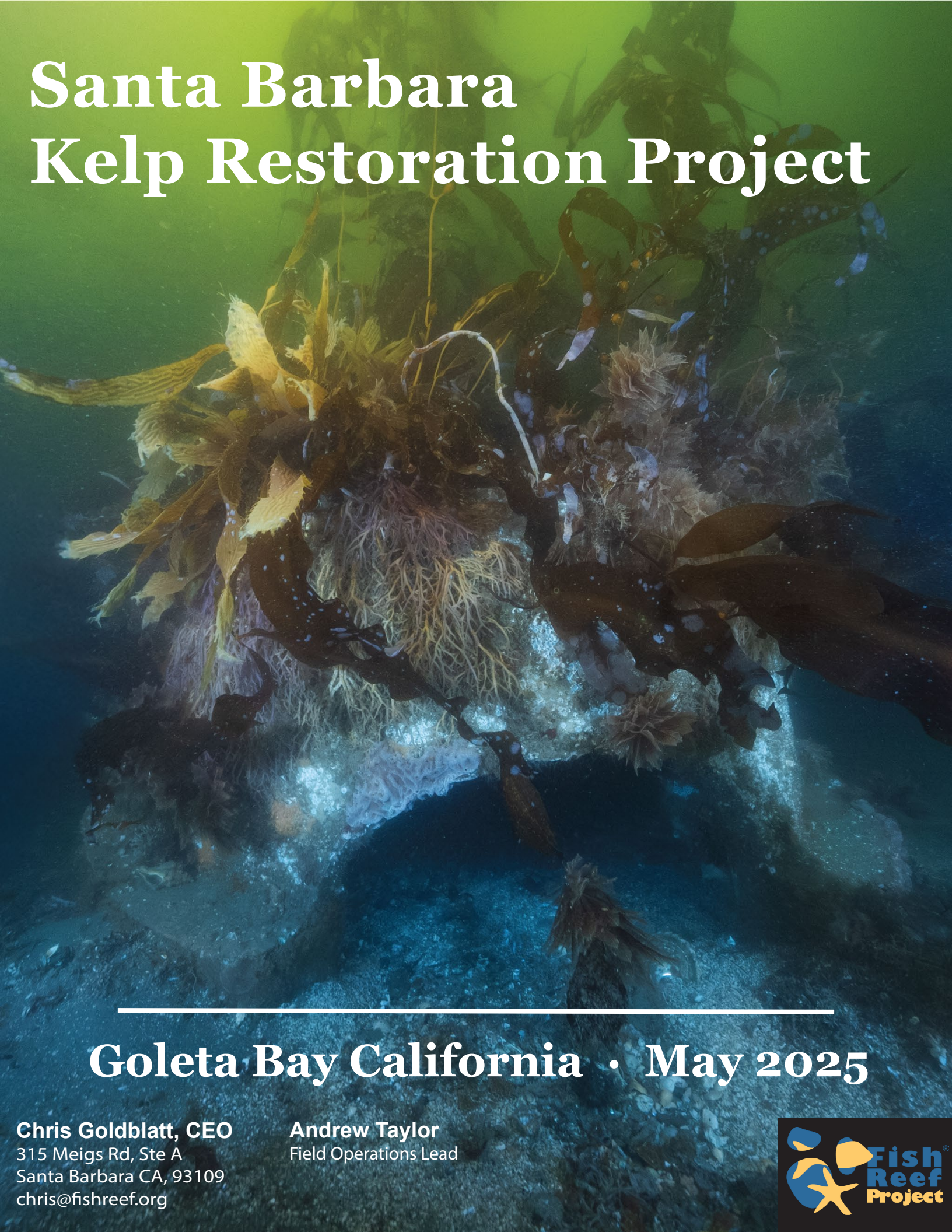
# Santa Barbara Kelp Restoration Project



## Goleta Bay California · May 2025

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Fish Reef Project

Fish®
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## Introduction

The Santa Barbara Kelp Restoration Project—Goleta Reef, known as the Sea Cave® Reef—was developed to enhance both ecological function and economic opportunities in Goleta Bay. The primary objective is to increase the availability of hard substrate, thereby transforming relatively unproductive sandy and muddy bottom habitat into a more diverse and productive marine ecosystem. The introduction of biogenic Sea Cave® structures is intended to facilitate the recruitment of macroalgae and invertebrates, which, in turn, can attract mobile macroinvertebrates and fishes.

This pilot project aims to assess the feasibility of using Sea Cave® units as long-term hard substrate in Goleta Bay and to evaluate their effectiveness in supporting a Macrocystis-dominated kelp reef over a five-year period. Previous deployments of Sea Cave® reefs in other regions have demonstrated their ability to withstand dynamic oceanographic conditions—resilience that is now being tested in the waters off Goleta.

In addition to ecological benefits, the Sea Cave® design is intended to attract a range of nearshore marine species, including commercially and recreationally important species such as spiny lobster, calico bass, halibut, and sheephead, with the potential to enhance local fisheries and stimulate related economic activity.

In March 2024, sixteen individual Sea Cave® units were deployed on sandy, soft-bottom habitat at a depth of 38 feet in Goleta Bay, California (Figure 1 & 2). This report summarizes the third round of post-deployment biological monitoring, conducted in May 2025 (Table 1). For details on pre-deployment site conditions and prior monitoring, please refer to earlier reports. The May 2025 surveys include monitoring results from the Sea Cave Reef site, an artificial reef control site, a natural reef control site, and a soft-bottom control site. Conditions during the monitoring period were particularly poor for fish surveys; therefore, this report focuses primarily on the benthic community at the control sites and the Sea Cave Reef site.

## Methods

A combination of survey methods was employed to monitor four distinct sites: the Sea Cave® Reef site, the artificial reef control site (located near the Goleta wastewater outfall pipe), a natural reef control site, and a soft-bottom control site. At all three control sites, 20 m × 2 m benthic swath transects were used to survey mobile invertebrates and algae. Uniform Point Contact (UPC) surveys were conducted along the same transects to quantify benthic cover and document newly recruited species. Additionally, paired bottom and midwater fish transects were performed to identify and measure fish assemblages. Each control site had a total surveyed area of 80 m².

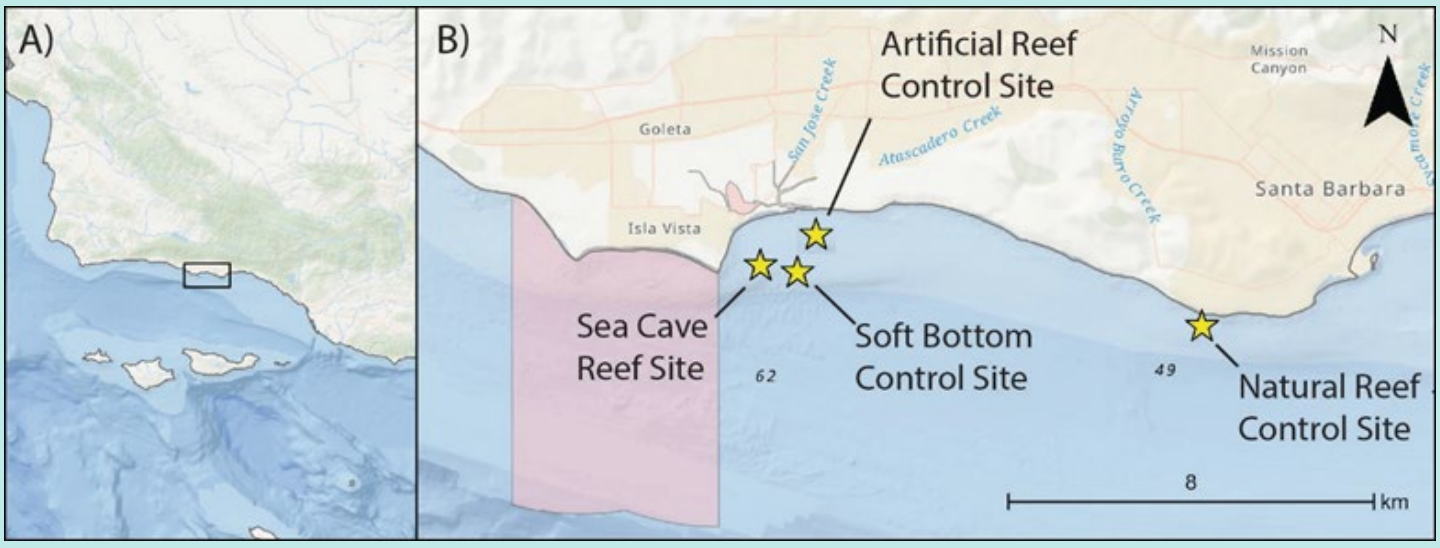


**Figure 1.** Panel A shows the location of the pilot Sea Cave® Reef study site within the Santa Barbara Channel and the greater Southern California Bight. **Panel B** provides a detailed view of the Sea Cave® Reef site within Goleta Bay, along with associated control sites along the Santa Barbara coast. Sixteen individual Sea Cave® units were deployed at the reef site in March 2024.

Fish surveys were attempted on May 10 and May 25, 2025. However, survey conditions at the natural and artificial reef control sites were poor during both attempts, with strong swell and underwater visibility below 2 meters. As a result, very few fish were recorded at either control site. Due to these suboptimal conditions, the fish data collected are likely to be excluded from long-term analyses, as they do not accurately reflect the resident fish communities. Long-term monitoring programs in the region, such as UCSB's PISCO and the Santa Barbara Coastal LTER, typically conduct fish surveys from late summer through early fall when conditions are more favorable. Fish surveys conducted by the Sea Cave® Reef team during these months will provide more meaningful comparisons over time.

At the Sea Cave® Reef site, surveys were conducted along the longest axis of the reef complex to capture both the newly introduced hard substrate and the soft-bottom habitat between individual units—effectively characterizing the emerging kelp forest ecosystem. Three 13-meter transects were laid parallel to each other, covering a total area of 78 m². Divers surveyed benthic invertebrates, algae, and both bottom and midwater fishes along each transect.

## Results

*Soft-Bottom Control*

The soft-bottom control site was composed of low-rugosity sandy substrate and showed minimal algal abundance or diversity. Algal presence was sparse, with benthic cover dominated by bare sand. A few individuals of brown algae (*Desmarestia spp.*) were recorded on UPC transects.

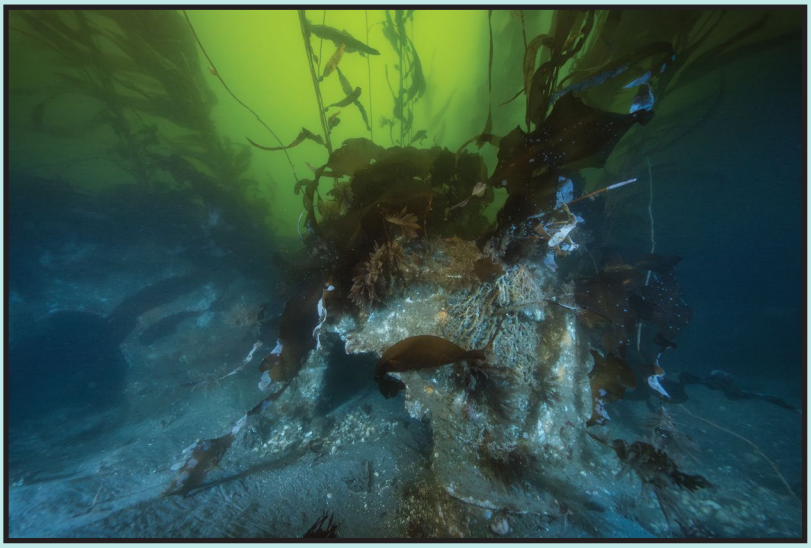

**Figure 2.** Two Sea Cave® Reef units in Goleta Bay showing mature growth of *Macrocystis pyrifera* and *Pterygophora californica*. The image highlights successful algal recruitment and attachment to the biogenic reef structures approximately one year post-deployment.

Eelgrass was present but rare, with 12 and 7 individuals recorded on swath transects 1 and 2, respectively. Mobile invertebrate observations were similarly limited; only a few armored sea stars (*Astropecten armatus*) and wavy turban snails (*Megastraea undosa*) were encountered.

Visibility was poor, ranging from 1 to 2 meters. The only fish species observed was the Pacific sanddab (*Citharichthys sordidus*), a bottom-dwelling flatfish.

*Natural Reef Control*

This site featured consolidated hard-bottom reef with moderate to high rugosity (0.5–2.5 meters), characteristic of a temperate kelp forest ecosystem. Benthic cover was dominated by colonial tube worms

| | | Nov/Jan 2023 | March 2024 | July 2024 | Nov 2024 | *May 2025 | Sept 2025 |
|---|---|---|---|---|---|---|---|
| | | Baseline | Install | | | | |
| **Sea Cave Reef** | Fish | X | NA | X | X | X | |
| | Benthic | X | NA | X | X | X | |
| **Soft Bottom Control** | Fish | X | NA | X | X | X | |
| | Benthic | X | NA | X | X | X | |
| **Natural Reef Control** | Fish | X | NA | X | X | X | |
| | Benthic | X | NA | X | X | X | |
| **Artificial Reef Control** | Fish | | NA | | X | X | |
| | Benthic | | NA | | X | X | |

**Table 1.** Timeline of past, current, and planned monitoring activities for the Goleta Bay Sea Cave® Reef kelp restoration project. This report focuses on data collected during the May 2025 monitoring event, with comparisons to earlier surveys used to assess changes associated with the Sea Cave® Reef deployment. Note that while monitoring is expected to continue beyond September 2025, future activities are excluded from this table for clarity in visualization.

(*Salmacina tribranchiata* & *Phragmatopoma californica*) and bryozoans including *Diaperoecia californica* and *Thalamoporella californica*. Additional cover included *Macrocystis* holdfasts, *Pterygophora californica* stipes, and various red algae.

Swath surveys recorded various mobile invertebrates. Observed species included wavy turnban snail (*Megastraea undosa)*, purple sea urchins (*Strongylocentrotus purpuratus*), and giant keyhole limpets (*Megathura crenulata*). The stalked tunicate *Styela montereyensis* was commonly seen on both transects.

Fish surveys were impacted by low visibility (1–2 meters). On May 25, a single painted greenling (*Oxylebius pictus*) was observed during the survey.

*Artificial Reef Control*

The Goleta wastewater outfall pipe served as the artificial reef control. UPC surveys identified the bryozoan *Diaperoecia californica* as the dominant space holder. Other taxa included hydroids (*Aglaophenia*, *Hydractina*, and *Plumularia spp.*), red algae, and *Macrocystis* holdfasts.

Invertebrate densities averaged 0.300 and 0.350 individuals per $m^2$ for red and purple sea urchins, respectively. Additional species included bat stars (*Patiria miniata*), giant keyhole limpets (*M. crenulata*), and rock crabs.

Algal surveys recorded a mean *Macrocystis* stipe density of 2.13 stipes per $m^2$. *Pterygophora californica* and *Stephanocystis osmundacea* were also observed.

Visibility was limited to under 2 meters. Only two kelp perch (*Brachyistius frenatus*) and one barred surfperch (*Amphistichus argenteus*) were recorded across all transects.

*Sea Cave® Reef Site*

The most notable change since the November 2024 survey was the maturation of the algal community. While previous observations documented high recruitment of *Macrocystis* and *Pterygophora*, the current survey showed well-established *Macrocystis* holdfasts and large, adult *Pterygophora* as dominant space holders. A significant portion of the reef was also covered in dead barnacle shells, which were actively being consumed by crabs and other mobile invertebrates. These shells created a secondary substrate of calcium carbonate, forming microhabitats that may enhance invertebrate recruitment.

Swath surveys recorded a mean *Macrocystis* stipe density of 5.6 stipes/$m^2$ and a mean *Pterygophora* density of 3.5 individuals/$m^2$. Invertebrate observations were dominated by mobile species such as rock crabs, decorator crabs, and lobsters. Slower-moving species (e.g., urchins, sea stars, snails) were less abundant than at the control sites. Notably, lobster sightings declined —from an estimated 5 per Sea Cave unit in November to fewer than 1 in May.

Visibility at the Sea Cave® Reef site was better than at the controls, with horizontal visibility ranging from 3 to 4 meters. The fish community consisted mostly of surfperches, juvenile rockfishes, and small cryptic species. As in previous surveys, numerous juveniles from the Kelp/Gopher/Copper rockfish complex (KGBC), Bocaccio, Vermillion, and Olive/Yellowtail rockfish (OYT) were observed.

Sedimentation remained absent. The Sea Cave structures were clearly visible and free of subsidence; all units remained upright and in their original orientation (Figure 3).

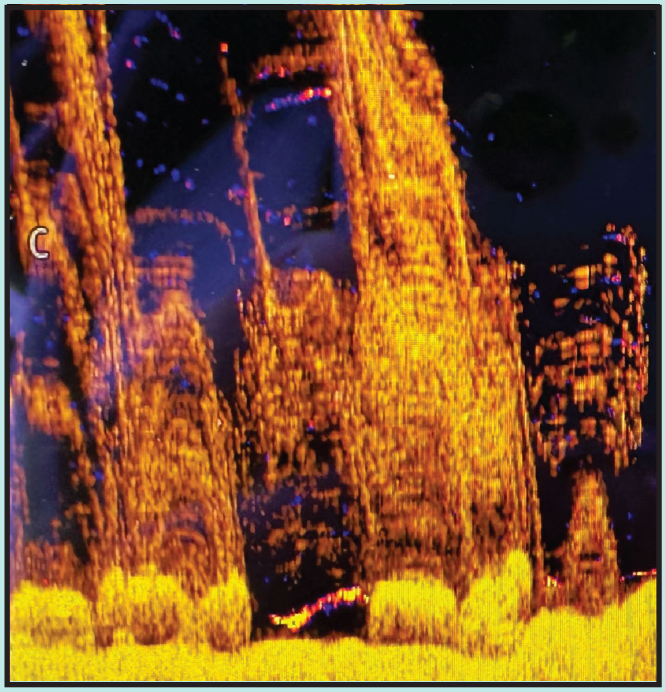


**Figure 3.** Sonar image of Sea Cave® Reef units located in 34 feet of water in Goleta Bay. The image shows kelp (*Macrocystis pyrifera*) extending throughout the water column and reaching the surface, indicating successful canopy development and vertical habitat structure one year post-deployment.

## Conclusion

The most apparent difference between the Sea Cave Reef site and the artificial and natural reef controls was in the benthic cover and dominant space holders (Figure 4). Both the natural reef and the artificial control were characterized by large colonial tube worms (*Salmacina tribranchiata* and *Phragmatopoma californica*) and various bryozoan species—organisms likely representing later successional stages (categorized as 'Sessile Invert.' in Figure 4). These species occupy substantial benthic space and may inhibit the recruitment of seasonal algae such as *Macrocystis pyrifera* and *Pterygophora californica*.

In contrast, the Sea Cave Reef appears to be in an early successional phase that readily supports the recruitment and growth of seasonal algal species. Adult *Macrocystis* stipe density at the Sea Cave Reef was nearly two to three times higher (5.7 stipes/m²) than at the natural reef and artificial reef controls (3.6 and 2.1 stipes/m², respectively). It's worth noting that the Sea Cave survey transects traversed sand channels between individual units, meaning the reported densities are conservative compared to surveys placed solely on contiguous reef structure. The structural design of the Sea Cave units also appears to provide a favorable and consistent surface for kelp recruitment and growth. In contrast, kelp on natural and pipeline reef habitats was more sparsely distributed, with holdfasts often limited to high-relief points, potentially restricting overall kelp development. If the goal is kelp restoration, these results suggest that Sea Cave Reef structures may offer an effective and scalable method for enhancing kelp habitat in soft-bottom systems.

Another major benthic feature of the Sea Cave Reefs was the presence of calcium carbonate barnacle shells that remained after predation by mobile invertebrates (Figure 5). These empty shells appear to create microhabitats that may serve as recruitment refuges for sessile invertebrates, potentially supporting post-settlement survival and increasing biodiversity. Ongoing monitoring of the benthic community on the Sea Cave Reefs will provide valuable insight into temperate reef succession dynamics in Southern California. As these reefs mature, it will be important to assess whether colonial tube worms and bryozoans become dominant space holders, as observed on the control reefs. Notably, increased water movement observed at the control sites (*based on observations by the Sea Cave Reef team*) may contribute to their ability to support larger populations of filter feeders—conditions that appear less pronounced at the Sea Cave Reef site.

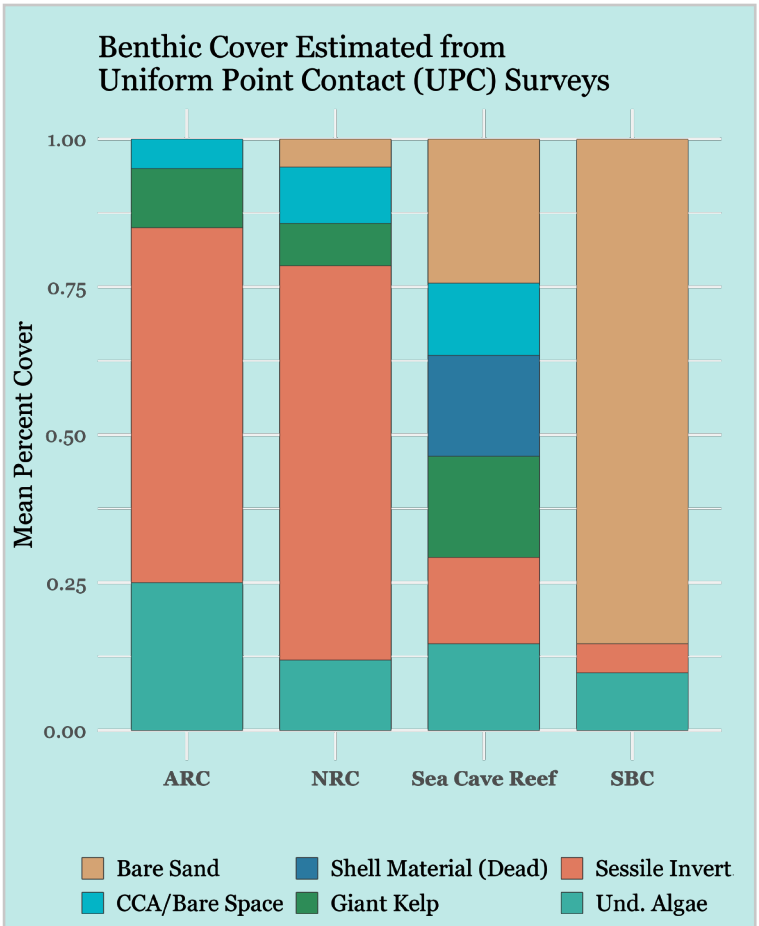


**Figure 4.** Proportional benthic cover at each survey site based on Uniform Point Contact (UPC) data collected in May 2025. Stacked bars represent the relative abundance of six benthic categories: Bare Sand, CCA/Bare Space, Shell Material (Dead), Giant Kelp, Sessile Invertebrate, Understory Algae. Each bar corresponds mean percent cover by site, with color-coded sections indicating the percent cover of each category. Data are shown for artificial reef control (**ARC**), natural reef control (**NRC**), Sea Cave Reef, and soft bottom control (**SBC**) sites.

The mobile invertebrate community at the Sea Cave Reefs was dominated by relatively mobile species such as crabs and lobsters, in contrast to the control reefs, which supported a more diverse assemblage that included lower-mobility species such as urchins, sea stars, and snails. This suggests that the invertebrate community at the Sea Cave Reef remains in an early successional stage, characterized by species that are actively immigrating to the reef. Lobster abundance, in particular, declined significantly between surveys, from an

estimated five lobsters per Sea Cave unit in November to fewer than one per unit in May. This decline is likely due to multiple factors, including seasonal movement and fishing pressure. Throughout the lobster season, both commercial traps and recreational divers were regularly observed at the Sea Cave Reef site (*see November report for images and further discussion*). Seasonal offshore migration during the colder winter months may have also contributed to the lower lobster counts, as individuals often move to deeper water refuges. Future surveys in 2025 will help assess whether the Sea Cave Reefs are able to accumulate lobster biomass during the off-season, and how those patterns shift with the reopening of the fishery in October.

Fish surveys at the Sea Cave Reefs documented a community dominated by surfperches, juvenile rockfishes, and small cryptic species. Notably, no California sheephead or kelp bass were observed during the May surveys, in contrast to the November surveys, where both species were abundant. Although surveys were completed at the natural and artificial reef controls, poor visibility and moderate swell conditions severely limited fish observations. Across both control sites, only four individual fish were recorded on transect, and none were seen off transect—indicating that survey conditions were generally unfavorable. More comprehensive fish community data from the control sites will likely come from the fall surveys, when underwater visibility tends to improve

## Future Outlook

The Sea Cave® Reef site will continue to be monitored to assess its capacity to support temperate marine ecosystems, including diverse assemblages of macroalgae, invertebrates, and fishes. Continued ecological success at this site would strengthen the case for Sea Caves as a sustainable solution for enhancing marine habitats while supporting local economies through increased fishing opportunities and recreational use.

Overall, the Sea Cave® Reef project seeks to build on the successes demonstrated at other deployment sites—including Baja California, South Carolina, and Papua New Guinea—by fostering a richer, more resilient marine ecosystem in Goleta Bay. At the same time, it aims to deliver tangible economic benefits to the local community while contributing to broader climate adaptation and ecological restoration strategies in coastal environments.

**Figure 5.** Left: A Sea Cave® Reef unit in Goleta Bay with dense kelp (*Macrocystis pyrifera*) growth on its upper surface, illustrating the structure's capacity to support kelp recruitment. Right: A California sheep crab (*Loxorhynchus grandis*) foraging on the outer surface of a Sea Cave® Reef unit. These mobile invertebrates were frequently observed utilizing the reef structure for both shelter and foraging habitat.