Testing & Evaluation Report:

# Luma360: Intelligent Sensing for Marine Domain Awareness

Suburban Marine

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# Luma360 AIS Test and Evaluation: A lightweight automatic identification system (AIS) receiver for marine domain awareness

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## Introduction

This paper presents the findings of a field test evaluating Luma360 AIS: a compact, low-cost Automatic Identification System (AIS) receiver deployed at Hopkins Marine Station in Monterey Bay. Conducted as a collaborative research effort between the Synchro tech testbed program and Suburban Marine, we evaluated the value of localized AIS receivers in near-shore environments and explored their potential to address coverage gaps in coastal AIS data collection networks.

AIS is a maritime communication technology that enables vessels to broadcast their identity, position, speed, and heading via VHF radio signals. These signals are received by other ships, terrestrial stations, and satellites to enhance navigational safety, prevent collisions, and facilitate vessel tracking (Emmens et al. 2021). While AIS is widely used by commercial shipping, port authorities, coast guards, and maritime agencies, its effectiveness can be limited in complex coastal zones where terrain or distance impedes signal reception by large-scale monitoring systems. Nearshore applications also include marine protected area management, where marine protected areas sometimes only extend a few miles from the coast. These data are also now in regular use by Regional Associations of the Integrated Ocean Observing System such as in the Alaska Ocean Observing System (AOOS, Wright et al. 2019) and the Central and Northern California Ocean Observing System (CeNCOOS). Such data can be very valuable and processed using models into classifications of vessel classes, activities and more (e.g. Meyer and Kleynhans 2025), but the utility of AIS depends on various quality and quantity aspects that balance signal and noise (e.g. Emmens et al. 2021).

The system developed by Suburban Marine offers a modular, portable, and cost-effective alternative to conventional AIS infrastructure. Designed for edge deployment, the receiver captures AIS beacon transmissions in challenging near-shore regions and transmits the data via cellular/LTE, Starlink, Iridium, or other communication networks to a centralized server for processing and archival in a spatial database. A live web interface enables both real-time and historical vessel track visualization.

To assess performance, the collected AIS data was compared against the U.S. Coast Guard-sourced dataset available via the Marine Cadastre (https://hub.marinecadastre.gov). The core hypothesis of this technical evaluation was that the Luma360 AIS receiver would demonstrate higher sensitivity in detecting vessel transmissions in coastal areas compared to data available via the Marine Cadastre. The results offer insight into how locally deployed AIS nodes can complement national-scale systems, enhancing maritime domain awareness in data-sparse regions.

In the area of investigation, AIS information users include the Marine Exchange of the San Francisco Bay Region, the Monterey Bay National Marine Sanctuary, the California Department of Fish and Wildlife, and Monterey Harbor authorities. We discuss the applicability of the assessed system to their AIS data needs.

## Methods

The Luma360 system was installed on the rooftop of the Agassiz Building (36.62, -121.91) at Hopkins Marine Station in Pacific Grove, CA on March 26th, 2024 (Figure 1) through May 29, 2025. The hardware took approximately 1.5 hours to set up and was powered by a standard 120VAC outlet. The system was online and reporting data to Suburban Marine on the same day (Figure 2). Data was received by the antenna 24 hours per day, every day while in service. The Luma360 AIS system consists of an i.MX 93 single board computer, AC/DC power supply, LTE router, and AIS receiver. A weather proof enclosure and sealed connectors provide ingress protection. The two internal LTE antennas provide diversity, while a larger external antenna is used to receive AIS. A web based user interface allows viewing ship traffic with time and MMSI filters. More advanced queries can be created via spatial queries on the Postgres+PostGIS data backend (Figure 2).


Figure 1: The Luma360 AIS system is shown as mounted to a non-penetrating antenna roof mount system which is portable and easily installed for short term deployments.

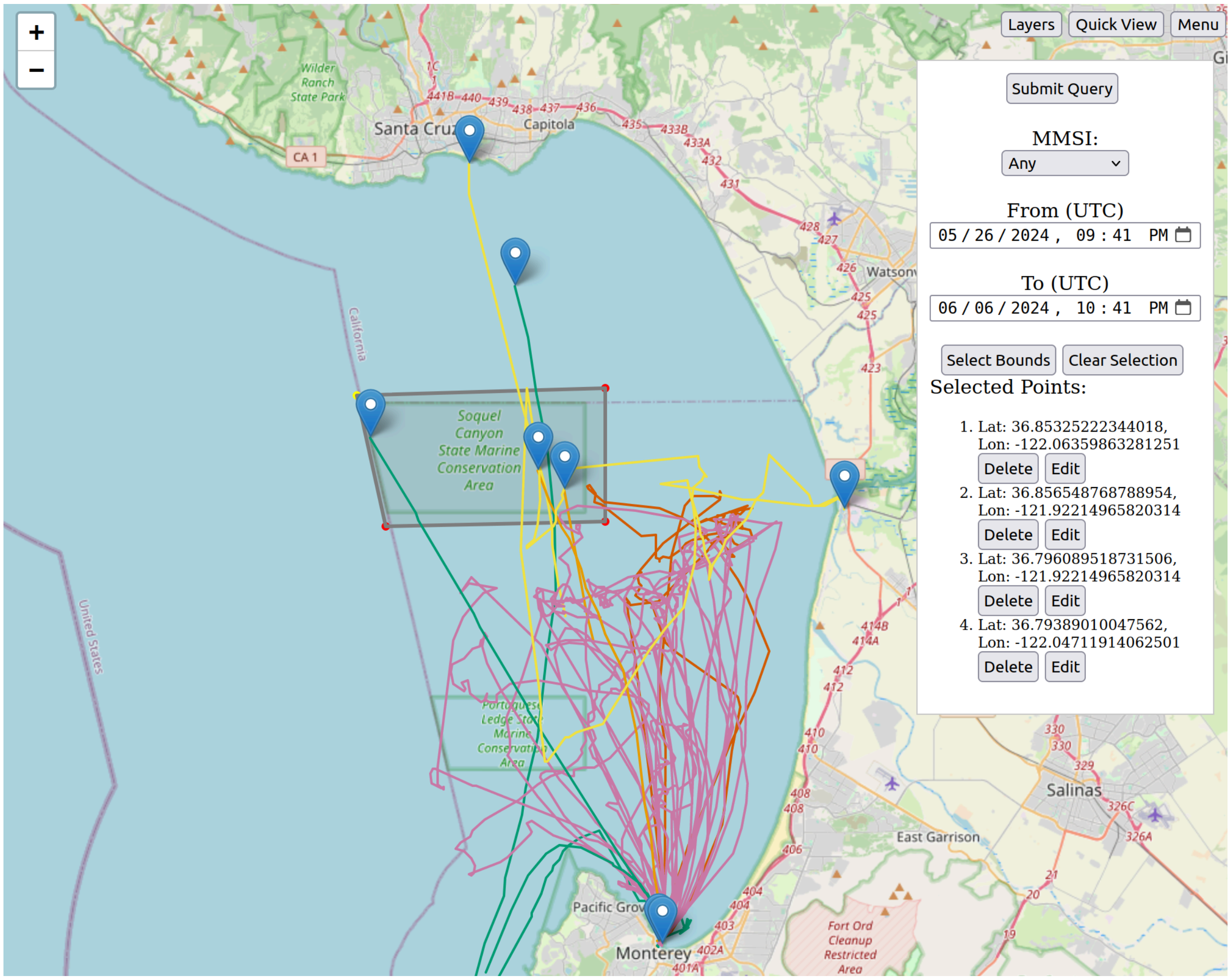

Figure 2: A live view map overlay allows viewing AIS data received by the system in near-real time.

To analyze the performance of the Luma360 system, AIS data from this site was exported and compared to the Marine Cadastre dataset in a region of interest around the installation. The region of interest was set to within Monterey Bay in order to filter out targets greater than 40 km away from the Luma360 antenna. Many targets were received beyond 40 km from the installation, even as far as San Francisco Bay; however evaluating the system performance at that distance was outside of the scope of this project's hypothesis. The data comparison was done for the period of July 1, 2024 through December 6, 2024.

To compare the data sets fairly, both data sets were averaged to 1 minute data. The Marine Cadastre data were supposed to be every minute but that was not found to always be the case. Data from both data sets were only used when the speed over ground was greater than zero.

For all AIS data, the position of the data were computed as distance from the location of the Luma360 antenna. The data were looped through for each unique ship identified by the Marine Mobile Service Identifier (MMSI). Distances were binned based upon 0.1 km bins, as distance from the antenna. The total observations were then summed over distance-based bins. We calculated cases where both systems observed the same MMSI at a given distance (Figure 3). That data were counted as one “ping”. If only one system saw the ship then that “ping” was assigned to that specific system (Marine Cadastre - Figure 4 or Luma360 - Figure 5).

We also calculated the percentage of the total pings observed by both systems as a function of distance from the antennae (Figure 4).

**Results**

The total unique MMSI’s (i.e. unique vessels) simultaneously observed July 1, 2024 to December 6, 2024 by the Luma360 and Marine Cadastre were 411 (Figure 3). Separately, the Marine Cadastre data observed 537 MMSIs (Figure 4) vs 415 by the Luma360 (Figure 5). The distribution of these detections was substantially greater nearer to the tested antenna, particularly within 5 km of the antenna. Though this distribution is likely due to the antenna being adjacent to an active harbor for tourism and both recreational and commercial fishing.

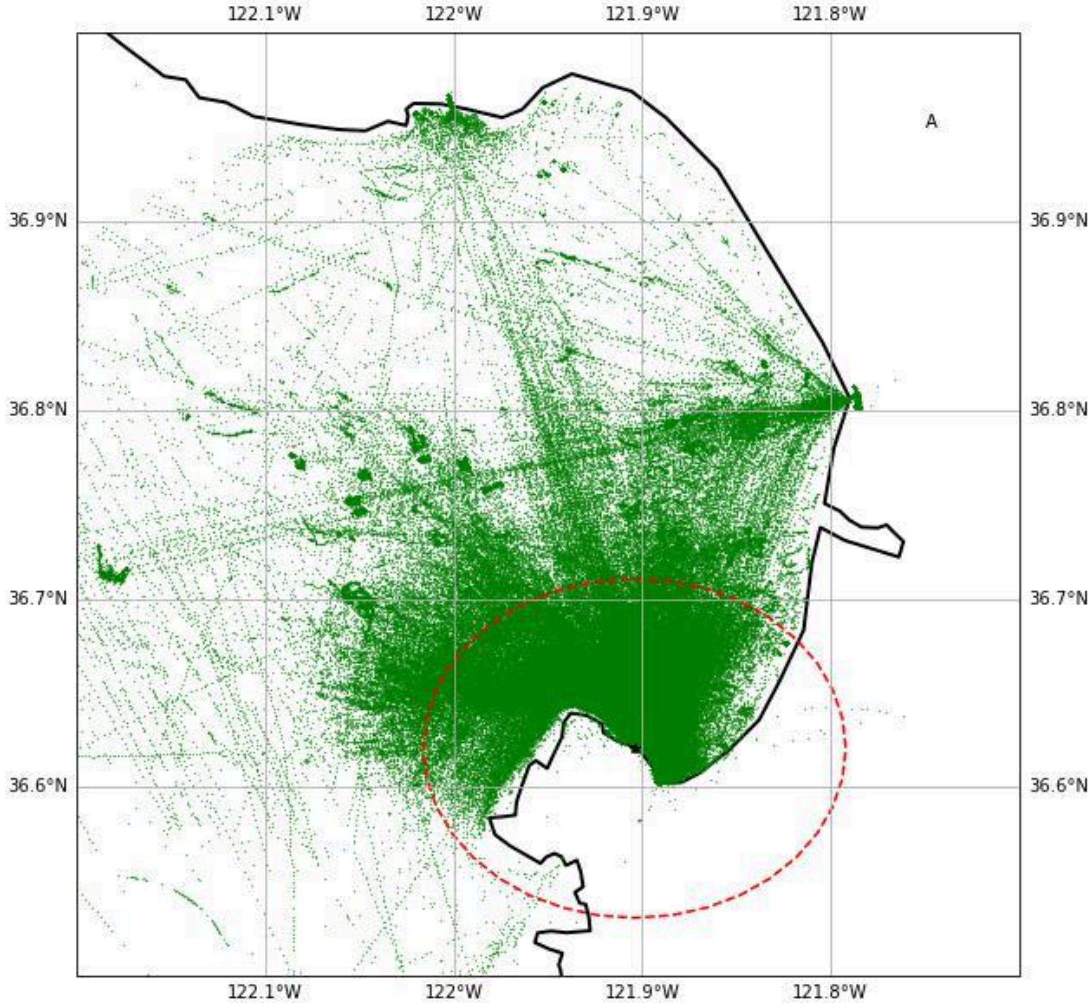


Figure 3. MMSI positions of ships observed from July 1,2024 until December 6, 2024 that were simultaneously observed by Luma360 and found in the Marine Cadastre data. The dashed ring on the figures represents a range ring of 10 km around the tested antenna. The small black star is the location of the antenna at Hopkins Marine Station.

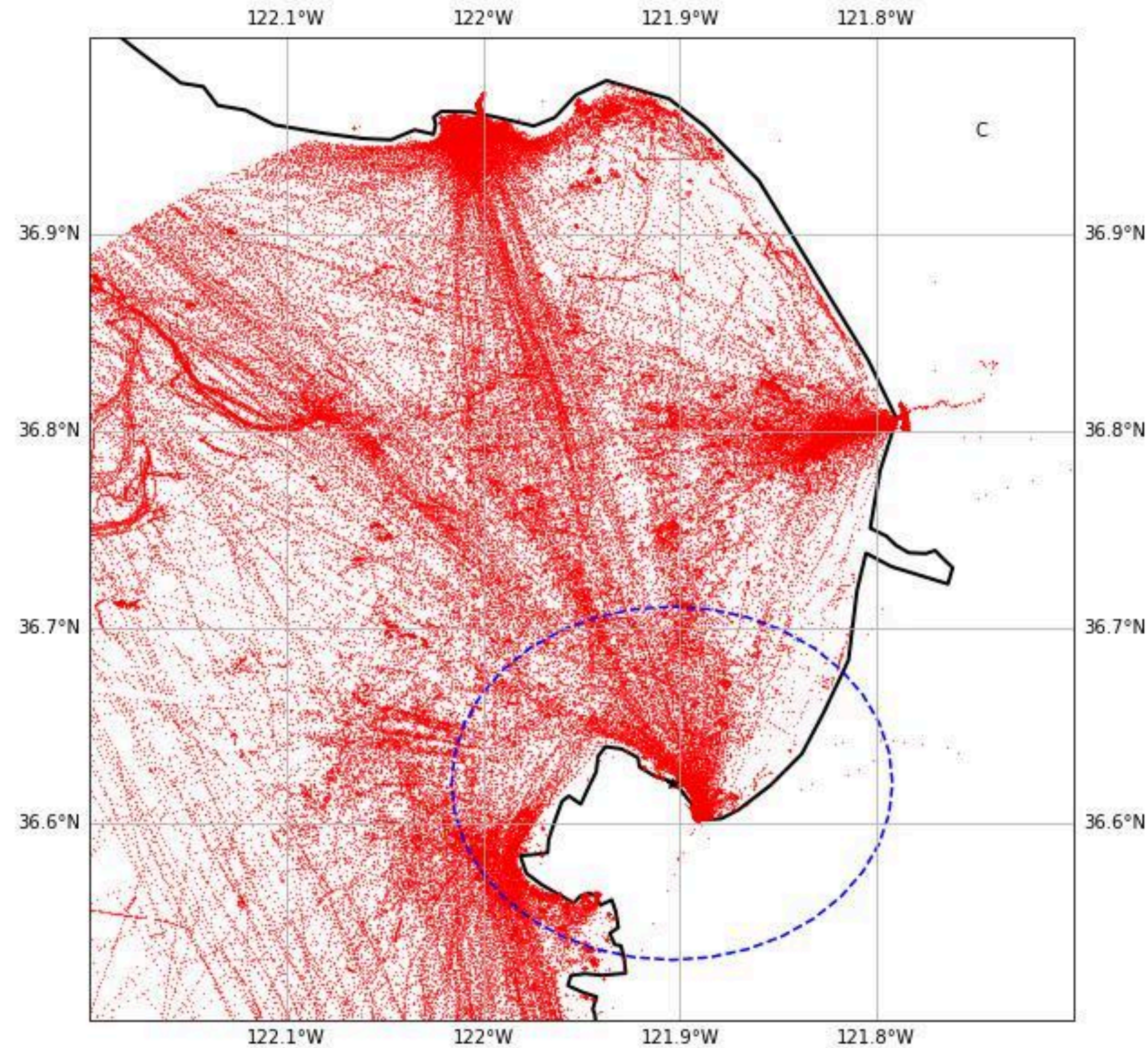


Figure 4. MMSI positions of ships observed were found in the Marine Cadastre data. The dashed ring on the figures represents a range ring of 10 km around the tested antenna. The small black star is the location of the antenna at Hopkins Marine Station.

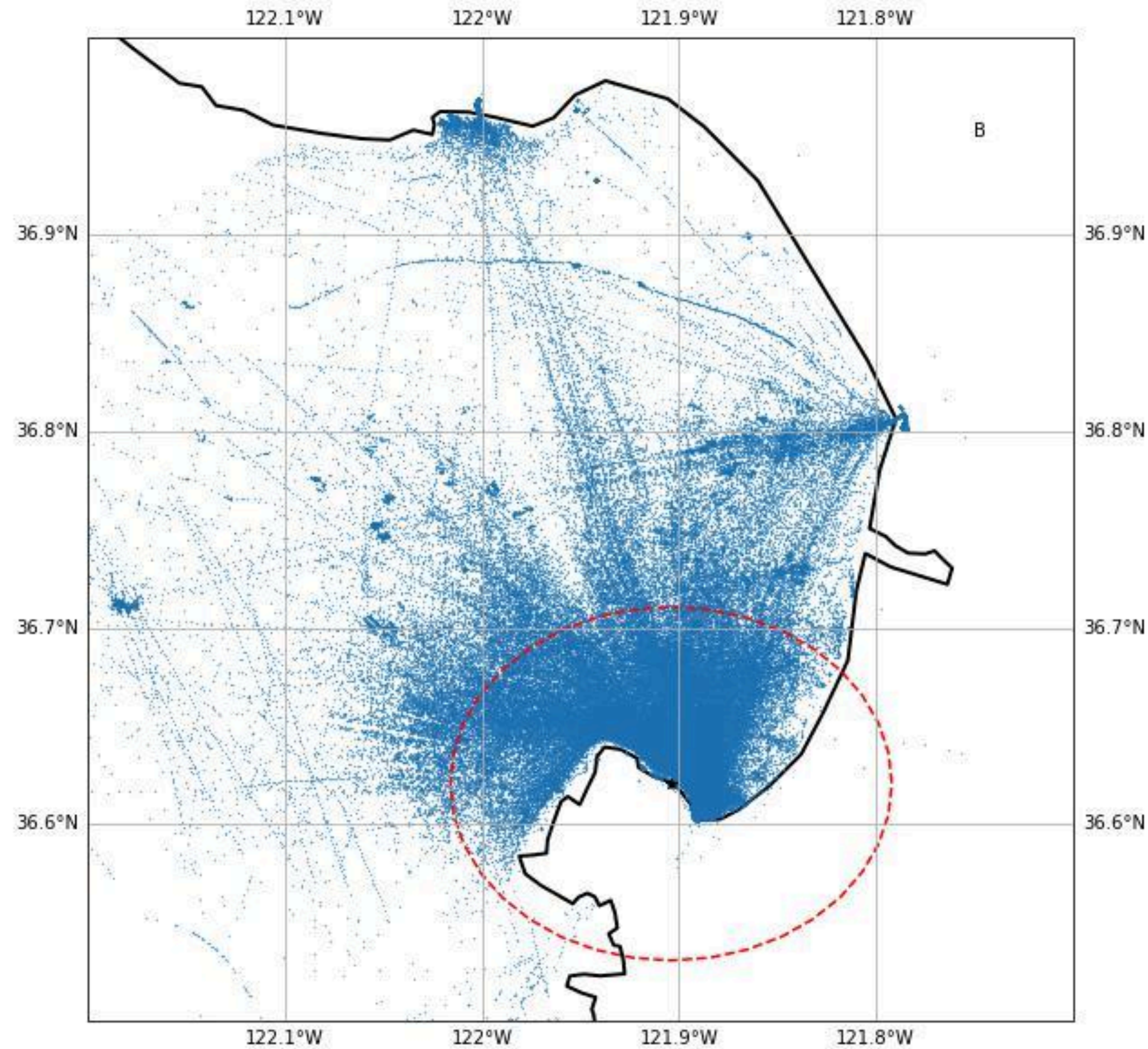


Figure 5. MMSI positions that were observed by the Luma360 system. The dashed ring on the figures represents a range ring of 10 km around the tested antenna. The small black star is the location of the antenna at Hopkins Marine Station.

As a function of distance from the antenna, the percentage of total vessel pings that were observed by Luma360 AIS (blue) was about 50% higher than Marine Cadastre (red) for the first ~7 km (Figure 6). This data comparison indicated that the Luma360 system received more vessel pings out to approximately 8-10 km away from the antenna. At a range of ~10 to ~20 km from the antenna, both perform about the same in receiving vessel pings. Beyond 20 km from the antenna, Marine Cadastre data had a higher proportion of receiving targets. It should be noted that the exact source of individual Marine Cadastre pings is anonymised in the public data records.

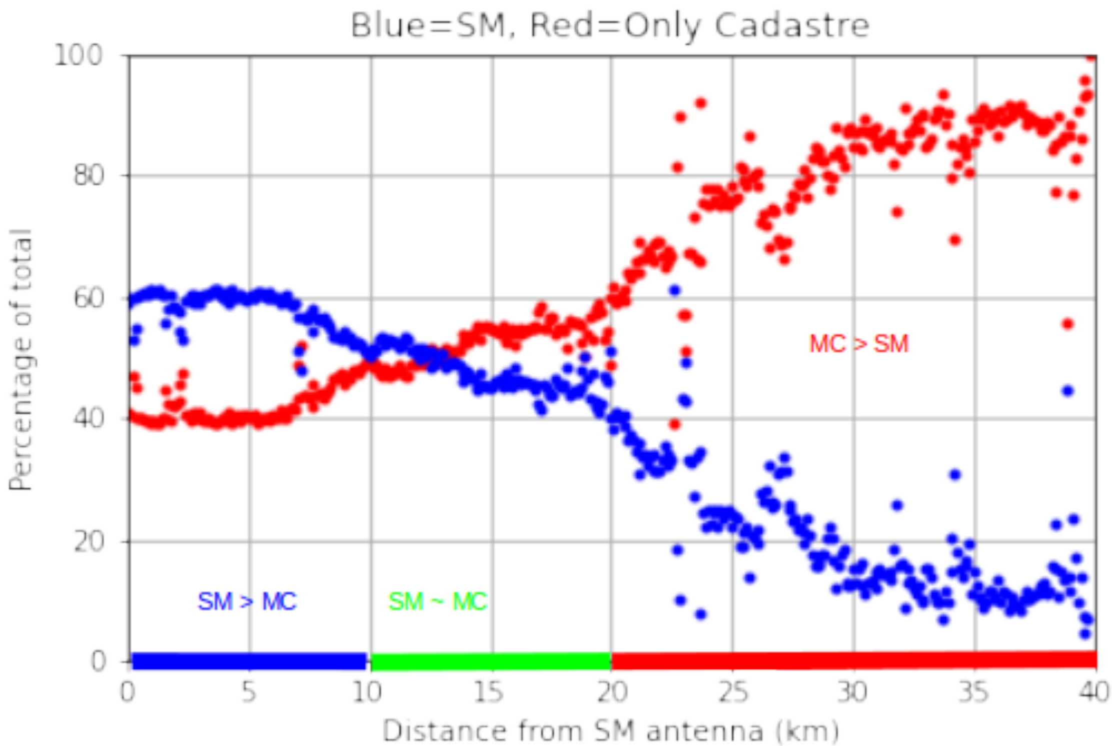


Figure 6: Percentage of targets received by Suburban Marine (blue) and Marine Cadastre (red) in 0.1km incremental distances from the antenna installations at Hopkins Marine Station.

**Discussion**

This analysis shows stronger detection performance by Luma360 in the 0–8 km nearshore environment compared to conventional Marine Cadastre data. The deployment of localized AIS receivers in nearshore environments reveals clear advantages in data fidelity and coverage over traditional wide-area systems. This enhanced resolution is particularly valuable in coastal zones where vessel density is high and signal interference from terrain or infrastructure is common.

Monterey Harbor and the Monterey Bay National Marine Sanctuary (MBNMS) monitor marine traffic to support harbor facilities management and assess potential impacts of vessel activities in the area. Transiting vessels can pose risks such as pollutant discharges, groundings, and sinkings. Improving AIS data coverage near these harbors can enhance response times and provide higher-resolution tracking of vessel movements in these high-traffic waters, which are shared with protected marine life such as marine mammals.

MBNMS has previously used AIS data from MarineTraffic and the U.S. Coast Guard to produce Vessel Traffic Reports that evaluate compliance by cargo vessels and tankers with International Maritime Organization (IMO) recommended vessel lanes. They also implemented a customized alert zone between Point Sur and Pigeon Point that issues notifications when large vessels deviate from the lanes and enter sensitive areas, prompting coordination with the U.S. Coast

Guard to request that vessels move farther offshore. Expanding the described technology beyond Monterey Bay to include this alert zone could provide additional management value—especially if it can distinguish vessel types and deliver real-time alerts of large vessels deviating from established tracks. In addition, adapting the technology to detect non-AIS recreational craft, such as kayaks or personal watercraft, could help address wildlife disturbance near sensitive haul-out sites. This could complement existing MBNMS outreach to kayak operators during harbor seal pupping season and allow comparison of tracked vessel data with wildlife disturbance reports collected by Bay Net volunteers.

As some marine protected areas (MPAs) are located near shore or adjacent to terrain features that may limit conventional AIS coverage, localized AIS systems also offer value for tracking vessel traffic in and around these sensitive zones. This capability can be further strengthened by integrating local radar stations to detect non-cooperative targets—vessels not broadcasting AIS signals—or, more critically, to identify vessels that intentionally disable their transponders upon entering MPAs. Such layered sensing approaches enhance enforcement and support conservation efforts by providing a more complete operational picture.

Similar benefits could extend to the regional scale. The Marine Exchange of the San Francisco Bay Region (SFMX), which supports maritime safety, efficiency, and environmental compliance in one of the nation’s busiest port regions, regularly collects and shares AIS data. SFMX relies on International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA)-certified AIS infrastructure for “official” operations such as vessel traffic services, cable monitoring, and maritime incident response, and is partnering with the U.S. Coast Guard to provide redundancy for their systems. However, gaps remain in nearshore coverage, especially in areas with complex terrain. Localized AIS receivers, such as those deployed by Suburban Marine, could help fill these gaps and provide valuable supplemental data for statistical analysis and for generating alerts in areas where SFMX does not maintain its own transceivers.

A specific example of the Luma360 technology currently in use is the mobile turnkey system offered by Protected Seas. The M2 can be rapidly deployed to a specific coastal region and operate entirely off-grid, relaying real-time vessel tracking along with imagery of targets too small to require AIS (see Appendix).

Collectively, these findings highlight the added value of modular, edge-deployable AIS systems as a complement to national AIS data products, especially in regions where traditional coverage is limited or inconsistent. Integrating localized AIS receivers into existing monitoring networks could enhance data quality, improve response times, and support both conservation and operational objectives across multiple spatial scales.

**Acknowledgements**
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**References**

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**Appendix**
The Marine Monitor M2 brochure is available here.

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