

Marine Monitor (M2) Shore-Based Radar Data in California Marine Protected Areas

Submitted by: ProtectedSeas



Introduction

The ProtectedSeas Marine Monitor (M2) utilizes commercial-off-the-shelf marine radar to continuously and autonomously track vessels on the water out to five nautical miles from shore. As resource managers and marine law enforcement seek ways to monitor and understand vessel traffic around marine protected areas (MPAs), reduce monitoring and patrolling costs, and utilize technologies to track vessels and build historic data over time, the M2 system is an efficient and effective shore-based asset for informing nearshore marine management. For more information on M2 visit <https://protectedseas.net/marine-monitor-m2>. This report describes M2 data that can inform California's MPA Management Program by utilizing novel technology to collect MPA monitoring data to advance enforcement and compliance.

Since 2015, a collaboration of scientists, agency partners, and nonprofits have deployed M2 systems in California to monitor vessel activity in nearshore areas of interest along the coast including specific state MPAs. High-level outcomes to date include:

- Nine systems deployed (six currently active)
- Vessel activity monitored in the vicinity of 12 state-managed MPAs
- 375 square miles of marine area monitored
- Continuous coverage day and night, over 7,000 combined days of monitoring (roughly 20 years)
- 110 M2 account holders accessing California M2 sites

This report is submitted by ProtectedSeas, a California-based organization that works to provide open data and monitoring solutions to enhance awareness of and compliance with ocean protections. Partners in this effort include California Marine Sanctuary Foundation, WILDCOAST, Channel Islands National Marine Sanctuary, UC Santa Barbara Mechanical Engineering Department, Cal Poly School of Engineering, Global Conservation, Keith Campbell Foundation for the Environment, The Nature Conservancy, and Resources Legacy Fund.

M2 System Technical Overview

M2 software stores, replays, and analyzes vessel traffic generated from the radar to provide managers and enforcement personnel with marine domain awareness and alert them to unusual vessel traffic patterns around marine areas of concern, such as MPAs (Figure 1). Data are transferred to the cloud, enabling M2 users to have 24/7 monitoring of vessel traffic and to access historical data to understand traffic patterns.



Figure 1. M2 system in Encinitas. This system is deployed at the Moonlight Beach Marine Safety Center and tracks vessels in the vicinity of the Swami's State Marine Conservation Area with both live and historical data accessible from anywhere with the M2 Viewer.

M2 systems can also integrate additional sensors such as pan-tilt-zoom cameras that follow vessel pathways and capture still photographs. These photos are automatically paired with vessel tracking records in the M2 Viewer to help identify the specific vessel and its activity type. An Automatic Identification System (AIS) receiver also provides more detail on vessel identity for those larger vessels broadcasting AIS data. And a meteorological sensor supplies weather-related data to contextualize vessel activity and maximize remote awareness of the area.

Highlights and Key Findings

California M2 Systems Provide 24/7 Vessel Tracking in MPAs

The M2 systems deployed in California monitor vessel activity near 12 state-managed MPAs, including both state marine reserves (SMR), state marine conservation areas (SMCA), and the Monterey Bay National Marine Sanctuary (NMS) and Channel Islands NMS. To date, nine M2 systems have been deployed in California, three of which have been retired or decommissioned after access to deployment sites expired. Active M2 sites (as of January 28, 2022) are shown in Figure 2. M2 systems are optimized to reliably track vessels within 5 nautical miles of the system. The reported marine areas in Table 1 reflect the area within this range at each site, although this is a conservative estimate as vessels can be detected beyond this range in some scenarios, such as calm surface conditions.

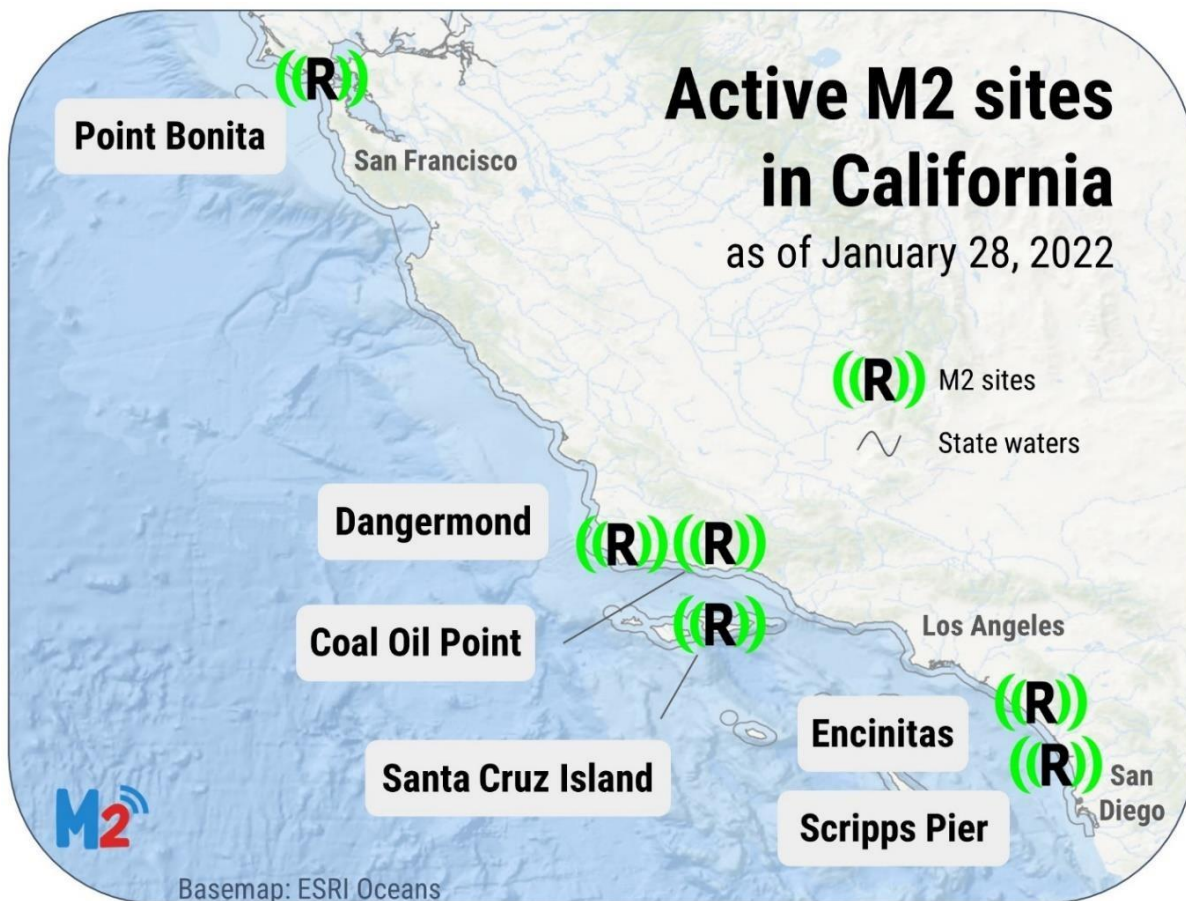


Figure 2. Currently active M2 sites along the California coast, as of January 28, 2022.

Table 1. M2 site details. The total monitoring days indicate those days when data were collected from the time of deployment to November 1, 2021.

Site	Areas of interest	Marine area (mi ²)	Dates	Monitoring days
Moss Landing	Monterey Bay NMS	42	2015 – 2021	1,474
South La Jolla	South La Jolla SMR South La Jolla SMCA	42	2017 – 2021	1,380
Piedras Blancas	Piedras Blancas SMR Piedras Blancas SMCA	62	2017 – 2020	513
Santa Cruz Island	Carrington Point SMR Skunk Point SMR Channel Islands NMS	59	2017 –	846
Coal Oil Point	Campus Point SMCA Naples SMCA	49	2017 –	1,304
Scripps Pier	San Diego-Scripps SMCA Matlahuayl SMR	38	2019 –	901
Encinitas	Swami’s SMCA	48	2020 –	341
Dangermond	Point Conception SMR	31	2020 –	265
Point Bonita	Approach to San Francisco Bay	4	2020 –	268
Monitoring total	12 state-managed MPAs	375 mi ²	2020 –	7,292 days

M2 systems can assist enforcement authorities with tracking marine vessels in real-time, especially in remote areas, at night, or during periods of poor visibility. Identifying the coordinates around areas of concern, such as MPA boundaries, alerts users via text message or email when trigger activities occur, such as loitering in no-fishing areas - and in California, all M2 systems are located adjacent to formal management areas. A mobile-friendly, password-protected version of the M2 Viewer is also available so that wardens and researchers can securely access information while in the field.

In 2021 (January 1 through November 1), M2 detected an estimated total of 34,051 vessels via radar in state-managed MPAs in California. Because many vessels operating in nearshore areas are not required to carry AIS, M2 complements data collected by AIS or vessel management systems (VMS). The average monthly totals shown in Table 2 demonstrate the value of radar tracking and the utility of M2 in capturing a more complete picture of vessel activity in managed areas.

Table 2. Estimated average monthly vessel count within MPAs in 2021. M2 applies automated methods for identifying and removing duplicate or erroneous track records that can occur in radar data. The remaining records estimate the true count of vessels present.

Site	State-managed MPAs	Detected by radar-only	Provided by AIS
South La Jolla	South La Jolla SMR South La Jolla SMCA	914	18
Santa Cruz Island	Carrington Point SMR Skunk Point SMR	122	22
Coal Oil Point	Campus Point SMCA Naples SMCA	1,144	243
Scripps Pier	San Diego-Scripps SMCA	246	1
Encinitas	Swami’s SMCA	619	3
Dangermond	Point Conception SMR	705	105

M2 Contributions to Marine Domain Awareness: Summary Reports, Vessel Pattern Tracking, and Research

To provide further insight into historical patterns of past activity, M2 software provides auto-generated daily, weekly, and monthly activity summaries, and users can create custom reports for specific times, locations, and activities of interest. Analytical reports support strategic enforcement by directing resources to locations and times of day when illegal fishing or other activities of interest are most likely occurring. Current M2 users can receive curated data products, including monthly summaries of “Tracks of Interest”, that identify the times, dates, and activity patterns of vessels that may be of interest to marine managers.

In addition to MPA and fisheries compliance monitoring, M2 provides a research tool for documenting human use in nearshore marine areas that does not rely on outside data sources like AIS, and has been featured in peer-review journals, including *Frontiers in Marine Science* and *The Journal of the Acoustical Society of America*, and at international conferences, including the annual Marine Technology Society/IEEE Oceanic Engineering Society OCEANS Conference and the Biennial Conference on the Biology of Marine Mammals.

Human activity patterns can help management evaluate existing and future regulation of marine resources. Spatial data on small-scale vessel activity, documented using radar and a camera by M2, may have a number of applications to research in the field of marine science, such as vessel speed and activity monitoring in endangered species' habitats. Ultimately, M2 can help fill gaps in vessel monitoring data where human activity in marine areas is of interest.

Selected Case Studies at California MPAs

The following case studies highlight different examples of how M2 systems have been utilized in California to better understand human use of the marine environment in and around MPAs and other areas of interest. The featured case studies show data collected 100% autonomously with the M2 system without human interaction, and these examples were identified upon review of historical data over the past few years.

- Case Study 1 - Confirmed poaching within an MPA
- Case Study 2 - Identifying research vessel activity
- Case Study 3 - Fishing the line

A more extensive collection of case studies, including additional examples related to commercial fishing, an emergency container ship fire, and recreational fishing, can be found at the link below:

https://m2.protectedseas.net/resources/docs/external/CA_DMR_CaseStudies.pdf

Case Study 1 - Confirmed poaching within an MPA

Commercial passenger fishing vessels (CPFVs) are common along the coast of California and often tracked by M2 via both radar and AIS. Since M2 deployment at the Encinitas site, CPFVs have consistently been detected by M2 idling near the northwestern boundary of the Swami's SMCA. The high-resolution track line (provided by M2 radar) of the CPFV Electra at this site in December 2020 showed potential fishing activity (Figure 3). The rules within SMCA's state that it is unlawful to injure, damage, take, or possess any living, geological, or cultural marine resources except for select commercial or recreational harvest specifically authorized, and for authorized research, restoration, and monitoring.

Encinitas

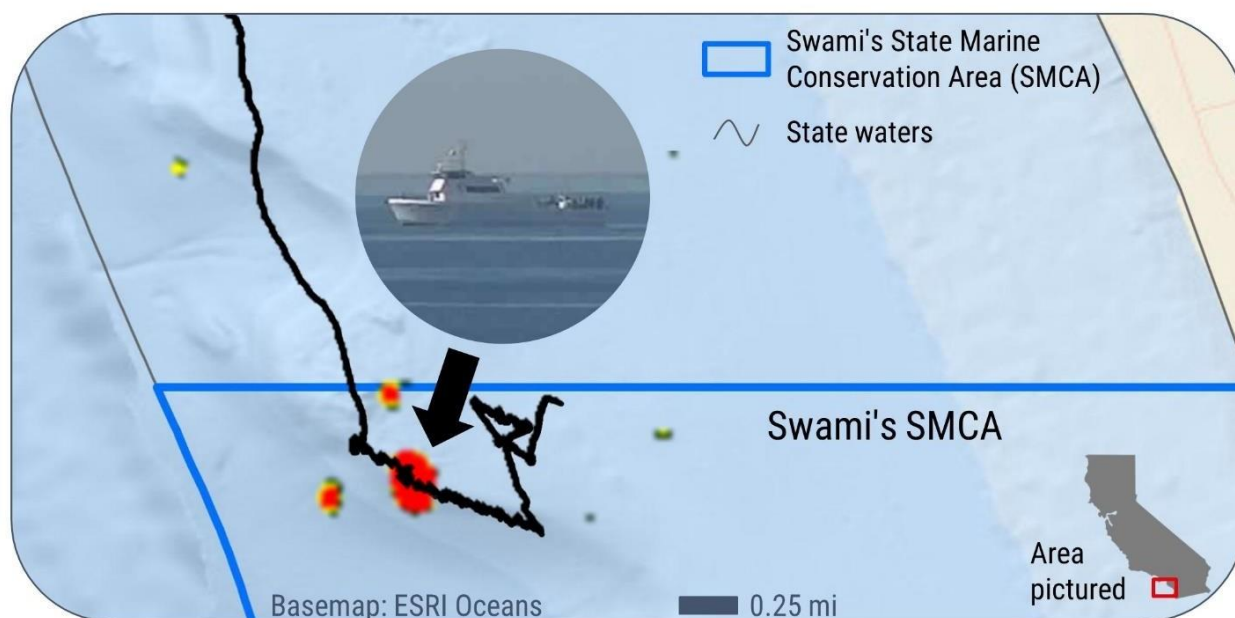


Figure 3. Track line of the CPFV Electra. Photos confirm the vessel's presence, and radar imagery shows the vessel within the boundaries of Swami's SMCA. Boundary coordinates for the MPA can be found at <https://www.wildlife.ca.gov/MPAs>.

California Department of Fish and Wildlife (CDFW) officers that were present on site observed fishing activity, boarded the vessel, and cited the vessel's captain for fishing in the SMCA. The resulting legal case against the vessel operator, Helgren's Sportfishing, through owner Joseph Helgren, was tried in San Diego County Superior Court and solidified by supporting information provided by M2, including the vessel's track line, radar imagery, and vessel photos. In violation of Fish and Game Code, section 12012.5, the vessel owner received a commercial poaching fine of \$5,000 and was ordered to stay out of the SMCA for one year. M2 provides a method for continuing to monitor the presence and compliance of CPFV Electra and other commercial and recreational fishing vessels in the vicinity of the SMCA. More details can be found in the CDFW press release at the following link: <https://wildlife.ca.gov/News/commercial-poachers-convicted-for-illegal-fishing-in-marine-protected-areas>

Case Study 2 - Identifying research vessel activity

During a review of recent vessel activity within the vicinity of the Campus Point SMCA, M2 partners at the National Oceanic and Atmospheric Administration (NOAA) identified a track of interest detected by radar from July 2, 2021. The track line displayed a consistent pattern both inside and outside of the eastern MPA boundary (Figure 4). Since the M2 system also collects AIS data from participating vessels, the vessel was identified as the F/V Outer Limits using a matching AIS record from the same date and time. M2 partners confirmed that the vessel was used on that date by Marine Applied Research and Exploration (MARE) to conduct a biological survey of the MPA in partnership with CDFW.

Coal Oil Point

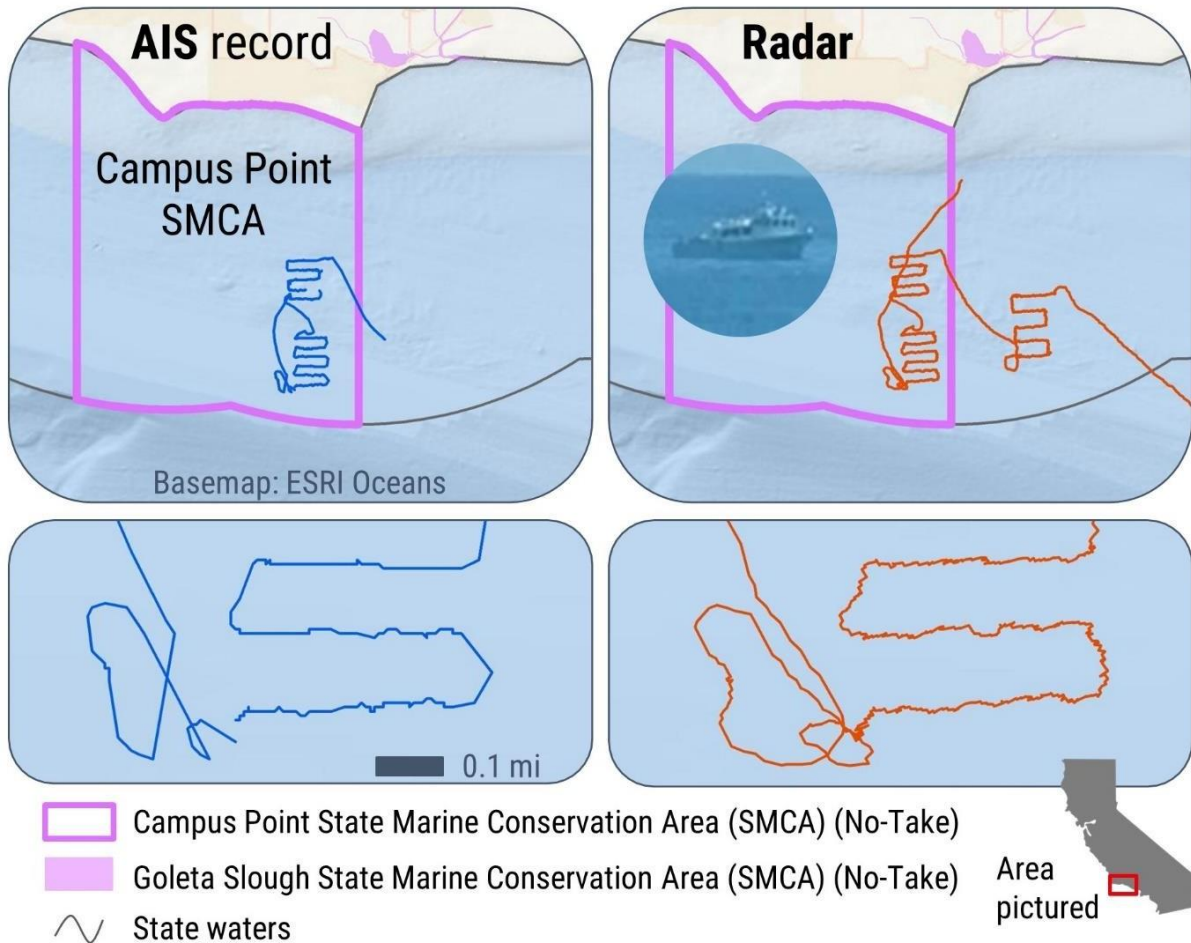


Figure 4. Track line examples. M2 track records from Automatic Identification System (AIS) data (left) and radar (right) of the same vessel in the Campus Point SMCA. Boundary coordinates for the MPA can be found at <https://www.wildlife.ca.gov/MPAs>.

This event highlighted the robust tracking data provided by M2. Vessel locations are also typically reported more frequently by radar than AIS which results in a track line with higher resolution and highlights how radar systems like M2 can provide enhanced vessel tracking, particularly in the nearshore environment. Fine-scale track lines can be useful in evaluating vessel behavior patterns and activity in relation to MPA boundaries.

Case Study 3 - Fishing the line

Vessels tracked by M2 have shown a persistent awareness of MPA boundaries. A selection of track lines observed at the Coal Oil Point and Santa Cruz Island sites between 2018 and 2021 is shown in Figure 5. The track lines show the detailed path a vessel traveled. The repetitive patterns suggest a purposeful activity targeting a specific area, opposed to a simple transit or idling behavior, which could indicate fishing activity. When paired with vessel photos, the specific activity or a fishing vessel's gear and targeted species can often be identified. For example, photos collected by M2 have helped confirm that lobster trapping occurs at MPA boundaries at the Coal Oil Point site. Similar vessel behavior in the vicinity of MPAs has been observed at additional M2 sites in California and generally occurs in relation to local fishing seasons.

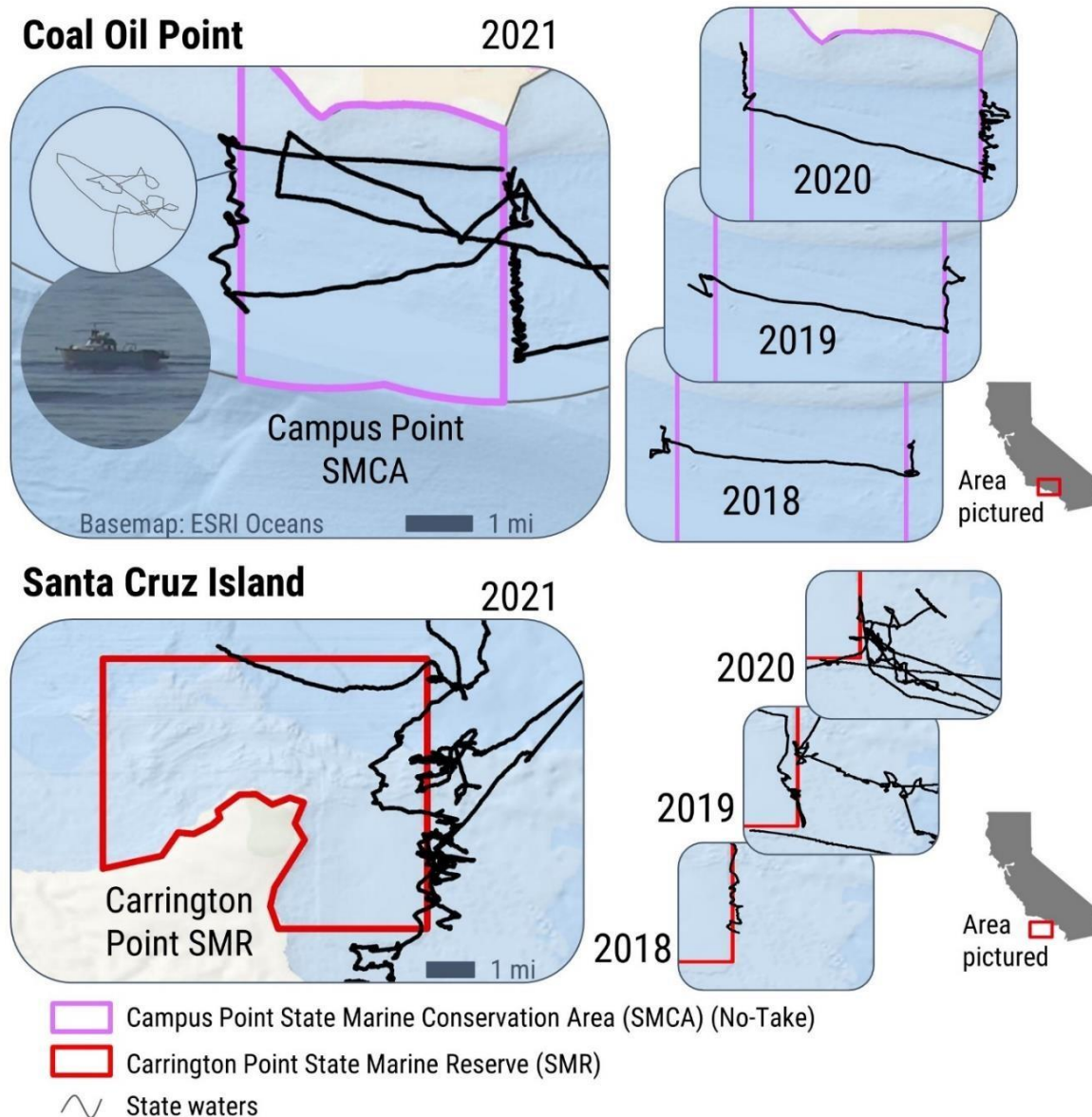


Figure 5. Activity at area boundaries. Examples of vessel behavior focused at the MPA boundary line of the Campus Point SMCA (top) and Carrington Point SMR (bottom). Boundary coordinates for the MPAs can be found at <https://www.wildlife.ca.gov/MPAs>.

Challenges

This effort has collected more than 7,292 days of data - equivalent to more than 19 years of continuous monitoring at 12 of California's MPAs. This significant accomplishment has required the coordination and creativity of nonprofits, agencies, landowners, academic partners, scientists, and engineers to make the system function in remote marine environments and provide data that is tailored to CDFW and other enforcement partners in California.

Over the last five years, this project has faced challenges including:

- While relatively inexpensive for an autonomous radar system (~\$75,000 - \$150,000 per unit for equipment), costs still must be budgeted for ongoing management and maintenance which is currently supported by nonprofit and on-the-ground partners.
- The M2 data viewer products are most useful when viewed directly by enforcement officers working in MPAs. M2 real-time data shows when boats are loitering in MPAs; M2 historical data can also help wardens understand traffic patterns over time. However, it can be challenging to access the system while on the water when reception is spotty, and ProtectedSeas continues to refine a mobile interface and other products that can provide data in a timely and useful format.
- As demonstrated at the three discontinued sites, this project requires coordination with landowners to support installation of the system over a number of years.
 - For example, an M2 system was deployed at Piedras Blancas through an agreement with the landowner, Bureau of Land Management (BLM), for six months to one year which was extended to more than two years due to a successful partnership. However, when the pilot concluded, the system had to be removed which ceased data collection at that site.
- M2 systems deploy marine-grade electronics in remote locations that require satellite data connectivity, a reliable power system, and system maintenance. While the M2 unit uses durable materials that are made to last on boats and in the marine environment, all units have required various levels of upkeep that include: resetting power when it fails, replacing radar parts, repairing radar towers, and constructing solar arrays to ensure consistent power. Partnerships with UCSB Mechanical Engineering Department as well as on-the-ground maintenance by partners like WILDCOAST and CMSF have been crucial for maintaining functionality at California pilot sites.

With each deployment, the M2 team and ProtectedSeas have learned how to better install, maintain, and communicate the findings of the M2 system. We are confident that this robust system can provide valuable vessel data to managers and enforcement officials, and we look forward to continuing to refine the system so that it provides utility and helps with monitoring and ensuring compliance with California's landmark network of MPAs.

Knowledge Gaps and Recommendations

In future and existing deployments, the following recommendations can ensure that the data collected by M2 have a meaningful impact and inform the state's understanding of vessel activity in MPAs:

- When vessel tracks indicate prolonged activity within MPAs, send M2 data to CDFW wardens to create real-time feedback regarding on-the-water activity
- Compare CDFW vessel contacts with M2 data, allowing managers to understand vessel activity during and prior to their engagement
- Identifying priority vessel hotspots for CDFW wardens and exploring opportunities to establish new M2 systems to support enforcement and management
- Continue to share data reports with CDFW and other resource management agencies in California to create a historical record of vessel traffic in MPAs of interest
- Increase use of M2 data by enforcement, which will help wardens become more familiar and comfortable with using the M2 Viewer to support their boat-based patrols
- Signage or reporting of M2 system deployment to vessel operators has value as potential deterrent of fishing activity in MPAs

Conclusion

M2 deployments have provided meaningful data related to human use of MPAs and other managed areas along the California coast. Continuous data collection over time, multiple years at most sites, has revealed patterns of activity which suggest high levels of compliance with MPA regulations. This baseline information, combined with current and future data that M2 will continue collecting, can reveal both large- and small-scale changes in activity to inform MPA management. Future reviews of MPA design and efficacy beyond 2022 can be supported by these long-term datasets.

M2 also provides a method for monitoring MPA compliance and supporting active enforcement in real-time. The autonomous, cloud-based platform offered by M2 promotes rapid digital information sharing, which was especially valuable in overcoming challenges related to the coronavirus pandemic. M2 allowed for remote sensing of vessel patterns while at-home orders were in place and while social distancing recommendations impacted the ability for in-person coastal monitoring. ProtectedSeas and its partner organizations have identified additional key locations within California's MPA network where M2 deployments would be beneficial to management, are actively pursuing approval at some sites, and will continue to do so in 2022 and beyond.