



The Impact of Keystone Species in Marine Ecosystems: the Sea Otter and Sunflower Sea Star

Madeline Cho

Abstract

Kelp forests, consisting of giant kelp that many sea creatures call home, are rapidly becoming more endangered. For example, purple sea urchins are currently rapidly razing the kelp forests due to changing ecosystem dynamics. Keystone species like the sunflower sea star are essential in keeping purple sea urchins in check, as the sunflower sea star is one of the urchins' major predators. However, the sunflower sea star is facing sea star wasting disease, drastically decimating its population. Sea otters, another natural predator of the sea urchin, are also remaining endangered from the lingering effects of overhunting. Because of the dropping numbers of their natural predators, purple sea urchins continue to overgraze kelp forests. Fortunately, there are strategies for remediating this problem. One of the main proposed solutions is to remove purple sea urchins from the environment by employing freelance divers. This can also create some profit for divers removing urchins creates space for the kelp to slowly grow back. Another solution is to raise sunflower sea stars in labs, breeding stronger and more resistant stars to sea star wasting disease. The cause of sea star wasting disease was recently discovered after being a mystery for over a decade, which will likely lead to more strategies for their repopulation. This paper will explore the history and current status of disappearing kelp forest populations. Furthermore, this research will examine how keystone species have impacted kelp forest ecosystems and how external factors, such as climate change, may be advancing these dynamics.

Keywords: Kelp Forest, Sea Star Wasting Disease, Sea Otter, Purple Sea Urchin, Urchin Barrens

Introduction:

Kelp forests cover 25% of the world's coastlines and provide shelter and food sources for over 1000 different species (World Resources Institute, 2023). They are crucial in photosynthesizing carbon dioxide into oxygen, helping to mitigate climate change, but ocean warming and acidification further limit kelp forest resilience in the face of a massive problem: purple sea urchin barrens.

Overpopulation of the purple sea urchin is contributing to an unprecedented decline of kelp forests. For example, sea urchins have begun to consume kelp forests at rapid rates, in the process creating "urchin barrens," or underwater deserts. This greatly limits the regrowth of the forests, while the urchin population only increases, devastating 95% of kelp forests in Northern California alone (People, 2025).

One main reason that the urchins have grown out of control is due to a lack of predators. In past years, urchins were primarily eaten by kelp forest keystone species: sea otters and sunflower sea stars. However, sea otters eat a varied diet, making the urchins far from a main source of food. Sea stars are a more common predator; however, in recent years, sea star wasting syndrome (SSWS) has become extremely damaging to sea star populations, especially sunflower sea stars. This disease renders sea stars completely defenseless and eventually leads to their disintegration (The Washington Post, 2025). Even though it has afflicted much of the sunflower sea star population and inspired extensive scientific research, the cause of SSWS

was unknown until recently (Prentice et al., 2025). Many scientists hypothesize a correlation between climate change and the newly discovered bacterial infection, caused by *Vibrio pectenicida*, as will be discussed in this paper.

Kelp Forests

As previously discussed, kelp forests provide critically important coastal habitat. By reducing the impact of large waves on beaches, kelp forests also increase sedimentation, providing important nutrients like nitrogen. Since they grow near shores, kelp forests act as a natural barrier that lessens the impact of waves and encourages sediment deposition, providing calm and nutrient-dense waters for a variety of aquatic organisms (National Park Service, n.d.). Moreover, with long, outstretched leaves, kelp forests produce 70% of Earth's total oxygen due to their vast capacity for photosynthesis (National Park Service, n.d.).

The mechanisms that kelp forests are responsible for are heavily relied upon by both marine and terrestrial life, but these ecosystems are in danger due to their rapid decline. Between 2014 to 2021, the kelp forests declined 82% from the historical average in the Monterey Bay region (The Nature Conservancy, n.d.). One of the biggest threats to kelp forest growth is climate change, especially the rapid, detrimental increase of carbon dioxide in Earth's atmosphere. As the Earth warms, oceans absorb the excess carbon dioxide in an attempt to cool Earth's temperatures. In doing so, the ocean has warmed by 1.5 °F since 1901, and become more acidic, making conditions unfavorable for kelp regrowth (Woods Hole Oceanographic Institution, n.d.). As a result, the kelp forests are already weakened and are much more susceptible to harm from physical disturbances like out-of-control grazer populations.

Climate change also disrupts and increases the frequency of El Niño events, in which the Pacific coast significantly warms and has more rain events and less wind (Shenton, 2024). This causes large decreases in cold deep-water upwellings that bring nutrients, which are heavily depended on by kelp forests as a source of growth. The large reduction in favorable environments and a lack of nutrients greatly reduces the growth rate of kelp forests. With climate change comes an increase in these events, and there are fewer overall nutrients available for kelp forests to utilize, which ultimately adds to the deforestation of kelp forests and the rise of urchin barrens.

Again, the stability of kelp forests relies on keystone species. Both sunflower sea stars and sea otters are keystone species within kelp forests; however, without them, kelp forests are suffering. By studying how keystone species are being affected and why their populations have decreased, the first steps to figuring out how to care for and maintain kelp forests can be taken. Additionally, researchers can begin to research more on how to prevent the loss of organisms within each species to effectively combat the rapid increase in the deforestation of kelp forests and instead promote sustainable ecosystems.

Purple Sea Urchins

Purple sea urchins are one of the Pacific Coast's most resilient species, found primarily near the shore. They are most commonly found within the kelp forests that grow from Baja California up to Alaskan waters. With a diet of algae and kelp, kelp forests provide the protected habitat necessary for sea urchins to thrive and a seemingly limitless source of food for this grazer species (Aquarium of the Pacific, n.d.). However, with such abundant resources available, the purple sea urchin population can rapidly grow out of control and turn once-limitless kelp forests into underwater ocean deserts when the food chain is disrupted.

History demonstrates that this isn't the first time purple sea urchins have taken over an ecosystem. In the 1800s, when sea otters—a main predator of the purple sea urchin—were hunted near extinction, sea urchin populations grew to an unsustainable amount (Steinhardt, 2022). The sea urchin overpopulation played a big role in sea otters' eventual protection. Similarly, this is happening once again because of a large decrease in urchin natural predators.

These urchins have two main predators: the sunflower sea star and sea otter (Galloway et al., 2023). With the rise of sea star wasting syndrome, which will be further discussed later in this paper, and the addition of new foods to sea otter diets, the purple sea urchin predators are unable to manage urchin populations.

Not only do the purple sea urchins overgraze the kelp forests, but they also create barren, underwater wastelands. With the rise of overpopulated purple sea urchins, a kelp forest's resources are entirely used up, and the urchins enter a state of dormancy, creating what is called an "urchin barren", in which the purple sea urchins will lie on the ocean floor clumped in large groups, within deserts of their own creation (Reef Check, n.d.). They can live for long periods of time without food, and their presence alone inhibits further growth of kelp forests.

Unfortunately, there are very few strategies to remove overpopulated sea urchins. Though it is tedious and slow, one of the most effective strategies is manual labor, with the help of human hands. Groups like Reef Check have been encouraging local divers and fishermen to remove purple sea urchins, which can have a noticeable effect on kelp forest regrowth (Reef Check, n.d.). After all, humans are predators too, and some urchins can be kept to fatten and to sell on the seafood market. In this way, profit is made to fuel finding other solutions, while also allowing space for kelp forests to slowly grow back in hopes of achieving their goal of restoring them to their former glory and heights.

Sunflower Sea Star

The largest predator of purple sea urchins is the sunflower sea star. Even though the sea stars live within the same range of coastline as the urchins, these organisms are not nearly as resilient as the urchins, and they easily succumb to sea star wasting disease. Sea star wasting disease causes the disintegration and fragmentation of sea star limbs and can be fatal in mere days (University of California, Santa Cruz, n.d.). The cause of sea star wasting disease was previously unknown, but recent studies have discovered that the bacteria *Vibrio pectenicida* is one of the major factors contributing to this issue, and more studies will most likely soon be released (Prentice et al., 2025).

Even though there was skepticism about the true cause of the disease as false causes were identified in previous years, various in-depth tests lasting over four years of research proved them wrong, and Prentice's 2025 study outlines all of the steps and methods taken to ensure the accuracy of the data collected (Prentice et al., 2025). Researchers have found that the effects of the syndrome are exacerbated by climate change, possibly because of a warmer environment within an optimal range for the pathogen causing this disease. However, there is no confirmed cause-and-effect relationship at this time.

One of the major solutions to combat the rapidly increasing purple sea urchin population is the growing of sunflower sea stars within community labs, which are then released to urchin barrens. Doing so removes purple sea urchins from the ocean floor and allows space for the kelp forests to slowly regrow. A local example is in Moss Landing, where the Sunflower Sea Star Laboratory is working towards this goal. Currently, they care for California's largest sunflower sea star under human care, "Titan" (Youtube, 2020). Their work is just one example of many labs that are trying to repopulate kelp forests with sunflower sea stars, and one can only hope

that progress will be made in strengthening them to be able to fend against bacteria and changing ocean conditions. Further steps will likely focus on discovering how to prevent the spread of the bacteria and why it has emerged prominently over the last decade.

Sea Otters

Sea otters are the only species of marine mammal that depend solely on dense fur for homeostasis, with up to 1,000,000 hairs per square inch (Seattle Aquarium, n.d.). As a result, sea otters were hunted and endlessly slaughtered for the fur trade. Similar to what is occurring now, the sea otter decline increased purple sea urchin populations. Sea urchin populations spiked out of control, which led to the rapid deforestation of kelp forests, reducing these ecosystems along the West Coast throughout the 1800s (Kingery, 2021).

The Monterey Bay Aquarium was essential in its role in restoring sea otters to their previous population size (Monterey Bay Aquarium, n.d.). However, due to factors such as climate change, great white shark threats, and lasting impacts of the fur trade, both northern and southern sea otter populations are still within limited ranges as compared to the past, only reclaiming about 13% of their previous territory (U.S. Fish & Wildlife Service, n.d.).

Adding to the way that sea otter populations are scattered, contrary to popular belief, not all sea otters eat purple sea urchins. Typically, sea otters all have different tastes and preferences for prey, and these preferences are often learned from their mother (UC Davis Wildlife Health Center, n.d.). A sea otter with a mother who doesn't reach for purple sea urchins as a large staple in her diet will do the same and pass down this trait to further offspring. Moreover, sea otters will not actively seek purple sea urchins as food sources because of urchin barrens, as these urchins consist primarily of starved and empty sea urchin shells (Elakha Alliance, n.d.).

Unfortunately, the extreme displacement of so many otters, along with the more nutritious and preferred sources of food, causes sea otters not to prey upon purple sea urchins in mass quantities.

Discussion

When faced with the complex reality of kelp forest deforestation, solutions must also be complex, combining scientific research, community involvement, and technological innovation. For example, to assist with kelp forest regrowth in Humboldt, California, research labs at Cal Poly Humboldt have been lab-growing kelp seedlings and organizing their manual planting into a previously urchin-barren area. Students at Cal Poly Humboldt were able to join in on this important issue with a new technique that effectively combats kelp forest deforestation, ensures community involvement, and is sustainable (Humboldt State University, 2025). A collaboration between the university and the nonprofit, Greenwave, allows students to learn how to cultivate the native kelp through the aquaculture farm and have the resources to experiment with different cultivation methods. By using "droppers" (ropes hanging from horizontal grow lines), researchers can determine how seaweed grows at different depths to effectively introduce kelp growing to the field of aquaculture (Humboldt State Now, 2020).

For another long-term solution, labs throughout the California coast have been working towards sunflower sea star conservation. As previously mentioned, sunflower sea stars have been grown successfully in labs. This ensures that the sea star can mature and strengthen itself before being released to the wild, where it will withstand harsh conditions in the hopes of reproducing. By doing so, the new sunflower sea stars can repopulate and, ideally, bring back kelp forests by reducing the number of purple sea urchins.

Additionally, now that the cause of the disease has been identified as bacteria, future studies could entail investigating the optimal conditions of the bacteria, their origins, and why it has a greater impact in climate change conditions, as well as finding cures for this infection.

Communities throughout the coast can also work on reducing their impact. Humans cause a variety of problems that also contribute to the slow regrowth of kelp forests. Fertilizer, trash, and other pollutants are easily swept into the ocean as runoff. Since kelp forests grow so close to shore, they often bear the most harm from human runoff. By living near the coast, every person is responsible for the care of the ocean. From cleaning up trash outside and not littering to actively fighting policies that could harm the oceans, every action is important in ensuring the replenishment and protection of kelp forests.

By changing habits regarding fertilizer/runoff of any kind, excess water use, or anything harmful to the coastal environment, kelp forests are put in a better position to regrow. Furthermore, maintaining good practices that protect the oceans and implementing new ones under the most recent research ensures the conservation of both kelp forests and the keystone species that call kelp forests home.

Sea otters, on the other hand, are still considered an endangered species (Monterey Bay Aquarium, n.d.). As sea otters are slowly regaining their historical range, the population is increasing, but not at a rate that quickly brings them back to a sustainable number of individuals. They cannot be forced to eat certain foods, so sea otters are ineffective in managing sea urchin populations. This is especially due to the lack of sea otters in certain kelp forest areas, and the differing preferences in terms of diet, so sea otters cannot be depended on as a primary predator of the purple sea urchins. Instead, the focus should shift towards continued conservation and advocacy for rebuilding sea otter populations so that, in time, they may begin to create larger effects upon stabilizing the number of purple sea urchins found in kelp forests.

Conclusion

The kelp forests of the West Coast are in danger, primarily due to the overpopulation of purple sea urchins, a grazer species, especially with the current lack of keystone predators, like sunflower sea stars and sea otters, to maintain a stable environment. Humans also have an impact through their actions, especially concerning climate change and pollutants that run into the ocean, preventing kelp forest regrowth. Although kelp forests play a crucial role in the ecosystem by providing various mechanisms of survival for marine life, they are declining at a rapid rate and must be protected. Future research should focus on effectively ensuring the survival of kelp forests and all the marine life that depends on them, with the hope of future advancements to protect the keystone species of the kelp forests, such as sea otters and sunflower sea stars. In the meantime, humans should continue to preserve the environment, ensuring the many benefits that the ocean, particularly kelp forests, provide.

References

1. Christensen, S., Potouroglou, M., & Pedder, K. (2023, May 2). What Is Kelp and Why Is it Vital to People and the Planet? Retrieved September 6, 2025, from <https://www.wri.org/insights/what-kelp-forests-protect>
2. People Staff. (n.d.). 5 billion sea stars have shattered and died over the past 10 years, scientists may finally know why. People. Retrieved August 28, 2025, from <https://people.com/5-billion-sea-stars-have-shattered-and-died-over-the-past-10-years-scientists-may-finally-know-why-11786338>
3. Grandoni, D. (2025, August 4). Scientists say they've solved the mystery of starfish that turn to goo. The Washington Post. Retrieved August 28, 2025, from <https://www.washingtonpost.com/climate-environment/2025/08/04/starfish-sea-star-wasting-disease/>
4. Prentice, M. B., Crandall, G. A., Chan, A. M., Davis, K. M., Hershberger, P. K., Finke, J. F., ... Gehman, A.-L. M. (2025, August 4). *Vibrio pectenica* strain FHCF-3 is a causative agent of sea star wasting disease. *Nature Ecology & Evolution*. <https://doi.org/10.1038/s41559-025-02797-2>
5. National Park Service. (2016, May 13). Kelp forests. U.S. Department of the Interior. Retrieved August 28, 2025, from <https://www.nps.gov/subjects/oceans/kelp-forests.htm>
6. Zuckerman, C. (2023, May 26). The vanishing forest. The Nature Conservancy Magazine. Retrieved August 28, 2025, from <https://www.nature.org/en-us/magazine/magazine-articles/kelp-forest/>
7. Woods Hole Oceanographic Institution. (n.d.). Ocean warming. Retrieved September 7, 2025, from <https://www.whoi.edu/ocean-learning-hub/ocean-topics/climate-weather/ocean-warming/>
8. Shenton, W. (2024, January 24). El Niño shows us the true face of climate change. College of the Environment, University of Washington. Retrieved September 6, 2025, from <https://environment.uw.edu/news/2024/01/el-nino-shows-us-the-true-face-of-climate-change/>
9. Aquarium of the Pacific. (n.d.). Purple sea urchin report card. Retrieved August 28, 2025, from https://www.aquariumofpacific.org/reportcard/info/purple_sea_urchin
10. Steinhardt, K. (2022, August 19). The edge of extinction. Alert Diver. Retrieved from <https://dan.org/alert-diver/article/the-edge-of-extinction/>
11. Galloway, A. W. E., Gravem, S. A., Kobelt, J. N., Heady, W. N., Okamoto, D. K., Sivitilli, D. M., Saccomanno, V. R., Hodin, J., & Whippo, R. (2023). *Sunflower sea star predation on urchins can facilitate kelp forest recovery*. *Proceedings of the Royal Society B: Biological Sciences*, 290(1993), Article 20221897. <https://doi.org/10.1098/rspb.2022.1897>
12. Reef Check. (n.d.). Kelp forest urchin barren dynamics. Retrieved August 28, 2025, from <https://www.reefcheck.org/kelp-forest-program/kelp-forest-urchin-barren-dynamics/>
13. MARiNe (Multi-Agency Rocky Intertidal Network). (n.d.). Sea star wasting disease. Retrieved August 28, 2025, from <https://marine.ucsc.edu/data-products/sea-star-wasting/>
14. [Video]. (n.d.). Sunflower sea star project seeks to release purple urchin-eating machines [YouTube video]. Retrieved August 28, 2025, from <https://www.youtube.com/watch?v=2uBlI93V0r8>



15. Seattle Aquarium. (n.d.). The densest fur of any animal on Earth: All about sea otters. Retrieved August 28, 2025, from <https://www.seattleaquarium.org/stories/the-densest-fur-of-any-animal-on-earth-all-about-sea-otters/>
16. Kingery, R. (2021, May 31). The death of an ecosystem: Understanding the collapse of Northern California's kelp forests. Oceanbites. Retrieved from <https://oceanbites.org/the-death-of-an-ecosystem-understanding-the-collapse-of-northern-californias-kelp-forests/>
17. Monterey Bay Aquarium. (n.d.). Sea otter program timeline. Retrieved July 15, 2025, from <https://www.montereybayaquarium.org/animals/sea-otter-program-timeline>
18. U.S. Fish & Wildlife Service. (n.d.). Southern sea otter (*Enhydra lutris nereis*). Retrieved September 6, 2025, from <https://www.fws.gov/species/southern-sea-otter-enhydra-lutris-nereis>
19. Wildlife Health Center, School of Veterinary Medicine, UC Davis. (n.d.). Sea otter facts. Retrieved August 28, 2025, from <https://whc.vetmed.ucdavis.edu/programs-projects/ca-conservation/sea-otter/facts>
20. Elakha Alliance. (n.d.). Sea otters and purple sea urchins in California: A nuanced story. Retrieved August 28, 2025, from <https://www.elakhaalliance.org/sea-otters-and-purple-sea-urchins-in-california-a-nuanced-story/>
21. California Polytechnic State University, Humboldt. (2021, September 17). Kelp is on the way. Humboldt NOW. Retrieved August 28, 2025, from <https://now.humboldt.edu/news/kelp-is-on-the-way>
22. Humboldt State Now. (2020, September 11). Introducing HSU's new seaweed farm, a first for California [Video]. Humboldt State Now. <https://now.humboldt.edu/news/the-first-seaweed-farm-in-california>