Restoration Notes v4n1 2019

Restoration of the West Coast Kelps

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The West Coast coastal environment includes a number of kelp species that harvest sunlight, take in carbon dioxide and release oxygen, and provide critical food and habitat for a wide range of species. They grow best in areas of upwelling where the waters are clean, cold and high in nutrients. Two of the most important species are the perennial Giant Kelp (*Macrocystis sp.*) and annual Bull Kelp (*Nereocystis luetkeana*). The kelps have provided valued resources for humans on the Pacific Coast for thousands of years.

Giant kelp forests are dominated by float-bearing plants up to 150 feet long that grow from the bottom and can spread thick canopies across the sea surface. Giant kelp flourishes in wave-exposed areas with nutrient-rich, cool water ranging from 20 to 120 feet deep. The kelp attaches to rocky areas or cobbles on the sea floor with a holdfast. They can also be found growing on sandy bottoms with the holdfast on exposed worm tubes or the remnants of old holdfasts.

Giant kelp absorbs nutrients from the water through all its surfaces. Under optimal conditions the fronds can grow up to 2 feet per day and a large kelp may have more than 100 fronds. Healthy kelp forests can produce as much oxygen by photosynthesis as the Amazon rainforests do with 100 times less biomass. Giant kelp can live for up to 25 years, but the extent and health of the kelp forests can change rapidly with changes in sea surface temperature, nutrients, turbidity, wave action, and the density of sea urchins and other herbivores.

Bull kelp lives for only one year and without successful reproduction every year a bull kelp forest may decline rapidly. Bull kelp also thrives in dynamic coastal waters and also has a rootlike holdfast with many fingerlike projections (haptera). A flexible stem (stipe) extends up to 60 feet, gradually enlarging to form a single, round float. As many as 60 long, narrow blades grow from the float and form a golden brown canopy on the water's surface. Bull kelp grows from a spore to maturity within a single year, growing up to 10 inches a day. Bull kelp develops spore patches (sori), which are heavy and fall to the ocean floor, hopefully close to the parent plant on a suitable substrate.

Kelp and sea otters

Sea otters helped control the sea urchins, amphipods, isopods, fish, and other species that eat or damage kelp. Studies of otters near Pacific Grove, California, found they were each eating more than 100 urchins a day. The removal of the sea otters from the West Coast in the early 1800s by the fur traders[1] eliminated a key predator of sea urchins and other kelp eaters. The full extent of

[1] More than 600,000 and perhaps a million sea otters were taken from the Pacific Coast from Baja to Alaska during the rush for ‘Soft Gold.’ Bainbridge in draft, Ecological and Cultural Effects of the Fur War the West 1765-1840

the kelp forests before the otter were removed is unknown, but it is likely they were very well developed along much of the coast.

The removal of the sea otters and decline in the kelps made the sea coast ecosystem much less productive. A study in Alaska found that nearshore productivity was two to five times higher in in areas with kelp. You can see the difference today on beaches where even a small fragment of kelp in the sand creates a boom of insects and other organisms. Offshore kelp provides food for insects enjoyed by Phoebes, Canyon Wrens, Whimbrels, and other shore birds when fragments wash ashore.


KELP BARREN

After otters and other predators, including lobsters and fish, are removed sea urchin populations can increase exponentially and overgraze the kelp, creating 'urchin barrens.' Once threshold urchin densities are attained, phase shifts between kelp beds and barrens are abrupt. Destructive grazing creates positive feedback mechanisms that accelerate the shift to barrens. Actively grazing sea urchins have unlimited, high quality food, and that enables them to grow rapidly and reproduce quickly. In these urchin barrens the sea floor is dominated by the purple and red spines of urchins as they scour the rocks for food. Even the hard, calcified, pink crustose algae can't withstand high-impact urchin grazing. Recovery can be very slow as these urchin barrens are fairly stable. One diver compared the current depauperate kelp beds with a visit to a Serengeti Plain in Africa that no longer had any of the large mammals. Another research diver and recreational abalone diver, says, "*It's like seeing a forest you once knew turn into a desert. Not only do you lose all the trees, but all the smaller plants around them die, until there's nothing left*."

Sea stars as urchin eaters

Sea stars, another important predator of urchins, were virtually wiped out by diseases starting in 2013. Sea star wasting disease (SSWD) extended from Mexico to Alaska and devastated over 20 species. In the Northwest the density of one of the more common sea stars, *P. helianthoides*, decreased 97%. SSWD appears to have multiple causes and may involve different disease organisms. Rising sea temperatures and pollution may have played a role.

Lobsters as urchin eaters

Lobsters are also predators of sea urchins and have been observed to play a significant role in urchin density in some studies. The continuous over-harvesting of spiny lobsters (*Panulirus interruptus*) in California and Baja California for more than 100 years has probably contributed to the decline of kelp forests. One study of the Atlantic lobster found captives ate only about an urchin every 3 days (compared to sea otters at up to 100 per day). Rising prices for lobsters have increased fishing effort and the commercial lobster fishery in California took almost a million pounds during the 2014-2015 fishing season.

Lobster populations can recover when protection is provided. The number and mean size of legal lobsters captured inside protected marine reserves were greater than in traps placed outside in fished areas. Population density was up to 1 lobster per 50 m2 in a reserve. Benefits developed within 5–6 years of reserve establishment and included larger mean size, shifts in population structures toward larger size classes, and approximately four to eight times population increase based on trap yield (lobster/trap). Before European settlement and the development of commercial lobster fishing the population density was probably much higher.

Algal blooms

More recently harmful algal blooms have also killed large numbers of marine invertebrates and mammals[2] and this can increase kelp losses. The relative influences of upwelled versus anthropogenic nutrients is uncertain. Stormwater discharge, sewage outfalls, and agricultural runoff can contribute to algal blooms.

Paralytic shellfish poisoning (PSP) results from a number of saxitoxin derivatives produced by dinoflagellates in the genus *Alexandrium*. Sea otters are not immune to paralytic shellfish poisoning toxins (PSPT) but do have some the ability to detect and avoid consumption of lethal amounts.

Domoic acid poisoning (DA) is caused by diatoms in the genus *Pseudo-nitzschia*. These can affect people who ingest the poisons in food. DA poisoning has also led to thousands of sick or dead seals, sea lions, sea otters, dolphins, birds, and whales along the West coast in recent years. DA has been detected in seafood species along the California coast (bivalve shellfish, sardines, anchovies) almost every year since 1991.

Invasive algae

An invasive algae species was accidentally introduced in 2003. This brown algae (*Sargassum horneri*) was accidentally brought over to the Port of Long Beach by a cargo ship from Japan. The spores of this plant then traveled to Catalina Island on a recreational boat and quickly took root. Sargassum can tolerate much warmer water (50-75ºF) and is commonly known as ‘Devil

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[2] These blooms also occurred in the past. In 1799 more than 150 Aleut sea otter hunters working for the RussianAmerican ‘Fur’ Company were poisoned and 100 died after eating contaminated mussels.

Weed.' It is an annual and can self-fertilize, so multiple generations can develop very rapidly. This can displace kelp.

Sea otters and fish

Some fish graze on kelp and will damage kelp forests when present in large numbers. Sea otters helped control some of the fish species that eat kelp.

Sheephead fish as urchin eaters

Many fish that eat urchins and other kelp eaters have also been virtually eliminated in many areas by commercial and recreational fishing. Sea urchins ranked only 7th in relative importance in the diet of the long-lived California sheephead (*Semicossyphus pulcher*) at San Nicolas Island, but when the fish were removed from experimental areas the sea-urchin population increased 26% in the first year. Each sheephead was eating more than 20 urchins a day or about 8,000 urchins per hectare every year.

Archeological sites in the Channel Islands suggest the sheephead was once both highly abundant and an important target of fishing activities by native people. Analysis of bones showed they were first in abundance at many sites. The average size of sheepheads along the northern Channel Islands today is significantly smaller than in the past as a result of commercial and recreational anglers and deteriorating ecosystem health.

During the late 1800s, Chinese fishermen caught large numbers of sheepheads to dry and salt for the market. After fishing pressure on sheephead and lobsters increased in the 1940s kelp deforestation became more obvious along the Channel Islands. In the 1980s pressure increased again as commercial fisheries began to supply live small sheepheads to Asian markets and restaurants. This fishery grew rapidly, with sheepheads becoming a large share of the catches.[3] This intensive commercial exploitation has become a complex, multimillion-dollar industry and no doubt disadvantaged the kelps.

Sheepheads removal can adversely affect the structure and function of kelp forest ecosystems. Overfishing can trigger trophic cascades and widespread ecological dysfunction when other urchin predators are also lost from the system. No early data is available but it appears likely sheepheads are much less common than they were originally. Density is much higher in protected reserves and the biggest sheepsheads are found in the center of reserves.

Current status

In a recent study kelp in California only occupied a third of the range measured in 1911, and that was likely much less than originally found on the coast before the sea otters were wiped out from 1795 to 1840. A historical study of the Palos Verde kelp forest showed maximum extent in 1928 of almost 2,500 acres, this dropped to a low of 4 acres in 1974, restoration work has helped the kelp to rebounding to 500-700 acres in recent years.

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[3] this pressure put it as vulnerable on the IUCN Red List for endangered species

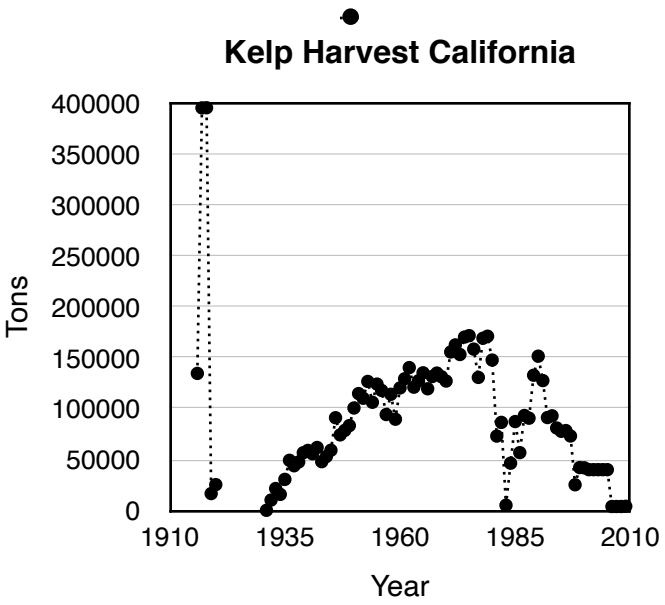
Kelp decline continues to be widespread across the fur trapping coasts. Dr. Tom Mumford, Washington Department of Natural Resources, reports that floating kelp beds have all but disappeared from southern Puget Sound. Declines are also reported generally from the Salish Sea, including the coast of British Columbia. The northern coast of Washington has done a little better thanks to the return of sea otters.

Declines in bull kelp, once common on the northern California coast, have been equally catastrophic. Recent studies showed only 7 percent of the kelp found in previous years. This has created starvation conditions for herbivores and greatly reduced habitat for fish, invertebrates, and mammals. The suggested causes include: toxic algae blooms, the widespread sea star disease, and the increasingly warm water from climate change. Bull kelp may die in water temperatures above 63°F (17°C). The collapse of the kelp forests has adversely affected the coastal economy.

The giant kelps are also becoming a victim of global warming. The ocean warming event of 2013-2016 caused extensive damage to kelp forests. Abnormally high sea surface temperatures reduce the upwelling of nutrients that the giant kelp need to prosper.

Discharges of hot water have also damaged and destroyed kelp forests. Hot water from the San Onofre Nuclear Generating Station in northern San Diego County eliminated 150 acres of kelp. Some studies suggests that the kelp losses in southern California have been caused primarily by large increases in contaminated sewage discharged into coastal waters, sedimentation from coastal development, and reduced upwelling.

The Giant Kelp forests were heavily harvested beginning in the early 1900s. By 1911 several companies from San Diego to Santa Barbara were active.



This peaked during World War I when giant kelp was used to make potash and acetone for explosives and munitions. Ground up and liquefied kelp was fermented and then processed. The potash was used to make black powder and the acetone was use to make smokeless cordite.

At the outbreak of World War I, Germany had been the world's largest supplier of potash and they immediately embargoed the supply. The price of potash rose 1,000 percent by 1916 and new sources had to be found. In February 1916, the Hercules Company started construction of a $7 million kelp processing plant

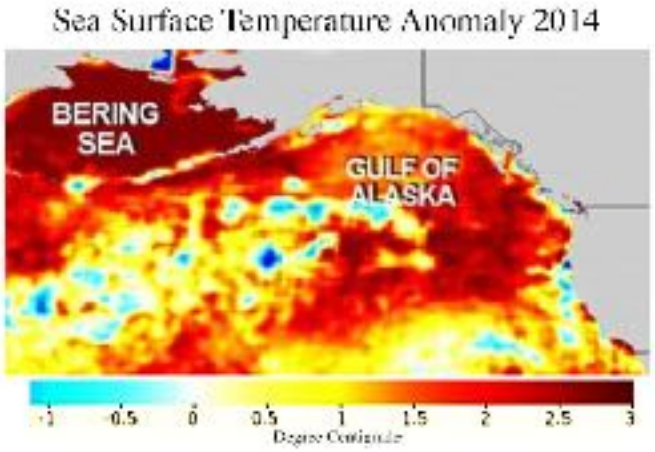
in Chula Vista (south of San Diego). Completed in just six months, the plant had more than 150 50,000 gallon redwood tanks to digest the macerated kelp.

After the war ended the harvest of kelp declined dramatically. In 1928 a San Pedro company began harvesting kelp again and adding it to livestock and poultry food. In 1929, the Kelco Company of San Diego began harvesting and processing giant kelp for livestock feed and algin and agar for foods and other products. Mexican harvesters in Ensenada have also taken kelp from beds off Baja California. Over the years more than 8 million tons of kelp were harvested!

From 1970 to 1979 the harvest averaged nearly 150,000 tons a year and in 1978 the California harvest employed 800 people, from sea captains and divers to physicists and chemists. Kelco operated five huge kelp harvesting ships at one point. Hedge-clipper knives led to conveyor belts that carried the cut kelp on board. Each ship could take 500 tons of wet kelp every day or two and each load was enough to make 2,500 pounds of algin. From 1980 to 1989 the average harvest had declined to 66,000 tons. In 2001, the kelp harvesting industry was valued at more than $30 million. The harvest dropped dramatically in 2006 when ISP Alginate (successor to Kelco) closed its operations in response to growing regulations and moved to Scotland. Some kelp is harvested from the coast as food for abalone, commercial uses, and a small amount for food for people.

Kelp Restoration

Restoration efforts have been made in many areas with modest success. The most persistent kelp beds appear to occur on solid rock substrate with moderately low relief and moderate coverage by sand. In one restoration effort the highest density of adults was on larger boulders that provided sufficient stability for growth and development of the young sporophytes.



Between 1967 and 1980, kelp restoration was conducted along the Palos Verdes Peninsula by the Institute of Marine Resources and the California Department of Fish and Game. This work combined sea urchin control and kelp transplanting, with the hope of establishing several small stands of giant kelp that would provide seed stock for new and expanding beds. In 1974, the first naturally expanding kelp stand in 20 years was observed off the Palos Verdes Peninsula. By 1980, when restoration work was discontinued, the stand covered nearly 600 acres. Today the forests typically range from 500-700 acres.

In another project more than 3 million urchins were removed over 4 years, reducing the density from 18.5 purple urchins per square meter to 1.4. It helped, but the cost of continuous urchin removal and kelp planting would be very high for the entire coast. Ocean Cove was the location of the Watermens Association first urchin removal event on Memorial Day weekend in 2018. One hundred divers removed 56,000 purple sea urchins from the cove.

This is a good first step to restore the health of the ocean that has been recently disrupted by an explosion of the urchin population.And in the worst areas with 100 sea urchins per square meter the cost of removal would be staggering. Off the northern California coast an urchin removal vacuum cleaner has been developed. Diver Jon Holcomb found he could clear almost a tennis court sized area in two hours. Faster than hand cleaning, but he admits, “It's much like trying to scratch the paint off a house with a pin,” says Holcomb. “It's not gonna be easy.”

Marine biologist Nancy Caruso has addressed the cost issue by working with local high school students to raise juvenile *Macrocystis* in their classrooms and then outplanting the kelp with volunteer divers. One project included 5,000 students (ages 11 to 18) and 250 skilled volunteer divers. They planted kelp in 15 different areas off the coast of Orange County. Only one spot near Dana Point had kelp that could serve as a resource base. They collected reproductive blades from these kelp and the students cleaned them. Then they were left out of water in the refrigerator overnight, covered with paper towels. The next morning they would put them back in ice-cold seawater and the “shocked” kelp blade would release millions of spores. These are 400 times smaller than you can see. The spores would land on small ceramic bathroom tiles. Students would raise the kelp in the classroom nurseries for about four months. At this point you can see them with your naked eye, and then they would be set out in the ocean by divers.

In Tasmania lobsters were reintroduced to help control urchins. On isolated patches of urchin barrens this really helped. But on the big kelp barrens, you can pour in large lobsters, and they will eat hundreds of thousands of urchins; but they cannot reduce the urchins enough for any kelp to reappear.

Recent work with edible kelp farming on the East Coast offers new hope for rapid establishment of kelp using submerged cables and a string with a young kelp established in a lab. These sugar kelp farms not only offer a remarkable vision of how to grow kelp, but under the kelp they also grow mussels, clams and oysters. On the West Coast The Puget Sound Restoration Fund and a team of scientists are using kelp farming to determine if these ‘seaweeds’ can help fight the growing problem of ocean acidification by taking up carbon dioxide from the ocean water.

The decline of the kelp forest exhibits many of the problems facing restoration ecologists. You can’t easily fix the kelp ecosystem by considering the kelp. A good kelp forest needs sheephead fish, sea otters, sea stars, crabs, clams, lobsters and more. In turn the sea otters depend on the kelp for shelter as the rest or to hold the pups in place while the mothers hunt. Trying to return just one part can be helpful, but is likely to require persistent and costly efforts on several fronts for success. A combined sea urchin removal effort and seeding with kelp culture can help start

recovery, but the goal should be to return sea otters, allow sheephead and lobster numbers to increase, and to reduce the discharge of stormwater, pollutants, nutrients and hot water into coastal waters.

A comprehensive plan for kelp restoration along the Pacific Coast is long overdue. In addition to the kelp planting we also will need to expand the population and range of sea otters. Improved understanding of the methods for growing kelp also make it more likely that successful reintroductions can be made. An ocean based section of the California Conservation Corps could provide training and jobs for hundreds of young men and women removing urchins and growing and transplanting kelp.

Further information

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Kelp and algae farming

Kelp farming is offering new understanding of the kelps. Many species are harvested for food, including Bull Kelp. Others are grown or harvested for commercial use in cosmetics, food, fuel, and other industrial uses. A few of the pioneers include:

Louis Druehl started farming kelp back in 1982 at Kelp Bay, just west of Port Alberni, BC. His was the first commercial seaweed operation on the Pacific Coast. Druehl started farming a one-

acre patch of ocean, using ropes seeded with kelp, and sold his produce to a handful of health food stores keen on the plant's nutritional benefits. He continues to grow kelp and other marine algae today.

Michael Graham has been farming on a small scale in big tanks at Moss Landing, on the central coast of California. Using big tubs he produces between 50 and 100 lbs of seaweed a week. His family sells their seaweed to upscale restaurants in Monterey and the San Francisco Bay Area.

Tessa Emmer, Catherine O'Hare, and Avery Resor constitute the all-female braintrust behind Salt Point Seaweed (saltpointseaweed.com). They've been harvesting wild seaweed off the coast of Mendocino County, located a few hours north of San Francisco, for two years and selling it to chefs at local restaurants, seafood CSAs, and retail. They are planning to establish an active, open-water farm.

Daniel Marquez manages a 25-acre plot off the Central California coast to grow seaweed (pharmersea.com). Marquez uses the seaweed to make beauty products, sold through Ama SeaBeauty, in downtown Santa Barbara.

Many others are now developing or contemplating farming operations in tanks on shore or at sea in California, Oregon, Washington, and British Columbia. The growth of production has been inhibited by complex and overlapping layers of regulations.

GreenWave is an ocean farmer and fisherman-run organization dedicated to building a new blue-green economy that creates jobs, mitigates climate change and grows healthy food for local communities. GreenWave.org

The California Center for Algae Biotechnology (Cal-CAB) is a consortium of academic researchers from around the State of California, primarily focused on industrial use and fuels. Email: calcab@ucsd.edu. California Center for Algae Biotechnology (Cal-CAB), University of California, San Diego, 9500 Gilman Drive, MC:0435, La Jolla, CA 92093-0435.

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