

Giant Kelp

History of the Use and Harvest

Various species of kelp, including giant kelp (*Macrocystis pyrifera*) have been used for hundreds of years in many parts of the world as food for humans and animals. Kelp has also been used for many years in Asia and Europe as a fertilizer and as a component of gunpowder. Algin, found in the cell walls of kelp, is valuable as an efficient thickening, stabilizing, suspending, and gelling agent. Algin is used in a wide range of food and industrial applications including desserts, gels, milk shake mixes, dairy products, and canned foods. It is also used in salad dressings to emulsify and stabilize them, in bakery products to improve texture and retain moisture, in frozen foods to assure smooth texture and uniform thawing, and in beer to stabilize the foam. In industrial applications, it is used for paper coating and sizing, textile printing, and welding-rod coatings. In pharmaceutical and cosmetic applications, it is used to make tablets, dental impressions, antacid formulations, and facial creams and lotions. Giant kelp is harvested in California to supply food to several aquaculture companies for rearing abalones. It is also used for the herring-roe-on-kelp fishery in San Francisco Bay.

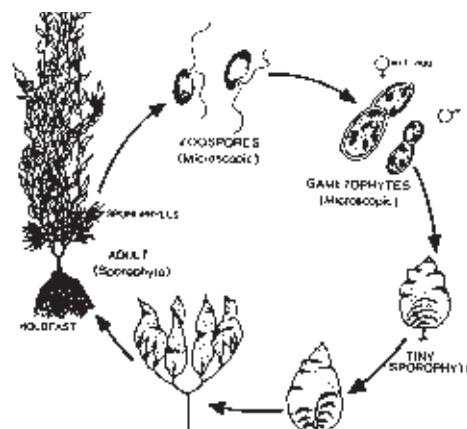
Giant kelp was first harvested along the California coast during the early 1900s. Many harvesting companies operated from San Diego to Santa Barbara beginning in 1911. Those companies primarily extracted potash and acetone from kelp for use in manufacturing explosives during World War I.

In the early 1920s, having lost the war demand, kelp harvesting virtually stopped. In the late 1920s, giant kelp was again harvested off California. Philip R. Park, Inc., of San Pedro began harvesting kelp in 1928 to provide ingredients for livestock and poultry food. The following year, Kelco Company of San Diego (now ISP Alginates, Inc.) began harvesting and processing giant kelp.

Since 1917, kelp harvesting has been managed by the California Department of Fish and Game (DFG) under regulations of the Fish and Game Commission. Although the surface canopy can be harvested several times each year without damage to the kelp bed, regulations state that kelp may be cut no deeper than four feet beneath the surface. There are 74 designated kelp beds and each is numbered; a kelp harvesting permit is required. Specific beds can be leased for 20 years; however, no more than 25 square miles or 50 percent of the total kelp bed area (whichever is greater) can be exclusively leased by a company holding a harvesting permit. In addition to leased beds, there are "open" beds that can be harvested by any company holding a permit. Permit holders pay an additional royalty of \$1.71 to \$1.91 per wet-ton of kelp harvested, depending on the international market price.

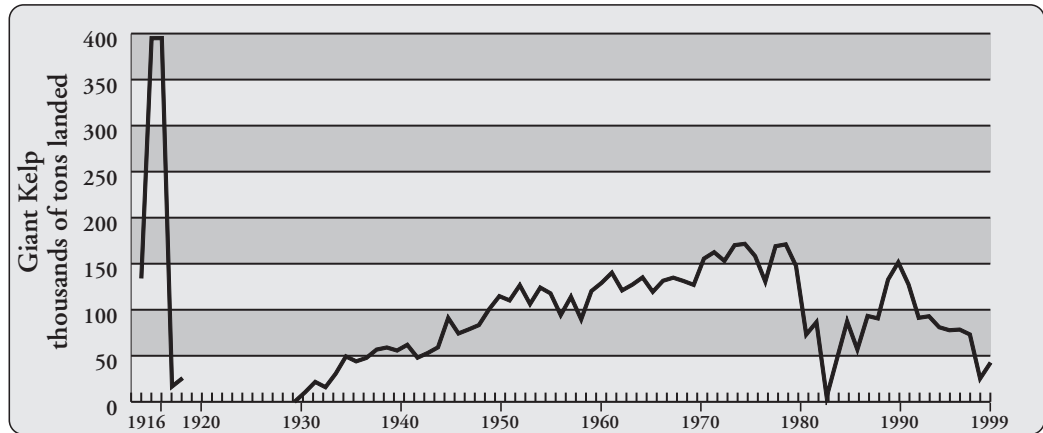
Today, giant kelp is harvested on kelp beds from Imperial Beach, near the U.S.-Mexico border, to Monterey Bay, California. Mexican harvesters in Ensenada provide another source of kelp from beds off Baja California. Giant kelp is one of California's most valuable living marine resources and in the mid-1980s supported an industry valued at more than \$40 million a year. The annual harvest has varied from a high of 395,000 tons in 1918 to a low of less than 1,000 tons in the late 1920s. Such fluctuations are primarily due to climate and natural growth cycles, as well as market supply and demand. During the 10-year period 1970 to 1979, the harvest averaged nearly 157,000 tons, while from 1980 to 1989 the average harvest was only 80,400 tons. The harvest was low in the 1980s because the kelp forests were devastated by the 1982-1984 El Niño and accompanying storms, and by the 200-year storm that occurred in January 1988. In most areas, the beds of giant kelp recovered quickly, with the return of cooler, nutrient rich waters. Harvests in California increased to more than 130,000 tons in 1989 and to more than 150,000 tons in 1990. During the 1990s, increasing international competition from Japan for the "low end," or less purified end of the sodium alginate market caused ISP Alginates to reduce harvests by about 50 percent. ISP Alginates anticipates California's harvest in this decade will be approximately 80,000 tons annually.

Methods of harvesting are used to suit the harvesters' purposes and needs. The ISP Alginates Company uses specially designed vessels that have a cutting mechanism on the stern and a system to convey the kelp into the harvester bin. A propeller on the bow slowly pushes the harvester stern-first through the kelp bed, and the reciprocating blades mounted at the base of the conveyor are lowered to a depth of three feet into the kelp as harvesting begins. The cut kelp is gathered on the conveyor and deposited in the bin. These vessels can each collect up to 600 tons of kelp in one day and to facilitate its harvesting operations, the company conduct regular aerial surveys. The survey



Giant Kelp, *Macrocystis pyrifera*
Credit: DFG

**Commercial Landings
1916-1999, Giant Kelp**
Data Source: commercial
landing receipts.
Kelp landings consist primarily
of giant kelp; commercial kelp
harvest data is not available for
1921 through 1930.



information is used to direct harvesting vessels to mature areas of kelp canopy with sufficient density for harvesting.

The Pacific Kelp Company uses a modified U.S. Navy landing craft with a cutting device and conveyor system mounted on the bow to harvest giant kelp off central California. The Pacific Kelp Company vessel holds approximately 25 tons of kelp. In contrast, for the herring-roe-on-kelp fishery, kelp is harvested by hand from small skiffs or other small boats and then transported by truck to San Francisco Bay.

Status of Biological Knowledge

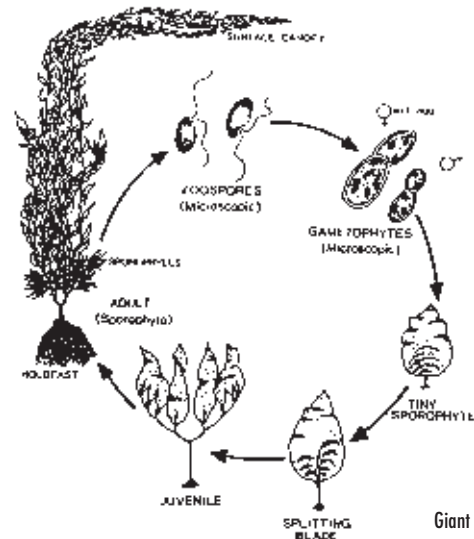
Forests of giant kelp occur in the temperate oceans of the world. These forests are especially well developed along the West Coast of North America from Punta Abreojos, about midway down Baja California, Mexico, to San Mateo County. They create a unique habitat that provides food, shelter, substrate, and nursery areas for nearly 800 animal and plant species. Many of these animals and some plants are of importance to sport and commercial fisheries.

Typically, giant kelp flourishes in wave-exposed areas of nutrient-rich, cool water that is 20 to 120 feet deep. By means of a root-like structure called a holdfast, the kelp attaches to rocky substrate. Along the protected shoreline of Santa Barbara County, however, giant kelp also grows on sand substrate. Here, it attaches to exposed worm tubes or the remains of old holdfasts. Kelp fronds originate from the holdfast, and eventually grow to the surface. A frond is composed of a stem-like stipe and numerous leaf-like blades. A gas-filled bladder (pneumatocyst) at the base of the each blade helps buoy the frond in the water column.

Giant kelp absorbs nutrients from the water through all its surfaces. Under optimal conditions of high nutrient levels

and low ocean temperatures (50° to 60° F), fronds can elongate up to 24 inches a day. Fronds can reach a length of more than 150 feet, and large plants can have more than 100 fronds. The fronds eventually mature, die, and break away (slough) naturally, giving way to young fronds. Although giant kelp plants can live up to eight years, individual fronds survive for only about six to nine months, and individual blades about four months.

Giant kelp reproduction involves two very different growth forms, the large canopy-forming sporophyte and the microscopic gametophyte. Specialized reproductive blades (sporophylls), located just above the holdfast on an adult sporophyte, liberate trillions of microscopic zoospores each year. The zoospores then settle on the bottom and develop into microscopic male and female gametophyte plants. Fertilization of the female gametophyte produces an embryonic sporophyte. This tiny plant will develop into a canopy-forming adult within seven to 14 months if it survives competition with other plants and avoids being eaten by grazers or being destroyed by undesirable environmental factors.



Giant kelp life cycle.

Status of the Beds

The density and abundance of a kelp canopy varies by location, year, and season. In central California, sloughing and deterioration occur in late summer and early fall. Canopies virtually disappear during the late fall and winter, when storms cause frond and plant loss. Canopies usually begin forming again in the spring, becoming dense in the summer. Off southern California, kelp canopies frequently grow throughout the year in the mild weather conditions. Dense canopies often develop during the winter, when there are virtually no canopies in central California.

During the last 30 years, the size, distribution, and location of the kelp canopy throughout California has fluctuated considerably. Fluctuations can be viewed as seasonal events and as long-term changes. Decreases in canopy area were due to both natural and man-induced disturbances. Increases were due to natural growth and in some instances may have benefited from restoration efforts. An aerial survey conducted in 1967 showed a total of 70 square miles of kelp canopy along the entire California coast. Of that, 53.9 square miles was recorded for southern California. The southern California portion showed that 33 square miles occurred along the mainland coast and 20.9 square miles around the Channel Islands. A similar survey conducted in 1989 reported 40.7 square miles along the entire coast. Of this, 17.5 was recorded for southern California. The Channel Islands accounted for 9.8 square miles, while the mainland coast of southern California totaled 7.7 square miles. During the most recent statewide kelp forest survey, conducted in 1999, a total of 17.8 square miles of giant kelp was charted along the California coast, 11.4 square miles of that recorded off southern California, including the offshore islands. The 1999 survey shows only 3.7 square miles of the 17.8 total along the mainland coast, while 7.7 square miles was recorded in the Channel Islands.

The methodology used to conduct aerial surveys is subject to a high degree of error. The photographic method utilizes infrared film to highlight temperature differences between kelp canopy at the water's surface and the background water temperature. Kelp immediately below the surface is invisible to this method. So the results can vary due to wind waves and local currents. These errors could be greatly reduced by more frequent surveys.

This being said, it is still evident that a declining trend is occurring, particularly in southern California. This can be at least partly explained by the warming trend of the past twenty years and the frequency of severe El Niños.

However, when the distribution of kelp canopy in southern California between the Channel Islands and the mainland coast is examined, the warming trend should be factored

out, since both areas are likely to experience the same oceanographic conditions in any year. So the change in relative abundance of kelp between these two areas is of greater concern. It suggests that factors other than the warming trend is responsible for the declines along the mainland coast.

The health and long term survival of the kelp forests are influenced by a variety of factors, including storms and climactic events, grazing, competition, sedimentation, pollution, and disease. These can be divided into natural and human induced causes. Because water of the Southern California Bight is warmer than the rest of the state, fluctuations in water temperature may have a more profound affect on kelp survival there compared to central and northern parts of the state. Human-induced impacts, pollution, and coastal development also tend to be greater in southern California where there are more people.

The southern California kelp beds, in particular, provide examples of both. Waters south of Point Arguello, referred to as the Southern California Bight, are considerably warmer than the rest of the state. Accordingly, fluctuations in water temperature tend to have a more profound affect on kelp survival than in the central and northern parts of the state. Human induced causes also tend to be greater in southern California due to the concentration of the state's population within this region, with its associated pollution and coastal development.

Excessive wave action from storms and surge can break kelp fronds and dislodge entire plants. Dislodged plants increase kelp loss by entangling nearby kelp, pulling them from their attachment. During the 1980s and 1990s, at least three major oceanographic events affected kelp beds: 1) the 1982-1984 El Niño and a devastating storm; 2) the 1992-1994 El Niño and subsequent storms; and 3) the 1997-1998 El Niño, which was the warmest of the three. The warm water and storms associated with the El Niño destroyed plants, inhibited kelp growth, and resulted in minimal canopy development throughout southern California. During the 18 year-period from 1981 to 1998, sea surface temperatures exceeded the previous 60-year mean in all but a single year (1988). In 1967, there were approximately 18 square miles of kelp canopy near Santa Barbara, compared to only six square miles remaining in 1989. The giant kelp forests on sand substrate near Santa Barbara had still not returned in 2000.

Fishes such as opaleye and halfmoon regularly graze upon kelp. Large numbers of these fishes can damage the kelp forests, especially when conditions are unfavorable for kelp growth. Crustaceans, such as amphipods, isopods and crabs, can also graze and damage kelp. The historical removal of the southern sea otter from southern California certainly changed the balance of the predator/prey

relationship in the kelp bed community. But finally, the intensive fishing for the remaining sea urchin predators such as sheephead and spiny lobster, and for sea urchin competitors such as abalone, tremendously altered the sea urchin population dynamics in the forest. As a result, sea urchin populations increased exponentially in some areas and overgrazed the kelp, creating areas referred to as "urchin barrens."

Human-caused disturbances include sedimentation of the rocky bottom, which can retard kelp growth and even bury young plants, preventing development and reproduction. Pollution can affect kelp forests in a variety of ways. Industrial and domestic wastewater discharges carrying toxins, including pesticides and heavy metals, are released into coastal waters where they can accumulate in the sediments. Such chemicals alter the physical and chemical environment near the discharge and may decrease growth and survival of the kelp forests. Thermal outfalls from power plants also have localized effects on kelp forests. Wastewater and thermal discharges can increase turbidity and redistribute sediments into nearby kelp forests, affecting kelp growth and survival. A variety of pathogens are known to affect kelp but their broad impacts on kelp forests have not been studied. While tumors, galls, and lesions have been observed on kelp, only occasionally have they caused severe damage.

Short and long-term declines, or in one case a complete disappearance of southern California kelp beds, associated with human activity have been documented. Prior to the 1920s, an extensive kelp bed, known as Horseshoe Kelp existed off the coast of what is now Los Angeles Harbor. It was reported to have measured a quarter- to a half-mile wide and two miles long. A department Information Bulletin reported interviews with "old time fishermen" who recalled the kelp bed beginning to decline during the 1920s and 1930s coinciding with the widening of the main channel and west basin of Los Angeles Harbor, which included the dredging removal of an entire island, (Deadman's Island). Some recalled that the Whites Point Sewer Outfall, which began discharging in 1934, was associated with the disappearance of the last remnants of this bed. The Horseshoe Kelp Bed grew in a water depth of 80 to 90 feet. While kelp at this depth is still common in the Channel Islands, no kelp grows along the southern California mainland coast at this depth today.

Several years' declines to kelp beds near Salt Creek in Orange County and Barn Kelp near Las Pulgas Canyon off Camp Pendleton Marine Base in San Diego County were associated with extensive grading of land around drainages adjacent to these beds.

The most thoroughly documented human induced decline was associated with the start-up of the San Onofre Nuclear Generating Station in northern San Diego County.

The discharge of heated and turbid cooling water caused the loss of approximately 150 acres of kelp. This single event was the only time when the damage was so well documented that mitigation could be required as compensation for the loss.

In the 1950s and 1960s, once-productive kelp forests off Point Loma and La Jolla in San Diego County and along the Palos Verdes Peninsula in Los Angeles County began to deteriorate. This too was attributed to biological and physical factors related primarily to human activities. Currently, there are several areas where the status of kelp is of concern, including the entire Santa Barbara/Ventura coastline, the Malibu coast, portions of the Palos Verdes Peninsula, the coast between Newport and Laguna Beach, San Onofre, south Carlsbad and Point Loma. Other kelp losses have undoubtedly occurred as a direct result of human activities along the southern California coastline, but the lack of strong baseline data prevents resource agencies from proving damages and seeking compensation. The development of computerized Geographic Information Systems may provide effective tools to document and analyze such damages in the future.

Kelp Restoration

In 1963, Scripps Institution of Oceanography and Kelco began a cooperative project to develop techniques to protect and restore kelp forests off San Diego. Work involved sea urchin control, including the use of lime and crushing of individual urchins and kelp transplanting. Later experimentation between 1991 and 1992 involved feeding urchins along a front to discourage feeding on attached plants and to increase urchin reproduction, so that commercial harvesting might be encouraged. This work appears to have succeeded in restoring kelp to these beds. However, this is a labor intensive effort, and there are indications that when the work ceases, the urchin fronts redevelop, calling into question the long term benefits of any one-time restoration effort, as well as the economic feasibility of conducting such work as a long term solution and over a broader area.

Between 1967 and 1980, kelp restoration was conducted along the Palos Verdes Peninsula (PVP) by the Institute of Marine Resources and the department. This work also combined sea urchin control and kelp transplanting. The objective was to establish several small stands of kelp, which would provide seed stock for new and expanding beds. In 1974, the first naturally expanding kelp stand in 20 years was observed off PVP. By 1980, when restoration work was discontinued, nearly 600 acres of kelp had become established. By 1989, aerial surveys revealed over 1,100 acres of kelp off PVP. Two subsequent El Niño events have severely decreased the size of these beds.

Kelp restoration work has also been conducted in storm damaged areas off Santa Barbara and along the Orange County coast. Shortly after the 1982-1984 El Niño, Kelco began developing techniques for restoring kelp beds in Santa Barbara County. In 1987, under contract with the department, Kelco implemented operations for anchoring giant kelp in the sandy habitat near Santa Barbara. Several kelp forest nuclei were established; however, sea urchin grazing and unfavorable water conditions impeded progress. By the early 1990s, it became evident that this restoration attempt had failed.

Loss of Orange County kelp forests from Newport Harbor to San Mateo Point was caused by heavy rainfall and siltation in 1980, the 1982-1984 El Niño, and the effects of urchin grazing. Under contract with the department, MBC Applied Environmental Sciences company established kelp forest nuclei between Newport Harbor and Laguna Beach. This was done by transplanting adult and juvenile giant kelp and controlling sea urchins. Those kelp forests south of Laguna Beach recovered naturally after a few years. Those beds north of Laguna Beach, where restoration efforts took place, have not recovered.

In 1992, the department Artificial Reef Program built a 10-acre, low relief (three feet or less in height) reef outside the harbor entrance channel to Mission Bay, San Diego County. The reef was constructed from broken slabs of concrete provided by the demolition of a nearby roadway. By 1993, a kelp bed had naturally established itself on this reef. This bed has persisted through the spring of 2000.

During the fall of 1999, the Southern California Edison Company built a 22-acre experimental reef off the city of San Clemente, aimed at mitigating the damage to kelp from the San Onofre Nuclear Power Station. It is still too early to evaluate the success of this project, although based on a great deal of research, and the success of the Mission Beach reef, there is great optimism that it will succeed. If it does succeed in providing substrate for

a persistent kelp bed, the reef will be expanded to a minimum of 150 acres in five years.

It appears now that the creation of new reef substrate, rather than other techniques, may provide a valuable mechanism for increasing the capacity for kelp bed expansion throughout southern California in future years.

Management Considerations

See the Management Considerations Appendix A for further information.

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A kelp cutter operating near Santa Barbara
Credit: DFG