Restoring California's Kelp Forests

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The Destruction of California's Underwater Landmark

Imagine if all the skyscrapers in New York City disappeared one day. How would losing the buildings that define the city's iconic skyline impact the character and culture of New York? What would happen if the landmarks grounding the city in its history were no longer there to help sustain and propel it into the future? Thankfully, New York does not have to grapple with such losses or answer the difficult questions that come with grieving them. Unfortunately, California does not remain free of such devastation. Instead of immense destruction to its cities, California is experiencing a massive die-off of the kelp forests which have defined the state's coastline and underwater landscape.

From 2014 to 2016, around 95 percent of the kelp forests along California's 350 mile coastline have disappeared.[1, 2] Many of these forests are being replaced by urchin barrens — former sites of healthy kelp forests once rich in biodiversity, but now overpopulated with sea urchins. Urchin barrens pose a threat to the biodiversity along the Pacific Northwest of the United States, the fishing industry, and the fight against climate change.[2] The question remains: what are economically feasible, ethical, and efficient methods of restoring these dying kelp forests?

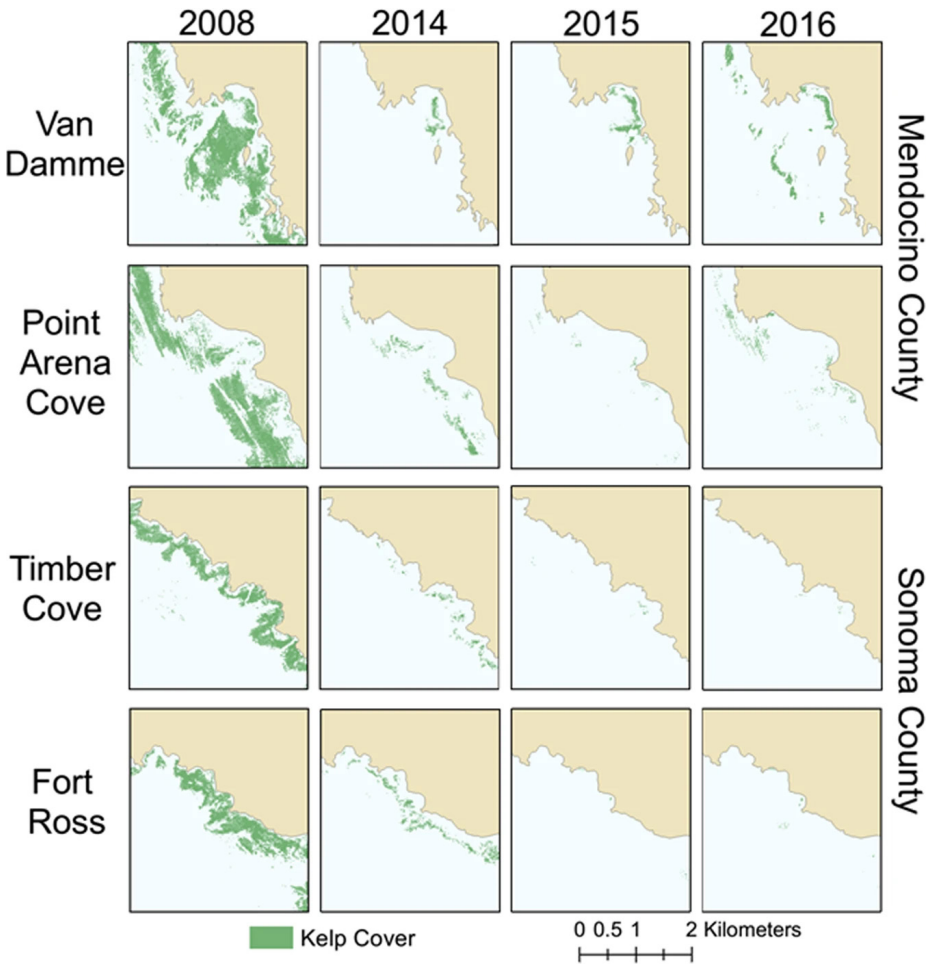

Figure 1: This model shows the canopy area of kelp in Sonoma and Mendocino counties of northern California in 2008. From 2014 to 2016 aerial surveys showed the significant decline in kelp canopy area.[2]

What Caused Kelp Deforestation

The threat of urchin barrens began in

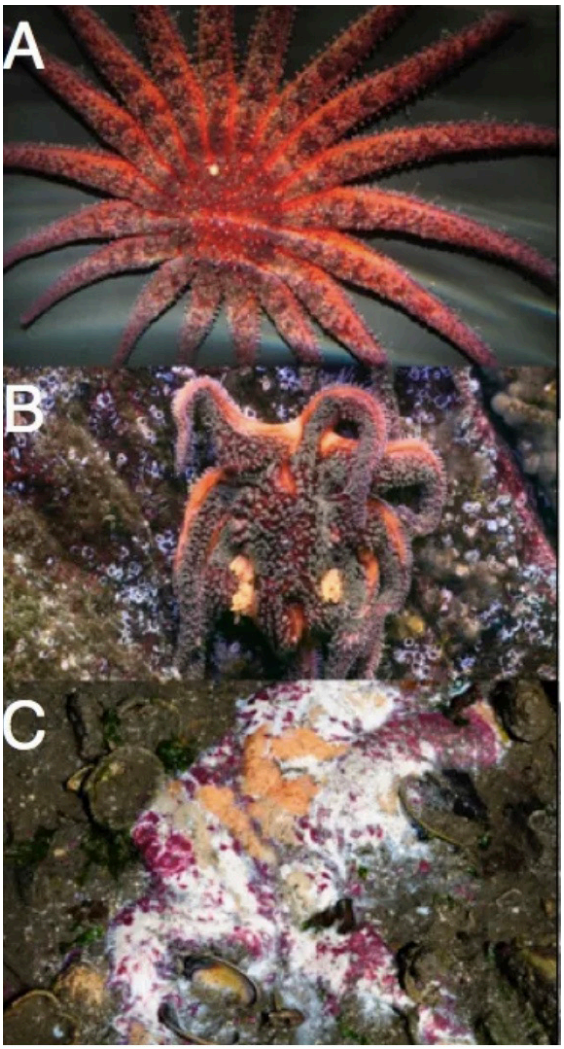

Figure 2: The effects of Sea Star Wasting Disease including body disintegration.[1]

2013 when a disease called Sea Star Wasting Syndrome decimated sea star populations. Sea stars are one of the main predators of purple sea urchins.[3] Sea Star Wasting Syndrome is a bacterial infection that causes the arms of sea stars to separate from the center and the remaining body to melt into a goo.[2] Pycnopodia helianthoides, among the largest sea stars in the world, has been critically endangered with few signs of recovery since the 2013 population decline of 97%.[3] With sea stars no longer populous, urchin populations boomed.[2] Freed from predation, the urchins were then able to eat the kelp's holdfasts – root-like structures anchoring the kelp to rocks and other substrates – and uproot the organism.[4]

Another event that provoked kelp deforestation occurred in 2013 when Northern California experienced a record-breaking Marine Heat Wave causing ocean surface temperatures to become 2.5 °C warmer than normal for 226 days.[1] A simultaneous record-breaking El Niño event from 2014-2017 compounded the effects of the Marine Heat Wave.[1] El Niño events describe climate patterns in which the normal upwelling of oxygen and nutrient-rich water from the deep upwells to the ocean's surface weakens or completely stops. Additionally, ocean temperatures rise along the coast of the United States.[5] Due to a lack of nutrients and water temperatures that exacerbated Sea Star Wasting disease and stressed kelp above its

Figure 3: This image compares healthy kelp forests to urchin barrens.[2]

temperature tolerance range, kelp populations struggled to survive.[1, 2, 3] These combined factors created the perfect conditions for a huge spike in purple sea urchin populations and the proliferation of urchin barrens.[2]

Southern California, in comparison to Northern California, did not see as much kelp loss. This is potentially because of the presence of urchin predators such as the California spiny lobster and California sheephead fish that live only in Southern California due to their temperature range tolerances.[6] However, kelp forests did suffer when fishing operations targeted larger lobsters and sheephead because these predators change their diets based on their size.[6, 7] Since larger lobsters and sheephead feed on more and larger urchins, conservation methods such as marine reserves which ban fishing and allow organisms to grow in size may indirectly facilitate kelp forest recovery and bolster ecosystem resilience.[6]

Currently, a positive feedback loop of behaviors and trophic (relating to the food chain) interactions help ecosystems persist as urchin barrens. With a shortage of floating algae called drift kelp that sinks to the seafloor for urchins to eat, the urchins become active foragers grazing directly on any kelp that try to regrow.[8] Even when there is not enough food, the urchins are still able to dominate the ecosystems since they can regulate their metabolism in such a way that allows them to survive in a near-starvation state for years.[3, 4]

When urchins enter the near-starvation state, their gonads — sexual organs eaten by both animals and humans and commonly referred to as uni or sea urchin roe — shrink in size. Predators like lobsters prefer to eat urchins from kelp forests instead of those from barrens for their larger gonads. Therefore, even if lobsters were present in the barrens they may not eat the urchins since they are not as nutritious. This may be another compounding feedback loop that maintains urchin barrens.[9]

However, there is some hope for kelp regrowth besides human restoration efforts. In January 2015, both red and purple sea urchins were found at the Palos Verdes Peninsula in Southern California with lesions indicative of 'black-ring disease.' This bacterial infection causes dark lesions and spine loss, eventually resulting in death. Decreases

Figure 4: This shows the devastation by lesions from the bacterial infection called 'black- ring disease' on purple sea urchins.[2]

in urchin populations in areas infected with the disease had similar recovery success to ecosystems that were restored through human intervention efforts like urchin culling.[10]

Grieving the Loss of Kelp

Kelp forests serve as intricate habitats supporting diverse marine life by offering shelter, food, and nursery grounds. They alter their surroundings by reducing light penetration, retaining nutrients, and protecting coastlines from storms by disrupting and slowing down waves. Healthy kelp forests contribute to various ecosystem services including food provision, maintenance of fisheries, and recreational opportunities.[11, 12] Additionally, the disappearance of kelp forests removes a large carbon sink — a natural or artificial reservoir that stores carbon — which ultimately helps exacerbate climate change.[11]

With the loss of kelp forests comes the loss of biodiversity, economic opportunities, and connections to cultural heritage. For instance, organisms like abalone depend on the kelp as a food supply.[11] Kelp deforestation and the proliferation of urchin barrens forced 80 percent of abalone in California to die off in 2017. With this mass mortality event came the closure of a recreational abalone fishery worth an estimated 44 million USD and the collapse of the North Coast commercial red sea urchin fishery worth 3 million USD.[1] This economic loss is intensified when considering that abalone also hold significant historical, cultural, and social value. Abalone diving has a long history in California with Chinese fishermen establishing the first commercial abalone fishing camps in Alta and Baja, California during the Gold Rush of 1848 and Japanese and Euro-American fishermen establishing abalone canneries in the 1930s.[13] Abalone are valuable to indigenous communities such as the Chumash, Yurok, Hoopa, Karuk, Pomo, Wiyot, Ohlone, Tongva, and Kumeyaay who harvest them for food, tools, spiritual rituals, ceremonies, jewelry, and cultural identity.[14]

How to Restore California's Kelp Forests

The devastating effects of urchin barrens and the disappearance of kelp forests can be reversed. Devoted effort and collaboration provide hope for a better future for kelp forests. Efforts such as urchin ranching and studies on various conservation methods in the Greater Farallones National Marine Sanctuary are only a few examples of the work being done to restore kelp forests. The many potential restoration methods include: urchin ranching, urchin culling, kelp seeding and transplantation, and creating protected marine areas.

i) Urchin Ranching

One way to restore kelp forests and support the economy is by removing urchins from barrens and using aquaculture to feed them. This enlarges their shrunken gonad size and improves their taste (the fed urchins will produce more desirable tasting amino acids than the ones in urchin barrens), thus making them viable to be sold as food.[15, 16] An experiment by researchers Renee Angwin, Brian Hentschel, and Todd Anderson involving feeding wild-caught purple urchins whole kelp or specially formulated feeds showed that the gonad index doubled in six weeks and reached marketable levels in nine weeks. This method could provide a rapid means of producing high-quality seafood while aiding kelp forest restoration efforts.[16]

ii) Urchin Culling

Urchin culling — a way to describe the systematic extermination of urchins in a given area — has shown promising results in terms of facilitating the recovery of kelp forests. Culling can be done using quicklime (CaO), which creates fatal legions in urchins, or by having SCUBA divers smash urchins with hammers.[12, 17] Some studies have seen culling can effectively reduce the mean density and aggregation of urchins in a specific area for about 12 months.[18] However, smashing of urchins with hammers may have unintended and undesired consequences. Some of these consequences include potential physical damage to the reef due to the act of hammering the urchins and artificial fertilization — which may cause the subsequent recruitment of more urchins if reproductively viable urchins are smashed and release reproductive material. To avoid this, culling should only happen when the urchins have low reproductive condition.[19] Additionally, one-off removal of urchins via culling does not have long-lasting improvements in kelp populations since urchins are likely to quickly return to sites where they have been removed. Therefore, culling must be done multiple times to effectively decrease urchin populations.[12] Since culling is costly, has many logistical constraints, and may raise ethical concerns, it should be implemented with other restoration methods.[18]

iii) Seeding and Transplantation

Figure 5: This image shows the increase in urchin gonad size (in orange) after removing them from an urchin barren and feeding them at an urchin ranch.[5]

Introducing kelp spores or transplants can aid in regrowing kelp forests. Transplantation of kelp from healthy forests to urchin barrens has been successful, but it can disturb intact forests and requires thousands of individuals to establish stable populations.[12] In their experiments at the Greater Farallones National Marine Sanctuary from 2021 to 2023, researchers Bennet Bugbee and Andrew Kim have explored less resource-intensive methods, like seeding areas with bags containing reproductive individuals and rocks called green gravel substrates that have established kelp spores on them.[20] For both methods of introducing kelp it is important to consider genetic diversity, which helps make the ecosystem healthier and more resilient to disturbances. This concern can be mitigated by sourcing propagules from multiple locations.[12]

iv) Marine Protected Areas

Marine protected areas (MPAs) like the Greater Farallones National Marine Sanctuary are another potential way to restore balance in the food web by restoring predator populations. MPAs can help key predators like California sheephead and spiny lobsters grow and reproduce by providing them a safe habitat away from fisheries. Fishing practices that remove large fish capable of preying on urchins might indirectly hinder kelp forest restoration efforts. Within MPAs, safety from fishing can allow organisms to live longer, grow in size, and reproduce; this can lead to increased predation rates on urchins. However, it may take over a decade for predator population densities to increase sufficiently. Therefore, additional management actions, such as raising size limits for fishing, could further aid the growth of urchin predator populations.[6, 21]

Moving Towards a Brighter Future

In the face of losing an iconic part of California's underwater landscape, it is imperative that restoration efforts be collaborative, innovative, and adaptive. The loss of California's kelp forests underscores the interconnectedness of ecosystems and the urgency of addressing environmental threats. Collaboration is needed between the scientific community, governments, citizens, and companies to find the most effective and efficient restoration methods. By implementing comprehensive restoration strategies and fostering stewardship of marine habitats, we can work towards rebuilding California's kelp forests and preserving these vital ecosystems for generations to come.

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