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RECOVERY OF KELP FORET OFF PALOS VERDES

Kelp forests are among the most prominent and ecologically important features of the southern California rocky coastal area. Several species of brown algae, particularly the giant kelp, *Macrocystis pyrifera*, attach to solid bottom and form dense underwater kelp forests, which provide essential habitat for fishes and invertebrates. *M. pyrifera* is also commercially harvested and processed for use in a large number of industrial and household products.

In the early 1940's, the surface canopy of the kelp beds off the Palos Verdes Peninsula covered more than 5 sq km (1,280 acres). In the next three decades, these beds declined; between 1968 and 1971, they were apparently entirely absent. This situation has been attributed in part to Los Angeles County's discharge of municipal wastewaters off Whites Point, which was initiated in 1937 (California State Water Quality Control Board 1964).

In the past few years, kelp beds have reappeared off the Peninsula. Here, we report a review of data from several sources on the present status of these beds and on events that may be associated with their decline and partial recovery.

HISTORY AND KELP RESTORATION ACTIVITY AT PALOS VERDES

Most kelp beds undergo annual and long-term fluctuations in size and density. Beds off Palos Verdes and sites to the south began a continuous decline in size in the 1930's (Figure 1). Wastewater discharge, a possible factor in the decline, began at Whites Point in shallow

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water (27 meters) in 1937 and was diverted to deeper waters (60 meters) in 1954. Proliferation of grazing invertebrates, absorption of light by particulate matter, and siltation of rocky substrates are wastewater-related mechanisms that have been considered important inhibitors of kelp growth. The local extinction of the sea otter in the last century and reductions in the numbers of other urchin predators, such as the sheephead (*Pimelometopon pulchrum*), may also be implicated in longer-term instabilities of kelp populations.

In 1970, the Kelp Habitat Improvement Project, under the direction of Dr. Wheeler North (California Institute of Technology), transplanted 450 adult kelp plants from Paradise Cove to Abalone Cove (Figure 2). All plants died within 4 months; although a few offspring of these plants were observed, they also disappeared. More transplanting was conducted during 1971, when the Sport- fish-Kelp Habitat Project of the California Department of Fish and Game joined and continued the kelp restoration effort. Much of the kelp transplanted was destroyed that summer by waves from Pacific Hurricanes Gwen and Joanne. Transplanting efforts were renewed during the first half of 1973, when large numbers of juvenile and adult *M. pyrifera* were translocated from Santa Catalina Island to Abalone Cove. By 1974, thousands of naturally recruited juvenile plants were observed throughout the cove to depths of 7 meters; these—along with nearly 4,000 additional transplants—have grown and reproduced and are now providing transplant material for other areas, including Los Angeles Harbor.

The transplant operations have been accompanied by other activities. Steps have been taken to control grazing sea urchin and fish populations; for example, quicklime (CaO) has been spread on dense aggregations of sea urchins. Scientists from Dr. North's group have on several occasions "seeded" Abalone Cove and other areas with billions of laboratory-cultured M. pyrifera embryos. Biologists from the Department of Fish and Game, the Los Angeles County Sanitation Districts, Cal Tech, and Kelco Company have made a number of reconnaissance dives and surface observations to quantify the abundances of organisms associated with the kelp and to determine patterns of recruitments of young kelp plants, sea urchins, and other marine species. Beginning in 1972, scientists from Cal Tech and the Department of Fish and Game instituted quarterly aerial photographic surveys using infrared film to measure the size of kelp canopies.

By 1974, some beds were sufficiently large to merit detailed inventories of canopy size; by late 1976, biologists from the Department of Fish and Game and the County Sanitations Districts were reporting data on several beds of *M. pyrifera* (Table 1) . The most recent data indicate that the *M. pyrifera* beds monitored by the Department of Fish and Game range in canopy size from 0.1 to 18 hectares and cover a total of 34.3 hectares. Kelp canopy growth has not been continuous, however: A Notable decrease in size occurred between January and April 1977, largely because of a major canopy loss at Bluff Cove. In addition, all beds underwent a pause in canopy growth between April and August 1976.

Not all of the beds listed in Table 1 originated from transplants. The bed at Bluff Cove recruited naturally, and its canopy was first documented in July 1975. Biologists have also documented scattered *M. pyrifera* plants and small beds at Portugese Bend, the KOU radio towers, and Bunker Point (Meistrel 1976; Mearns and Shafer 1977). There has also been confirmation of 1976 reports of *M. pyrifera* plants at a depth of 22 meters at Horseshoe Kelp, a flat rocky area several kilometers east of Whites Point (Figure 2).

Recent appearances of kelp species other than *M. pyrifera* and of small brown algae have also been reported. North (1975) noted a major recruitment (beginning with a few plants in January 1973) and proliferation of beds of the feather boa kelp, *Egregia laevigata*, along the coast between Abalone Cove and Whites Point. *E. laevigata* beds have proliferated off the southeastern coast of Palos Verdes (particularly between Long Point and Point Fermin) since May 1973 (Figure 2). Beds of other kelps, *Cystoseira osmundacea* and *Pterygophora californica*, also increased during 1974. Since 1973, Department of Fish and Game biologists have been observing recruitment of Cystosezpa and smaller brown algae (species of *Ectocarpus*, *Taonia* and *Dictyota*), especially in areas recently cleared of urchins. According to North (1975), the proliferation of kelps other than *M. pyrifera* may be an important precursor to the establishment of M. pyrzfer'a beds.

The recent increases and fluctuations in recruitment and growth of kelps off Palos Verdes may, in part, be related to changes in natural conditions. Damage done in 1972 by hurricane-generated swells has already been mentioned. In addition, kelp beds in this and other coastal areas were damaged by a storm in January 1974 (North 1975). North's initial transplant efforts at Abalone Cove were also severe-ly hampered by the grazing of opaleye (Girella nz.grz.oans) _, senoritas (Oxyjutz-s oalzfor'n-ica), and halfmoon (Medi-atuna oatzfomz.ensz-s). More recently, persistence of abnormally warm and possibly nutrient-deficient water in the fall of 1976 and winter of 1977 may have contributed to the tem-porary decline in canopy size.

RELATIONSHIPS BETWEEN KELP RECOVERY AND CHANGES IN WASTEWATER CHARACTERISTICS

Although it is apparent that restoration activities have contributed to the reappearance of kelp off Palos Verdes, it is also possible that recent changes in wastewater quality have had a beneficial effect. Effluent concentrations of settleable solids decreased between 1971 and 1974 but began to rise in 1975, reaching levels in 1976 that exceeded the 1971 levels (Figure 3). New sewage treatment plant equipment put into operation this spring has just reduced settleable solids concentrations to a level (1.8 ml/liter) that is about 32 percent of the 1976 peak level and 64 percent of the 1971-77 average (2.81 ml/liter). Another change in the effluent over the past 6-1/2 years is the decline in DDT concentration, a result of source control in 1971. As shown in Figure 3, effluent concentrations of this substance were apparently already decreasing when monitoring first began in the first half of 1971; by 1976, concentrations had undergone a 97 percent decrease, from about 70 to 2 pg/liter (ppb). Other changes in effluent characteristics have also occurred—there have been slight longterm decreases in flow and concentrations of supended solids over the past 6-1/2 years.

Although it is possible that control of materials such as DDT or settleable solids may be having a beneficial impact on nearby kelp beds, a more penetrating study is needed to define the response of kelp to this discharge.

Data from other areas indicate that there is no simple relationship between wastewater discharges and changes in kelp beds (North 1965). For example, during the 1940's and 1950's, kelp beds in two areas south of Palos Verdes were also declining in size—these were the beds off Point Loma, which is at the mouth of San Diego Bay, and those off La Jolla (Figure 1). During this time, San Diego City's municipal wastewaters were discharge into San Diego Bay. Recovery of the Point Loma beds became obvious in 1963 and 1964: At this same time, culturing activities began, and the San Diego wastewater discharge site was moved to a deepwater location about 2 km offshore of the kelp beds. For the next 3 years, both primary-treated effluent and digested sludge were discharged at this site; during this time, the kelp bed canopy continued to increase in size and spread to the north and south. Discharge of sludge was terminated in 1967, but effluent discharge has continued; the beds are also harvested regularly by the Kelco Company.

The decline of the La Jolla kelp beds, which are not close to a major municipal wastewater discharge, followed a pattern similar to that seen off Palos Verdes and Point Loma. Culturing activities began in this area in 1963, and partial recovery was obvious by the mid-1970's.

At present it is difficult to identify the events-kelp culture, transplanting, wastewater management changes, or natural episodes—that have been most instrumental in the recovery of kelp beds near discharge sites. All are probably important, and perhaps the role of waste-water management will become clearer in the coming years as ecosystems react to the recent changes in waste treatment.

Ken Wilson and Pete Haaker of the Department of Fish and Game Sportfish-Kelp Habitat Project have courteously allowed us access to their recent observations and experiences, and we thank Mr. Wilson for allowing us to report these data here. We also thank Ron McPeak (Kelco Company, San Diego), Dr. Craig Barilotti (San Diego State University), and Dr. Irwin Haydock (Los Angeles County Sanitation Districts) for additional data and information.

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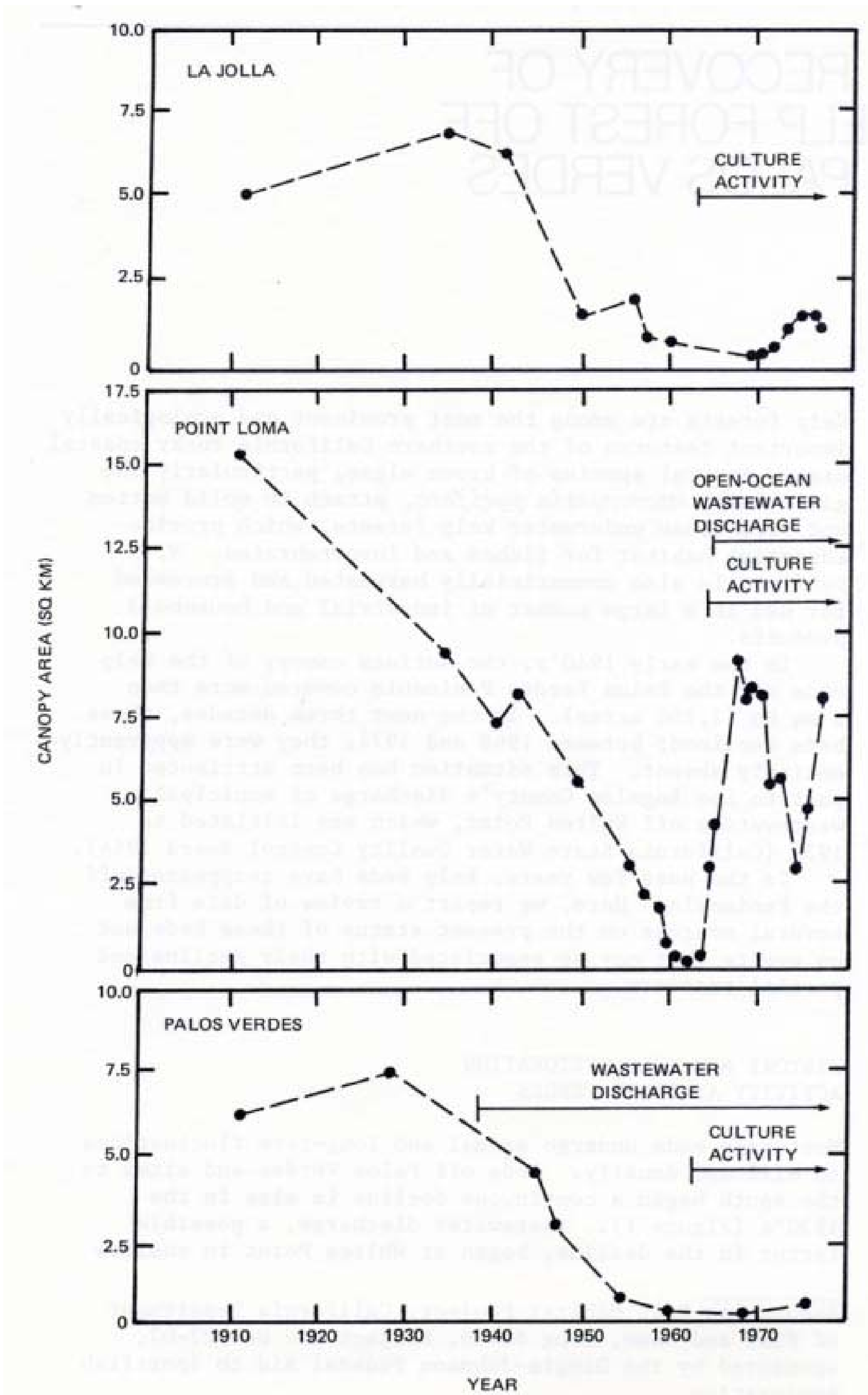

Figure 1. Summary of historical changes in kelp canopy size at three coastal sites. Data for La Jolla and Point Loma are from North 1975 and from Ron McPeak (Kelco Co., personal communication). Data for Palos Verdes summarized by Dr. Craig Baralotti (San Diego State University, personal communication from Dr. Wheeler North.

These photographs taken by Dr. Richard Grigg, University of Hawaii during his recent survey of kelp on the Palos Verdes shelf (to be described in detail in next year's annual report). Purple sea urchins rest on the bottom at 9-meter depths off Point Fermin.

Blue rockfish (*Sebastes mystinus*) swim above a survey quadrant marker on a stand of *Muricea californica* in Bluff Cove.

Fishes swim amid fronds of Egregia laevigata at 9-meter depths off Palos Verdes Point.

The canopy of Cystoseira osmundacea is quite thick at 9-meter depths off the KOU radio towers.

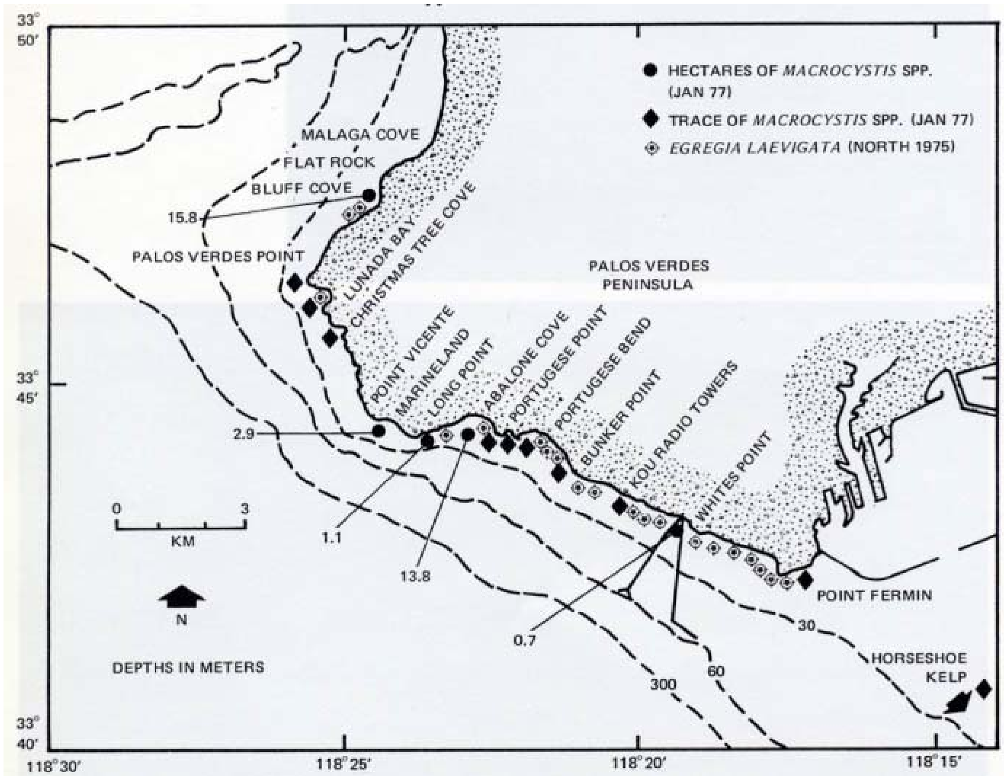

Figure 2. Approximate locations of kelp beds and isolated stands of kelp along the Palos Verdes coastal shelf in recent years. Data on *Macrocystis* spp. Are from Sportfish-Kelp Habitat Project, California Department of Fish and Game. Data on *Egregia laevigata* are from North 1975. Additional stands of *E. laevigata* have been observed by Mearns and Schafer (1977) and by Dr. Richard Grigg (University of Hawaii, personal communication). Figure modified from Meistrel (1977).

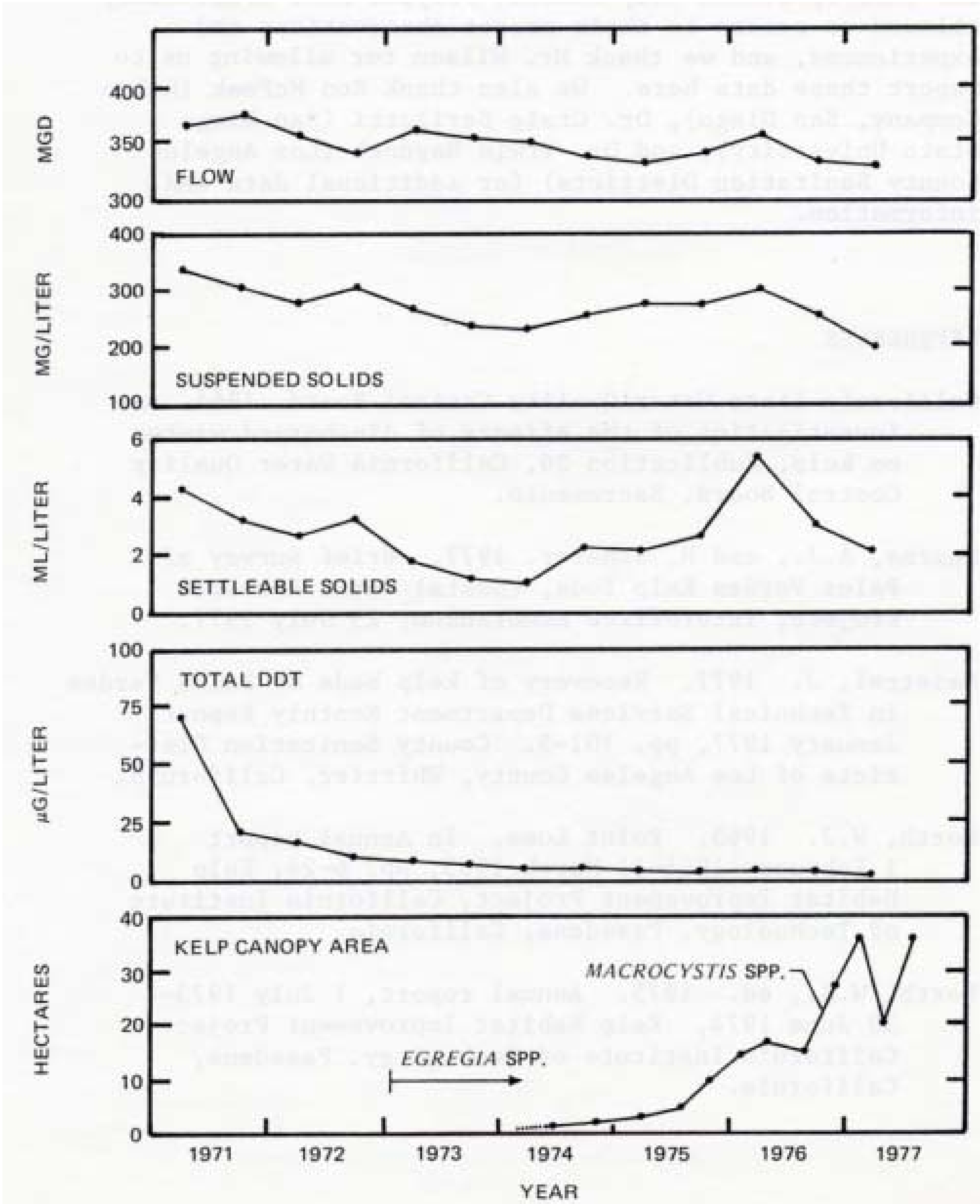

Figure 3. Average semiannual variations in flow and selected constituents of Los Angeles County's JWPCP effluent, January 1971 to March 1977 and growth of species of *Macrocystis* and *Egregia* over the same period. *Egregia* data are from North 1975.

Table 1. Variations in size (hectares) of Macrocystis sp. Surface canopies at eight areas along the Palos Verdes Peninsula, June 1974 through July 1977. Values are estimates, based on aerial photographic surveys, made by California Department of Fish and Game.

	1974		1975			1976				1977		
	Jun	Oct	Mar	Jul	Oct	Jan	Apr	Aug	Nov	Jan	Apr	Jul
Whites Point								0.1	0.9	0.7	0.2	0.93
Portugese Point								0.03	0.04	0.08	0.12	0.12
Abalone Cove*	0.6	1.5	2.8	4.2	5.7	9.1	10.4	9.5	11.6	13.8	10.6	11.96'
Marineland (Long Point)						0.2	0.3	0.3	1.3	1.1	0.4	0.2
Point Vicente**				0.1	0.8	0.9	1.1	1.4	3.5	2.9	2.1	2.99
Christmas Tree Cove									0.04			
Lunada Bay								0.01	0.04	0.02	0.03	0.12
Flat Rock to Palos Verdes Point (including Bluff Cove)				0.2	3.0	3.9	3.9	3.2	8.8	15.8	2.7	17.98
TOTAL	0.6	1.5	2.8	4.5	9.5	14.1	15.7	14.5	26.2	34.4	16.2	34.3

*Subtotals from three beds.
**Subtotals from two beds.