UC SANTA BARBARA
Bren School of Environmental Science & Management

msi Marine Science Institute

MESM Group Project Proposal 2025 - 2026

Drones for Kelp Conservation:

Investigating Applications of Unmanned Aerial Vehicles To Improve Upon Kelp Canopy Monitoring Strategies

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Objectives

Unmanned Aerial Vehicle (UAV) technology is changing how we think about conservation and restoration. Controlled and precise high resolution imaging from UAVs has been successfully deployed on terrestrial ecosystems, however the marine setting remains a new frontier. The Marine Science Institute (MSI) has begun to utilize UAVs in kelp conservation efforts and is looking to further identify and quantify the benefits to monitor kelp canopy coverage and health to refine management and decision-making. Beyond kelp conservation, this work aims to inform future avenues of UAV deployment in kelp aquaculture. The objectives of this project are two-fold:

Objective 1: Identify where UAV technology, offering higher spatial resolution and flexible scheduling, can best inform kelp monitoring, conservation, and aquaculture efforts.
Objective 2: Develop and validate correlations between remotely-sensed variables, using UAV technology, and kelp physiological health

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Background

Kelp forests are foundational marine ecosystems that provide essential habitat, buffer coastline against erosion, and contribute to global carbon sequestration. Yet, these critical ecosystems face escalating threats from climate change, including rising ocean temperatures, increased storm frequency, and ocean acidification[5]. Monitoring the health and productivity of these ecosystems is essential for their conservation.

Remote sensing technologies have proven useful in monitoring changes in kelp canopy cover. However, current satellite-based methods may fail to capture nearshore kelp canopies with insufficient spatial and temporal resolution[10]. Additionally, assessments of a kelp forest's physiological health involve costly dive surveys and chemical sampling. Developing methodologies to remotely assess kelp health, allowing for reduced frequency of field-based surveys, could benefit conservation and aquacultural efforts.

The Santa Barbara Channel, specifically the Mohawk and Arroyo Quemado reefs, serves as the geographic focus of this project. These reefs are vital for their ecological and coastal protective functions[16]. Historical efforts, such as the UAV-based kelp monitoring work by Tom Bell and Kyle Cavanaugh, have established foundational methodologies for mapping kelp canopy cover and understanding ecosystem changes. Their work demonstrated the necessity for higher spatial resolution for kelp monitoring. Complex topography near the coast can complicate kelp coverage calculation and result in underestimates. UAV's pivotal role in high-resolution kelp monitoring and adaptive management strategies, sets the stage for more comprehensive comparisons in other geographic locations and for other applications[4].

Implications

This project aims to expand upon the established methodologies and insights from previous research to explore the comparative advantages of UAV and satellite data for kelp canopy monitoring within the Santa Barbara Channel[10].

Furthermore, we intend to begin to build novel remote sensing methods for assessing kelp condition with UAVs which is particularly beneficial to stakeholders in kelp aquaculture. The global kelp product market was valued at $643.4 million in 2022 and is now projected to increase to $1.2 billion by 2032[2]. Applications of kelp products include plant-based foods, pharmaceuticals, biofuel[16] and livestock feed that reduce cattle methane emissions by 82%[2, 6, 7]. By remotely-sensing kelp conditions, kelp farming operations can be optimized to maximize growth or determine ideal harvest time at a low cost.

For the client, our insights will offer MSI new recommendations on the timing and frequency of future UAV deployments. The development of remote assessments of kelp condition will help MSI and stakeholders in aquaculture build a portfolio of UAV applications in monitoring kelp. The outcomes of this project are also intended to inform a wide audience, including environmental managers, conservation organizations, policymakers, and coastal communities. Insights gained from this project can help quantify impacts of disturbance events, guide resource allocation for kelp restoration, inform climate adaptation strategies, and enhance community-driven conservation and ecosystem management.

Ultimately, the contribution to applied research and the development of management and decision making tools advances the application of UAV technology in marine settings.

Equity

Democratization of Data

A cornerstone of this project is the commitment to data equity and democratization. We are committed to ensuring that collected data is accessible and understandable to community stakeholders, including Indigenous groups, local residents, and policymakers. Landsat data is public, but Planet imagery is only accessible through paid licensing. Therefore, we intend to publish our Planet data derivatives—the data products we generate from their imagery (e.g. shapefiles or polygons of kelp canopy). Data products will follow models of historic public kelp monitoring sources (kelpwatch.org). Furthermore, our methodology and conclusions will be documented in accessible language through a publicly available white paper.

The team will also explore UAV deployment training for youth, conservation, government and indigenous groups to build skills in remote sensing across disciplines and engage the local community.

Engagement with Indigenous Stakeholders

Given the recent designation of the Chumash Heritage National Marine Sanctuary and its proximity to the kelp monitoring sites, we intend to seek and understand indigenous perspectives[9]. We recognize that kelp forests hold profound cultural and subsistence significance for Indigenous communities along the Pacific coast.The decline of kelp ecosystems due to climate change and other anthropogenic factors has disrupted these traditional connections, impacting food sovereignty and cultural heritage[15]. Under our primary objective we intend to interview leaders and stakeholders involved in the Chumash Heritage National Marine Sanctuary. We hope to involve these groups in future deployment of UAV technology. However, we also recognize the value of the tribe's time and resources and are aware of their broadly sought after perspective.

Available Data

The MSI in partnership with the Long Term Ecological Research Network has collected UAV imagery data for two sites, Mohawk and Arroyo Quemado along with diver surveys, monthly for the past four years. UAV imagery is collected using a high resolution multispectral camera, which allows for direct comparison with satellite data.

Under Objective 1, the UAV data will be directly compared with satellite imagery from Landsat and Planet satellites. Under Objective 2, the UAV data will be compared with completed diver surveys of biodiversity within the kelp forests, abundance of submerged kelp, and chemical sampling of kelp blades.

Table 1. Available Data Sources

Data	Objective	Access	Specifications
UAV imagery (for Arroyo Quemado and Mohawk Reef)	Objective 1 Objective 2	Provided by the Marine Science Institute	8 cm/pixel multispectral imagery
Planet Satellite Imagery	Objective 1	Available through UCSB license	3 m/pixel multispectral imagery
Landsat Satellite Imagery	Objective 1	Open Source from the USGS Earth Explorer	Spatial resolution: 30 m/pixel multispectral imagery
Diver Surveys in kelp forests: Submerged kelp abundance, fish and invertebrate populations	Objective 2	Provided by the MSI	Collected monthly
Chemical sampling of Carbon and Nitrogen content	Objective 2	Provided by the MSI	Collected monthly

Possible Approaches

Objective 1: Identify where UAV technology, offering higher spatial resolution and flexible scheduling, can best inform kelp monitoring, conservation, and aquaculture efforts.

1. *Conduct stakeholder interviews to inform management needs:* We plan to engage the Northern Chumash Tribal Council regarding management needs of Arroyo Quemado kelp forest, located within the Chumash National Marine Sanctuary. We will also conduct interviews with kelp conservation managers and aquaculture stakeholders to better understand the current approaches to management and needs-based opportunities.

2. *Compare kelp canopy estimates calculated from Landsat, Planet, and historic UAV imaging and assess potential benefits and challenges of UAV technology in monitoring kelp canopy coverage:* We will leverage existing tools (such as the Kelp-O-Matic Segmentation Tools developed by the Hakai Institute) to apply image processing techniques for estimating kelp coverage

3. *Investigate the feasibility of utilizing UAVs for event-based monitoring of kelp canopy, before and after storms:* UAV-based monitoring can be particularly useful when the timing of high resolution data collection is important. External advisor Matt Riley has agreed to support data collection efforts by providing a UAV system, involving a licensed UAV pilot, and covering any fuel and boating costs. (Provided the team has capacity for data collection).

Objective 2: Develop and validate remote sensing methods using UAV technology to assess kelp physiological health

1. *Develop correlations between remotely-sensed metrics with physiological health metrics obtained through field surveys:* We will expand upon methodology developed in prior studies[2] with additional variables from completed field-based surveys: nitrogen and carbon concentration in kelp blades and biodiversity richness.

2. *Apply correlations to assess health and productivity of kelp aquaculture in the Santa Barbara Channel:* By partnering with aquaculture managers, we will assess the practical value of remotely-sensed kelp correlations.

Deliverables

1. **GIS story map:** The story map will describe the project sites, summarize data analysis steps, and present conclusions on the opportunities for UAV technology to improve kelp monitoring in accessible language

2. **Technical documentation describing methodology for calculating kelp canopy extent:** To ensure transparency and reproducibility of methodology, we will describe the data analysis applied to the imagery datasets in greater detail and accessible language

3. **White paper describing methodology for estimating health and condition of kelp forests**: This deliverable will target external stakeholders in kelp aquaculture, conservation, and indigenous marine sanctuary management. We will describe the development of health correlations using remotely-sensed UAV data and field surveys. We will also document efforts to assess utility of these correlations in an applied setting.

Internships

The MSI welcomes one Bren student as a summer intern to support the development of this work. Funding is not confirmed at this time.

APPENDIX

Budget and Funding

Matt Riley, MESM 2003, has agreed to support this project financially if additional funding beyond the $1,000 provided by the Bren School is required. Matt is specifically interested in supporting pilot projects of drone application in marine conservation and aquaculture settings. This may include purchasing and deploying UAVs at the project sites or in subsequent focused regions, as outlined in the approaches.

Additionally, because of Matt's enthusiasm and interest in UAVs he is providing networking opportunities and professional introductions to relevant stakeholders and organizations for the team. These include Norah Eddy from the Nature Conservancy.

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Dear Capstone Committee,

I am writing to offer my full support of the MESM capstone proposal entitled “Drones for Kelp Conservation: Comparing Unmanned Aerial Vehicle data to satellite imagery to improve upon kelp canopy monitoring strategies”. This project will utilize Uncrewed aerial vehicle (UAV) imagery along with satellite (Landsat and Planet) imagery to evaluate the use of these different data types as tools for monitoring coastal kelp forests. The UAV data is collected through the Santa Barbara Coastal LTER and will be made available to the Capstone group. Landsat data is public and Planet data is available through a UCSB licensing agreement. Additional datasets, such as tide height, sea surface temperature, waves, and seawater nutrients can all be obtained through publicly available datasets.

I am also writing to commit to being a mentor for a summer internship. I will mentor one student, but there is no funding available. The internship will include training and license attainment for research/commercial UAV flying from the FAA, hands-on data collection in the field using UAVs and other survey methods, and data processing and analysis. The Capstone group will select a group member for the summer internship. There are no non-disclosure agreements required for this project.

This project will evaluate the tools readily available for monitoring kelp forests, including UAV and satellite-derived color and multispectral imagery. These data products can be used to assess the extent of kelp forests, change in area over time, and the condition of the kelp. The findings of this study will be relevant to managers seeking to monitor kelp forests (e.g., marine protected areas, national marine sanctuaries, national parks, etc.) as well as aquaculture and kelp farming operations. Collaboration with stakeholders, including managers and kelp farming operations, will be a critical aspect of this project by bridging the best-available research with the needs of those in conservation and industry.

Practical applications of kelp forests, including biofuels, carbon storage and food, are rapidly expanding across the globe. There will be an increasing demand for monitoring tools and procedures. This project can help inform these needs and be at the forefront of research regarding the monitoring and determination of kelp forest extent and condition, including how those protocols can be applied to aquaculture operations.

Sincerely,

Kyle Emery, PhD
Assistant Researcher
Marine Science Institute, UCSB