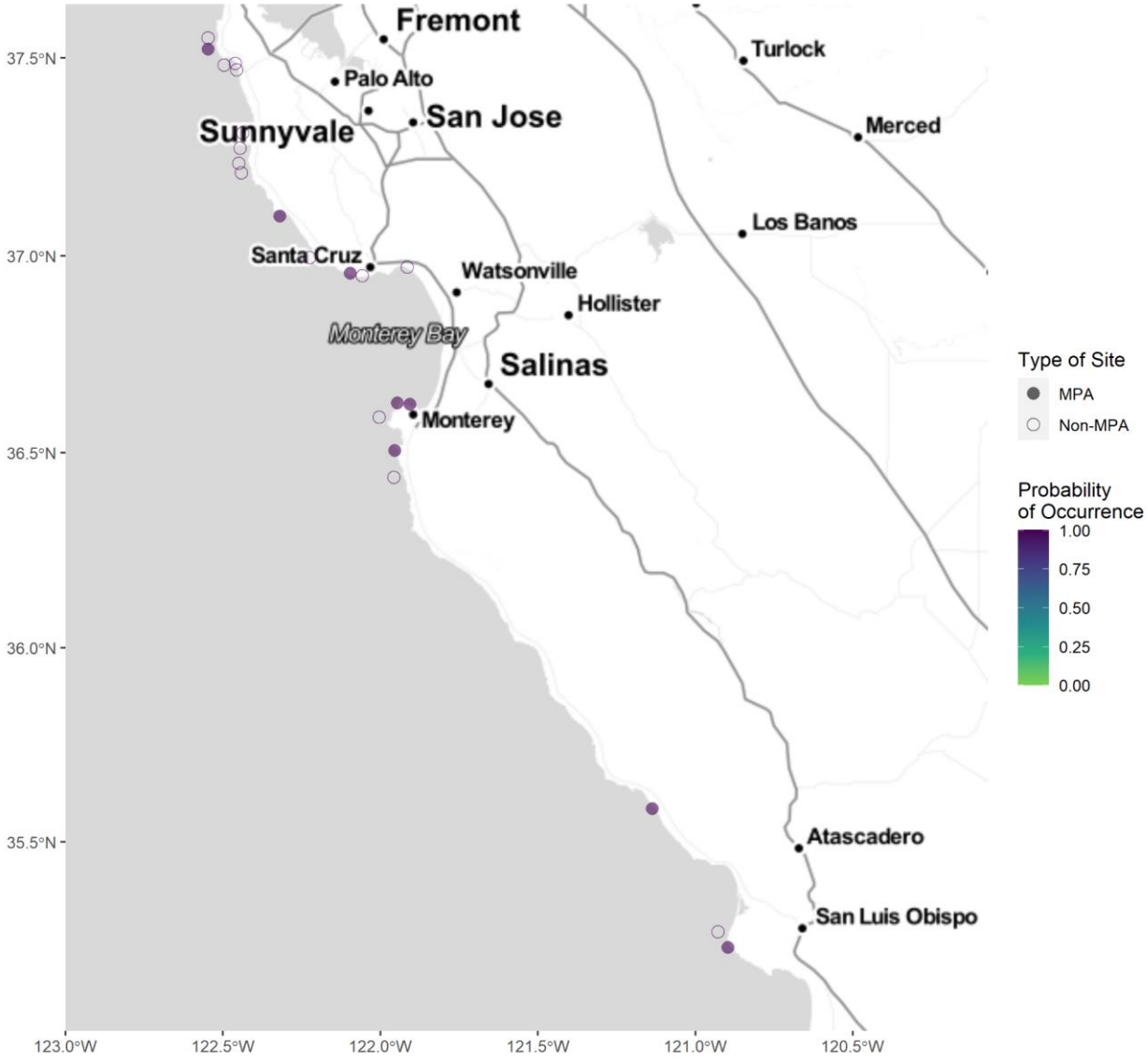


Domestic Animals - South Coast

Onshore recreation - North Coast

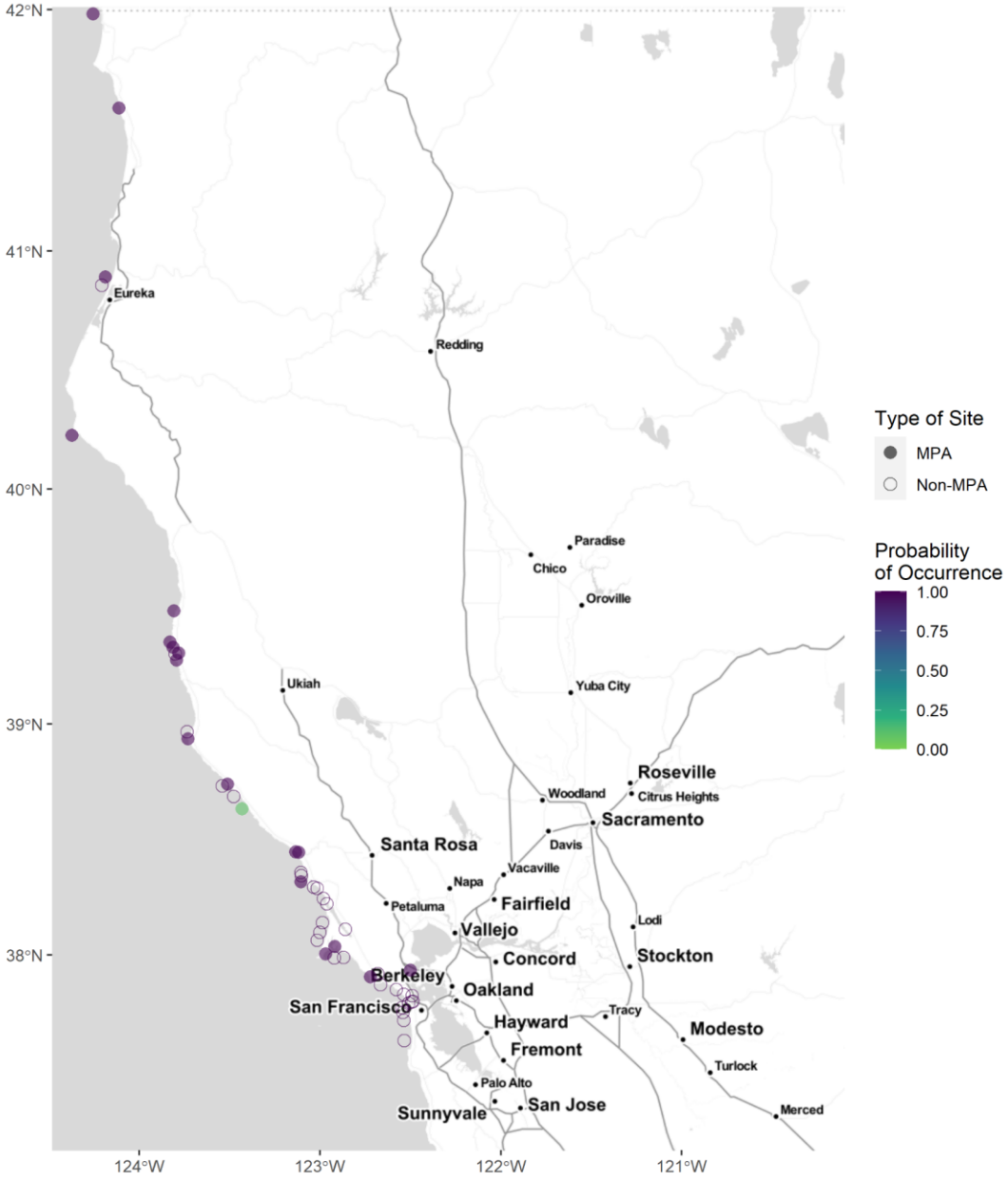


Onshore recreation - Central Coast

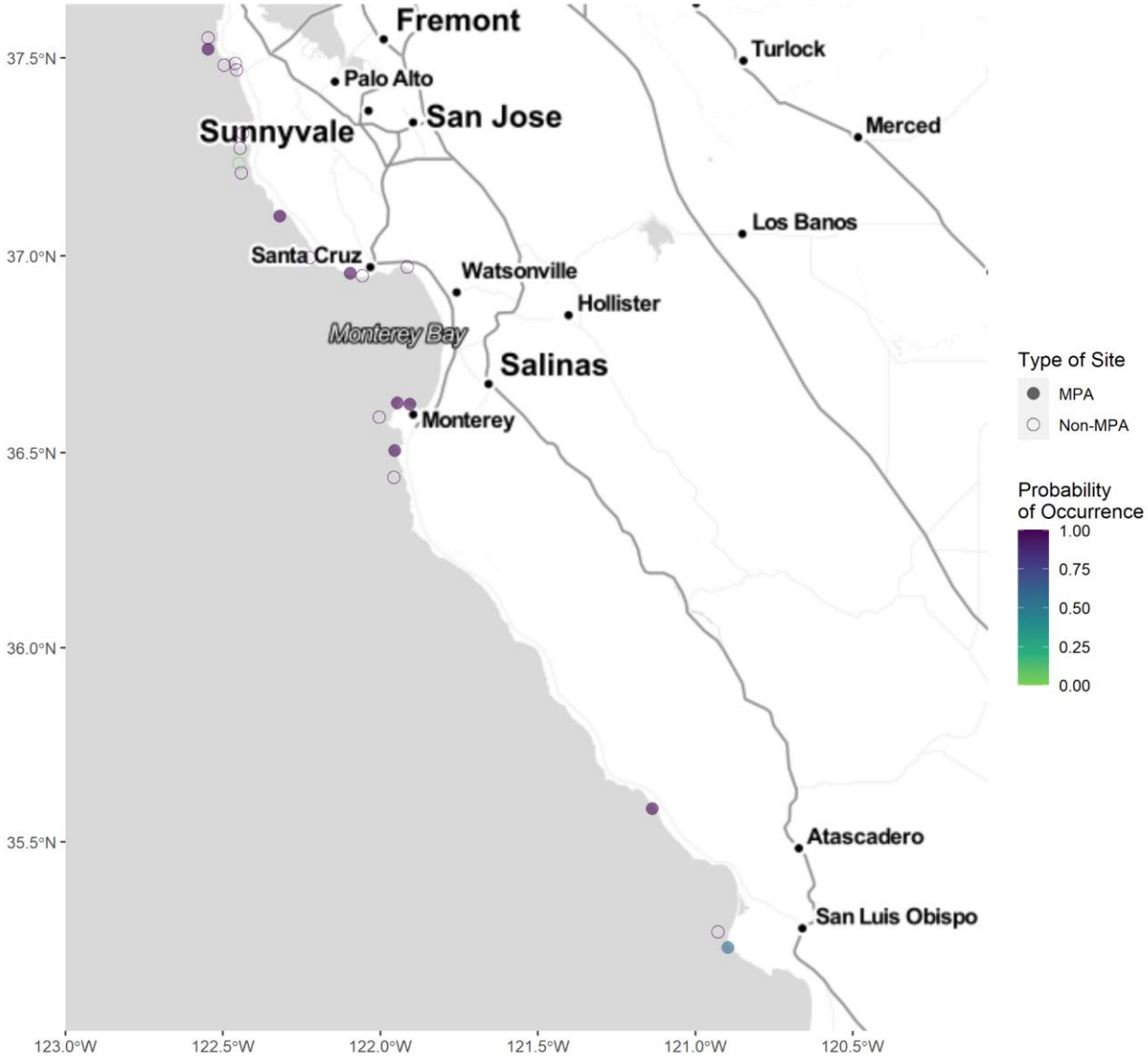


Onshore recreation - South Coast

Offshore Recreation - North Coast

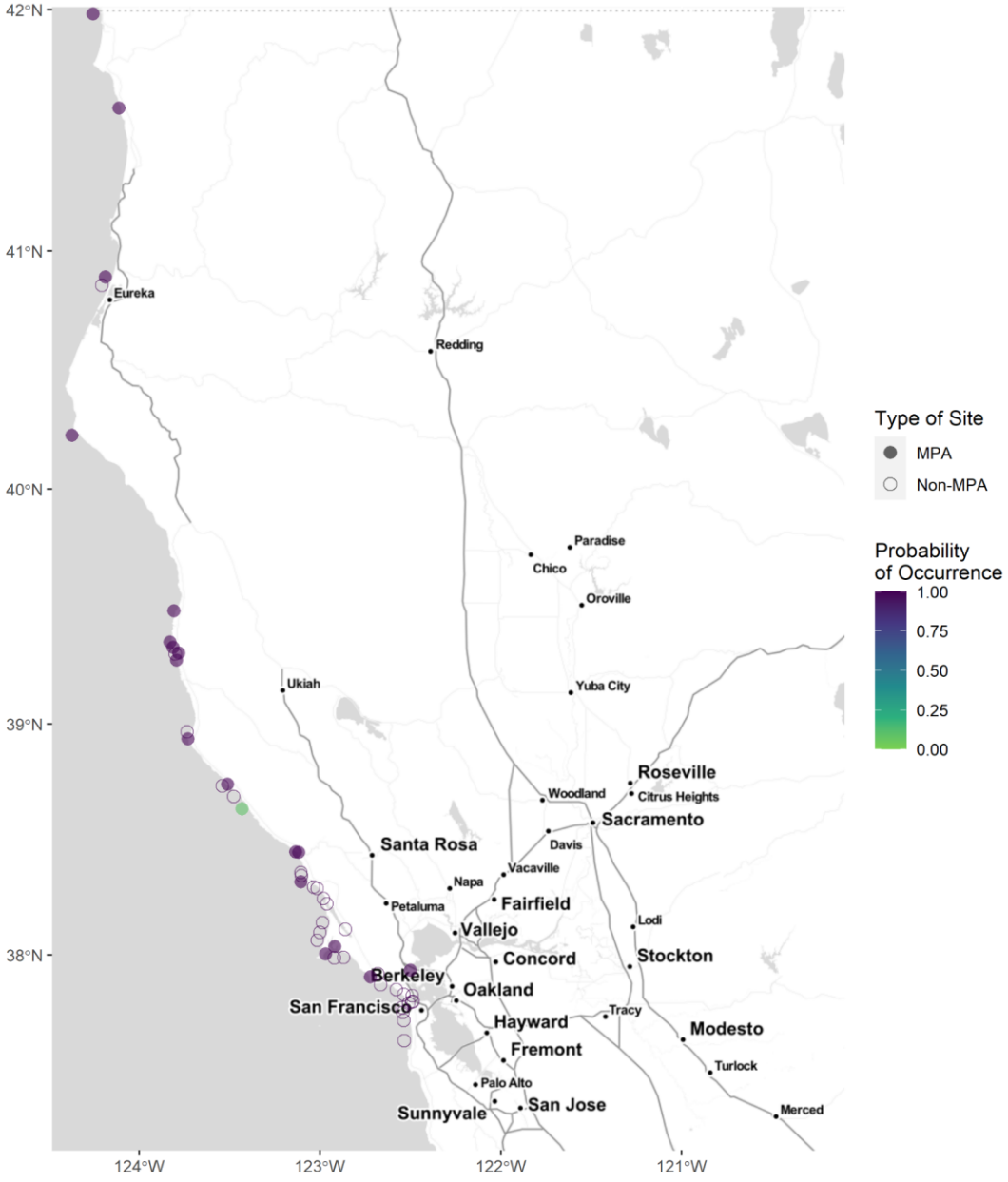


Offshore Recreation - Central Coast

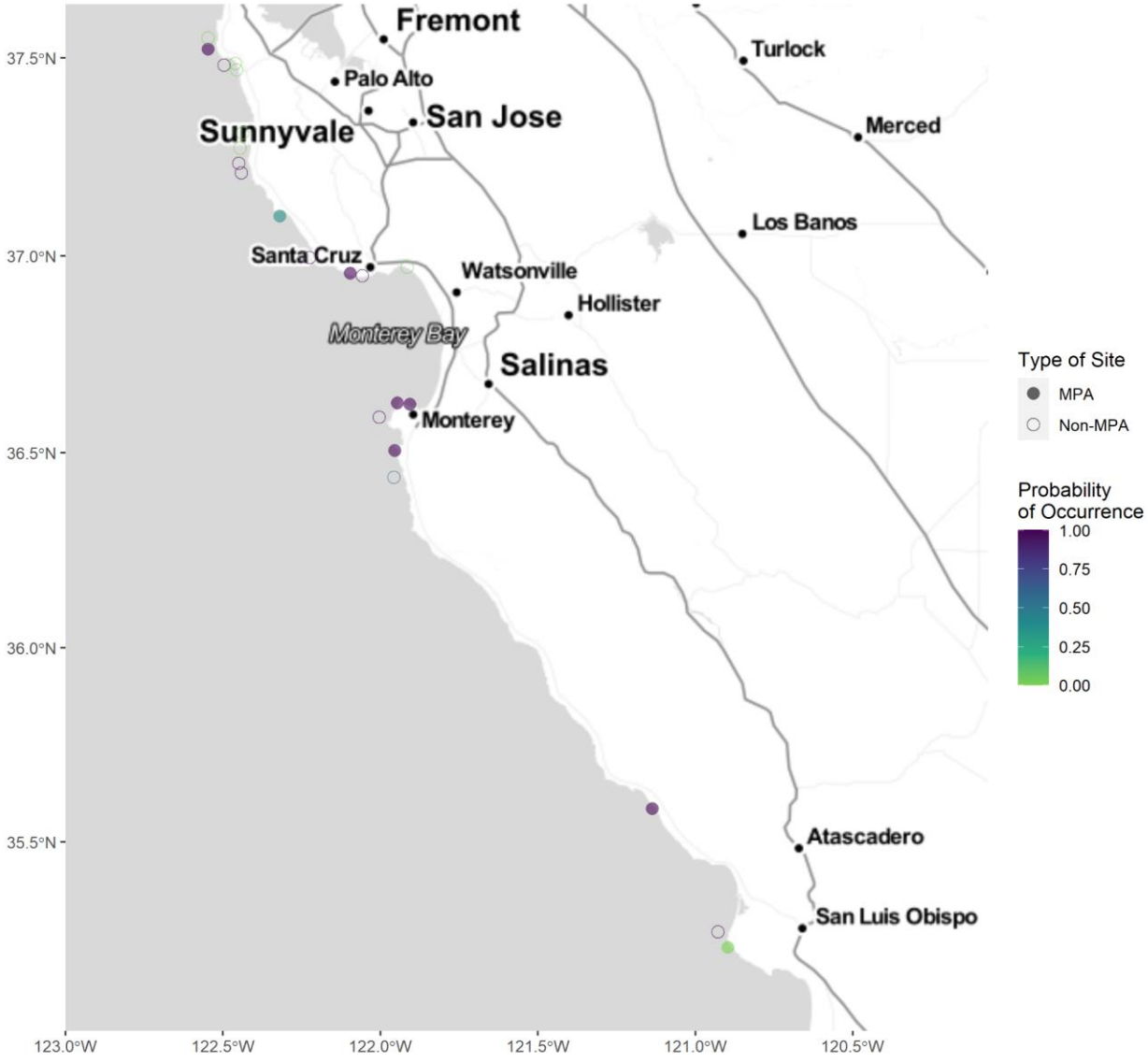


Offshore Recreation - South Coast

Tidepooling - North Coast

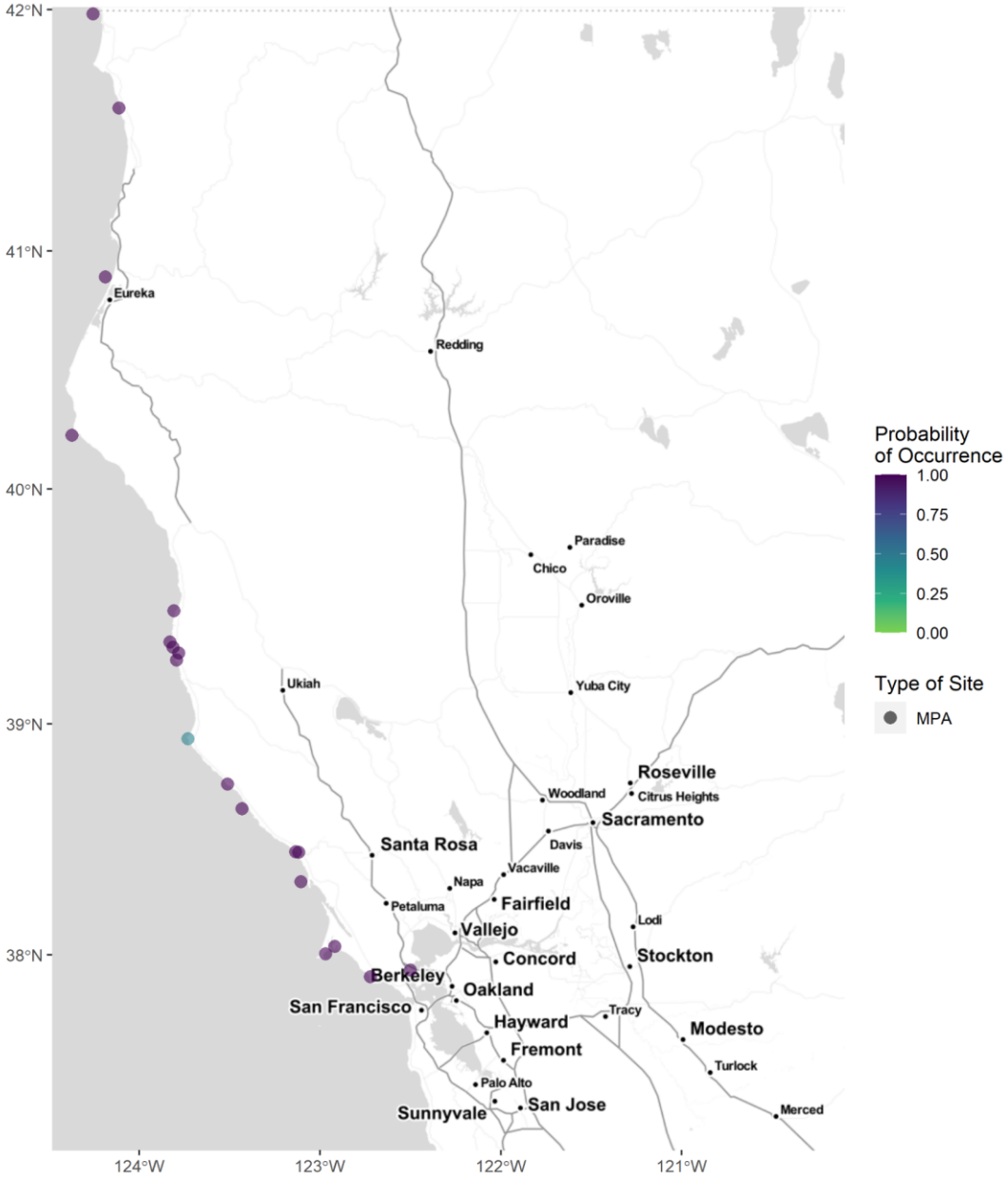


Tidepooling - Central Coast

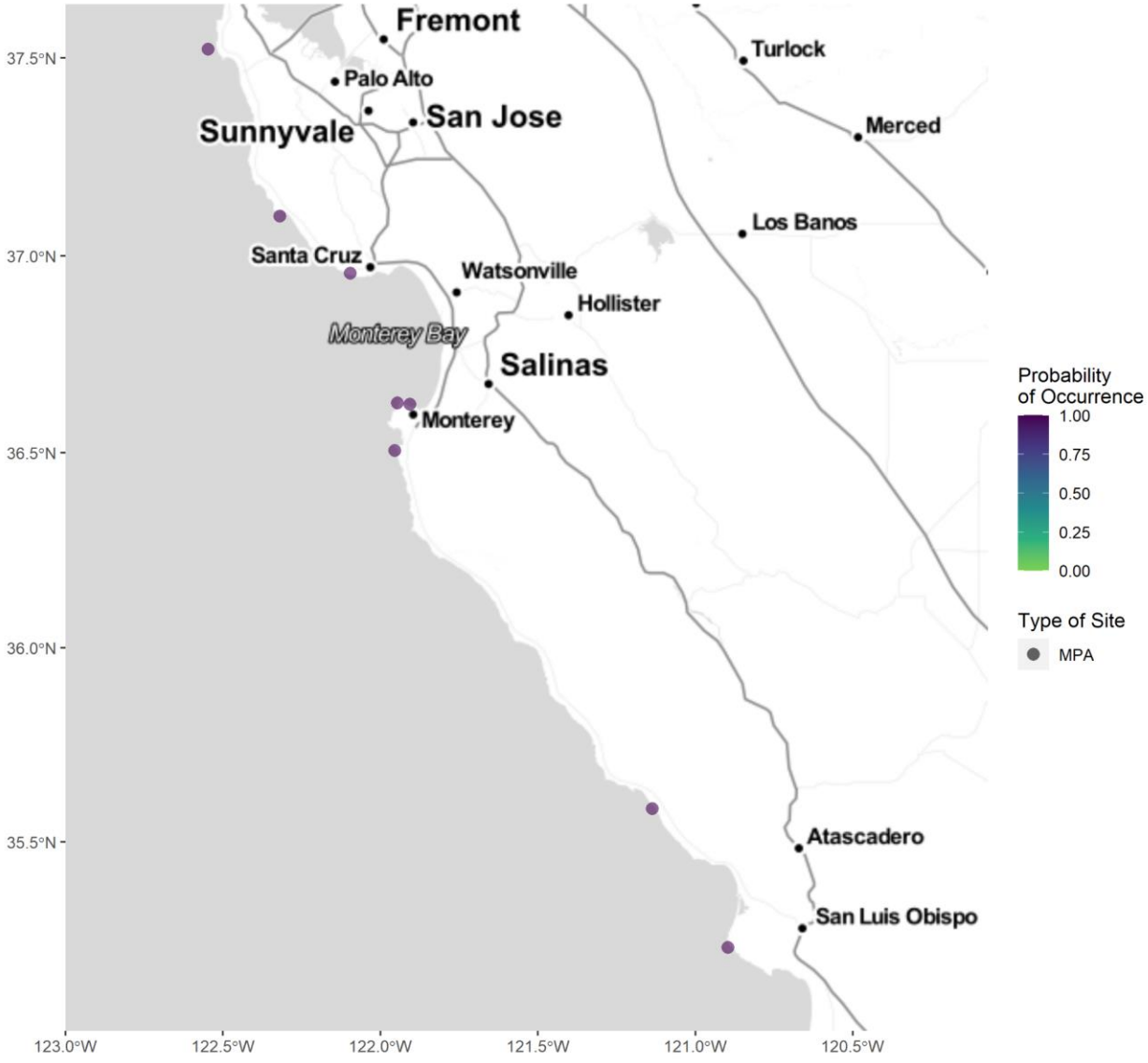


Tidepooling - South Coast

Potential Violations - North Coast



Potential Violations - Central Coast



Potential Violations - South Coast

Appendix B: MPA Watch Occupancy Model Technical Writeup

Appendix B has been omitted from the Microsoft Word version of this report, due to incompatibility with graphical components. Appendix B is available at https://education.ucdavis.edu/ccs-marine-and-coastal-ccs.