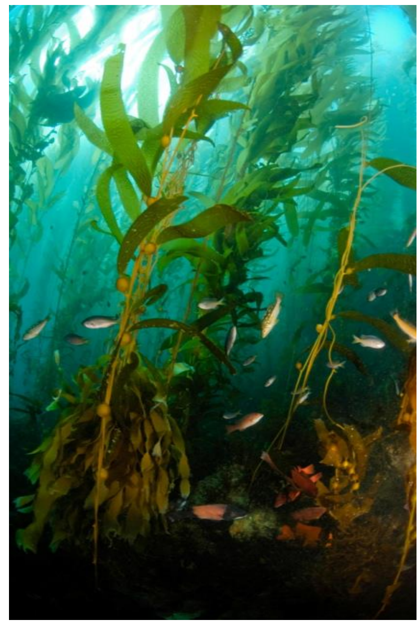
STATUS OF THE KELP BEDS 2013



July 21, 2014

Kelp Bed Surveys: Ventura, Los Angeles, Orange, and San Diego Counties

Prepared for:

Central Region Kelp Survey Consortium and Region Nine Kelp Survey Consortium

Prepared by:

MBC *Applied Environmental Sciences*
Costa Mesa, California

MBC

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EXECUTIVE SUMMARY

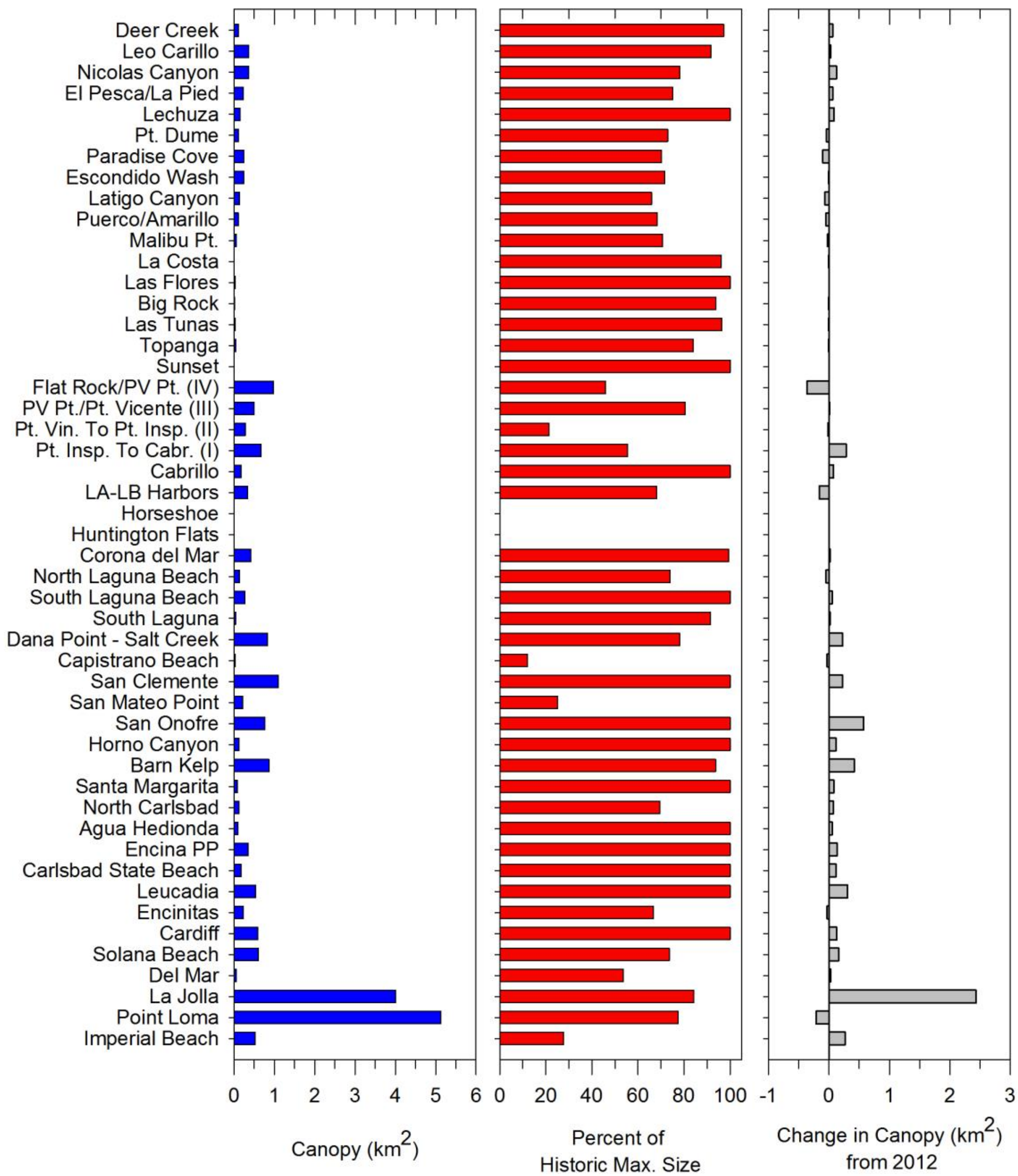
Giant kelp beds have been mapped quarterly off Ventura, Los Angeles, Orange, and San Diego counties for both the Central Region and Region Nine Kelp Survey Consortiums (CRKSC and RNKSC). The CRKSC was formed in 2003 as a result of regulations from the Los Angeles Regional Water Quality Control Board (LARWQCB). The program was based on that of the long-established Region Nine Kelp Survey Consortium RNKSC that formed in 1983, also as a result of regulations promulgated by the San Diego Regional Water Quality Control Board (SDRWQCB). When combined, the two organizations provide continuous and synoptic monitoring for approximately 355 kilometers (km) of the 435-km coastline of the Southern California Bight (SCB), from Ventura Harbor to the Mexican Border.

Aerial imaging surveys of the giant kelp beds were conducted by MBC *Applied Environmental Sciences* (MBC) on 13 May, 15 July, 23 September, and 16 December 2013. Digital color and color infrared photos were taken of the entire Central Region and Region Nine coastline during each survey. These photos were then processed and the kelp depicted on each photo was transferred to base maps to facilitate intra-annual comparisons and for ease of analysis (Appendix A).

Total canopy size within the 50 kelp beds monitored as part of the CRKSC and RNKSC programs was above average in 2013, and increased 29% from the previous year. Results from the 2013 kelp surveys differed between regions, however. Total canopy coverage was 22.7 km^2, with 5.6 km^2 in the Central Region and 17.1 km^2 in Region Nine. Since 2012, coverage decreased by 1% in the Central Region, but increased considerably (by 44%) in Region Nine. There was no evidence to suggest that any of the two regions' various dischargers had any perceptible influence on the persistence of the giant kelp beds.

Central Region Results. In the Central Region, the maximum total kelp canopy decreased from 5.665 km^2 in 2012 to 5.614 km^2 in 2013. The number of kelp beds displaying canopy has remained the same in the Central Region (at 24 of 26 historic kelp beds). The total amount of kelp peaked in 2009 with 6.406 km^2 of canopy coverage, an amount greater than during any past CRKSC survey or of any past synoptic surveys (when all areas were surveyed) since 1989.

The beds farthest upcoast—from Deer Creek to Lechuza—all gained canopy, and two of those beds doubled in size. However, 11 of the 12 beds between Point Dume and Sunset lost canopy in the last year. The average change in size from 2012 was about 14%. The angle of the coastline from Point Dume to Santa Monica Bay is slightly different from that in other areas of Region Nine, and this affects the exposure to waves. The upcoast part of the Palos Verdes beds also faired poorly, and decreased in size by about 27%. The PV II and PV III beds were similar in size compared to last year, while the PV IV and Cabrillo beds increased substantially (>75%). Most of the beds in the Central Region reached their maximum extent in fall or winter. However, many kelp beds, including ones that lost canopy between Point Dume and Sunset, were at their greatest extent in May.



Central Region and Region Nine kelp canopy coverage, percent of maximum size at Region Nine since 1983, Central Region since 2003, and canopy change since 2012.

Region Nine Results. In Region Nine, the maximum measured kelp canopy increased from a total of 11.882 km^2 in 2012 to 17.064 km^2 in 2013. Only three beds lost coverage in 2013, and one—Santa Margarita kelp bed—appeared for the first time in 21 years. The much longer history of consecutive monitoring (47 years) in Region Nine (compared to that of the Central Region—11 years) encompasses several very favorable kelp growth periods. It is also apparent that the La Jolla and Point Loma kelp beds dominate and account for a large percentage of the Region Nine canopy coverage. In 2013, these two beds accounted for 54% of canopy area from Newport Beach to the Mexican border.

The kelp beds at North Laguna Beach, Encinitas, and Point Loma decreased slightly; all other Region Nine beds increased in 2013. Almost all of the Region Nine kelp beds reached their maximum extent in winter (December overflight); Point Loma, however, peaked in the fall. The three losses were fairly minor (-4% to -26%), and, despite reductions, these three beds were still considered to be large compared to canopies recorded in the last few decades.

Environmental Variables

Sea surface temperatures (SSTs) followed similar patterns throughout southern California. Temperatures during the first three months of 2013 were mostly below average, and, even though they increased to above the norm from March through May, there were several influxes of cold water between Point Dume and Scripps Institution of Oceanography (SIO) Pier, but not at Point Loma. The upwelling index (from 33°N latitude, 119°W longitude) indicated strong upwelling in February, March, and April compared to the average since 1946. This probably explains why most of southern California's kelp beds had above-average canopy coverage in May 2013.

The SSTs throughout the region increased in May and June, and upwelling was reduced. Strong cold-water pulses were evident in both regions from June through September. One of the most notable events that occurred in 2013 was the region-wide drop in temperature in July and August. Temperatures throughout southern California were below average to well below average during a period that is usually not conducive to kelp growth. Even though the upwelling index calculated normal upwelling in July and August, there were multiple cold-water events during these months. In September, temperatures returned to average (and above average) and remained so for the rest of the year.

The calculated Nutrient Quotient values were relatively high during the first half of 2013, but below average throughout southern California in the second half of the year. Despite this, kelp fared well in both regions. Review of SSTs revealed that the number of days at Scripps Pier with relatively low temperatures (<14°C) was high the past three years compared to the long-term mean, and conversely, the number of days >16°C has been below average. The Nutrient Quotient values are based on monthly mean temperatures, and may not adequately capture multiple, brief periods of cold-water influx. At Point Dume, the number of days <13–14°C has been below average the last two years, and the number of days >16–20°C has been above average the last two years, suggesting a shift to warmer temperatures. At Newport, the temperature/day relationship in 2013 was similar to the long-term mean.

Rainfall in 2013 was the lowest on record in southern California (two to three inches), so effects from runoff were negligible. Red tide was reported off San Diego County in the fall, but kelp beds in the vicinity of the bloom (La Jolla and Del Mar) gained canopy, so effects, if any, were limited. The wave climate in 2013 was normal, with the largest waves arriving from January through April. Wave heights exceeded three meters at all stations during a few storms, and exceeded four meters off Point Loma. These waves were not likely to cause lasting damage to the kelp beds.

Conclusions. Kelp canopies grew considerably in 2013, although most of the growth occurred from Newport Beach downcoast to the Mexican Border. There was no evidence of any adverse effects on the giant kelp resources from any of the region's dischargers. Predictions for a developing El Niño by summer or fall could have negative effects on kelp growth. However, total coverage in 2013 was among the highest on record.

INTRODUCTION

Giant kelp (*Macrocystis pyrifera*) beds along most of the southern California mainland coast have been mapped quarterly by the Central Region Kelp Survey Consortium (CRKSC) since 2003 and by the Region Nine Kelp Survey Consortium (RNKSC) since 1983. The CRKSC covers kelp beds from Ventura to Newport Beach, and the RNKSC covers Newport Beach to the Mexican border. It was agreed among the funding participants that the monitoring programs would be methodologically based upon aerial kelp surveys that had been conducted since 1967 by the late Dr. Wheeler J. North. With the formation of the two monitoring programs, continuous and synoptic coverage is provided of the kelp beds along approximately 354 of the 435 km (220 of the 270 miles) of the southern California mainland coast from Ventura Harbor to the Mexican Border. The geographical ranges and the ocean dischargers located within the CRKSC and RNKSC are shown in Figures 1 and 2.

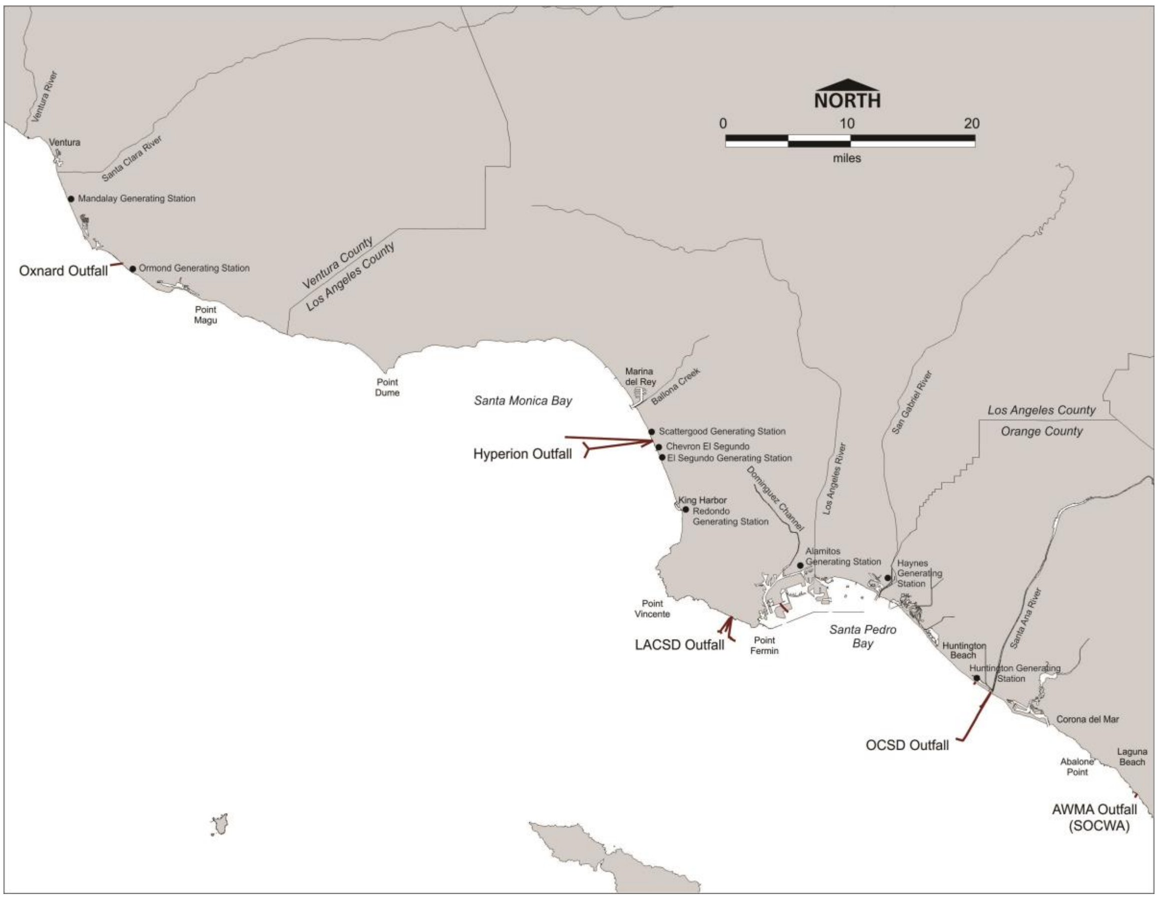


Figure 1. Ocean dischargers located within the Central Region kelp survey area.

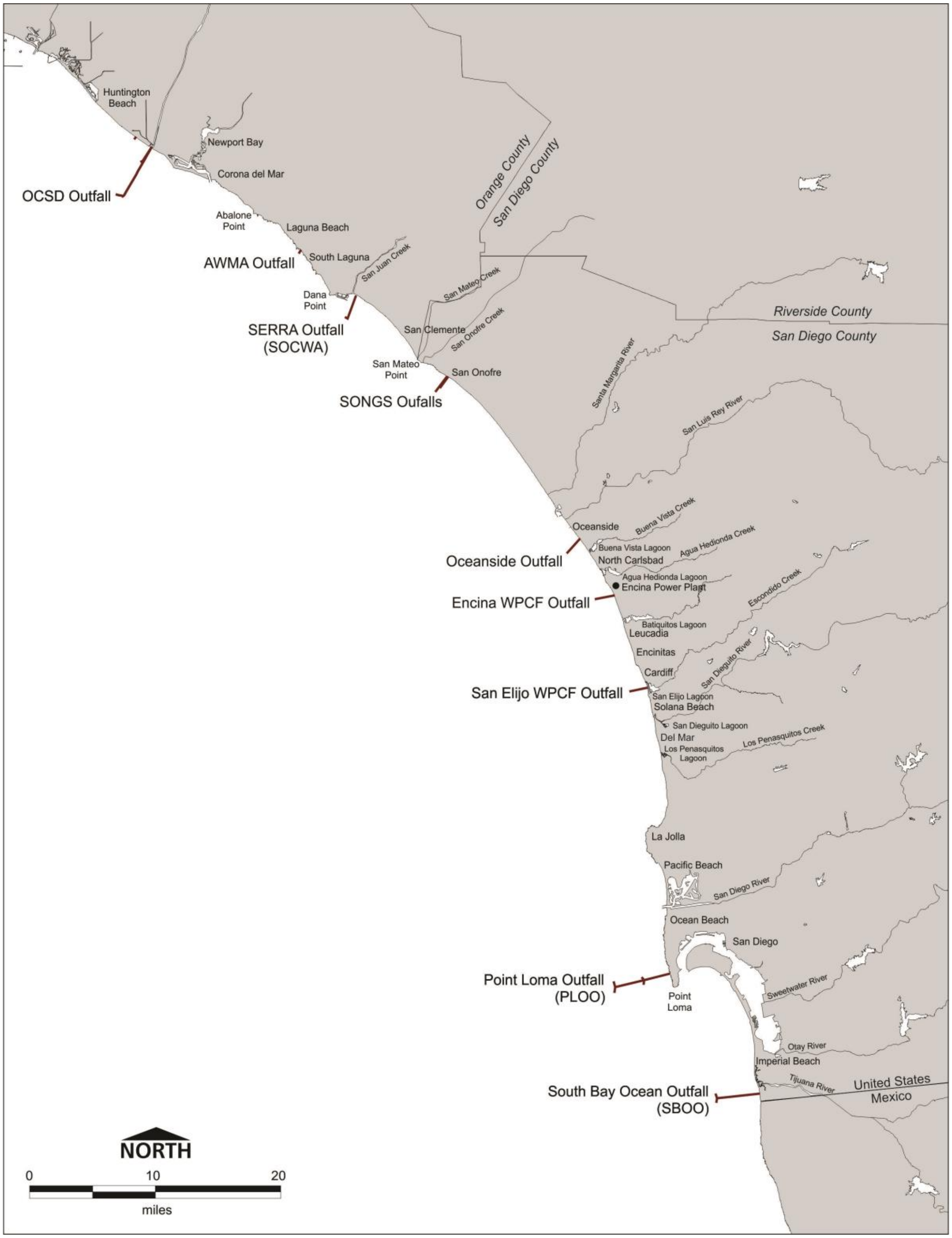


Figure 2. Ocean dischargers located within the Region Nine kelp survey area.

LIFE HISTORY OF GIANT KELP

Kelp consists of a number of species of brown algae, of which 10 are typically found from Point Conception to the Mexican Border (the Southern California Bight [SCB]). Compared to most other algae, kelp species can attain remarkable size and long life span (Kain 1979, Dayton 1985, Reed et al. 2006). Along the central and southern California coast, giant kelp (*Macrocystis pyrifera*) is the largest species colonizing rocky (and in some cases sandy) subtidal habitats. Giant kelp is a very important component of coastal and island communities in southern California, providing food and habitat for numerous animals (North 1971, Patton and Harmon 1983, Dayton 1985, Foster and Schiel 1985). Darwin (1860) noted the resemblance of the three-dimensional structure of kelp stands to that of terrestrial forests. Because of its imposing physical presence, giant kelp has been the focus of considerable research since the early 1900s so that a sizable literature on *Macrocystis* biology and ecology exists. Much effort was expended in the early years deciphering its enigmatic life history (Neushul 1963, North 1971, Dayton 1985, Schiel and Foster 1986, Witman and Dayton 2001, Reed et al. 2006). Giant kelp commonly attains lengths of 15 to 25 m and can be found at depths of 30 m. In conditions of unusually good water clarity, giant kelp may even thrive to depths of 45 m (Dayton et al. 1984).

Giant kelp forms beds wherever suitable substrate occurs, typically on rocky, subtidal reefs. Such substrate must be free of continuous sediment intrusion. Giant kelp beds can form in sandy-bottom habitats protected from direct swells where individuals will attach to worm tubes; this occurs along portions of the Santa Barbara coastline. Like other plants, algae undergo photosynthesis and therefore require light energy to generate sugars. For this reason, light availability at depth is an important limiting factor to kelp growth. Greater water clarity normally occurs at the offshore islands, and as a result, giant kelp is commonly found growing there in depths exceeding 30 m. Along the mainland coast, high biological productivity, terrestrial inputs and nearshore mixing result in greater turbidity and hence lower light levels. Consequently, kelp generally does not commonly grow deeper than 20 m along the coastal shelf, although exceptional conditions in San Diego produce impressively large beds that can grow vigorously beyond 30 m.

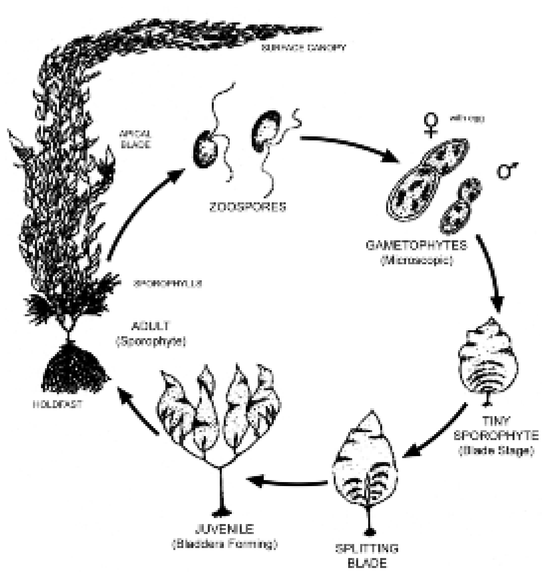


Figure 3. Kelp life cycle.

Giant kelp has a complex life cycle and undergoes a heteromorphic alternation of generations, where the phenotypic expression of each generation does not resemble the generation before or after it (Figure 3). The stage of giant kelp that is most familiar is the adult canopy-forming diploid sporophyte generation. Sporophyll blades at the base of an adult giant kelp release zoospores, especially in the presence of cold, nutrient-rich waters. These zoospores disperse into the water column and generally settle a short distance from the parent sporophyte. Within three weeks, the zoospores mature into microscopic male and female gametophytes that in turn produce sperm and eggs. This second generation does not resemble the sporophyte. The life cycle is completed when fertilization of the gametophyte egg develops into the adult sporophyte stage. Successful completion of the life cycle relies on the persistence of favorable conditions throughout the process.

Giant kelp is known as a biological facilitator (Bruno and Bertness 2001), where its three-dimensional structure and the complexity of its holdfast provides substrate, refuge, reduction of physical stress, and a food source for many fishes (Carr 1989) and invertebrates (Duggins et al. 1990). Stands of kelp can also affect flow characteristics in the nearshore zone, and enhance recruitment (Duggins et al. 1990), thus increasing animal biomass. For these reasons, giant kelp is also of great importance to sport and commercial fisheries.

HISTORICAL KELP SURVEYS 1911–2012

Giant kelp bed size and health are known to be highly variable but there has been a downward trend in canopy coverage since the inception of surveying in 1911 (Crandall 1912). In 1911, a mapping expedition of canopy-forming kelps along most of the Pacific coast was conducted to determine the amount of potash (potassium carbonate, an essential ingredient in explosives at the time) potentially available from the kelp. Using rowboats, compass, and sextants to triangulate positions, U.S. Army Captain William Crandall produced one of the most complete surface density kelp maps of the west coast of North America. Using this methodology, all of the existing kelp beds in the Central Region and Region Nine areas were mapped and these measurements have been used to define a baseline for southern California kelp beds (Table 1) (Appendix B).

Despite the value of Crandall's maps, the accuracy of his measurements was questioned (Hodder and Mel 1978 [SAI 1978], Neushul 1981). These authors contended that measurement errors might have resulted from using a rowboat and triangulations from shore to compute the bed perimeters, particularly on very large beds such as Palos Verdes, Point Loma, and La Jolla. Although Crandall's ability to accurately triangulate a position was adequate, his measurements of large beds resulted from fewer fixed points and estimation of the area between points. Modern aerial surveys reveal numerous holes and a fair degree of patchiness in such beds. Crandall's estimates did not account for these natural gaps and therefore the 1911 survey probably overestimated the size of these larger beds. Given this ambiguity, Crandall's measurements should be viewed qualitatively rather than as quantitative estimates comparable to aerial survey data taken since the 1920s. However, the data are a very good approximation to use as a baseline. Anecdotal reports from area stakeholders reported by Cameron (1915) indicate kelp beds in 1911 were in fairly poor condition compared to previous years.

Although the historical El Niño Southern Oscillation (ENSO) index suggests that the five years prior to 1911 were favorable to the kelp, the Pacific Decadal Oscillation (PDO) (another environmental metric that has historical data extending back to that period) is in agreement with Cameron's 1915 statement. While the PDO is a poor predictor of oceanographic conditions in the Southern California Bight (Di Lorenzo et al. 2008), it does correlate with sea surface temperature (SST). Therefore, it provides some insight into the local hydrographic conditions at the time. The annual mean PDO was slightly negative between 1909 and 1911, before transitioning to a warm phase from 1912 through 1915. This is suggestive, but not conclusive, of lower nutrient concentrations in 1912–1915 that would result in poor kelp growth. To add further credibility to the premise that beds were larger than current trends would indicate, aerial photos of Palos Verdes kelp beds taken in 1928 (measured by North in 1964) found the area to be more than 10% larger than Crandall reported in 1911.

In 1964, Dr. Wheeler North, working for the State Water Quality Control Board (1964), re-measured Crandall's Palos Verdes charts and found the 2.66 square nautical miles (Nm^2 [9.12 km^2]) Crandall reported to be very similar to his measurement of 2.42 Nm^2, but North's measurement did not include much of Malaga Cove (that added an additional 0.130 Nm^2 of kelp to the Palos Verdes beds), resulting in North's measurement of about 2.55 Nm^2 (Appendix B).

Due to the large sizes reported by Crandall, Neushul (1981) assumed there was a scaling error, re-measured the maps, and calculated a value that was 10% less than Crandall's original measurement. However, Neushul (1981) wrote that his measurements resulted in only slight improvements from what Crandall measured: "*The smaller areas obtained by measurements from more recent maps of southern California kelp beds probably reflect both a slight increase in mapping precision over Crandall's methods, and an actual decrease in size."* In 2004, Crandall's original maps of Palos Verdes were re-measured by MBC Applied Environmental Sciences (MBC) using computer-aided spatial estimation software (including Malaga Cove), and the resulting area (2.57 Nm^2) was about 3% smaller but very similar to that reported by Crandall (2.66 Nm^2). Therefore, the actual sizes of the beds that Crandall reported were probably relatively accurate because the areal survey extent and configuration he reported was subsequently confirmed from contemporary charts (Hodder and Mel 1978, Neushul 1981).

Thus, Crandall's kelp bed areas are retained as the baseline estimate, and the total regional area was probably larger from 1928–1934 than the area Crandall measured in 1911 (Tables 2 and 3). Based on the sizes of the Palos Verdes beds in 1928 (9.912 km^2) and La Jolla kelp beds in 1934 (8.161 km^2) from aerial photos that North measured in 1964 (SWRCB 1964), the bed sizes were well above Crandall's measurements of 9.124 km^2 (2.66 Nm^2) for Palos Verdes (including the bed at Malaga Cove) and 7.889 km^2 (2.3 Nm^2) for La Jolla. This lends credence to Cameron's comment that kelp harvesters reported that the beds were at minimal levels at the time of Crandall's survey, and suggests even larger losses have occurred over time (Cameron 1915).

Table 1. Kelp beds of the California coast, Crandall 1911.

Crandall Sheet (Map in report) No.	Kelp Bed No.	Density	Bed Name 2013	Area Square Nautical Miles	Area Square Statute Miles	Area Square Kilometers
Sheet 52		Medium	Imperial Beach	0.287	0.3801	0.9844
Sheet 18	1	Very Heavy.	Point Loma	5.400	7.1516	18.5226
	2	Very Heavy.	La Jolla	2.300	3.0461	7.8893
Sheet 17	3	Medium	Del Mar	0.240	0.3178	0.8232
		N. Present	No Solana Beach	0.000	0.0000	0.0000
		N. Present	No Cardiff	0.000	0.0000	0.0000
	4	Medium	Encinitas 30% (0.970)	0.291	0.3854	0.9982
	4	Medium	Leucadia 50% (0.970)	0.485	0.6423	1.6636
	4	Medium	Carlsbad St Bch 20%	0.194	0.2569	0.6654
	5	Medium	Encina Power	0.125	0.1655	0.4288
	5	Medium	Agua Hedionda	0.125	0.1655	0.4288
	6	Medium	Carlsbad	0.140	0.1854	0.4802
	7	Medium	Santa Margarita	0.250	0.3311	0.8575
	8	Thin	Barn Kelp	0.370	0.4900	1.2691
	9	Thin	Barn Kelp	0.080	0.1059	0.2744
	10	Thin	Barn Kelp	0.260	0.3443	0.8918
	11	Thin	Horno Canyon	0.050	0.0662	0.1715
	12	Thin	San Onofre	0.110	0.1457	0.3773
	13	Thin	San Onofre	0.130	0.1722	0.4459
	14	Thin	San Onofre	0.060	0.0795	0.2058
	15	Thin	San Mateo	0.360	0.4768	1.2348
Sheet 14, 15, and 16	16	Thin	San Clemente	0.060	0.0795	0.2058
	17	Medium	Capistrano	0.240	0.3178	0.8232
	18	Medium	Doheny	0.220	0.2914	0.7546
	19	Medium	Dana Point/Salt Creek	0.340	0.4503	1.1662
		N. Present	Laguna Beach	0.000	0.0000	0.0000
	20	Medium	Corona Del Mar	0.220	0.2914	0.7546
	21	Medium	Cabrillo to Port Bend	0.760	1.0065	2.6069
	22	Thin	Portuguese Bend	0.100	0.1324	0.3430
	23	Thin	Point Vicente, PV	0.070	0.0927	0.2401
	24	Medium	PV Pt to Flat Rk, PV	1.600	2.1190	5.4882
	25	Medium	Malaga Cove, PV	0.130	0.1722	0.4459
Chart 13	1	Thin	Sunset Beach	0.280	0.3708	0.9604
	2	Thin	Topanga (50%)	0.005	0.0066	0.0172
	2	Thin	Las Tunas (50%)	0.005	0.0066	0.0172
	3	Thin	Big Rock	0.005	0.0066	0.0172
	4	Thin	Las Flores	0.004	0.0053	0.0137
	5	Thin	La Costa	0.006	0.0079	0.0206
		N. Present	Malibu Point	0.000	0.0000	0.0000
	6	Thin	Puerco/Amarillo (10%)	0.100	0.1324	0.3430
	6	Thin	Latigo Canyon (13%)	0.130	0.1722	0.4459
	6	Thin	Escondido Wash (17%)	0.170	0.2251	0.5831
	6	Thin	Paradise Cove (40%)	0.400	0.5297	1.3720
Chart 13	6	Thin	Point Dume (20%)	0.200	0.2649	0.6860
	7	Thin	Lechuza (33%)	0.037	0.0485	0.1255
	7	Thin	Pescador/Piedra (67%)	0.073	0.0971	0.2515
	8	Medium	Nicolas Canyon (33%)	0.367	0.4855	1.2575
	8	Medium	Leo Carillo (67%)	0.733	0.9712	2.5153
		N. Present	Deer Crk	0.000	0.0000	0.0000
Totals				17.512	23.192	60.068

The next complete kelp survey of the southern California region was not undertaken until 1955. By that time, the beds in the Central Region had decreased greatly (to 6.750 km^2), and were only 36% of that recorded in 1911 (18.815 km^2). Beds in Region Nine were similarly reduced to 40% (16. 310 km^2) of the 1911 total of 41.563 km^2. The most significant loss during this period was that of Sunset Kelp (offshore of Santa Monica); Sunset Kelp covered almost 1.0 km^2 in 1911, but was very small by 1955. The Sunset kelp bed remained small or completely missing through the intervening years, and the Palos Verdes beds were also small, having decreased sometime after 1945. By 1947, the Palos Verdes beds were only

3.6 km^2, and further to 1.5 km^2 by 1953. During an aerial survey conducted in 1963, kelp canopies were in very poor condition, with Palos Verdes covering only 0.180 km^2 and the La Jolla and Point Loma beds covering only 0.9 km^2. Exceptionally good conditions in 1967 resulted in a total of 7.856 km^2 of kelp canopy coverage in the Central Region, but this was only about 42% of the estimate from 1911. Palos Verdes kelp beds south of Point Vicente were missing, but north of Point Vicente, they totaled almost 1.0 km^2. In Region Nine, similar results were observed in 1967 with the La Jolla/Point Loma kelp beds covering 3.03 km^2 and the total for the region was only 4.4 km^2. La Jolla kelp bed was only about 0.330 km^2 in 1967, and it stayed small until after 1975, when it became a consistently large kelp bed (over 1 km^2) through most of the next four decades.

Restoration activities began in 1974 by the Kelp Habitat Improvement Project. At that time, the Palos Verdes beds were only 0.015 km^2. In 1975, after restoration, those beds began increasing and covered 4.6 km^2 during the exceptionally favorable conditions in 1989 (North and Jones 1991). The impetus provided by the 1989 La Niña resulted in almost 6 km^2 of kelp canopy in the Central Region and more than 16 km^2 in Region Nine, but kelp coverage decreased to less than one-third of these totals during the subsequent two decades. In 2009 (Central) and 2008 (Region Nine), favorable conditions again increased canopy totals to about 6.5 km^2 in the Central Region and 18.7 km^2 in Region Nine, larger than they had been since 1967 and 1955, respectively (Tables 2 through 5).

Table 2. Historical canopy coverage in km² of the Ventura, Los Angeles, and Orange County kelp beds to Newport Beach, from 1911 to 2002. Values represent an estimate of coverage utilizing varying methods over the years.

	Canopy Area (km²)														
Kelp Bed	1911	1928	1945	1955	1963	1967	1972	1975	1977	1980	1984	1989	1999	2000	2002
1 Deer Creek	ND	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
2 Leo Carillo	2.515	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
3 Nicolas Canyon	1.258	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
4 El Pesc/La Pied	0.252	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
5 Lechuza	0.126	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
Total 1-5 (F&W 17)	4.151a	ND	ND	3.010	ND	4.144	2.589	1.606	1.579	ND	ND	0.914	0.530	ND	ND
6 Pt. Dume	0.686	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
7 Paradise Cove	1.372	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
8 Escondido Wash	0.583	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
9 Latigo Canyon	0.446	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
10 Puerco/Amarillo	0.343	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
11 Malibu Pt.	ND	ND	ND	p	p	p	p	p	p	ND	ND	p	p	ND	ND
Total 6-11 (F&W 16)	3.43a	ND	ND	2.140	1.780	2.538	1.813	1.502	1.528	ND	ND	0.220	0.033	ND	ND
12 La Costa	0.021	ND	ND	p	p	p	ND	p	p	ND	ND	p	p	ND	ND
13 Las Flores	0.014	ND	ND	p	p	p	ND	p	p	ND	ND	p	p	ND	ND
14 Big Rock	0.017	ND	ND	p	p	p	ND	p	p	ND	ND	p	p	ND	ND
15 Las Tunas	0.017	ND	ND	p	p	p	ND	p	p	ND	ND	p	p	ND	ND
16 Topanga	0.017	ND	ND	p	p	p	ND	p	p	ND	ND	p	p	ND	ND
17 Sunset	0.960	ND	ND	p	p	p	ND	p	p	ND	ND	p	p	ND	ND
Total 12-17 (F&W 15)	1.355a	ND	ND	0.020	0.000	0.026	ND	0.026	0.000	ND	ND	0.045	0.000	ND	ND
18 Malaga Cove-PV Pt. (IV)	5.934	ND	ND	p	p	p	ND	p	p	0.940	0.655	p	p	p	1.400
19 PV Pt-PT. Vic (III)	0.240	ND	ND	p	p	p	ND	p	p	0.215	0.692	p	p	p	0.028
Total 18-19 (F&W 14)	6.174	ND	ND	0.820	0.030	1.062	ND	0.009	0.026	1.155	1.347	3.312	0.737	0.648	1.429
20 Pt Vic to Pt Insp (II)	p	ND	ND	p	p	p	ND	p	p	0.190	0.171	p	p	p	0.039
21 Pt Insp to Cabr (I)	p	ND	ND	p	p	p	ND	p	p	1.052	1.342	p	p	p	1.208
22 Cabrillo	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0001	0.0001	ND	ND
Total 20-22 (F&W 13)	2.950	ND	ND	0.080	0.150	0.000	ND	0.259	0.104	1.342	1.513	1.248	0.530	0.582	1.247
Total 18-22 PV	9.124a	9.912a	5.591a	0.900	0.180	1.062	ND	0.268	0.130	2.497	2.860	4.560c	1.267	1.230	2.676a
23 POLA-POLB Harbor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
24 Horseshoe	ND	1.94b	ND	ND	ND	ND	ND	ND	ND	ND	ND	tr	0.0001	tr	0.0001
25 Huntington Flats	ND	ND	ND	ND	ND	-	-	-	-	-	-	tr	-	-	-
26 Newport-Irvine Coast	0.755	ND	ND	0.680	0.000	0.086	0.100	0.160	0.160	0.148	0.008	0.010	-	-	tr
Total 23-26 (F&W 10)	0.755	-	-	0.680	0.000	0.086	0.100	0.160	0.160	0.148	0.008	0.010	0.0001	-	0.000
TOTAL	18.815d	11.852d	5.591	6.750	1.960	7.856	4.502d	3.562	3.397	2.681d	2.893d	5.748	1.829	1.230	2.676d

ND = No Data; p = this bed included in the total below; tr = trace of kelp; "'-" = 0
red = warm year El Nino; **blue** = cold year La Nina; **green** = neutral year

a = Earlier measurement in naut mi² converted to km²
b = Estimate in mid-1920s
c = Ecoscan (1990) indicates 2.003 km² from a July 1989 survey. Used Wilson (1989) results for PV showing the kelp beds at greatest extent.
d = Total is not inclusive of all beds in region

Sources: Crandall (1912); 1928, 1945, 1955 from SWQCB (1964); 1955, 1963 from Neushul (1981); 1967, 1972, 1975, 1977 from Hodder and Mel (1978); Ecoscan (1990) and Wilson (1989), North (2000); TMLandsat 7 (2002); Veisze et al. (2004); MBC (2004-2011a).

Table 3. Historical canopy coverages in km² of the southern Orange County and San Diego County kelp beds from 1911 to 1994 surveys. Values represent the approximate maximum coverages for each year. Areal estimates from 1967 to present were derived from charts based on infrared aerial photographs.

	Canopy Area (km²)																					
Kelp Bed	1911	1934	1941	1955*	1959*	1963*	1967	1970	1975	1980	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
North Laguna Beach	Tr	ND	ND	p	0.160	ND	0.001	0.011	0.003	0.036	0.035	0.025	0.028	0.022	0.028	0.042	0.055	0.034	0.029	-	-	-
South Laguna Beach	Tr	ND	ND	p	ND	ND	0.001	0.011	0.003	0.036	0.040	0.028	0.077	0.041	0.087	0.145	0.264	0.243	0.093	0.056	0.028	-
South Laguna	Tr	ND	ND	p	0.180	0.020	-	0.014	0.008	-	0.004	-	-	-	-	0.023	0.041	0.023	0.030	0.009	0.006	0.005
Dana Point-Salt Creek	1.166	ND	ND	p	p	p	0.240	0.077	0.096	0.008	0.013	0.007	0.036	0.031	0.174	0.568	0.878	0.329	0.480	0.184	0.234	0.116
Capistrano Beach	1.578	ND	ND	p	p	p	0.080	0.050	0.070	0.020	-	-	-	-	-	0.032	0.233	0.110	0.134	0.148	0.022	-
Total F&W 9	2.744	-	-	2.020	0.340	0.020	0.322	0.163	0.180	0.100	0.092	0.060	0.141	0.094	0.289	0.810	1.471	0.739	0.766	0.397	0.290	0.121
San Clemente	0.206	ND	ND	6.310	3.710	0.010	0.080	0.050	0.070	0.020	-	-	-	-	0.017	0.124	0.444	0.304	0.243	0.044	0.051	0.010
San Mateo Point	1.235	ND	ND	p	p	p	-	0.057	0.140	0.360	0.163	0.045	0.152	0.077	0.200	0.432	0.870	0.472	0.120	0.103	0.220	0.080
San Onofre	1.029	ND	ND	p	p	p	-	-	0.300	0.160	0.102	0.031	0.042	0.053	0.045	0.348	0.638	0.763	0.170	0.053	0.163	0.201
Total F&W 8	2.470	-	-	6.310	3.710	0.010	0.080	0.107	0.510	0.540	0.265	0.076	0.194	0.130	0.262	0.904	1.952	1.539	0.533	0.200	0.434	0.291
Horno Canyon	0.172	ND	ND	ND	ND	ND	-	-	-	-	-	-	-	-	-	0.006	0.033	0.010	0.018	0.040	-	-
Barn Kelp	2.435	ND	ND	1.370	ND	0.130	0.017	0.019	0.160	0.056	-	-	-	-	-	0.008	0.116	0.382	0.262	0.124	0.002	0.010
Santa Margarita	0.858	ND	ND	ND	ND	ND	-	-	-	-	-	-	-	-	-	-	-	-	0.049	0.009	-	-
Total F&W 7	3.465	-	-	1.370	-	0.130	0.017	0.019	0.160	0.056	-	-	-	-	-	0.014	0.149	0.392	0.329	0.173	0.002	0.010
North Carlsbad	0.480	ND	ND	2.620	2.520	1.180	0.009	0.060	0.100	0.120	-	-	-	-	0.031	0.049	0.096	0.119	0.044	0.004	0.018	0.020
Agua Hedionda	0.429	ND	ND	p	p	p	-	0.006	0.036	0.019	-	0.001	0.011	0.018	0.021	0.032	0.047	0.046	0.016	0.004	0.012	0.004
Encina Power Plant	0.429	ND	ND	p	p	p	-	0.025	0.144	0.074	-	0.002	0.024	0.045	0.120	0.161	0.251	0.179	0.083	0.025	0.022	0.011
Carlsbad State Beach	0.499	ND	ND	p	p	p	0.032	0.120	0.200	0.078	-	-	0.027	0.018	0.077	0.032	0.049	0.081	0.035	0.008	0.002	0.011
Total F&W 6	1.837	-	-	2.620	2.520	1.180	0.041	0.211	0.480	0.291	-	0.003	0.062	0.081	0.249	0.274	0.443	0.425	0.178	0.041	0.054	0.046
Leucadia	1.996	ND	ND	p	p	p	0.240	0.440	0.500	0.670	0.001	0.002	0.104	0.074	0.426	0.197	0.291	0.341	0.163	0.084	0.035	0.010
Encinitas	0.832	ND	ND	p	p	p	0.065	0.173	0.153	0.228	-	0.016	0.083	0.032	0.177	0.153	0.209	0.241	0.080	0.036	0.037	0.016
Cardiff	ND	ND	ND	0.340	0.400	0.160	0.125	0.337	0.297	0.442	0.018	0.021	0.176	0.120	0.340	0.229	0.575	0.468	0.072	0.054	0.034	0.080
Solana Beach	ND	ND	ND	p	p	p	0.290	0.490	0.560	0.690	-	0.001	0.115	0.120	0.367	0.427	0.488	0.466	0.257	0.053	0.023	0.108
Del Mar	0.823	ND	ND	p	p	p	0.190	0.260	0.190	0.210	-	-	0.008	0.021	0.081	0.063	0.104	0.082	0.097	0.006	0.003	0.029
Torrey Pines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Tr	Tr	-	-	-	-	-
Total F&W 5	3.651	-	-	0.340	0.400	0.160	0.910	1.700	1.700	2.240	0.019	0.040	0.486	0.367	1.391	1.069	1.667	1.598	0.669	0.233	0.132	0.243
La Jolla F & W 4	7.889	8.161	7.847	1.660	6.490	0.640	0.330	0.290	0.840	1.900	0.032	0.034	0.720	0.930	2.369	2.200	4.755	3.632	3.230	1.301	0.681	1.119
Point Loma F & W 3&2	18.523	11.465	8.286	1.990	0.610	0.240	2.700	4.900	3.000	4.200	0.200	0.160	1.570	2.100	3.682	2.322	5.842	5.943	4.310	1.153	1.917	3.589
Imperial Beach F & W 1	0.984	ND	ND	ND	ND	ND	-	-	-	0.350	-	-	0.058	0.150	0.727	0.067	0.579	0.651	0.370	0.111	0.025	0.108
TOTAL	41.563	19.626	16.133	16.310	14.070	2.380	4.400	7.390	6.870	9.327	0.608	0.373	3.173	3.702	8.242	7.593	16.279	14.268	10.015	3.498	3.510	5.419

NOTE: p = part of above value; * = Incomplete data; ND - No Data; "-" = 0; Tr = Trace <100 m^2

Sources: 1934, 1941 from SWQCB(1964); 1955, 1959, 1963 from Neushul (1981).

Table 4. Historical canopy coverage in km² of the Ventura, Los Angeles, and Orange County kelp beds to Laguna Beach, from 2003 to 2013. Areal estimates for 2003-2013 were derived from infrared aerial photographs.

	Canopy Area (km²)										
Kelp Bed	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1 Deer Creek	0.089	0.107	0.053	0.026	0.046	0.074	0.105	0.062	0.055	0.041	0.104
2 Leo Carillo	0.318	0.399	0.171	0.150	0.145	0.207	0.255	0.232	0.226	0.337	0.366
3 Nicolas Canyon	0.308	0.362	0.195	0.038	0.473	0.268	0.433	0.291	0.130	0.240	0.369
4 El Pesc/La Piedra	0.243	0.314	0.141	0.063	0.255	0.173	0.238	0.164	0.136	0.173	0.236
5 Lechuza	0.105	0.104	0.041	0.022	0.106	0.075	0.105	0.096	0.096	0.066	0.154
Total 1-5 (F&W 17)	1.063	1.286	0.600	0.298	1.025	0.797	1.136	0.844	0.642	0.857	1.229
6 Pt. Dume	0.012	0.029	0.028	0.053	0.065	0.070	0.104	0.094	0.078	0.154	0.113
7 Paradise Cove	0.162	0.258	0.035	0.036	0.100	0.223	0.244	0.259	0.109	0.346	0.244
8 Escondido Wash	0.214	0.250	0.078	-	0.339	0.278	0.321	0.267	0.104	0.248	0.243
9 Latigo Canyon	0.125	0.161	0.032	0.007	0.186	0.124	0.195	0.142	0.070	0.202	0.133
10 Puerco/Amarillo	0.074	0.051	0.039	0.055	0.095	0.064	0.115	0.126	0.069	0.153	0.105
11 Malibu Pt.	0.011	0.013	0.008	0.008	0.016	0.011	0.012	0.066	0.074	0.084	0.060
Total 6-11 (F&W 16)	0.598	0.762	0.220	0.158	0.801	0.769	0.991	0.954	0.504	1.189	0.897
12 La Costa	0.001	0.002	-	-	-	-	0.001	0.001	-	0.003	0.003
13 Las Flores	0.009	0.023	0.004	-	0.005	0.001	0.005	0.005	0.008	0.025	0.022
14 Big Rock	0.005	0.014	0.002	0.001	0.004	0.002	0.005	0.006	0.007	0.018	0.017
15 Las Tunas	0.003	0.018	0.004	-	0.008	0.005	0.019	0.015	0.007	0.030	0.029
16 Topanga	0.0002	0.002	0.0001	-	-	0.001	0.002	0.052	0.041	0.048	0.044
17 Sunset	-	-	-	-	-	-	0.004	0.008	0.007	0.008	0.010
Total 12-17 (F&W 15)	0.017	0.059	0.010	0.001	0.017	0.009	0.035	0.087	0.069	0.131	0.123
18 Malaga Cove-PV Pt. (IV)	0.196	0.245	0.204	0.859	1.151	1.839	2.122	1.136	1.139	1.337	0.974
19 PV Pt-PT. Vic (III)	0.045	0.040	0.056	0.135	0.074	0.300	0.570	0.624	0.452	0.488	0.502
Total 18-19 (F&W 14)	0.241	0.285	0.260	0.993	1.225	2.140	2.692	1.760	1.591	1.825	1.476
20 Pt Vic to Pt Insp (II)	0.059	0.023	0.034	0.082	0.034	0.108	0.163	0.222	0.238	0.295	0.279
21 Pt Insp to Cabr (I)	1.063	0.211	0.702	0.951	0.703	0.608	0.980	0.389	0.465	0.384	0.672
22 Cabrillo	0.062	0.070	0.102	0.161	0.100	0.060	0.163	0.124	0.103	0.095	0.174
Total 20-22 (F&W 13)	1.184	0.304	0.838	1.194	0.837	0.776	1.306	0.734	0.805	0.774	1.124
Total 18-22 PV	1.425	0.589	1.098	2.187	2.062	2.916	3.998	2.494	2.396	2.599	2.600
23 POLA-POLB Harbor	ND	ND	0.147	0.494	0.118	0.213	0.151	0.277	0.397	0.495	0.337
24 Horseshoe	-	-	-	-	-	-	-	-	-	-	-
25 Huntington Flats	-	-	-	-	-	-	-	-	-	-	-
26 Newport-Irvine Coast	0.002	0.002	0.000	0.023	0.054	0.089	0.095	0.161	0.419	0.395	0.428
Total 23-26 (F&W 10)	0.002	0.002	0.147	0.517	0.172	0.302	0.246	0.438	0.816	0.890	0.765
TOTAL	3.105	2.698	2.075	3.161	4.076	4.793	6.406	4.817	4.427	5.665	5.614

ND = No Data; "-" = 0
Sources: MBC (2004-2013).

The Imperial Beach kelp bed south of San Diego measured 0.984 km^2 in 1911, and was never again measured to be larger than about 0.727 km^2 for the rest of the century (occurring in 1987). However, by the end of 2007, Imperial Beach kelp bed measured 1.493 km^2 (Table 5, MBC 2011b), almost 50% greater than what Crandall measured, lending further credence to Cameron's (1915) statement that beds were in poor condition in 1911 compared to earlier years. It therefore follows that the Palos Verdes, La Jolla, and Point Loma kelp beds of Central and Region Nine prior to 1911 were likely much larger than they are today.

Table 5. Canopy coverages in km² of the southern Orange County and San Diego County kelp beds from 1989 to 2013 surveys. Values approximate the maximum coverages for each year. Areal estimates derived from charts based on infrared aerial photographs.

	Canopy Area (km²)																		
Kelp Bed	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
N Laguna Beach	-	0.001	-	-	-	-	-	-	0.0004	-	-	-	-	0.002	0.005	0.093	0.147	0.192	0.142
S Laguna Beach	-	-	-	-	-	-	-	0.005	0.0002	0.008	-	-	0.001	0.025	0.058	0.098	0.221	0.214	0.273
South Laguna	-	-	-	-	-	0.003	0.002	<0.001	0.004	0.009	0.003	-	0.004	0.023	0.017	0.023	0.018	0.017	0.038
Dana Pt/Salt Crk	0.076	0.061	0.034	0.005	0.080	0.170	0.314	0.432	0.303	0.278	0.123	-	0.302	1.068	0.892	0.839	0.442	0.607	0.835
Capistrano Beach	-	-	-	-	<0.001	<0.001	0.044	0.118	0.069	0.008	-	0.011	0.002	0.071	0.071	0.124	0.010	0.056	0.099
Total F&W 9	0.076	0.062	0.034	0.005	0.080	0.173	0.359	0.555	0.376	0.303	0.126	0.011	0.309	1.189	1.043	1.178	0.838	1.086	1.385
San Clemente	0.010	0.047	-	-	0.006	0.005	0.124	0.316	0.352	0.182	0.178	0.014	0.016	0.203	0.210	0.710	0.795	0.874	1.097
San Mateo Point	0.010	0.073	0.098	-	0.051	0.050	0.090	0.155	0.242	0.123	0.258	0.016	0.201	0.487	0.545	0.583	0.203	0.216	0.219
San Onofre	0.096	0.196	0.108	<0.001	0.005	0.020	0.041	0.030	0.162	0.109	0.065	-	0.320	0.476	0.419	0.458	0.127	0.191	0.767
Total F&W 8	0.116	0.316	0.206	-	0.062	0.075	0.255	0.501	0.755	0.414	0.501	0.030	0.536	1.166	1.174	1.750	1.124	1.281	2.083
Horno Canyon	-	-	-	-	-	0.002	0.034	-	0.001	-	-	-	0.015	0.083	0.018	0.081	-	0.008	0.125
Barn Kelp	0.172	0.204	0.178	-	0.310	0.375	0.547	0.667	0.492	0.075	0.064	-	0.466	0.858	0.926	0.500	0.095	0.442	0.868
Santa Margarita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.080
Total F&W 7	0.172	0.204	0.178	-	0.310	0.377	0.581	0.667	0.494	0.075	0.064	-	0.481	0.941	0.944	0.581	0.095	0.450	1.073
North Carlsbad	0.008	-	-	0.003	-	-	0.017	0.053	0.017	0.003	0.013	-	0.026	0.108	0.135	0.078	0.017	0.052	0.125
Agua Hedionda	0.008	0.009	-	-	-	-	-	<0.001	0.002	0.001	0.008	-	0.016	0.080	0.092	0.031	0.022	0.046	0.102
Encina Power Plant	0.058	0.032	0.013	-	-	0.002	0.029	0.097	0.178	0.067	0.001	-	0.081	0.306	0.215	0.176	0.084	0.216	0.352
Carlsbad St. Bch	0.025	0.013	-	-	-	0.003	0.023	0.047	0.002	0.0001	-	-	0.064	0.121	0.127	0.069	0.024	0.058	0.178
Total F&W 6	0.099	0.054	0.013	0.003	-	0.005	0.069	0.197	0.199	0.070	0.023	-	0.187	0.615	0.569	0.354	0.147	0.372	0.757
Leucadia	0.189	0.087	0.062	-	0.015	0.090	0.209	0.334	0.185	0.048	0.001	0.016	0.233	0.421	0.429	0.215	0.119	0.232	0.541
Encinitas	0.061	0.023	0.048	-	0.029	0.040	0.131	0.153	0.050	0.016	-	0.002	0.205	0.346	0.205	0.128	0.124	0.260	0.231
Cardiff	0.092	0.026	0.031	0.016	0.063	0.150	0.309	0.405	0.202	0.045	-	0.004	0.286	0.484	0.520	0.213	0.395	0.459	0.590
Solana Beach	0.134	0.003	0.073	0.009	0.091	0.200	0.407	0.488	0.245	0.022	0.093	0.0003	0.457	0.823	0.505	0.328	0.504	0.442	0.606
Del Mar	0.082	-	*Tr	0.004	-	0.006	0.015	0.035	0.030	-	-	-	0.037	0.057	0.044	0.038	0.074	0.024	0.056
Torrey Pines	-	-	-	-	-	-	-	-	-	-	-	0.010	-	0.001	0.0004	0.003	0.031	0.034	0.081
Total F&W 5	0.558	0.139	0.214	0.029	0.198	0.486	1.071	1.415	0.712	0.131	0.094	0.032	1.218	2.133	1.703	0.925	1.247	1.452	2.106
La Jolla F & W 4	0.824	0.371	0.478	0.215	1.146	1.250	2.555	3.366	3.444	1.029	0.873	0.117	2.750	4.145	2.274	2.776	2.565	1.569	4.006
Point Loma F & W 3&2	1.134	1.187	2.235	0.295	1.725	3.290	6.574	3.799	4.509	1.924	2.152	1.767	3.616	6.623	4.909	3.977	4.212	5.340	5.127
Imperial Beach F & W 1	0.053	0.008	0.027	-	0.019	0.020	0.078	0.210	0.083	0.191	0.400	0.400	1.493	1.895	0.861	0.004	0.152	0.333	0.526
TOTAL	3.032	2.341	3.385	0.547	3.540	5.676	11.542	10.710	10.572	4.136	4.233	2.358	10.591	18.706	13.476	11.545	10.379	11.882	17.064

NOTE: "-" = 0; Tr = Trace <100 m²

As these measurements indicate, most of the beds remain smaller than those of a century ago; an attempt is made herein to determine what environmental factors have changed in the intervening years to cause such large declines.

FACTORS AFFECTING GIANT KELP GROWTH

Many factors determine whether giant kelp will recruit successfully, form a bed in a given area, and persist. These include the obvious factors such as available habitat, adequate light, nutrient availability, exposure to currents, prevailing swells, storms, predator-prey interactions, and the presence of herbivores. There are also less obvious but potentially more far-reaching effects on the kelp beds in both time and scope, such as the El Niño Southern Oscillation (ENSO) (Bjorkstedt, et al. 2010), decadal regime shifts or climate shifts/variation (Miller et al. 1994, Breaker and Flora 2009), the Pacific Decadal Oscillation (PDO) (referring to events that are Pacific-wide and decades long in nature), and the El Niño/La Niña events (that refer to more local effects of the ENSO) that result in warming or cooling of the waters along the western coasts of South and North America.

Light. Giant kelp needs adequate light to photosynthesize. Turbidity resulting from natural (e.g., phytoplankton blooms, sediment resuspension, etc.) or anthropogenic sources (construction runoff) reduces light penetration and impacts photosynthesis. Phytoplankton blooms are typical in the spring and fall due to an increase in nutrients to inshore waters from upwelling, but blooms of phytoplankton can sufficiently occlude light that they negatively affect kelp health. Phytoplankton blooms were probably responsible for the large, region-wide decrease in canopy coverage in 2005 and 2006. Shading effects on kelp recruitment were well documented by Dean et al. (1989). Consecutive years of large giant kelp canopy can result in recruitment failure due to shading. Recruitment failures are typically manifested in the areal canopy years later as the older plants reach senescence and break away from the holdfasts. Because the amounts of rainfall/runoff were below average in 2013, and phytoplankton blooms were not persistent, shading was probably not a major factor.

Sedimentation. Several kelp forests have been affected by sedimentation, but the most notable are the Palos Verdes and Barn kelp forests. Palos Verdes kelp historically suffered extensive damage related to wastewater discharge prior to effluent improvements initiated in the 1970s, as well as from landslides. Historically, treated wastewater discharge included fine particulate matter that reduced light penetration while it was suspended, and also buried rocky reef habitat when it settled (Hampton et al. 2002). Additional giant kelp habitat was lost due to the Portuguese Bend landslide (Kayen et al. 2002, Pondella 2012 pers. comm.). Sedimentation impacts to Barn kelp are less demonstrative, but the coincidental timing of terrestrial reshaping, storm wave activity, and the disappearance and reappearance of the once-persistent kelp forest is highly suggestive. Kuhn and Shepard (1984) detail the extensive landscape modifications made in the Horno Canyon area in the 1970s that resulted in substantially accelerated erosion. Bence et al. (1989) reaffirmed the increased sedimentation in the area after elevated rainfall during the 1978–1980 rainy seasons. The surface canopy at Barn kelp disappeared in 1980 and did not reappear until 1989 after a large storm in January 1988 resulted in anomalously high subtidal erosion (Dayton and Tegner 1989). While insufficient data exists to empirically test this theory, the timing of these events is striking and highly indicative of sedimentation effects at Barn kelp.

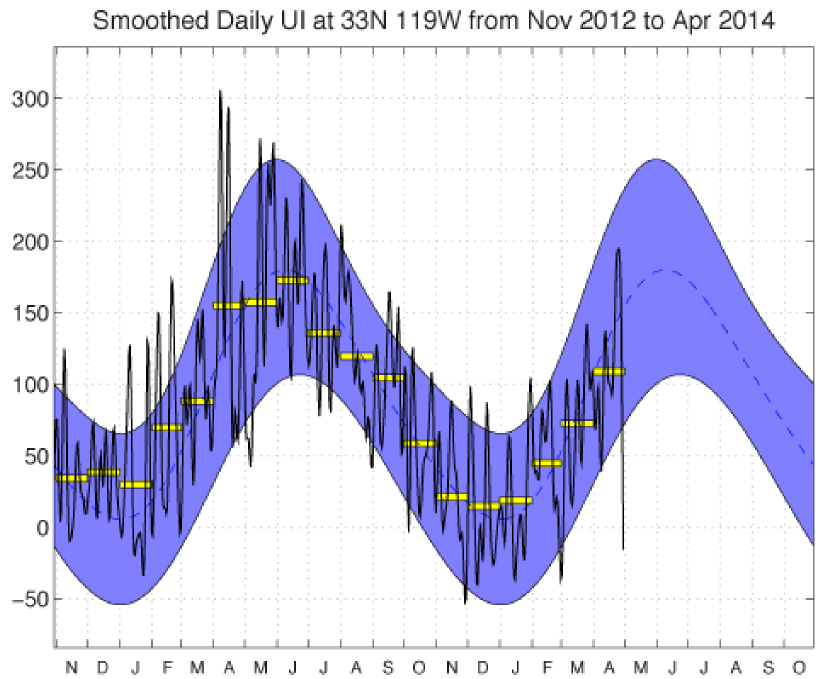
Nutrients. In addition to light, kelp also requires nitrates and other nutrients in solution to spur adequate growth (Jackson 1977, Haines and Wheeler, 1978, Dayton et al. 1999). Unlike the waters of central and northern California, the southern California waters are typically depleted of nutrients such as nitrates. Nutrient availability is known to be one of the primary limiting factors to algal growth (Jackson 1977, Zimmerman and Kremer 1984). Unlike terrestrial plants that absorb nutrients only though roots, kelp absorbs nutrients directly through its tissues. Nutrients are generally recycled in the environment through the continuous raining of accumulated organic matter from the shallow, sunlit depths to deeper colder waters. Typically, the concentration of nitrates increases with depth (Sverdrup et al. 1942). However, shallow waters at depths where kelp commonly occurs tend to have higher temperatures due to solar insolation, and typically have reduced nutrient levels. This is due to the abundance of phytoplankton in the surface waters that compete for nutrients in surface waters where light penetration is good. This presents a physiological challenge for giant kelp plants, which must compete for nutrients and light. In typical, low-nutrient conditions generally encountered during the summer, giant kelp will persist only if it can adequately translocate nitrates from below the thermocline through its tissues (Jackson 1977). If the thermocline is depressed (along with nutrients) below the level where kelp is found for an extended period of time, extirpation of the kelp can occur. For this reason, kelp thrives best during periods of upwelling, where deeper, nutrient-rich waters rise from depths where light levels are too low to permit nutrient stripping by phytoplankton.

Upwelling in southern California generally occurs during the spring months, although canopy growth is also seen in late fall and winter when the nearshore water column is well mixed (Figure 4). Coastal upwelling events are usually wind-driven phenomena in southern California (such as periods of Santa Ana winds) where surface friction caused by prevailing winds from the north and east creates a southward flow due to Ekman transport (Pond and Picard 1983). As the warmer surface layer is moved offshore, colder bottom water rises from the depths to take its place, especially at the continental margin or near submarine canyons, but in shallow areas with persistent winds close to shore, smaller upwelling events can also occur. Upwelled waters are typically much colder than surface waters, so temperature tends to correlate with nutrient availability in coastal zones. Zimmerman and Kremer (1984) identified nitrates at 1 μmol NO_3 per liter as a generally minimal nutrient threshold concentration to support giant kelp growth. In their study, Kamykowski and Zentara (1986) found that nutrients are typically stratified in the water column with greater concentrations below the thermocline, and nutrients correlate strongly with temperature and density. Using this, Parnell et al. (2010) hindcasted the nutrient concentrations based on the seawater density and the nutrient concentration relationship, and were able to identify that these pulses of nutrients occur on a much finer scale than previously realized.

Konotchick et al. (2012) found that the discrepancies in the persistence of giant kelp in the northern and southern portions of the La Jolla kelp bed were caused by differential, alongshore vertical variations in temperature (and thereby nutrients) and topographically induced internal wave dynamics; however, instrumentation to elicit these parameters are not typically available in the scale of a regional study. However, studies demonstrating a correlation between the health of kelp beds and surface cooling events are numerous (e.g., Jackson 1977, Tegner et al. 1996, and Dayton et al. 1999) and surface temperature data are readily available from many locations.

Because of the strong negative correlation between temperature and kelp growth, episodic El Niño warm water events can have a severe negative impact on the health of kelp beds in the SCB. Various studies have described an inverse temperature/nutrient relationship indicating that water temperatures above 15 to 17°C (59–64°F) generally have very low nutrient content (Haines and Wheeler 1978, Gerard 1982, North and Jones 1991, Dayton et al. 1999, Kamykowski and Zentara 1986, Zimmerman and Kremer 1986, Lucas et al. 2011, and Konotchick et al. 2012). North and Jones (1991) combined the results of the earlier studies to make broader interpretations of the availability of nutrients based on surface seawater temperatures at discrete locations. They found that with roughly each one degree centigrade (1.9°F) temperature drop, the availability of nitrates essentially doubled.

Therefore, at a temperature of 12°C (54°F), 14 times more nutrients were theoretically available than at 16–17°C (62–64°F).



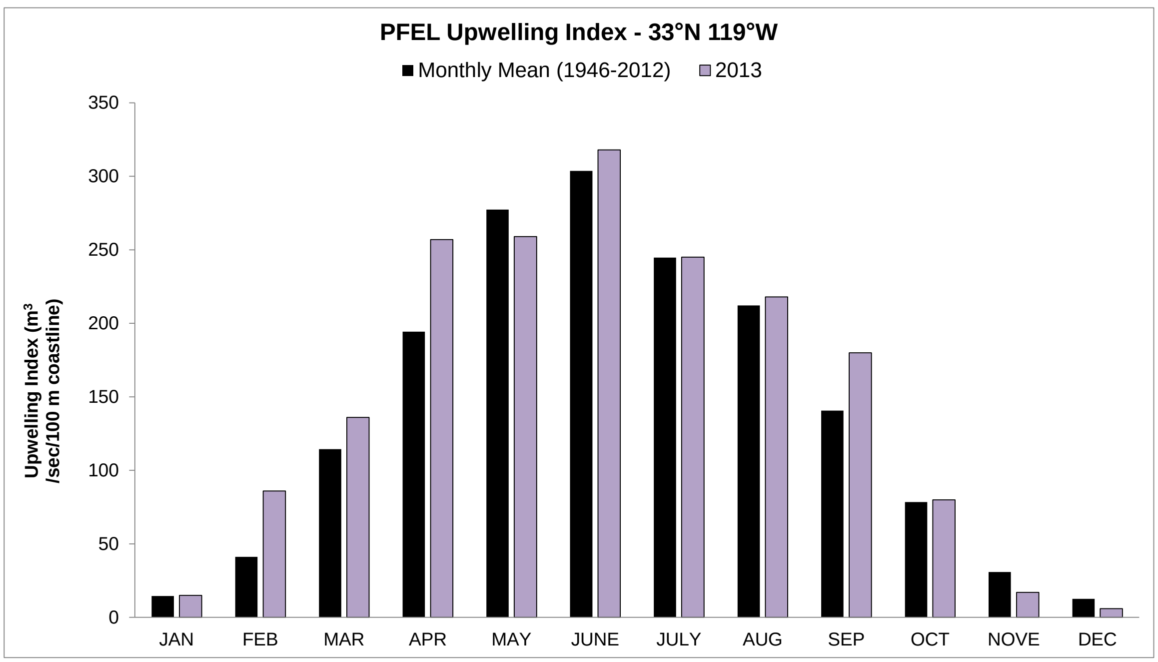


Figure 4. Top: Daily Upwelling Index (UI) at 33°N 119°W. The dashed curve is a smoothed biharmonic fit to the daily UI from 1967–1991. The purple area represents one standard error, and the yellow bars are monthly means. Units are cubic meters per second per 100 meters of coastline. **Bottom:** UI comparing monthly mean (1946–2012) to January–December 2013. Data from: http://www.pfeg.noaa.gov/products/PFEL

Grazing. Kelp herbivores (such as sea urchins) can also affect the size and extent of giant kelp canopies. A reduction in natural predators will allow herbivores such as urchins to proliferate unchecked, resulting in overgrazing of kelp (North 1983, Wilson and Togstad 1983, Dayton 1985, Harrold and Reed 1985, Harrold and Pearse 1987, Murray and Bray 1993). Urchins were implicated in the wholesale loss of kelp beds at San Mateo Point, Palos Verdes, and Imperial Beach, and they have caused detrimental effects on many other kelp beds (North and Jones 1991). In southern California, sea urchin (*Strongylocentrotus* spp and *Lytechinus pictus*) overgrazing results in areas devoid of kelp, also known as "urchin barrens". The sustainability of urchin barrens requires immigration from other, non-barren sites, because urchins from barrens are nearly devoid of gonad material while those from kelp forests have much larger gonads (Tegner and Dayton 1991).

The Palos Verdes kelp suffered persistent urchin overgrazing through the 1960s (Leighton et al. 1966). Clark et al. (1972) hypothesized that the elevated free amino acids discharged in the wastewater supported the urchins even after the area was denuded of kelp and algae. Urchin barrens persisted after the improvement of wastewater effluent and therefore their occurrence is not simply an effect of discharge, but additional factors likely trigger herbivore overgrazing (Foster and Schiel 2010). Tegner and Dayton (1991) concluded sea urchin overgrazing resulted from a reduction in drift algal biomass, which typically occurs during nutrient-deficient periods and higher sea urchin recruitment. When drift algal biomass was sufficiently common, sea urchins remained in cracks and crevices in the reef.

Tegner and Dayton (2000) hypothesized increased occurrence of urchin barrens was linked to fishing pressure on urchin predators, such as California sheephead (*Semicossyphus pulcher*). Many of these conclusions stem from work in Alaska where kelp forests lacking sea otters (*Enhydra lutris*) were heavily overgrazed, while those with healthy otter populations were not. Tegner and Dayton (2000) inferred a relationship between urchin predator abundance and urchin overgrazing based on gut content studies, laboratory experiments, field observations of urchin behavior, and size-frequency distribution. Recent work by Hamilton et al. (2011) described the co-occurrence of low predator populations, high sea urchin density, and low giant kelp density as site-specific phenomena.

Storms. Storms can hinder or stimulate kelp growth, depending upon how large they are and how much energy they contain. Waves cause a back and forth motion in kelp; large swells increase the severity of this motion. The heightened drag force on the kelp as a result of large swells can break fronds, and even break the holdfast free from its anchorage. As the fronds of giant kelp often entangle with other nearby giant kelp, the added drag of other loose giant kelp can rip a more firmly attached neighbor free from its holdfast. The resultant mass of entangled, loose giant kelp can drift through a kelp bed ripping out hundreds or thousands of giant kelp plants, which can wash ashore or become a floating kelp paddy offshore (Dayton and Tegner 1984, Ebeling et al. 1985).

Of particular concern are storms that produce swell heights that exceed four meters and that originate out of the west or southwest rather than from the Gulf of Alaska (GOA). The Northeast Pacific wave climate changed in 1976–1977 to one where waves out of the west or southwest, similar to those occurring during El Niño events, occurred more frequently (Adams et al. 2008, Seymour 2011). Prior to 1976, the wave climate was dominated by energy generated in the GOA. The SCB coastline was largely protected from GOA-sourced waves via the island shadow effect (Pawka et al. 1984; Seymour et al. 1989) (Figure 5).

A shift south in the dominant trajectory minimized the island protection for the coastal area and more waves delivered their full energy to the Orange and San Diego County coastlines. At times, this energy likely swamped all other physical and biological regulators of persistent kelp forests (Reed et al. 2011), such as occurred during the 1982–1983 El Niño, and the large storm in January 1988 (Seymour et al. 1989). These storms resulted in substantial damage to the coastal giant kelp forests, including the complete removal of some forests (Dayton and Tegner 1984, Ebeling et al. 1985, Seymour et al. 1989). Even though large storms generally are devastating to the kelp bed resources, the combination of the 200-Year Great Storm of January 1988 with the La Niña of 1989 produced kelp beds in areas that were devoid of kelp for years. This renewal was probably due to high wave energy abrading the multi-layered invertebrate coverage (thereby eliminating competition for space) and exposing previously buried bedrock for spore colonization (Seymour et al. 1989, Appendix B, MBC 1990).

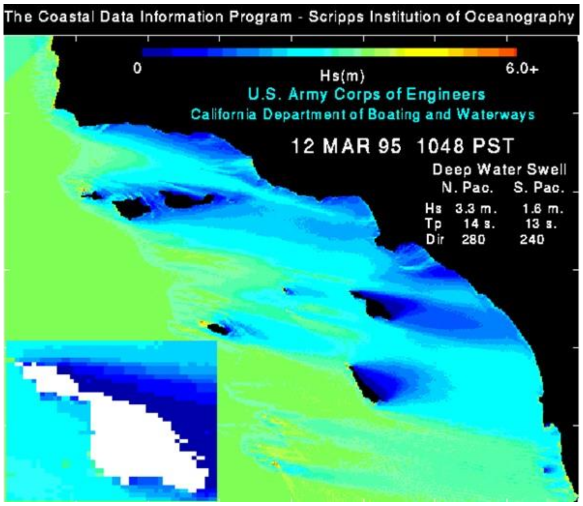


Figure 5. Depiction of the blue shadow effect from offshore islands providing protection to mainland kelp beds.

ENSO. Oceanographic variables change, often resulting in dramatic shifts in kelp abundance and density over seasons, years, and between locations (Hodder and Mel 1978, Neushul 1981, North 1983, Jahn et al. 1998, Dayton et al. 1999). The manifestation of global El Niño and La Niña events are thought to be two extremes of a naturally occurring meteorological oscillation in atmospheric pressure gradient near the equatorial latitudes of the Pacific Ocean, termed the El Niño Southern Oscillation (ENSO). These oscillations generally occur every two to seven years, with the strongest effects often observed in the equatorial eastern Pacific (the west coasts of South and North America) (Bograd and Lynn 2003).

El Niño conditions are commonly associated with warmer-than-average temperatures and a reduction in available nutrients in the upper water column as upwelling weakens, resulting in poor kelp growth (Zimmerman and Robertson 1985, Dayton and Tegner 1989). Conversely, the onset of La Niña conditions, when surface waters are much colder than average, usually coincides with enhanced kelp growth as a result of the influx of nutrient-rich, colder bottom waters into the surface layer. It should be noted, however, that not all Central Pacific ENSOs result in Californian El Niños, or those that quantifiably alter local conditions. Californian El Niños in 1982–1983 and 1997–1998 led to lower nutrient concentrations and increased wave energy striking the SCB coastline, resulting in substantial damage to local giant kelp forests (Seymour et al. 1989, Edwards and Estes 2006). However, El Niño conditions in 2009–2010 resulted in no measurable response in the SCB (Bjorkstedt et al. 2010). Clearly, conditions labeled as El Niño or La Niña encompass a wide gradient of southern California kelp bed responses, ranging from minor to catastrophic. Therefore, in years that are designated El Niño or La Niña years, there may not necessarily be locally poor or good kelp growth.

Using several oceanographic models and looking at a variety of variables, a multivariate ENSO Index that classifies cold water and warm water periods since the early 1870s was developed by NOAA (NOAA-MEI 2014; Figures 6 and 7). Based on this index, it is clear there was a transition in 2010 from a relatively warm period to a relatively cool period. This ENSO-negative period persisted for about two years, and in 2012, the standardized departure was positive for several months, before returning to negative in 2013.

As ENSOs have been recurring events for thousands of years, it was assumed in the long term that their effects have been neutral in regards to long-term maintenance of the kelp bed resources. However, a glance at the last approximately 50 years of the multivariate ENSO Index indicates that the 30 years between 1977 and 2007 were characterized by frequent warm periods. There were only two significant cold periods during the entire time period, whereas the previous 30 years were characterized by mostly cold-water events. Looking even further back from about 1872 to approximately 1918, it is clear that cold-water events lasted longer and probably had a very favorable impact on the kelp beds of that era. The last five years have been characterized by two long cold-water periods and two shorter warm-water periods.

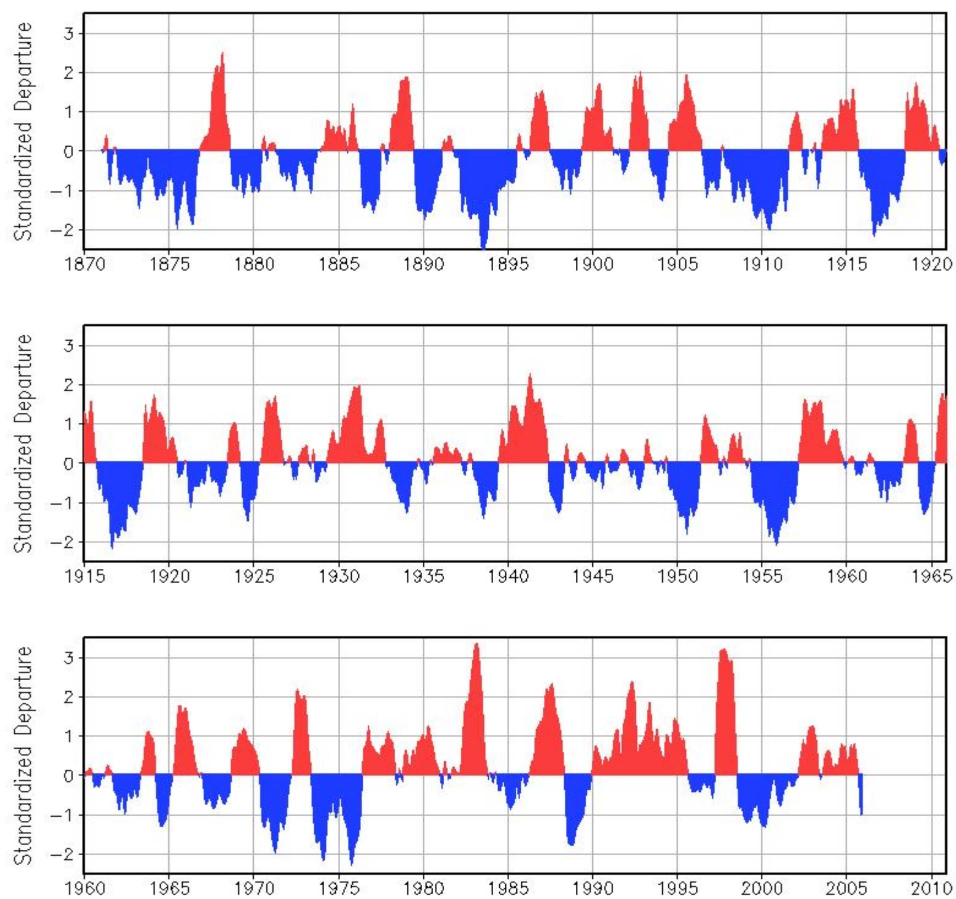


Figure 6. Multivariate ENSO Index from 1870 through 2006, NOAA-MEI.

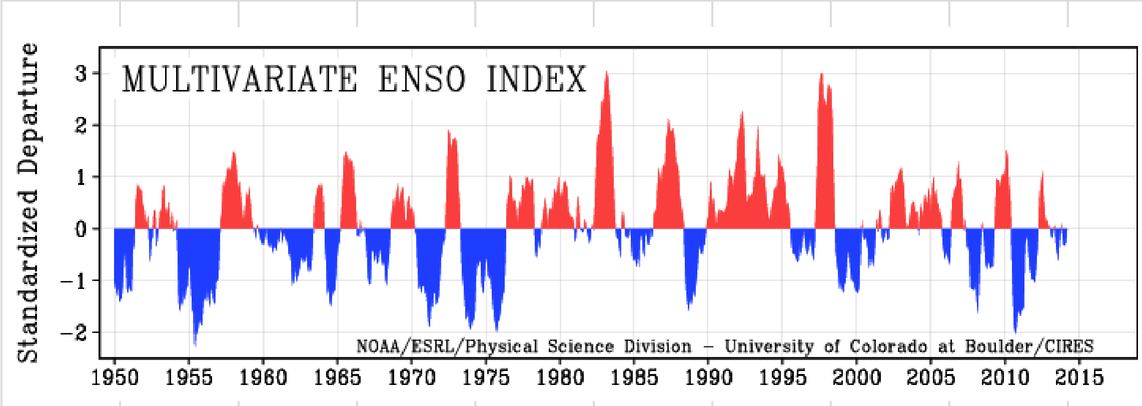


Figure 7. Multivariate ENSO Index from 1950 through 2014, NOAA-MEI.

Anthropogenic Effects. Because large-scale oceanographic cycles such as ENSO events are monitored closely, the ability of existing models to predict the onset of conditions that are either significantly warmer or colder than average increases every year as the profusion and quality of data increases. For this reason, it is far easier to correlate the variability of kelp bed abundance and health to natural physical phenomena than it is to relate it to anthropogenic causes. Anthropogenic effects on kelp beds have been documented, most notably the pollution-related loss of kelp beds offshore of Palos Verdes (from the late 1950s through much of the 1970s) and Point Loma (in the early 1990s) (SWQCB 1964, North 1968, Meistrell and Montagne 1983, Foster and Schiel 2010). The probably cause of the loss of kelp at the Point Loma outfall was not related to the wastewater, but probably the accompanying turbidity from particulates in the discharge (City of San Diego 1992a,b; North 2001). Other factors have included unchecked runoff from coastal construction, such as what appeared to have occurred during construction of Interstate 5 in the late 1960s (loss of Barn kelp for several years); construction of homes at Salt Creek in the late 1970s that resulted in the loss of the large Dana Point/Salt Creek kelp bed (North and MBC 2001); the loss of the Huntington Flats kelp bed in the early 1930s; and the loss of the Horseshoe Kelp bed offshore of San Pedro Harbor in the late 1930s, probably a result of turbidity due to an increasing population and dumping of sediment from dredging of the Los Angeles and Long Beach Harbors. The loss of the Huntington Flats kelp bed was probably a result of increased turbidity due to the construction of Anaheim Bay, Alamitos Bay, and the Long Beach breakwaters (North and MBC 2001).

Climate Shifts. With evidence of five climate-regime shifts in the last century, anthropogenic effects would appear to be relatively insignificant compared to the changes the shifting oceanographic regime has wrought upon the marine biota. Consequences of these regime shifts sometimes take decades to recognize. Contrary to what are generally assumed to be the responsible agents for the large-scale decreases in kelp in southern California (such as increasing urbanization, concurrent runoff, and discharges to the marine environment), there is now evidence that multi-decade-long oceanographic environmental changes have had a greater effect than previously believed. Low-frequency oceanographic regime shifts occur on 20- to 40-year cycles that result in sustained periods of comparatively high or low kelp canopy areas (Parnell et al. 2010). In the upper 200 m of the ocean, both density and temperature correlate well with nitrate concentrations (Kamykowski and Zentara 1986). A recent study that focused on seawater density, which may be a better indicator of the presence of nitrates/nutrients than temperature over time, found that a major shift occurred circa 1977 during a period previously assumed to be just a strong El Niño (Parnell et al. 2010).

Upon Parnell's review of water density data (collected since the 1950s incidental to fisheries management cruises by the California Cooperative Oceanic Fisheries Investigations) and pier temperature data from Scripps Institution of Oceanography (SIO), there is now evidence that nutrients were replete in the SCB for decades prior to the 1976–1977 regime or climate shift and in contrast have been more or less depleted since. The dramatic increases and decreases in kelp bed canopies observed during El Niño and La Niña events after the regime shift in the latter part of the 20th century were the result of a period of depleted nutrients; kelp bed responses to ENSOs were much more subdued during the period of sufficient nutrients prior to the regime shift (Parnell et al. 2010). This change in the apparent intensity of the ENSO events is the result of a nutrient-deficient regime with pulses of nutrients to sustain the beds only available during the rebound effects from ENSO events (La Niña). These regime shifts can come in the form of a gradual drift, smooth oscillations, or step-like changes as noted in the 1976–1977 regime shift and the later 1988–1989 shift (Miller et al. 1994, Miller and Schneider 2000). These far-reaching changes are usually decades in duration and can have profound effects on abundance and biodiversity of marine communities (Bakun 2004, Noakes and Beamish 2009).

A regime shift reportedly occurred in the California Current circa 1999 (Petersen and Schwing 2003), but this has not yet manifested as altered conditions in the SCB as all available metrics continue to indicate conditions consistent with the 1976–1977 shift (McGowan et al. 2003, Bograd and Lynn 2003, Pondella et al. 2012). Initial understanding of the 1976–1977 shift centered on increased SST, but salinity also declined as the mixed layer deepened with a deeper thermocline (McGowan et al. 1998, Bograd and Lynn 2003, McGowan et al. 2003).The PDO and the Inter Decadal Oscillation (IDO) appear as potential long-term climate changes from a colder to warmer regime, or the reverse (Mantua et al. 1997, Power et al. 1999, Fiedler 2002, Verdon et al. 2004). Both the negative and positive PDO phases are well within the range observed for the 111 years included in the PDO series. Many of these phases did not result in a corresponding giant kelp canopy area change that would be predicted by a direct PDO to kelp growth relationship. As these effects dissipated, it was assumed that conditions would become more or less normal; however, a closer look may reveal that the marine ecosystem has been fundamentally changed in a way that could portend serious consequences for the sustainability of the kelp bed resources.

Increased recognition of the unique oceanography of the SCB identified a disconnect between the waters inshore of the Channel Islands and the California Current flowing seaward of the Channel Islands (Hickey 1992, Bograd and Lynn 2003). This disconnect may have limited the relevance of common climate indices derived from environmental data gathered across the Northeast Pacific Basin such as the PDO, North Pacific Gyre Oscillation (NPGO), Multivariate ENSO Index (MEI), etc. (Figure 7). The PDO's minimal applicability to the SCB was best detailed by Di Lorenzo et al. (2008) and their conclusion that the PDO correlated with SST south of 38°N while the NPGO correlated with several productivity measures. Cavanaugh et al. (2011) found the NPGO correlated with Santa Barbara Channel kelp forests, but only at a 3-year lag. No such relationship was identified with the PDO. However, large scale and/or prolonged ENSO events impact the region's kelp beds, and this can be determined by comparing the long-term MEI data with the kelp canopy coverage estimates.

Sediment Regimes. Changes in sediment regimes have also contributed to the disappearance of several kelp beds since the 1911 Crandall surveys. Large kelp beds once thrived offshore of Point Dume, Sunset Beach (offshore of Santa Monica), Crystal Cove, Horno Canyon, Santa Margarita, and near the Mexican Border. Because there are no known human-induced causes for the loss of kelp at these areas, these beds likely disappeared due to inundation of low-lying reefs by shifting sediments (or kelp was growing on the sand at some of these locations). Subtidal observations on the seafloor at Sunset Beach, Crystal Cove, Santa Margarita, and the Mexican Border indicate the lack of suitable hard substrate that has limited the re-establishment of these kelp beds (Curtis 2012, pers. comm.). Sub-bottom profiling revealed that hard substrate is buried by as much as one meter of sand at San Onofre and in the Barn kelp area (Elwany 2007, pers. comm.).

DESCRIPTION OF THE CENTRAL REGION KELP BEDS

The CRKSC program area, extending from the Santa Barbara-Ventura County line to Abalone Point in northern Laguna Beach in Orange County, recognizes 26 existing or historic kelp beds, including three (Sunset kelp, Horseshoe kelp and Huntington Flats kelp) that have been missing or greatly reduced since the first half of the 20th century (MBC 2004a–2012a). One kelp bed, Sunset kelp (near Santa Monica), has not been observed since the initiation of surveys by the CRKSC in 2003, but it was reported as a very small bed during a 1989 survey (Ecoscan 1990). During the CRKSC surveys, kelp at Sunset has only been observed at the submerged breakwater off the Santa Monica Pier. The disappearance of these three kelp beds was likely the result of greater turbidity and sedimentation from increased industrialization (and population) throughout southern California during World War II and into the late 1960s. The kelp surrounding the breakwaters of the Ports of Los Angeles and Long Beach was included in the CRKSC surveys region upon realization in 2005 that there was considerable giant kelp in the Ports. One other historic kelp bed (Newport/Irvine Coast) reappeared (following restoration efforts) after absences of one to several decades resulting from a series of El Niño events in the 1980s and 1990s.

The continued absence of three of these 26 beds is likely the result of the loss of suitable substrate. Horseshoe kelp likely was buried during excavations of the harbor in the 1940s and 1950s and dumping of the sediment at that location, and the burial of suitable substrate by natural sedimentation processes at Sunset kelp (which occurred at several other historic kelp bed sites removed from population centers). However, it is possible that the Sunset kelp beds may have grown on sand. The loss of the Huntington Flats kelp bed was probably the result of increased turbidity due to the extension of the Long Beach breakwater, and the dredging of Alamitos Bay and Sunset-Huntington Harbors. The CRKSC surveys began following a strong La Niña event in 1999. All three missing beds had substantial canopies prior to 1950.

Administrative Kelp Bed Lease Areas. Each kelp bed in the following description is a portion of California Department of Fish and Wildlife's (CDF&W) administrative kelp bed lease areas that may include more than one giant kelp bed. The CRKSC and RNKSC programs identify these individual beds either using local names or geographical references for the name. By placing these beds under the Fish and Wildlife numbered bed, a more direct comparison of the data in this report can be related to that obtained by Fish and Wildlife. Some kelp stands grow outside of the Fish and Wildlife Kelp Beds; in such cases, a CRKSC or RNKSC designation has been assigned. Large declines and subsequent recoveries are common occurrences in the historical record (especially if we include all of the quarterly surveys). Drastic reductions may simply be short-term fluctuations of little importance to the long-term welfare of the bed. If, however, the decline represents a persistent change or develops into a downward trend, more evaluation may be needed to clarify the cause(s).

Administrative kelp bed areas in California waters are numbered, defined by compass bearings from known landmarks, and have applicable commercial regulations in the California Department of Fish and Wildlife Code. Although not all areas contain kelp beds, the entire California coastline, including the Channel Islands, is divided up into numbered administrative kelp beds (Figure 8). The administrative kelp beds are designated as closed, leasable, leased (from the state), or open. Closed beds may not be harvested. Leased beds provide the exclusive privilege of harvesting to the lessee, and open beds may be harvested by anyone with a kelp harvesting license. In 2013, only one administrative kelp bed was leased in the CRKSC and RNKSC areas: Bed Number 3 at Point Loma.

Giant kelp was first harvested commercially along the California coast during the early 1900s and has continued since. Since 1917, kelp harvesting has been managed by the CDF&W under regulations adopted by the California Fish and Wildlife Commission. Regulations currently allow kelp to be cut no deeper than four feet beneath the surface, although the surface canopy can be harvested several times each year without damaging the kelp beds. Kelp harvesting licenses are required to take kelp for commercial use. Kelp beds can be leased for up to 20 years; however, no more than 25 mi^2 or 50% of the total kelp bed area (whatever is greater) can be exclusively leased by any one harvester.

Many of the kelp studies between 1911 and 1989 consolidated all local kelp beds into the Fish and Wildlife Kelp Bed designations, making it difficult to discern patterns of specific sub-areas within the much larger Fish and Wildlife lease areas. For example, Fish and Wildlife Kelp Bed (lease area) No. 17 encompasses over 10 kilometers of coastline. Therefore, natural breaks in the beds were determined (as noted by either Crandall's 1911 survey or Ecoscan's 1989 survey) and assigned names that describe the location based on nearby canyon names, prominent features, or other local names in use.

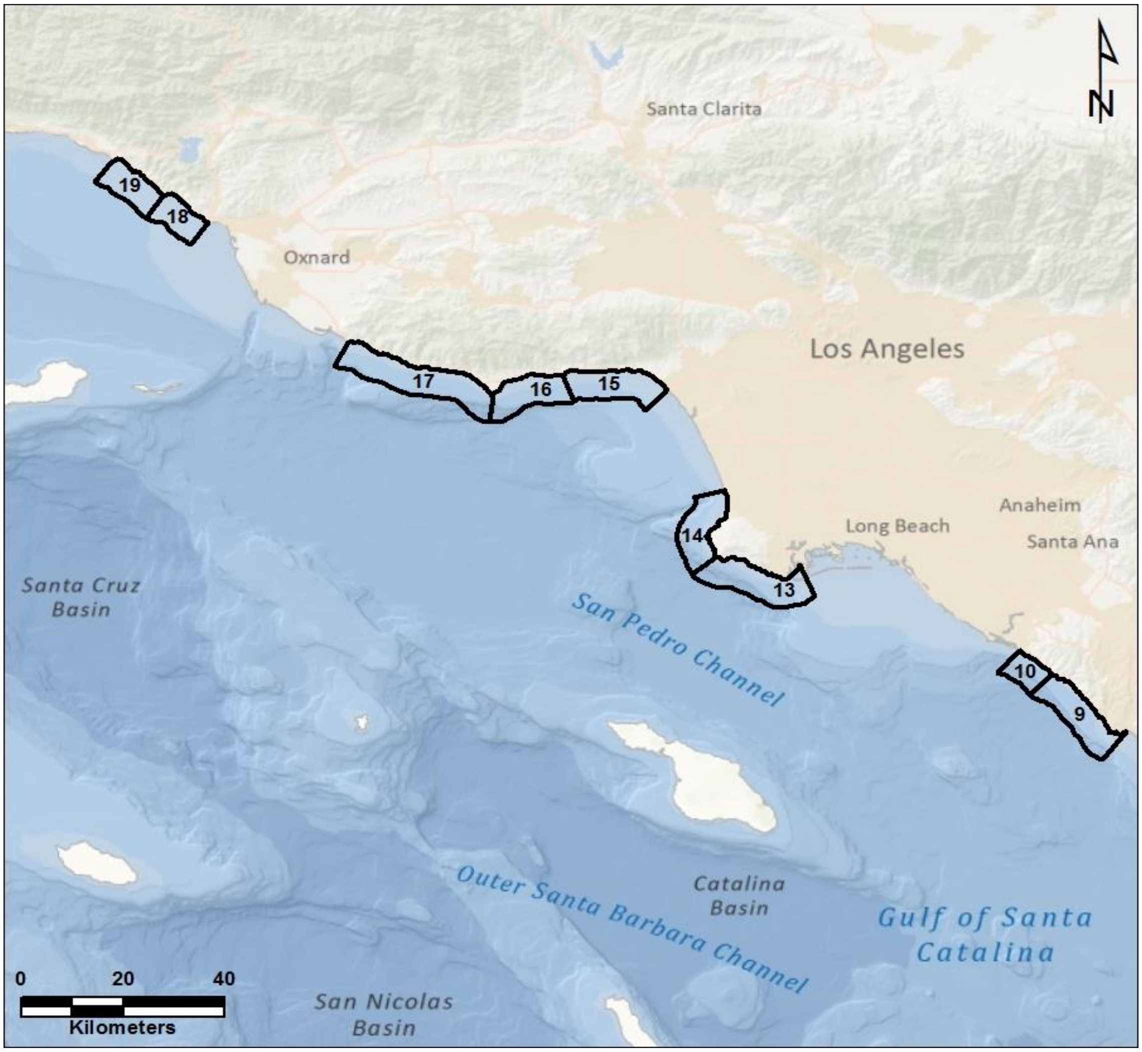


Figure 8. Administrative kelp bed leases in the Central Region study area. Beds 18 and 19 are upcoast from the CRKSC study area.

Fish and Wildlife Kelp Bed Number 17. The area designated as Fish and Wildlife Kelp Bed 17 includes five kelp beds in the CRKSC program (Appendix A). Bed 17 extends from south of Mugu Lagoon to Point Dume (Figure 8). In general, the seafloor upcoast of the Deer Creek kelp bed, the northernmost kelp bed under study, is composed predominantly of sandy substrate with virtually no hard bottom at depths conducive to kelp growth. Therefore, no substantial kelp beds are found upcoast of Deer Creek in the areas downcoast and offshore of Ventura Harbor, the City of Oxnard, the Mandalay Generating Station, Channel Islands Harbor, the Ormond Beach Generating Station, and from Port Hueneme downcoast to Point Mugu. There are, however, small kelp stands that form along the breakwaters of Ventura Harbor, Channel Islands Harbor, and Port Hueneme. Just downcoast from Point Mugu, there are five kelp beds: the Deer Creek, Leo Carillo, Nicolas Canyon, El Pescador/La Piedra, and Lechuza kelp beds. Kelp bed surveys have been conducted in this area only about 12 times during the past century, and therefore large gaps exist in the historical record. Historically, these beds covered more than 4 km^2, with the Leo Carillo and Nicolas Canyon beds accounting for a large portion of that areal coverage. This area totaled 4.151 km^2 in 1911, and it was markedly similar in 1967 (4.144 km^2). These five beds have persisted though time and have survived El Niños, La Niñas, and unusually persistent plankton blooms during the past decade; however, they have not consistently combined to obtain an areal coverage of much greater than 1 km^2 (Table 4). Kelp coverage began to decline after 1967, and the decline continued through 1999. At some point after the survey in July 1999, and coinciding with the La Niña of 1999–2000, kelp began to increase. In the 2003 survey, canopies covered 1.063 km^2, and increased slightly to a peak of 1.286 km^2 in 2004, 31% of the 1911 total. Kelp bed canopy coverage reached a low of about 0.3 km^2 in 2006, and then fluctuated between 0.642 and 1.136 km^2 through 2012. In 2013, the combined coverage of the five beds in Fish and Wildlife Bed 17 was 1.229 km^2, the largest total since 2004.

Fish and Wildlife Kelp Bed Number 16. Bed 16 begins at Point Dume and extends to the south of Malibu Point. The CRKSC monitoring program recognizes six kelp beds in the Bed 16 region: the Point Dume, Paradise Cove, Escondido Wash, Latigo Canyon, Puerco/Amarillo, and Malibu Point kelp beds. Kelp canopy coverage in Fish and Wildlife Kelp Bed 16 has varied considerably over time (Appendix A). The Bed 16 canopy coverage in 1911 (3.4 km^2) decreased by about one third by 1955 (2.14 km^2), and then increased to about 2.54 km^2 by 1967, equivalent to 74% of the 1911 measurement (Crandall 1912). These beds were in severe decline by 1989 (0.22 km^2) and by 1999, a decade later, the effects of the severe 1997–1998 El Niño resulted in coverage of only 0.03 km^2. By the first CRKSC survey in 2003, the canopy area increased to 0.598 km^2. The beds continued to increase in 2004 and totaled 0.762 km^2 during their largest extent, presumably responding to relatively favorable environmental conditions in the early portion of that year (MBC 2005a). With the exception of the Point Dume kelp bed, all of the other kelp beds in this area decreased in 2005 compared to 2004. However, in a continuing response to poor nutrient conditions, kelp canopy coverage decreased strikingly in 2006 to only 0.158 km^2. The beds recovered strongly in 2007 to 0.801 km^2, and remained large in 2008, although they were slightly smaller at 0.769 km^2, before increasing again by June 2009 to 0.991 km^2. The 2010 survey followed a mild El Niño in mid-to-late 2009 that reduced the kelp canopy; however, they began to recover throughout 2010 and reached a sizeable fraction (96%) of their 2009 status by December. Although conditions appeared favorable, most of the beds decreased by about one-half in 2011. In 2012, the kelp beds responded to favorable conditions and canopy coverage reached its largest extent (1.189 km^2) since CRKSC studies began in 2003. In 2013, coverage decreased by about 25% in total, and coverage at all five beds declined.

Fish and Wildlife Kelp Bed Number 15. This bed begins near Malibu Creek and kelp is found on every rocky point more or less continuous to Sunset kelp in Santa Monica Bay. Six kelp beds are found within Kelp Bed 15: La Costa, Las Flores, Big Rock, La Tunas, Topanga, and Sunset. Most of these beds were fairly small in 1911, with the exception of Sunset kelp, which covered 0.960 km^2. In 1911 this bed appeared similar in size to that in the U.S. Coast and Geodetic Survey Map of 1890 (Map 5100), suggesting the size of the bed Crandall noted was not an aberration. By 1955, the area encompassing Kelp Bed 15 was only a remnant of that noted in the 1911 survey, with only 0.02 km^2 of kelp reported. Presumably, the construction of a breakwater offshore of the Santa Monica Pier in the 1930s, the surge in population along the coastline, and increased industrialization within the coastal communities resulted in greater turbidity from terrestrial runoff. The beds in this area are much smaller than that reported by Crandall (1912). It is also possible that the bed at Sunset was similar to the kelp beds in Santa Barbara that grow on the sand and once extirpated, may not recolonize readily. In 2004, the total area of Fish and Wildlife Kelp Bed 15 was 0.059 km^2, less than 3% of that noted in 1911, and by 2006, the total areal coverage was further reduced to 0.001 km^2. In 2007, the kelp beds of Bed 15 were small, and three (La Costa, Topanga, and Sunset) were missing; however, Bed 15's total size was larger

(0.017 km^2) than in 2006. Although the Topanga kelp bed reappeared as a very small bed in 2008, the total kelp coverage of the region decreased further to 0.009 km^2. However, all of the beds appeared in 2009 (the first time all beds were present since CRKSC monitoring began) and increased to a regional peak in coverage of 0.131 km^2 by the end of December 2012. The area of Bed 15 decreased slightly (6%) in 2013, although the Sunset Bed increased slightly in size.

Downcoast of Sunset Beach there is another large gap in kelp cover to Malaga Cove at the northern edge of the Palos Verdes Peninsula. Kelp is missing because sandy bottom dominates this stretch of coastline. Therefore, no measurable kelp stands exist offshore of Santa Monica, Marina del Rey Harbor, the City of Los Angeles Bureau of Sanitation Hyperion Treatment Plant, Scattergood Generating Station, Chevron El Segundo Refinery, El Segundo Generating Station, Manhattan Beach, Hermosa Beach, the Redondo Beach Generating Station, King Harbor, or Torrance Beach. While no natural hard substrate exists for the attachment of kelp along this coastal stretch, individual subsurface giant kelp are often seen at the Marina del Rey and King Harbor breakwaters, and at the entrance to King Harbor.

Fish and Wildlife Kelp Bed Number 14. This bed begins about four kilometers south of the King Harbor breakwater and extends along the Palos Verdes Peninsula to Point Vicente. From Redondo Beach, sandy bottom predominates for about four kilometers in a downcoast direction, and then rocky substrate becomes prevalent at Malaga Cove and southward along the Palos Verdes Peninsula. The area between Malaga Cove and Point Vicente has intermittently supported large kelp beds. Historically, the kelp beds in this region totaled about 6 km^2, were larger in the late 1920s and were still very large in 1945, but were reduced to about 20% of the 1911 total by 1955 and 1967. Kelp coverage was very low (less than 0.1 km^2) in the surveys of the 1970s, but due to restoration efforts led by Dr. Wheeler North, giant kelp recovered, culminating with a regional coverage of over 3 km^2 in 1989. Kelp stayed robust through much of the decade of the 2000s, but was still only 30 to 50% of that observed historically. Coverage in 2013 was 19% lower than in 2012, but similar to coverage from 2011.

Fish and Wildlife Kelp Bed Number 13. Bed 13 begins at Point Vicente and extends along the Palos Verdes Peninsula to Point Fermin and Cabrillo Beach. Historically, this area supported very large kelp beds, with a coverage totaling almost 3 km^2. Based on aerial photos taken in 1928 and 1945, these beds were very large then, but began a steep decline by 1955 with virtually no surface canopy by 1967. Restoration efforts at White Point by Dr. Wheeler North and the extension of the wastewater outfall pipe initiated a recovery of Bed Number 13, and by the 1980s, the canopy was substantially larger. By 1984, kelp was at about 50% of its historical coverage; it peaked again to that level several times in the 2000s, but was still well below the levels seen prior to 1945. Coverage in 2013 was 45% higher than in 2012; canopy from Point Vicente to Point Inspiration decreased slightly, while the canopy from Point Inspiration to Cabrillo increased by 75%, and the canopy at Cabrillo increased by 83%. While CDF&W Bed Number 13 includes the area up to the San Pedro breakwater lighthouse, it is unclear whether or not Cabrillo kelp bed has historically been included since it is east of Point Fermin, which was designated as the eastern-most border to Fish and Wildlife Kelp Bed 13 in some past reports (unpublished aerial overflight surveys of the Palos Verdes Peninsula by Fish and Wildlife, 1984–1985).

Within and along the inner and outer Los Angeles and Long Beach Harbor breakwaters, kelp was intermittently observed as a small band of kelp fringing the rocky riprap. As more and more riprap was added to the harbor, it soon became apparent that a considerable amount of giant kelp was to be found within the two harbors. The first survey of the entire two harbors was conducted in 2005, and about 0.15 km^2 of kelp was observed. Subsequently, the CRKSC added the harbor to their quarterly aerial surveys, and canopy coverage peaked in 2012 at 0.495 km^2. Coverage decreased by about one-third in 2013.

HORSESHOE KELP. On the relatively shallow, alluvial deposition from the Los Angeles River that extends 10 to 15 km offshore of San Pedro, kelp beds were historically present in the first half of the 20th century. The largest bed (1.94 km^2) was found at Horseshoe kelp growing near the 20-m (11-fathom) isobath. Farther downcoast, past Alamitos Bay and Huntington Harbour, sand predominates in the nearshore area, at the groins at the entrance to Bolsa Chica Wetlands and the cliffs at Huntington Beach. Horseshoe kelp was located offshore of San Pedro Harbor at the 11-fathom curve at depths ranging from 18 to 25 m. Kelp was not noted at this location on the U.S. Coast and Geodetic Survey Map 5100 of 1890, nor did Crandall (1912) depict it in his 1911 map. However, estimated coverage in 1928 was about 1.94 km^2 (Schott 1976). Kelp in this area was reported to be lush and thick during the 1920s. It declined gradually through the 1930s, but remained a popular fishing spot (Simonin 1994, pers. comm.) until it vanished completely in the late 1940s. No canopy has been seen at Horseshoe kelp since the 1940s. This disappearance was probably a result of a combination of factors. Much of the dredged material from Los Angeles Harbor, including an island, was placed in this area and likely covered the hard substrate. A large increase in cargo and naval ship traffic, commercial fishing, dredge disposal operations, and an increase in industrial inputs into the San Pedro Bay are probably responsible for the loss also. It is possible that during periods of especially good water clarity and nutrient availability, kelp could recruit to the area.

Small kelp, up to two meters, were seen in the area in sporadic dive surveys through the 1970s and widely separated, individual giant kelp were noted on the surface in 1989, but no canopy formed (Wilson 1986, pers. comm.). Interviews with fishermen suggest that individual giant kelp were noted just beneath the surface in 18- to 25-m depths in the late 1980s (Simonin 1994, pers. comm.; Morris 1995, pers. comm.), but failed to form canopies, with all of the individual giant kelp eventually disappearing. The large kelp *Pelagophycus* is occasionally seen in the area reaching the surface (as relatively large beds of *Pelagophycus* sp have been observed offshore of Imperial Beach, it raised the possibility the bed may have been that species) and Southern palm kelp (*Pterogophora*) beds are prevalent over much of the hard bottom. When established, these kelp species may out-compete *Macrocystis* (Dayton and Tegner 1984), thus prohibiting establishment of giant kelp. Surface kelp has not been detected at the Horseshoe kelp fishing location since the 1940s (North 1968; Bedford, CDF&G 2004 pers. comm.; MBC 1994–2003, 2004a,b–2012a,b). Kelp was observed growing on cobble during a 2004 video survey of the seafloor at Horseshoe Kelp (Wong et al. 2012).

HUNTINGTON FLATS. A kelp bed was located off the northern end of Huntington Beach in the 1920s in an area known as Huntington Flats. The bed was on a low-lying reef in about 10 m of water, about 180 m northwest of Oil Island Emmy, and situated between Bolsa Chica State Beach and 23rd Street (North and Jones 1991). Kelp canopy was last noted in this area in the 1920s. No information is available on its size and it was not observed during aerial surveys by Fish and Wildlife in the 1950s. The construction of the Port of Long Beach, Alamitos Bay, and Anaheim Bay likely changed or interrupted sediment transport sufficiently to increase sedimentation, thereby reducing the likelihood of a kelp bed being sustained in this area.

In 1966, Dr. Wheeler North applied for a grant from the Fish and Wildlife Commission to transplant kelp to this area. A Fish and Wildlife Commissioner, an avid sport fisher, told North about the location of a kelp bed that used to grow offshore of Huntington Beach near the oil islands, but pre-dating their establishment (North 2000, pers. comm.). He took Dr. North on his boat and showed him the exact location. North dove the reef at a later date and found that it was a low-lying reef in 7 to 10 m of water, with approximately 0.3 m of relief above the surrounding sand. Visibility on the reef was low (less than one meter) due to the suspension of fine sediments.

In 1975, the Los Angeles Rod and Reel Club became interested in conducting a kelp transplant after reading of North's successful restoration of kelp at Palos Verdes Peninsula during the past several years. They contacted Dr. North for guidance on starting a kelp bed restoration project in the Huntington Flats area. They collected tires, filled them with concrete, chartered a sport fishing boat, and relocated 10 adult giant kelp tied to tires and placed them on the bottom. The plan failed when most of the tires washed up on the beach the following winter. Later observations in the 1970s and 1980s indicated that suitable low-lying habitat was available, but visibility continued to be poor and probably limited kelp growth (Curtis 2003, pers. comm.). The site is sufficiently removed in distance from any potential kelp spore source to be unlikely to recover even during good years when water clarity and nutrients might otherwise be favorable.

HUNTINGTON FLATS TO NEWPORT HARBOR. Farther downcoast, sandy bottom continues downcoast to Newport Harbor, and there is no suitable habitat for kelp along the coast from Huntington Flats downcoast to the Huntington Beach Generating Station and the Orange County Sanitation District outfalls, until reaching Newport Harbor. A small kelp bed formed offshore of Huntington Harbor in 1989 on the rocky riprap of the remains of Oil Island Esther (which was destroyed during storms in the 1980s). The kelp was present for approximately one year, but has not been seen since. A sandy bottom dominates the subtidal zone along this entire stretch of coastline. The movement of currents and the exposure of this portion of coast to breaking waves discourage the establishment of kelp beds, even on the abundant subtidal worm tubes. Kelp usually grows along the inside and outside of the northwest breakwater in Newport Harbor.

Fish and Wildlife Kelp Bed 10. From Newport Harbor downcoast to Abalone Point in north Laguna Beach, the CRKSC program monitors the Newport/Irvine Coast kelp beds that lie within the confines of Bed 10 (Figure 9). Small stands of kelp have occurred along the Newport Harbor breakwaters, particularly along the inside edge of the upcoast jetty. Continuing downcoast, rocky substrate is present out to the 12- to 18-m contour lines. Although this substrate supports a collection of small kelp beds, collectively they are referred to as the Newport/Irvine Coast kelp beds, and aggregately covered about 0.75 km^2 in 1911; since then they declined and were only about 30% of that size by the 1970s. They were virtually extirpated by the El Niño of 1982–1983, and very small beds briefly reemerged in the late 1980s due to kelp restoration efforts, but they were again extirpated during El Niños in the early 1990s. About a decade later, after the severe El Niño of 1997–1998, further restoration was initiated by MBC Applied Environmental Sciences in 2000, and by Orange County Coastkeeper in 2003, continuing until there were measurable kelp canopies by 2007 and the successful completion of the restoration by 2009 (MBC 2010c). These beds reached their maximum size in 2013, and canopy size was about 60% of historic coverage. These kelp beds are nearly contiguous from Newport Harbor to just upcoast of Abalone Point in Laguna Beach, where CRKSC coverage ends and RNKSC coverage begins.

DESCRIPTION OF THE REGION NINE KELP BEDS

The Region Nine kelp survey area, between Abalone Point in Laguna Beach (Orange County) and the Mexican Border, the CDF&W recognizes just 10 administrative kelp bed lease areas (Figure 9). In this same area, MBC has identified 24 kelp beds, 22 that are persistent and two other beds that appear ephemerally (Santa Margarita and Torrey Pines), as well as four other areas of interest (marinas and small boat harbors) (MBC 1994–2003, 2004b–2012b). The Consortium's monitoring began following a strong warm-water event: an El Niño in 1982–1983. This event was followed by a very large La Niña cold-water event in 1989–1990. Due to the impetus provided by this La Niña, all 24 of the kelp beds that have supported kelp in the last half of the 20th century were displaying canopy in 1991.

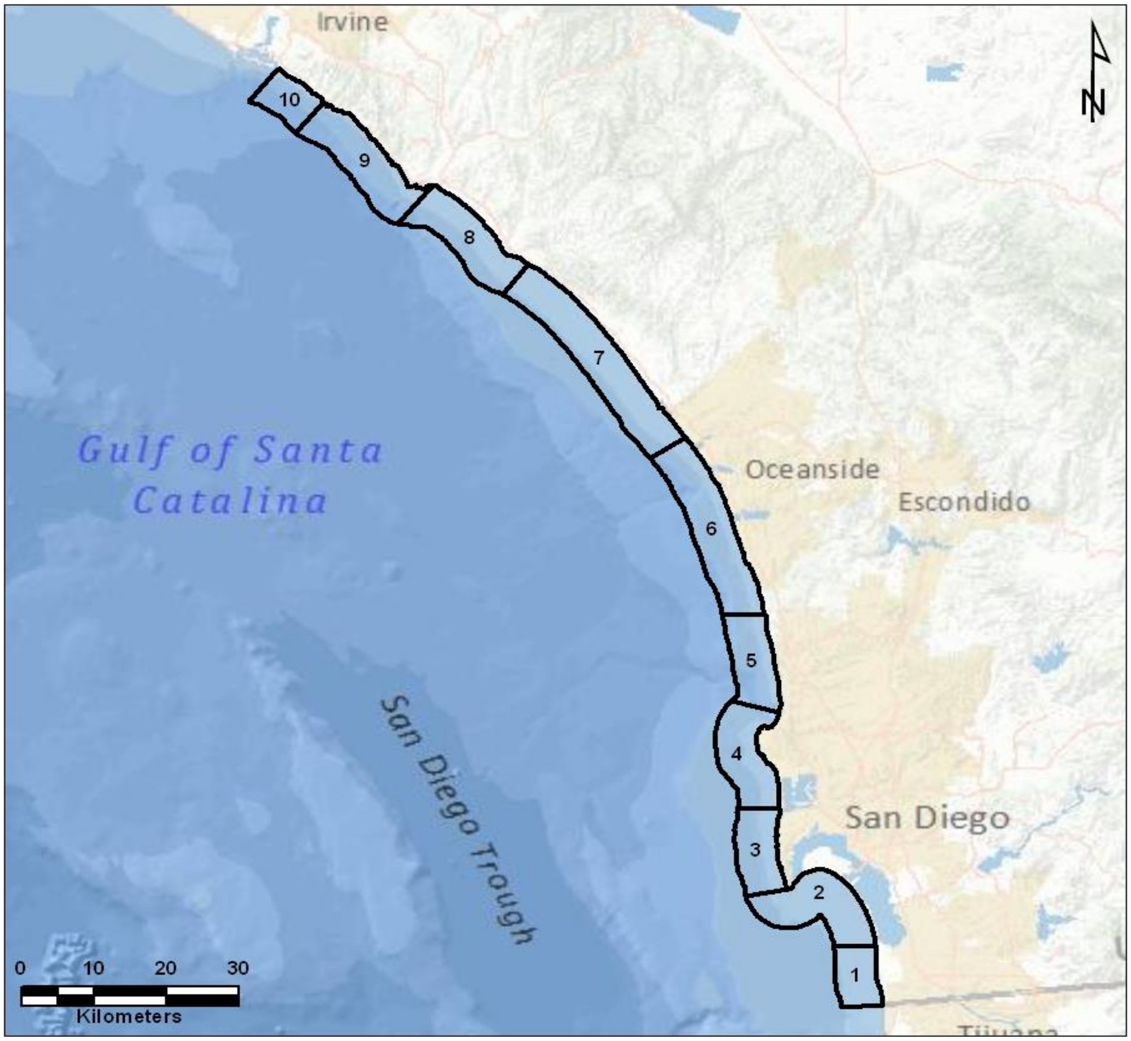


Figure 9. Administrative kelp bed lease areas in the Region Nine study area.

Fish and Wildlife Kelp Bed Number 9. Kelp Bed 9 encompasses five beds in the Region Nine program: North Laguna Beach, South Laguna Beach, South Laguna, Dana Point/Salt Creek, and Capistrano Beach. This lease area stretches from Abalone Point at the north end of Laguna Beach, through Laguna Beach, around the Dana Point headlands, and ends just upcoast of San Clemente. Available hard-bottom substrate is intermittent, and sandy substrate is predominant. There is a two-kilometer stretch of pronounced, hard-bottom habitat extending downcoast from about Main Beach (Laguna Beach). The hard substrate, where found, does not extend much beyond depths of 12 m until reaching Dana Point/Salt Creek. Crandall (1912) did not record giant kelp in the North and South Laguna Beach region, but he noted that kelp strands were unusually small, so it could have been a bad year for kelp in the area. By 1955, the bed at North Laguna Beach was fairly large and covered 0.68 km^2. The South Laguna, Dana Point/Salt Creek, and Capistrano kelp beds covered 2.7 km^2 in 1911. They were still large in 1955 (covering at least 2 km^2), but declined rapidly thereafter and stayed small through 1986. This area too was devoid of kelp from about 1993 until restoration efforts began in 2002. After several favorable years, combined canopy coverage increased to an 11-year high in 2002 of 0.555 km^2. After virtually disappearing in 2006 (with no canopy at Dana Point/Salt Creek), the beds recovered and have maintained a combined coverage of at least 1 km^2 during five of the last six years.

MBC began kelp restoration in several locations in both North and South Laguna Beach for a mitigation project, and Orange County Coastkeeper began kelp restoration in the North Laguna Beach area. Both programs met with varying degrees of success through 2007. In 2008, environmental conditions ultimately favored the restoration efforts, resulting in fair-sized canopies; the mitigation bed reached mitigation goals by 2009. The North Laguna Beach bed reached its maximum size (0.192 km^2) in 2012, and the South Laguna Beach Bed peaked in 2013 (0.273 km^2).

Rocky bottom extends to a depth of 18 m offshore of Dana Point/Salt Creek and supports large stands of kelp during favorable years. Another relatively large bed—Doheny kelp, at 0.75 km^2 in 1911—occurred just downcoast of Dana Point; this bed disappeared sometime after 1955, but well before the construction of Dana Point Harbor. A much smaller kelp bed has appeared in that location when environmental conditions are favorable. Downcoast of Dana Point, rocky bottom is restricted to depths of 15 m or less and intermittent rock, cobble, and sand substrates are found in the nearshore environment between Dana Point and San Clemente. In 2013, Fish and Wildlife Bed Number 9 increased in size by 28% to its largest size since 1989.

Fish and Wildlife Kelp Bed Number 8. Kelp Bed 8 consists of the San Clemente, San Mateo, and San Onofre kelp beds. They are located on cobble bottoms with intermittent sand patches to depths of 15 m. Crandall (1912) reported several large beds in this region. A small bed (0.206 km^2) was located just offshore of what is now the San Clemente Pier (Crandall 1912); this bed was much larger by the spring of 1956 (North and Jones 1991). Conversely, a large bed (1.235 km^2) was found off of San Mateo in 1911, but it was much smaller in 1956 (North and Jones 1991). At San Onofre, beds totaling 1.029 km^2 were present at the current location of the San Onofre kelp bed (Crandall 1912). This included a sizeable kelp bed (0.446 km^2) about three kilometers south of the main San Onofre kelp bed, and about one kilometer north of the location of Pendleton Artificial Reef. That bed was observed during the spring of 1956 but was reduced to about one-half its former size (North and Jones 1991). The bed was not observed during a 1963 survey, nor during any subsequent survey since (North and Jones 1991, North and MBC 2001). Most of the substrate transitions from cobble to predominantly sand about two kilometers downcoast of San Onofre with little or no hard substrate available for several kilometers until reaching Horno Canyon and Barn kelp, suggesting that reefs that apparently existed here in 1911 were inundated by sand. In 2013, Fish and Wildlife Bed Number 8 increased in size by 63% to its largest size–slightly more than 2 km^2–in more than 50 years. The size of Bed Number 8 has increased in recent years due to the addition of reef material by SCE for mitigation projects.

Fish and Wildlife Kelp Bed Number 7. Kelp Bed 7 extends from San Onofre to Oceanside, and includes Horno Canyon and Barn kelp. The Horno Canyon kelp bed is an ephemeral bed present during cold-water years and absent during warm-water years. It was a distinct patch of kelp totaling about 0.172 km^2 during Crandall's 1911 survey. It was not present in the 1956, 1963, or 1973 surveys (North and Jones 1991), but was present as a small, scattered bed in 1977 and 1978. It has been present during five of the last six years, and in 2013 reached its largest size since 1911 (0.125 km^2).

Barn kelp is a layered, shelf-reef community extending out to depths of 15 m. In 1911, it was a very large kelp bed, and covered 2.44 km^2. It has had a checkered existence, waxing (reaching a canopy size of almost 1 km^2), and waning (completely disappearing at times) over the past four decades. Downcoast from Barn kelp, large expanses of sand characterize the bottom with small areas of hard substrate that occasionally support kelp off the Santa Margarita River. Crandall mapped a very large kelp bed (0.858 km^2) just north of the Santa Margarita River in 1911, but this bed was only observed twice between 1955 and 2012. In 2013, this bed reappeared with a canopy measuring 0.080 km^2. Only small areas of hard substrate are found downcoast of Oceanside until offshore of Buena Vista Lagoon on the border of Oceanside and Carlsbad. No kelp beds are recorded in this range, probably because of the predominantly sand bottom and a dynamic environment. In 2013, kelp coverage in Bed Number 7 exceeded 1 km^2 for the first time since 1955.

Fish and Wildlife Kelp Bed Number 6. This bed encompasses the beds offshore of North Carlsbad, Agua Hedionda, Encina Power Plant, and Carlsbad State Beach. Rocky substrate that supports large kelp beds is found out to depths of 18 m, with intermittent sand patches between the beds. Crandall recorded two large beds in this region. One was at the present location of the North Carlsbad/Agua Hedionda kelp beds, and it totaled about 0.480 km^2. This bed manifests itself as two distinct patches during favorable years, corresponding to the locations of North Carlsbad and Agua Hedionda. The other bed mapped by Crandall was in the location of the Encina Power Plant bed; it was very large, and totaled about 0.858 km^2 in 1911. Kelp coverage in Bed Number 6 in 2013 was 0.757 km^2, which was twice the coverage measured in 2012.

Fish and Wildlife Kelp Bed Number 5. Bed 5 is located downcoast of North Carlsbad, and includes the kelp beds at Leucadia, Encinitas, Cardiff, Solana Beach, and Del Mar. Crandall (1912) reported a very large bed that ran continuously along the coast for almost 10 km in the area offshore of North Carlsbad, Leucadia, and part of Encinitas. Curiously, the two large beds found at Cardiff and Solana Beach were not observed by Crandall in 1911, but a large bed (0.8 km^2) was observed near Del Mar. Another large gap of predominantly sand bottom extends from Del Mar to Torrey Pines, where reefs periodically support kelp. Sandy substrate predominates downcoast beyond Scripps Pier to the La Jolla Kelp Bed. In 2013, the total canopy area in Bed Number 5 was 2.1 km^2, which was 45% higher than last year's total, but similar to the coverage measured in 2008.

Fish and Wildlife Kelp Bed Number 4. Bed 4 is the La Jolla Kelp Bed. Rocky substrate becomes prevalent offshore of La Jolla and is more or less continuous to offshore of Pacific Beach and supports, at times, very large kelp beds to a depth of at least 27 m. From Pacific Beach downcoast to just past the entrance to Mission Bay, sand predominates in the inshore environment and there is very little hard substrate. In 2013, the total canopy area in Bed Number 4 was 4 km^2, which was similar to the coverage measured in 2008, and more than twice the area measured last year.

Fish and Wildlife Kelp Bed Number 3. South of Mission Bay, rocky substrate again begins to dominate and hard substrate and giant kelp is found out to 30 m (and deeper during favorable conditions). This bed is the northern portion of a very extensive bed (Point Loma Kelp Bed) that runs the length of the peninsula. A proposal to lease this bed was approved by the Fish and Game Commission in April 2012. Point Loma kelp bed decreased slightly (by 4%) in 2013; however, it still exceeded 5 km^2, which has only occurred during 4 of the last 19 survey years.

Fish and Wildlife Kelp Bed Number 2. This bed is a southern portion of Point Loma Kelp. Kelp was found historically well south of the entrance to San Diego Bay and that area (including the area along the Coronado Strand and south to Imperial Beach) is identified as Fish and Wildlife Bed 2. Sand predominates just south of the San Diego Bay entrance to just north of the Imperial Beach Pier, so kelp is typically not observed in the southern portion of Bed Number 2.

Fish and Wildlife Kelp Bed Number 1. This is a group of kelp beds found on a low-lying, mostly cobble reef area beginning slightly north of the Imperial Beach Pier and extending downcoast to the Mexican Border. The kelp is situated in depths ranging from about 6 to 18 m. This area supported a bed that was almost 1.0 km^2 in 1911, and it covered 0.727 km^2 in 1987, but was never again as large as Crandall reported during the remainder of the century. In 2007, however, the beds in this region surpassed the area Crandall reported and canopy coverage was almost 1.5 km^2. In 2008, coverage at Imperial Beach was 1.895 km^2. Although very little kelp is noted beyond Imperial Beach to the Mexican Border due to a predominantly sandy bottom, this area supported a large kelp bed in the early part of the 20th century that started on the United States side of the border and extended beyond the Mexican Border. That kelp bed has not been recorded since 1911, apparently disappearing sometime between then and 1967. No kelp is currently found offshore of the International Boundary and Water Commission's outfall. Imperial Beach kelp bed increased in size by 58% in 2013.

MATERIALS AND METHODS

Environmental Data. Oceanographic data from shore and buoy stations were used to determine potential effects on kelp bed extent during the study year. These data sources included:

- Water temperature data from automated stations at Santa Monica Pier, Newport Pier, and Scripps Pier. At these locations, automated samplers measure conductivity, temperature, and fluorometry every one to four minutes. These data are made available in real time via the Southern California Coastal Ocean Observation System (SCCOOS) website (www. SCCOOS.org).
- Water temperature data were also provided by Los Angeles County Sanitation Districts from monitoring stations offshore Palos Verdes Peninsula (Stations PVS and PVN).
- Water temperature data from the National Data Buoy Center (NDBC) Point Loma South, Dana Point, and Point Dume data buoys that record water temperature, wave height, period, and direction every 30 minutes, and are available in real time via the NDBC website (www.ndbc.noaa.gov).

- Sea and swell height data from CDIP data buoys located off Ventura, San Pedro, Dana Point, and Oceanside. Wave direction, height, and period are available in real time via the CDIP website (cdip.ucsd.edu).

Kelp Data Collection-Aerial Surveys. Beginning in the early-1960s, the surface area of coastal kelp beds was monitored by aerial photography by the late Dr. Wheeler J. North of the California Institute of Technology, and later by MBC using a methodology that provided a consistent approach to determining kelp bed size (North 2001). MBC has conducted the Region Nine surveys since its inception in 1983, and began conducting surveys for the Central Region Kelp Consortium in 2003.

Direct downward-looking photographs of the kelp beds were taken from an aircraft modified by Ecoscan Resource Data to facilitate aerial photography. Approximately 425 photos are taken during each survey. Ecoscan conducted quarterly overflights of the coastline for the Consortium from Ventura Harbor (Ventura County) to the U.S./Baja California, Mexico border. Overflights were targeted as close to quarterly as possible. Due to prevailing weather conditions, it is not always possible to conduct them in the targeted months and, at times, multiple attempts are necessary to conduct the four quarterly surveys. Prior to each survey, the flight crew assesses the weather, marine conditions, and sun angle to schedule surveys on optimum dates. The pilot targets the following:

- Weather: greater than a 15,000' ceiling throughout the entire survey range and wind less than 10 knots,

- Marine: sea/swell less than 1.5 m and tide less than +1.0' MLLW, and sun angle greater than 30 degrees nadir.

Kelp Data Analysis. All photographs were reviewed after each overflight and the canopy surface area of each kelp bed was ranked in size by subjectively comparing them to the average historical bed size and to each quarterly survey. The ranking ranged from 1 for well below average, 2 for below average, 2.5 for average, 3 for above average, and 4 for well above average. Such ranking allows the archiving of the quarterly survey slides for later retrieval and assembly of a digitized photo-mosaic of each kelp bed that represents the greatest areal extent for each survey year. Individual beds in the composite were selected for detailed evaluation and the surface area of all visible kelp canopy in each distinct kelp bed was calculated.

All digital photographs from one of the four surveys that showed the greatest areal coverage were digitally assembled into a composite photo-mosaic that provided a regional view of whole kelp bed areas. The Photoshop mosaics were then transferred to GIS (ArcGIS 10.1) to geo-reference them, and to place them into specific Fish and Wildlife geo-spatial shape files. Each mosaic was geo-referenced to match at least three prominent features on the map and converted to Universal Transverse Mercator (UTM) or other acceptable coordinate system, and ultimately converted to a geo-referenced JPEG file. Surface canopy areas were calculated using the image classification function, an extension to the GIS program (SpatialEcology.com). The kelp beds from the photos were then layered on standard base maps to facilitate inter-annual comparisons.

Vessel Surveys. Once per survey year, typically between October and December, a vessel survey is conducted of all of the Region Nine kelp beds. The vessel surveys for the 2013 survey year were conducted on 13 December 2013 and 15 January 2014. Each survey entails locating the main canopies visually (or during poor years by latitude and longitude coordinates of the last remaining canopy) and determining the depth of the inshore and offshore edge of the kelp beds. Once located, there is a focused examination of the kelp health that includes:

- Extent and density of the bed
- Tissue color
- Frond length on the surface
- Presence/absence of apical meristem (scimitar = growing tips)
- Extent of encrustations of hydroids or bryozoans
- Sedimentation on blades
- Any evidence of disease - holes or black rot
- Composition of fronds - young, mature, or senile

During the vessel survey, two or three beds are usually selected for focused biologist-diver surveys. Typically, these surveys will investigate apparent causes of a bed's atypical condition (where it disappears or is greatly reduced) during a period when closely aligned regional beds are increasing. For example, we investigated a persistent hole in the San Mateo kelp bed and urchins have been found to be the cause; urchins have also been implicated in the disappearance of the Barn kelp and Imperial Kelp beds.

RESULTS

WATER TEMPERATURES AND NUTRIENTS

Temperatures at the sea surface (SST) are a useful surrogate for nutrient availability. Additionally; there appears to be convincing evidence that seawater density can also be used as a surrogate, and in some cases predict nutrient availability better than temperature; however, long-term measurements of density on smaller scales than the SCB are not readily available. In contrast, nearshore temperature measurements have been ongoing for decades, resulting in a readily available data set that can be used to evaluate nutrient availability. Two temperature/nutrient indices—one for each region—are presented in Tables 6 and 7. Based on the monthly Nutrient Quotient Index (NQ) described by North and MBC (2001), the average, early-morning SST for each month at each station was correlated with the amount of nitrate that is theoretically available for uptake by kelp (in micrograms-per-gram per-hour) (Haines and Wheeler 1978, Gerard 1982).

The value for each month was summed for the indexed year (July 1 to June 30). For example, a month with an average temperature of 14.5°C has a nutrient quotient (NQ) value of 4 while a temperature of 12°C has a value of 14. Values above 25 indicate average or above-average nutrients available to sustain growth. This method allows for an inter-annual comparison between nutrients available to kelp, making it possible to pinpoint those years when nutrients were abundant or depleted, and to establish possible temporal trends. Sea surface temperatures from Point Dume, Santa Monica Pier, two Palos Verdes stations, Newport Pier, San Clemente Pier, SIO Pier, and the Point Loma South CDIP buoy were used to determine the theoretical availability of nutrients in the region. (Graphs of SSTs at all locations are presented in Appendix C.)

The variability of SSTs in 2013 tracked closely between Point Dume in the north, Newport in between, and SIO in the south (Figure 10). In general, temperatures were slightly cooler than normal from January through March, increased to above normal through June, cooled through late summer, and increased to above average in fall and winter. There were multiple periods of cold-water influx (likely from upwelling) from late March through September.

Upwelling was most pronounced at the SIO and Newport Piers during this period, and less so at San Clemente and Point Dume.

The summer of 2013 was abnormally cool, with SSTs throughout southern California below average in July and August. The SSTs at Point Dume, which is the northernmost temperature station in the Central Region, are typically much cooler than at other stations in the Central Region. In summer 2013, however, there were periods when SSTs at SIO Pier and Newport Pier were much cooler than at Point Dume (Figures 10 and 11). The NQ values at Point Dume are typically the highest in the Central Region (Table 6). In 2013–2014, it was less than one-half of the 2012–2013 NQ value, and only one quarter of the 2010–2011 NQ value.

Table 6. Seasonal kelp nutritional index for Central Region based on weighting values given to monthly SST data derived from Point Dume (PD), Santa Monica Pier (SMP), Palos Verdes (PVN & PVS), and Newport Pier (NP). Weighting values are derived from nitrate versus temperature data from North and Jones (1991), and nitrate uptake rates from Haines and Wheeler (1978), and Gerard (1982). The season begins 1 July and ends 31 June. Years in Red denote warm-water years, Blue cold-water years, both colors are transition years, based on NOAA Multivariate ENSO Index (MEI), May 2014.

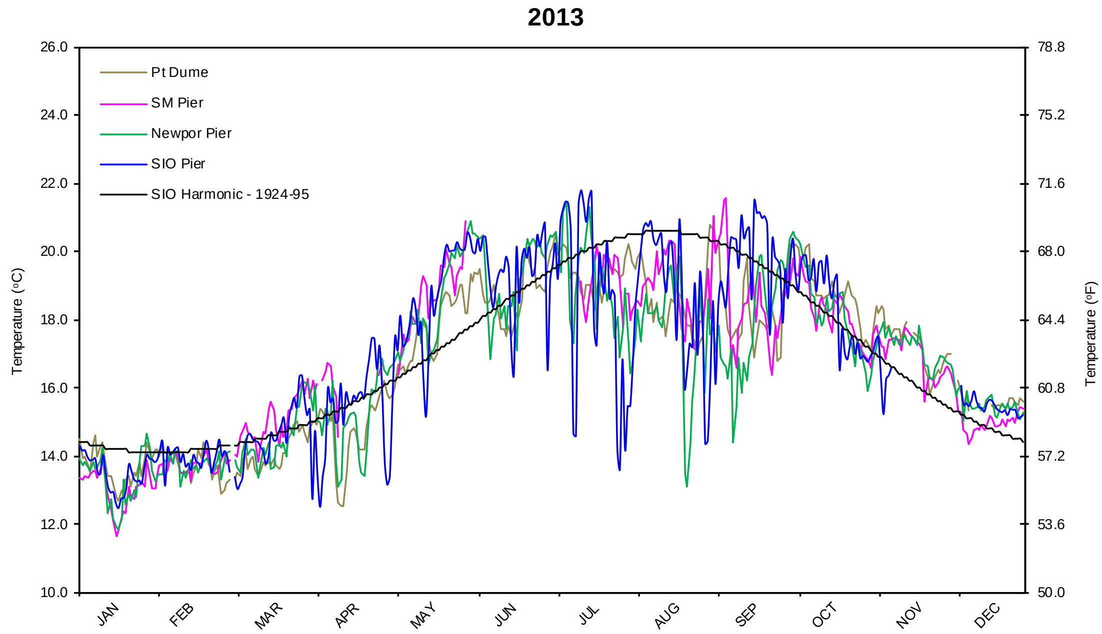
Number of months falling into indicated temperature range (Weighting Factor)	Temp. Range	Site	Season 2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014
14	12.01-13.00°C	PD	-	-	-		-	-	-	1	1	1	-	-
		SMP	-	-	-	1	-	-	1	-	-	-	1	-
		PVN	-	-	-	-	-	-	-	-	-	-	-	-
		PVS	-	-	-	-	-	-	-	-	1	1	-	-
		NP	-	-	-	-	-	-	-	-	-	-	-	-
8	13.01-14.00°C	PD	-	-	-	-	-	-	-	3	2	1	3	-
		SMP	-	-	-	-	-	2	1	-	3	2	2*	-
		PVN	-	-	-	-	-	-	-	-	2	-	2	-
		PVS	-	-	-	-	-	-	-	-	4	-	3	-
		NP	1	-	-	-	-	2	-	-	2	-	2	-
4	14.01-15.00°C	PD	-	-	-	-	-	-	-	3	4	2	1	1*
		SMP	3	1	2	3	3	3	3	5	3	4	1	1*
		PVN	-	-	-	-	-	-	-	-	2	2	1	-
		PVS	-	-	-	-	-	-	-	-	3	3	1	-
		NP	2	2	1	3	4	3	4	3	3	4	2	1*
2	15.01-16.00°C	PD	-	-	-	-	-	-	-	4	3	1	-	4*
		SMP	4	1	2	-	2	1	2	1	1	-	2*	3*
		PVN	-	-	-	-	-	-	-	-	2	1	2	3*
		PVS	-	-	-	-	-	-	-	-	2	1	1	2*
		NP	3	2	3	1	1	-	2	3	3	1	1	3*
1	16.01-17.00°C	PD	-	-	-	-	-	-	-	-	-	2	2	1*
		SMP	1	2	2	3	-	1	1	1	2	2	1*	3*
		PVN	-	-	-	-	-	-	-	-	3	1	1	-
		PVS	-	-	-	-	-	-	-	-	1	-	1	-
		NP	2	2	1	-	-	1	3	1	1	2	1	2*
Season	NQ	PD	-	-	-	-	-	-	-	58	52	34	30	13*
		SMP	21	24	22	37	16	33	25	23	40	34	31*	13*
		PVN	-	-	-	-	-	-	-	-	31	11	25	6*
		PVS	-	-	-	-	-	-	-	-	63	14	31	4*
		NP	24	14	11	22	18	29	23	19	35	34	27	12*

PD = Point Dume, SMP = Santa Monica Pier, PVN = Palos Verdes North,
PVS = Palos Verdes South, NP = Newport Pier; * = data set less than 12 months

Table 7. The kelp nutritional index for Region Nine of each month based on weighting values given to monthly SST data and derived from Scripps Pier (SIO) , Newport Pier (NP), San Clemente (SCP), Point Loma South (PLS), and historic Kerckhoff Marine Laboratory (KML) SSTs. The weighting values are derived from nitrate versus temperature data from North and Jones (1991), and nitrate uptake rates from Haines and Wheeler (1978), and Gerard (1982).

	Number of months falling into indicated temperature range					SIO	NP	PLS	KML	SCP
Weighting Factor	*14*	*8*	*4*	*2*	*1*					
Season	2.01-13.0°C	13.01-14.0°C	14.01-15.0°C	15.01-16.0°C	16.01-17.0°C	NQ	NQ	NQ	NQ	NQ
	NP (SIO)	NP (SIO)	NP (SIO)	NP (SIO)	NP (SIO)					
2013-2014	-(-)	-(-)	1(-)	3(5)	2(1)	10*	12*	7*	ND	9*
2012-2013	-(-)	2(2)	2(1)	1(2)	1(1)	25	27	12	ND	24
2011-2012	1(-)	-(1)	4(4)	1(2)	2(-)	28	34	21	ND	23
2010-2011	-(-)	2(-)	3(4)	3(-)	1(1)	17	35	20	ND	19
2009-2010	-(-)	-(-)	3(-)	3(4)	1(1)	9	19	11	ND	11
2008-2009	-(-)	-(-)	4(2)	2(2)	3(1)	11	23	15	ND	ND
2007-2008	-(-)	2(1)	3(2)	-(1)	1(3)	21	29	ND	ND	ND
2006-2007	-(-)	-(-)	5(2)	1(2)	1(-)	12	18	ND	23	ND
2005-2006	-(-)	1(-)	3(1)	1(4)	2(-)	12	22	ND	24	ND
2004-2005	-(-)	-(-)	2(-)	2(3)	1(2)	8	11	ND	13	ND
2003-2004	-(-)	-(-)	2(2)	2(2)	2(-)	12	14	ND	14	ND
2002-2003	-(-)	1(-)	2(-)	3(4)	1(3)	11	24	ND	23	ND
2001-2002	-(-)	-(1)	4(3)	1(1)	1(2)	24	27	ND	19	ND
2000-2001	-(-)	1(1)	1(4)	3(-)	1(1)	25	70	ND	19	ND
1999-2000	-(-)	-(-)	2(3)	3(2)	2(4)	20	51	ND	16	ND
1998-1999	-(-)	1(3)	4(2)	-(1)	3(2)	36	64	ND	27	ND
1997-1998	-(-)	-(-)	-(-)	-(-)	3(2)	4	11	ND	3	ND
1996-1997	-(-)	1(-)	-(2)	-(2)	1(1)	13	34	ND	9	ND
1995-1996	-(-)	-(-)	2(3)	1(1)	1(-)	15	32	ND	11	ND
1994-1995	-(-)	-(-)	2(2)	1(4)	3(-)	16	38	ND	13	ND
1993-1994	-(-)	-(-)	1(1)	2(3)	2(2)	12	10	ND	10	ND
1992-1993	-(-)	-(-)	-(-)	3(3)	1(2)	8	9	ND	7	ND
1991-1992	-(-)	-(-)	2(2)	1(1)	3(2)	12	16	ND	13	ND
1990-1991	-(-)	-(-)	2(2)	3(2)	1(-)	16	23	ND	13	ND
1989-1990	-(-)	1(1)	2(1)	1(3)	1(-)	15	21	ND	19	ND
1988-1989	1(-)	2(2)	1(2)	1(1)	-(1)	27	39	ND	36	ND
1987-1988	-(-)	1(-)	2(2)	1(1)	1(1)	11	21	ND	19	ND
1986-1987	-(-)	(-)	2(-)	1(3)	1(2)	8	11	ND	11	ND
1985-1986	-(-)	-(-)	2(-)	2(2)	2(3)	7	20	ND	14	ND
1984-1985	-(-)	3(-)	1(2)	1(3)	1(-)	14	35	ND	31	ND
1983-1984	-	-	1	3	2	ND	10	ND	12	ND
1982-1983	-	-	-	4	2	ND	12	ND	10	ND
1981-1982	-	1	3	1	1	ND	40	ND	23	ND
1980-1981	-	-	3	2	2	ND	23	ND	18	ND
1979-1980	-	-	2	3	1	ND	24	ND	15	ND
1978-1979	-	2	2	1	1	ND	40	ND	27	ND
1977-1978	-	-	-	2	3	ND	7	ND	7	ND
1976-1977	-	1	-	2	1	ND	17	ND	14	ND
1975-1976	-	2	4	-	-	ND	50	ND	32	ND
1974-1975	-	5	1	1	1	ND	41	ND	45	ND
1973-1974	-	3	1	1	1	ND	52	ND	31	ND
1972-1973	-	-	2	4	2	ND	19	ND	18	ND
1971-1972	2	1	3	-	-	ND	49	ND	48	ND
1970-1971	2	1	2	1	1	ND	52	ND	47	ND
1969-1970	-	2	-	3	2	ND	23	ND	24	ND
1968-1969	-	1	4	-	2	ND	29	ND	26	ND
1967-1968	-	-	3	2	2	ND	24	ND	18	ND
ND = no data					Average Since 1967	15.5	28.3	15.8	20.1	19.3
- = 0					Since 1977	15.5	26.0	15.8	16.5	19.3
					1967-1976	ND	35.6	ND	30.3	ND

* based on average monthly temperature July 1, 2013 though May 29-30, 2014



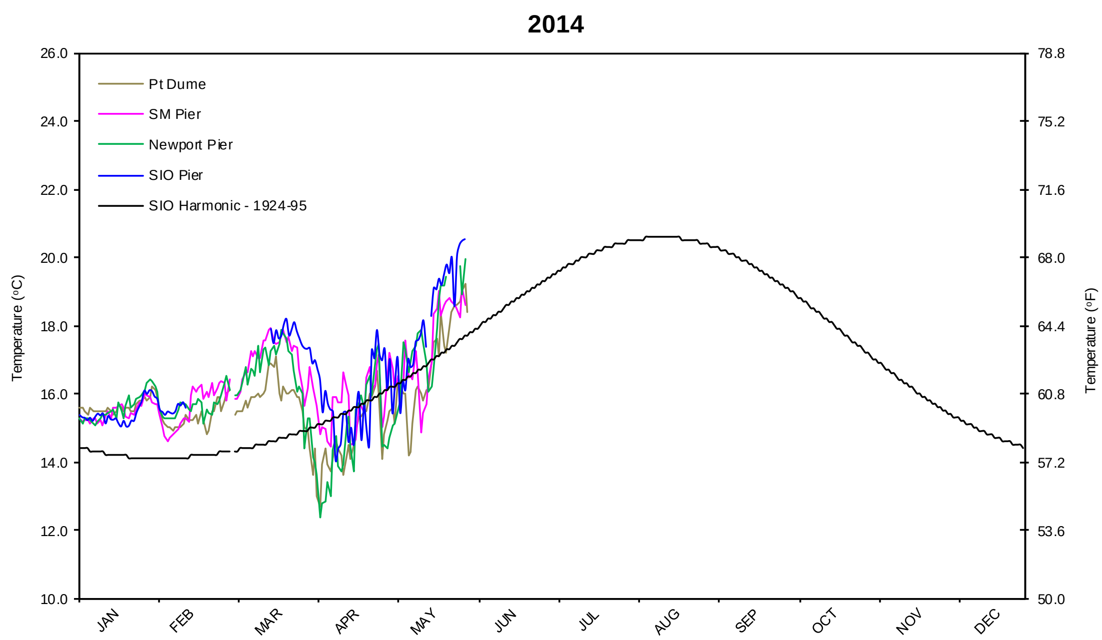
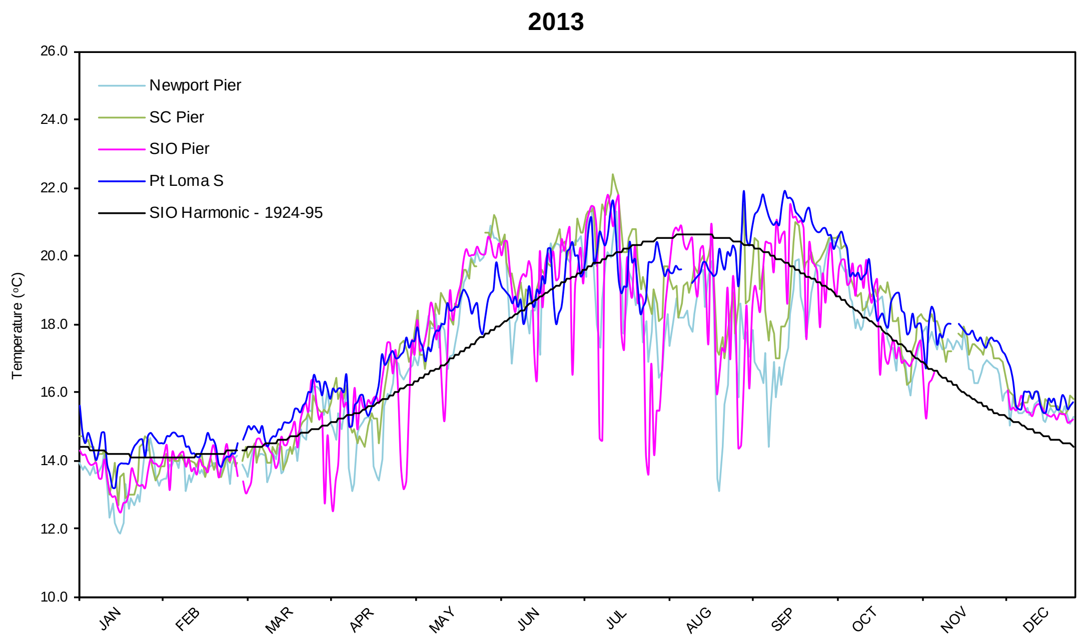


Figure 10. Sea surface temperatures (SST) at Point Dume, Santa Monica (SM) Pier, Newport Pier, and Scripps (SIO) Pier for 2013 and through May 2014.



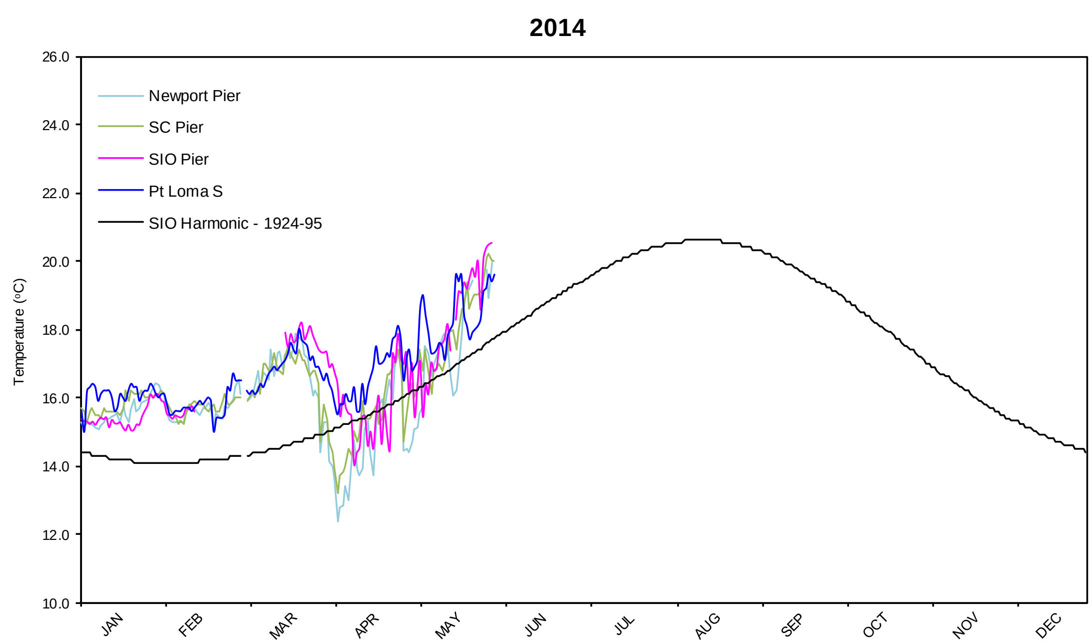


Figure 11. Sea surface temperatures (SST) at Newport Pier, San Clemente (SC) Pier, Scripps (SIO) Pier, and Point Loma South for 2013 and through May 2014.

Temperatures at Santa Monica Pier in 2013 followed the same pattern, with lower-than-normal SSTs in winter, warmer-than-average SSTs in spring, and cooler SSTs through summer (Figure 10). The NQ at Santa Monica Pier in 2013–14 (13) was substantially lower than in 2012–2013, and much lower than the average NQ (27.5) for the last 12 years (Table 6). Two stations farther south were located off the Palos Verdes peninsula: Station PVN was in the northern section near Lunada Bay, and Station PVS was in the southern end at Royal Palms (Appendix C). Temperatures tracked closely at these two stations, although the NQs of 6 and 4, respectively, were the lowest on record. (The extremely low values at PVN and PVS could have been due to gaps in data records.)

At the juncture of the Central Region and Region Nine, SSTs at Newport Pier were generally at or above average from January through June, below average from July through mid-September, and at or above average for the remainder of 2013 (Figures 10 and 11). The 2013–2014 NQ of 12 was the lowest recorded since 2004–2005 (Table 7). There were steep drops in temperature at Newport Pier throughout the year. Newport Pier is located near the mouth of Newport Canyon, and strong upwelling usually occurs in distinct pulses at this station. The Newport Coast (based on the SSTs) was characterized by conditions supportive of upwelling during summer, although temperatures through the remainder of the year were generally higher than normal. The SSTs at San Clemente Pier, in the mid-section of Region Nine, were similar to those at Newport Pier, except the periods of cold-water influx in spring and summer were less pronounced (Figure 11). The SSTs at Scripps Pier were the most variable of those in Region Nine in 2013, with marked upwelling events throughout spring and summer. The extreme southern portion of Region Nine was tracked by the Point Loma South buoy. Similar to 2012, Point Loma SSTs were muted in comparison to those at the SIO and Newport Piers, indicative of reduced nutrients available to the kelp.

The long-term average NQ values at SIO Pier (15.5), Point Loma South (15.8), and San Clemente Pier (19.3) are relatively low, and suggest the kelp beds from San Clemente to San Diego have had below-average nutrient availability (Table 7). The NQ values in Region Nine were above average at all stations (except Point Loma) in 2012–2013, and below average at all stations in 2013–2014. The long-term average NQ at Newport Pier (28.2) is substantially higher than at the other stations, and highlights the variability of nutrient supply in southern California. On average, kelp beds are stressed and must rely on above-average years to propagate effectively. The NQ index recorded during the 1997–1998 El Niño is a good example, because it indicated a particularly bad year for kelp beds in the SCB. During that season, NQ values ranged from 3 to 11. In contrast, during 1988–1989 (a year in which kelp beds reached their maximum extents in several decades) NQ values ranged from 27 to 39 (Table 7). The NQ values at all stations in both regions were above average in 2012–2013, but below average in 2013–2014, indicating nutrients were lacking. Values in 2013–2014 ranged narrowly from 4 at Palos Verdes South to 13 at Point Dume and Santa Monica Pier. The variability in SSTs and nutrients is driven by prevailing flow characteristics and bathymetric features that result in periodic upwelling along the rocky shores of the coastline, particularly from Deer Creek to Point Dume and along the Palos Verdes Peninsula, Dana Point, and La Jolla-Point Loma kelp beds.

WAVE HEIGHTS

Typical swell sizes and directions were observed through most of 2013, and at the northern portion of the range near Port Hueneme waves approached from the west to southwest about 80% of the time (Figure 12). Off San Pedro, waves originated out of the west about 60% of the time, the southwest 20% of the time, and the south about 20% (Figure 13). Offshore of Point Loma, at the southern end of the SCB, waves were also mostly from the south and west, but there was also a small fraction from the west-northwest (Figure 14). High-energy waves that negatively impact the kelp beds usually are low-frequency, high-amplitude waves approaching from the west. Significant wave heights (H_s) at Anacapa Passage (CDIP Buoy 111) and San Pedro (CDIP Buoy 092) exceeded 3.0 m February and 3.5 m in April 2013 (Figures 15 and 17). In Santa Monica Bay, significant wave heights exceeded three meters in March and April (Figure 16). About 30 km downcoast at Dana Point CDIP Station 096, and at Oceanside CDIP Buoy 045, waves were more subdued, with wave heights exceeding three meters only a few times from January through April (Figures 18 and 19). The Point Loma South CDIP Buoy 191 recorded high-amplitude waves exceeding 3 m in March, 3.5 m in January and February, and 4 m in April 2013 (Figure 20). These swells become breaking waves as they approach shallow coastal waters and potentially can rip loose kelp holdfasts causing a loss of whole kelp beds.

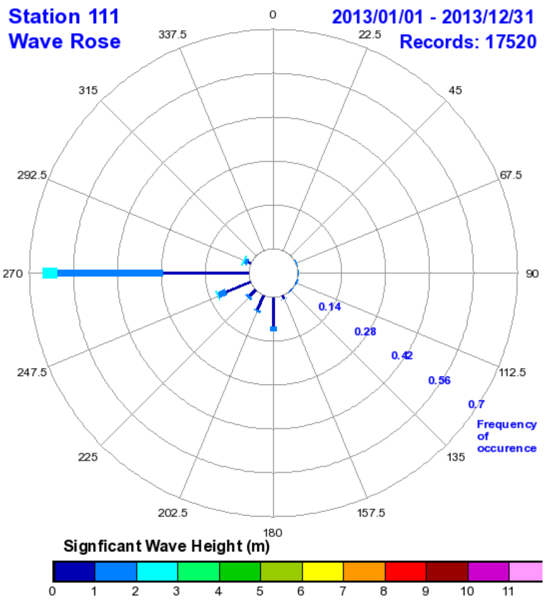


Figure 12. Wave Rose significant wave direction: Anacapa Passage, CA from January 2013 through December 2013.

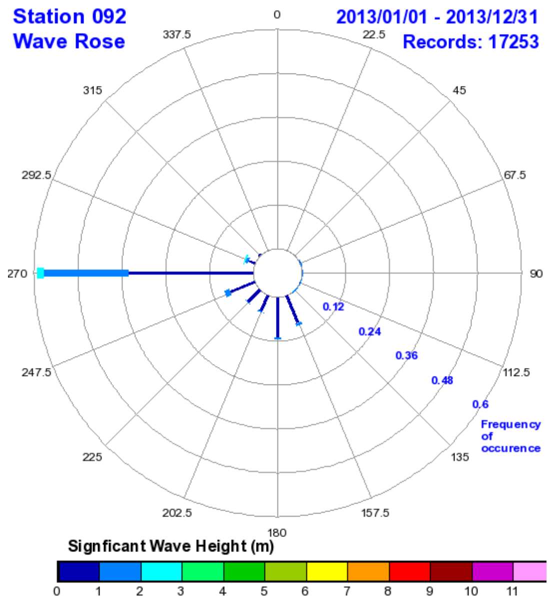


Figure 13. Wave Rose significant wave direction: San Pedro, CA from January 2013 through December 2013.

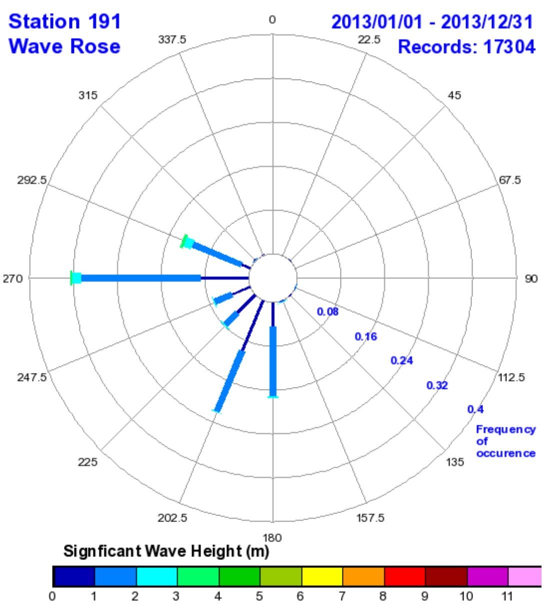


Figure 14. Wave Rose significant wave direction: Point Loma, CA from January 2013 through December 2013.

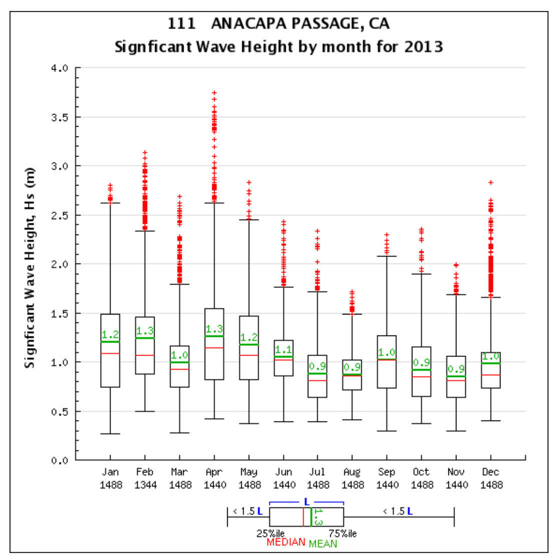


Figure 15. Significant wave heights for Anacapa Passage, 2013.

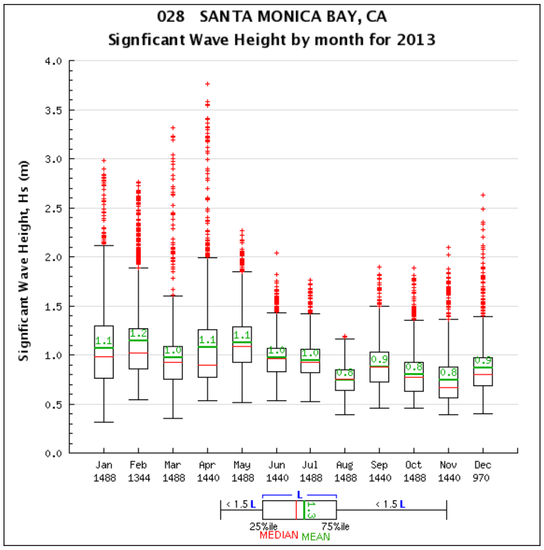


Figure 16. Significant wave heights for Santa Monica Bay, 2013.

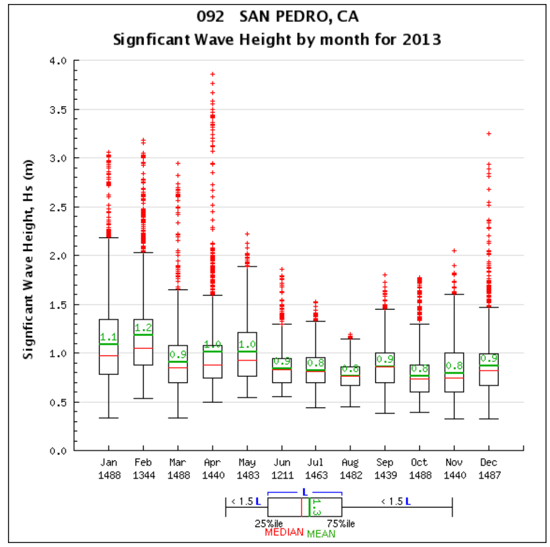


Figure 17. Significant wave heights offshore San Pedro, CA, 2013.

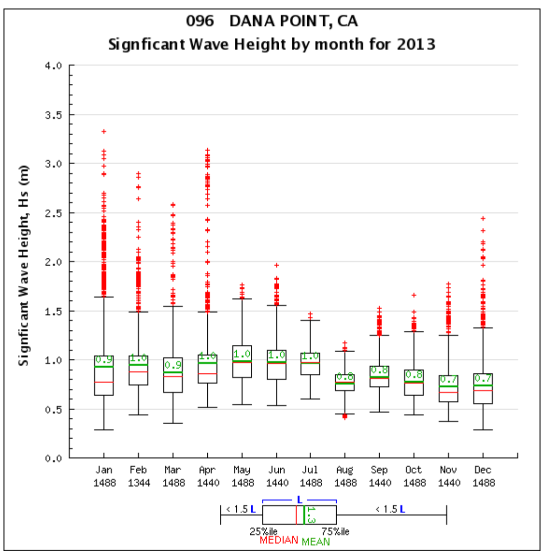


Figure 18. Significant wave heights offshore Dana Point, CA, 2013.

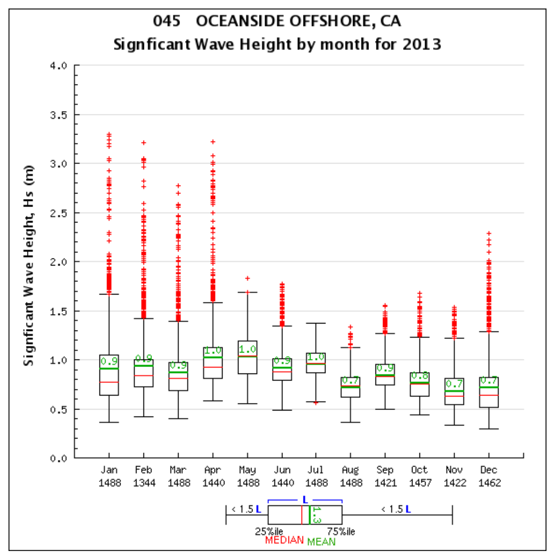


Figure 19. Significant wave heights offshore Oceanside, CA, 2013.

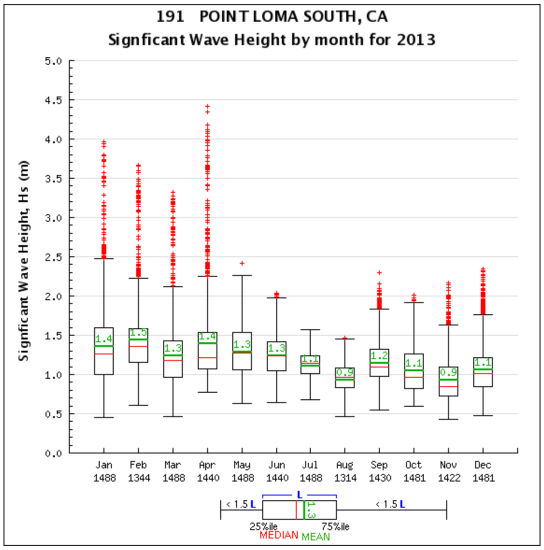


Figure 20. Significant wave heights offshore Point Loma, CA, 2013.

RAINFALL AND WATER CLARITY

Periods of sustained high turbidity in near-shore waters often result from high rainfall; however, rainfall was well below average for the second straight year. At Los Angeles International Airport (LAX), annual rainfall (2.14 inches) was the lowest annual total in the last 70 years. Precipitation was slightly higher in Orange County (John Wayne Airport; 2.75 inches) and San Diego County (Lindberg Field; 3.05 inches) (Figure 21, NOAA 2014). Therefore, turbidity from storm runoff did not likely play an important role in kelp health in 2013. All of the rain in Los Angeles and San Diego was recorded in January, February, and March. In Orange County, some rain was recorded during the last three months of 2013.

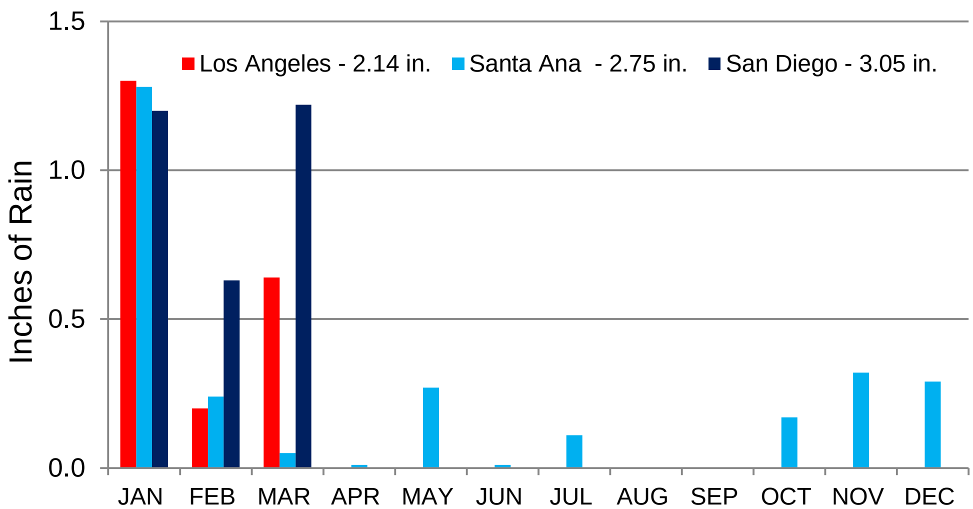


Figure 21. Monthly rainfall recorded for Los Angeles, Orange, and San Diego Counties,

Periods of increased phytoplankton concentrations (exceeding 10^4 cells/liter) were recorded in Santa Monica Bay and off SIO Pier in 2013 (Figures 22 and 23). Red tide (plankton bloom) formed in September 2013 at La Jolla, Torrey Pines, and Del Mar (SDUT 2013). This coincided with increased concentrations (1,000 to 10,000 cells per liter) of the dinoflagellate *Lingulodinium polyedrum* at SIO Pier (Figure 23, SCCOOS 2014). Similar concentrations of *L. polyedrum* were recorded at Santa Monica Pier in June, July, and October 2013. This species (*L. polyedrum*) has been associated with previous red tides in southern California, and blooms of that magnitude have occurred about once every five years during the past 25 years. Concentrations at over 350,000 cells per liter (Shipe 2006, pers. comm.) can effectively exclude light from all but the shallowest depths. This limits photosynthetic activity at depth and was probably responsible for a portion of the severe impacts on the kelp bed resources observed in 2005 and 2006 (Gallegos and Jordan 2002, Gallegos and Bergstrom 2005).

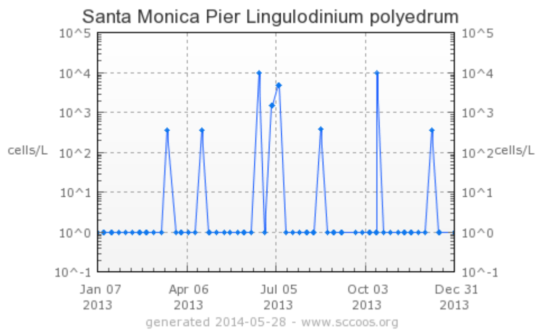


Figure 22. Phytoplankton concentrations at Santa Monica Pier, 2013. Data from SCCOOS.

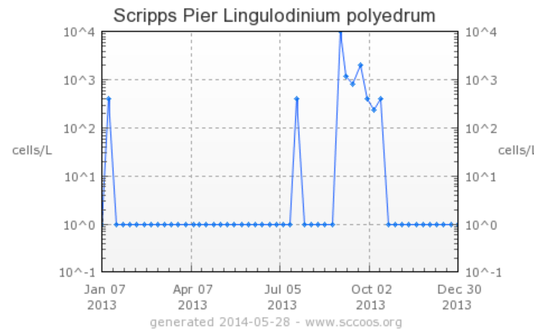


Figure 23. Phytoplankton concentrations at Scripps Pier, 2013. Data from SCCOOS.

Although the concentrations of these phytoplankton could have greatly reduced light availability on the bottom in 2013 and thereby decreased photosynthetic opportunities, their duration was probably not sufficient to have adversely affected the health of the Central Region or Region Nine kelp beds.

2013 QUARTERLY OVERFLIGHT SUMMARY

Aerial surveys were flown on 13 May, 15 July, 23 September, and 16 December 2013. One survey was completed for the 2014 survey year on 7 April (Appendix D). Reasonable attempts were made to conduct one aerial overflight within each of the four quarters in the year (Table 8). The overflight with maximum canopy coverage varied by region and kelp bed. Most of the beds in the Central Region displayed maximum canopies during the September 23 and December 16 overflights (Table 9). However, several beds in northern Santa Monica Bay (from Point Dume to Topanga) were at their greatest extent in spring (May 13). Almost all of the beds in Region Nine displayed the most canopy during the December overflight (Table 10). Exceptions to this included Point Loma, which peaked during the September overflight.

Table 8. Status of planned aerial overflights 2013.

Target Date	Mid-March	Status	Results
Planned Flight	19-Mar-13	Cancel	Wind, Seas,CloudsCover
	6-Apr-13	Cancel	Overcast Entire Range
	13-May-13	**Flown**	**Tide, Wind, Clear Skies**
Target Date	**Mid-June**	**Status**	**Results**
	15-Jul-13	**Flown**	**Tide, Wind, Clear Skies**
Target Date	**Mid-September**	**Status**	**Results**
	23-Sep-13	**Flown**	**Tide, Wind, Clear Skies**
Target Date	**Mid-December**	**Status**	**Results**
	16-Dec-13	**Flown**	**Generally Good Visibility Entire Range**

2013 VESSEL SURVEY SUMMARY

Boat surveys were conducted during most of the year from Newport Beach to Barn kelp, on 13 December 2013 from the Mexican border to Dana Point, and on 15 January 2014 along the Orange County coast, to document the apparent health and extent of the kelp canopies. On 13 December 2013, there was no cohesive bed at Horno Canyon, although there were scattered kelp plants on the sea surface. At San Onofre, kelp was patchy, but dense in some areas, with about 80% of the fronds classified as young. Biologists noted a healthy canopy at Torrey Pines, and many young kelp plants between the two areas of surface canopy. Kelp at Torrey Pines was limited to waters shallower than about 11 m. The beds at Solana Beach, Del Mar, and Cardiff appeared healthy. Kelp off Batiquitos Lagoon (Leucadia beds) was growing at a depth of 21 m.

The outside edge of the southern end of La Jolla kelp bed was in 24 m of water, encrusting organisms were noted on 10% of the fronds, and about 50% of the apical blades were tattered. Frond length at La Jolla kelp ranged from five to eight meters. At the northern end of La Jolla kelp, the outside edge of the bed was in 26 m of water. At Imperial Beach, there were a lot of subsurface kelp plants observed by divers, and 90% of the fronds were classified as young. The outside edge of the Point Loma kelp bed was in 24 m of water, although there were some encrusting organisms observed on the blades, and many of the apical blades were tattered.

On 13 December 2013, divers investigated an area offshore of the Santa Margarita River where subsurface kelp was observed during the boat survey. This was an area where a surface canopy has been absent since the early 1990s. Visibility during the dive survey was two to three meters, and the seafloor was characterized as cobble and low-relief reefs. Forty to 45 kelp plants were noted growing along the edges of the reefs, with none of the plants reaching the surface. No sea urchins were observed at this location. Fish reported included Black Perch (*Embiotoca jacksoni*), Kelp Bass (*Paralabrax clathratus*), and Giant Sea Bass (*Stereolepis gigas*).

Along the Orange County coast, a large and dense kelp bed was observed in the Dana Point/Salt Creek area. The kelp bed was as deep as 18 m on the outside edge, with a nearshore depth of about 9 m on the south side of the bed and 6 m at the northern end. About 90% of the kelp plants were young, but most of the apical blades were tattered or missing. Farther upcoast, several dense kelp beds were observed offshore of Laguna Beach. At South Laguna, the bed was composed of about 75% young plants with fronds up to five meters in length and some apical blades. Off Main Beach, a kelp bed composed of 90% young plants with about half of the apical blades viable was noted, with a nearshore edge in 14 m of water. At North Laguna Beach, the bed was composed of about 50% mature and 50% young individuals, and fronds were up to seven meters in length. Only about 10% of the apical blades were classified as “good”. At Scotchman’s Cove, along Newport Coast, a kelp bed of mature and young plants similar in size and composition to that found at North Laguna was noted, although more (20% to 40%) of the apical blades were considered “good”. Divers reported Santa Ana wind conditions and visibility to nine meters during the survey. At South Laguna, 18 green abalone (*Haliotis fulgens*) and two pink abalone (*H. corrugate*) were also observed.

2013 KELP CANOPY SUMMARY

Central Region. The following changes were documented in the 26 CRKSC kelp beds in 2013:

- 10 kelp beds increased in size
- 14 kelp beds decreased in size
- 2 kelp beds were not present (and have been absent for decades)

Overall, the maximum measured kelp canopy decreased by 1% from 2012 (from 5.665 km^2 to 5.614 km^2) (Table 4).

Region Nine. The following changes were documented in the 24 RNKSC kelp beds in 2013:

- 20 kelp beds increased in size
- 3 kelp beds decreased in size
- 1 kelp bed appeared for the first time since 1992 (Santa Margarita)

Overall, the maximum measured kelp canopy increased by 44% from 2012 (from 11.882 km^2 to 17.064 km^2) (Table 5). The largest increases were recorded at La Jolla (+2.4 km^2) and San Onofre (+0.6 km^2).

Graphical depictions of each bed are presented in Appendix A, and a mosaic of the kelp canopies along the coastline is presented in Appendix E.

Table 9. Rankings assigned to the 2013 aerial photograph surveys of the Ventura, Los Angeles, and Orange County kelp beds. The basis for a ranking was the status of a canopy during surveys from recent years, excluding periods of El Niño or La Niña conditions or following exceptional storms. A ranking of 2.5 represents the average status.

	2013 Surveys			
Kelp Beds	May 13	July 15	September 23	December 16
Ventura Harbor *	3.5	3.5	3.0	2.0
Channel Islands *	2.0	3.0	3.0	2.5
Port Hueneme *	3.0	3.0	3.0	3.0
Deer Creek	3.5	3.0	3.0	3.5
Leo Carillo	3.5	3.0	3.0	4.0
Nicolas Canyon	3.5	3.0	3.0	4.0
El Pescador/La Piedra	3.5	3.0	3.0	3.5
Lechuza Kelp	3.5	3.0	2.5	3.5
Point Dume	3.5	2.0	3.0	3.0
Paradise Cove	3.5	2.0	2.5	3.0
Escondido Wash	4.0	2.0	3.0	3.0
Latigo canyon	3.5	2.0	3.0	4.0
Puerco/Amarillo	4.0	2.0	3.0	3.5
Malibu Pt.	3.5	2.0	2.5	4.0
La Costa	2.0	-	-	2.0
Las Flores	3.5	2.0	1.0	2.5
Big Rock	4.0	2.5	1.0	3.0
Las Tunas	3.5	2.5	2.0	3.0
Topanga	3.0	2.5	1.5	3.0
Sunset	1.0	0.5	-	1.5
Marina Del Rey *	0.5	1.5	-	2.0
Hyperion Pipeline *	-	-	-	-
Redondo Breakwater *	2.5	2.0	2.0	3.0
Malaga Cove - PV Point (IV)	3.5	2.5	3.5	2.5
PV Point - Point Vicente (III)	3.0	2.0	3.5	2.5
Point Vicente - Inspiration Point (II)	3.0	2.0	3.5	3.0
Inspiration Point - Point Fermin (I)	3.0	2.0	3.5	3.0
Cabrillo	3.0	2.0	3.0	2.5
LB/LA Harbor and Breakwaters	2.5	2.0	3.0	3.5
Horseshoe Kelp	-	-	-	-
Huntington Flats	-	-	-	-
Newport Harbor *	2.5	2.0	3.0	3.5
Corona Del Mar	3.0	1.5	2.5	3.5
North Laguna Beach	3.0	1.5	3.0	3.5

Notes:
Ranking values: 0.5 = trace or very small amount of kelp present; 1 = well below average; 2 = below average; 2.5 = average; 3 = above average; and 4 = well above average. Red indicates maximum canopy size for the year; " - " = no canopy present; * = not part of the monitored beds; NI = no image due to clouds or fog.

Table 10. Rankings assigned to the 2013 aerial photograph surveys of the southern Orange County and San Diego County kelp beds. The basis for a ranking was status of a canopy during surveys from recent years, excluding periods of El Niño or La Niña conditions or following exceptional storms. A ranking of 2.5 represents the average status.

	2013 Surveys			
Kelp Bed	May 13	July 16	September 23	December 16
Newport Harbor *	2.5	2.0	3.0	3.5
Corona del Mar	3.0	1.5	2.5	3.5
No. Laguna Beach	3.0	1.5	3.0	3.5
So. Laguna Beach	3.0	2.0	3.5	4.0
South Laguna	3.0	2.5	3.5	4.0
Salt Creek-Dana Point	3.0	2.5	3.5	4.0
Dana Marina *	2.0	2.5	3.5	4.0
Capistrano Beach	1.0	1.0	1.5	2.0
San Clemente	3.0	2.5	3.5	3.5
San Mateo Point	1.5	1.5	2.5	3.0
San Onofre	1.5	1.0	2.0	3.0
Pendleton Reefs *	-	-	-	-
Horno Canyon	1.0	0.5	0.5	1.5
Barn Kelp	3.0	2.0	3.0	3.5
Santa Margarita	-	-	-	0.5
Oceanside Harbor *	2.0	1.0	1.0	2.0
North Carlsbad	3.0	3.0	3.5	4.0
Agua Hedionda	3.5	3.0	3.5	4.0
Encina Power Plant	3.5	3.0	3.5	4.0
Carlsbad State Beach	4.0	3.0	3.5	4.0
North Leucadia	3.0	2.0	3.0	4.0
Central Leucadia	3.0	3.5	3.0	4.0
South Leucadia	3.0	2.5	3.0	3.5
Encinitas	3.5	3.0	3.0	4.0
Cardiff	3.5	2.5	3.0	3.5
Solana Beach	2.5	2.5	3.0	4.0
Del Mar	0.5	1.5	2.5	3.0
Torrey Pines Park	3.0	1.0	2.0	3.5
La Jolla Upper	2.0	3.0	3.0	3.5
La Jolla Lower	2.0	3.5	3.5	3.5
Point Loma Upper	3.0	3.5	4.0	3.0
Point Loma Lower	2.0	3.5	4.0	3.0
Imperial Beach	2.0	1.0	3.0	3.5

Notes:
Ranking values: 0.5 = trace or very small amount of kelp present; 1 = well below average; 2 = below average; 2.5 = average; 3 = above average; and 4 = well above average. Red indicates maximum canopy size for the year; " - " = no canopy present; * = not part of the monitored beds; NI = no image due to clouds or fog.

STATUS OF THE 50 KELP BEDS IN CENTRAL REGION AND REGION NINE IN 2013

The following is a synopsis of the status of each individual bed during the 2013 survey year based upon the quarterly surveys. The kelp beds of the Central Region have been above the long-term average (4.086 km^2) since 1967 for six of the past seven years (Figure 24).

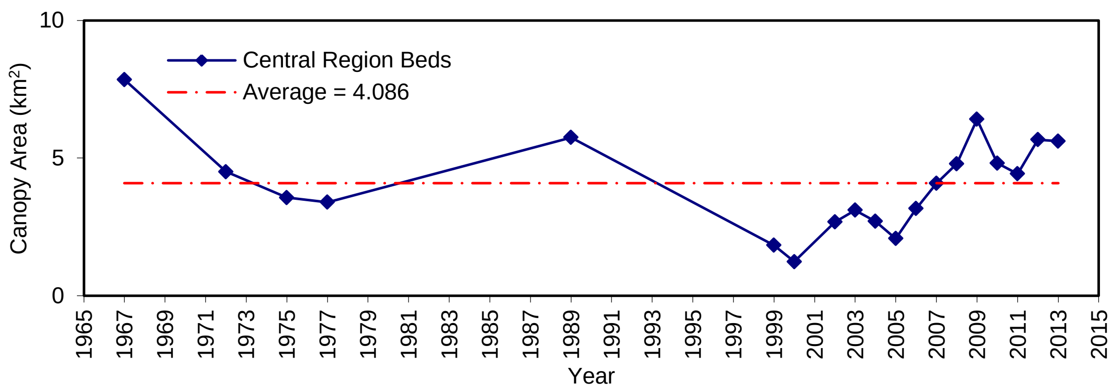


Figure 24. Combined canopy coverages at all kelp beds in Central Region from Ventura to Laguna Beach.

CENTRAL REGION KELP SURVEYS

Ventura Harbor, Channel Islands Harbor to Point Mugu. A small amount of giant kelp was noted growing along the breakwaters of Ventura Harbor (0.007 km^2), Channel Islands Harbor (0.010 km^2), and at Port Hueneme (0.010 km^2) in 2013. No kelp was noted offshore of the Mandalay and Ormond Beach Generating Stations, and no kelp was noted downcoast of Port Hueneme until Deer Creek. These results are consistent with those from 2012.

POINT MUGU TO POINT DUME

Deer Creek. The Deer Creek kelp bed was not noted by Crandall (1912), suggesting it was missing or relatively small during that period. All subsequent surveys of Fish and Wildlife Kelp Bed 17 encompassed the Deer Creek kelp bed, thus making it difficult to establish a long-term trend in canopy size for this specific bed. The bed was fairly large in 1989 (Ecoscan 1990), exceeding the 0.089 km^2 noted in the first CRKSC survey in 2003 (Table 4). The greatest areal coverage occurred in 2004 when it was measured at 0.107 km^2; it subsequently decreased and remained no larger than about one-half that size until 2009 when it again peaked (0.105 km^2). After consecutive declines from 2010 through 2012, the Deer Creek kelp bed peaked again in 2013 at 0.104 km^2. The Deer Creek canopy was compared to the average bed area per year (ABAPY) of the northern and central portions of the Central Region to determine whether it was responding synoptically with the beds from the same area. (Kelp beds in the Palos Verdes region were treated separately as they are typically larger beds and react differently from the other beds of the Central Region.) Even though the ABAPY was virtually unchanged in 2013 (0.132 km^2) compared to 2012 (0.128 km^2), the size of the Deer Creek kelp bed more than doubled (Figure 25).

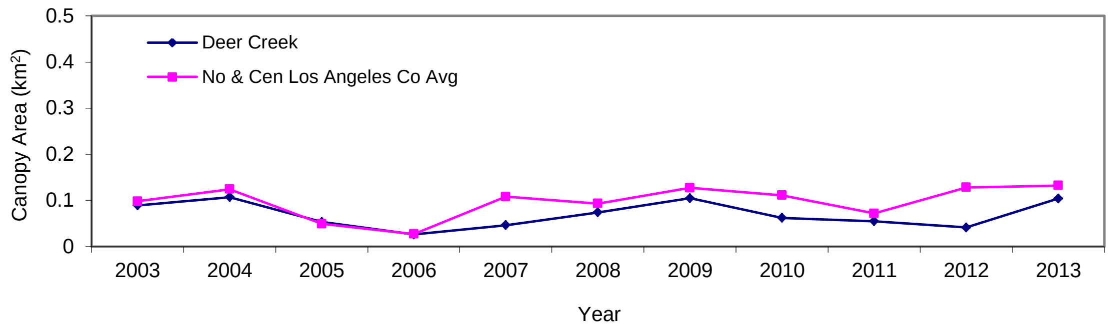


Figure 25. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Deer Creek for the years shown.

Leo Carillo. Leo Carillo kelp was included in the measurements of Crandall (1912). It was a very large bed in 1911 (covering 2.5 km^2). By 1967, it probably was still very large because the total area for all five beds was similar to what Crandall measured in 1911. Total canopy coverage for the Fish and Wildlife region decreased thereafter, from over 4 km^2 in 1967 to 2.6 km^2 in 1972, and down to 1.6 km^2 by 1977. By 1989, the beds were much smaller as noted in overflight photographs taken by Ecoscan (1990). Because the 1989 survey occurred during a period of exceptional nutrient availability (a very strong La Niña), it appears likely that the very strong storms of 1983–1984, and/or the 1988 "Great Storm" may have contributed to the much smaller size that appeared during that survey. Because they have not significantly recovered during the past 25 years, it also appears likely that either substrate was buried, or, like many of the Santa Barbara kelp beds, the beds may have been growing on a sandy bottom. These kelp beds all lie in the shadow of the Channel Islands, and the 1988 storm came from a direction that devastated the kelp beds from Point Conception to Santa Barbara, most of which were growing on sandy bottoms. Kelp beds upcoast of Point Dume may have suffered a similar fate. In 1989, this bed was slightly larger than in the 2003 CRKSC survey when accurate areal measurements of this bed were first made, and it was similar in size to that seen in 2004 when it peaked at 0.399 km^2. Subsequently, the bed decreased to about one-half its peak during the next seven years, but in 2013 reached its largest size since 2004 at 0.366 km^2. With the exception of 2007 and 2008, Leo Carillo kelp has reacted synoptically with the kelp beds in the region (Figure 26).

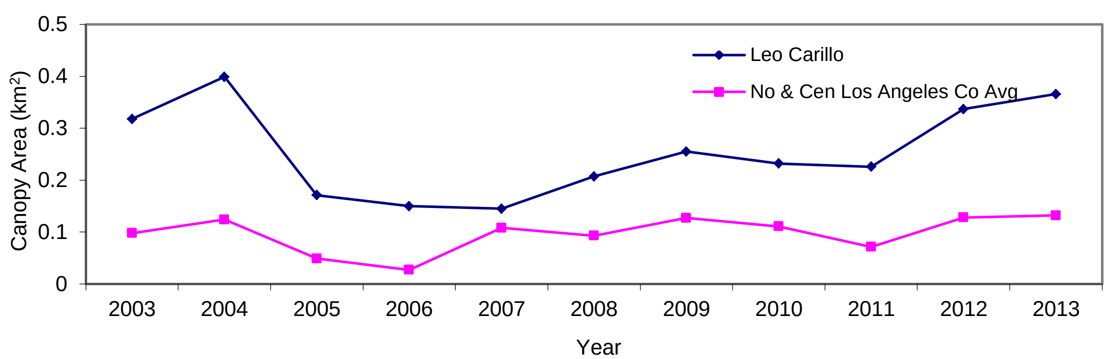


Figure 26. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Leo Carillo for the years shown.

Nicolas Canyon. Crandall (1912) measured a relatively large bed at Nicolas Canyon in 1911 (1.26 km^2). A 1967 survey that pooled the area of the five beds of Fish and Wildlife Kelp Bed 17, probably was still very large as the total area for the five beds was markedly similar to what Crandall measured in 1911. Through the 1970s, the bed probably shrank in size greatly as noted by the decreasing total kelp canopy coverage of Bed 17 (Table 2). Aerial photographs of the bed in 1989 (Ecoscan 1990) indicated this bed was much smaller than recorded previously, and was of a similar size to that noted in 2003 (0.308 km^2) and 2004 (0.362 km^2) (Table 4).

The Nicolas Canyon kelp bed appears to have a natural break in the center of the bed, and the westernmost half of the bed has continued to decrease in size while the easternmost portion appears to have increased in size. In any case, the bed's response to the availability of nutrients resulted in more than a 10-fold increase in size with a peak in 2007, at 0.473 km^2; it was larger than in any of the CRKSC surveys. After peaking again in 2009, canopy size shrank in 2010 and 2011, but increased each of the last two years. The bed reacted slightly more favorably than the ABAPY would indicate; Nicolas Canyon kelp bed is larger than the average bed in the region and appears to respond quicker to stimuli, such as when nutrients became more abundant in 2007 and 2009 (Figure 27).

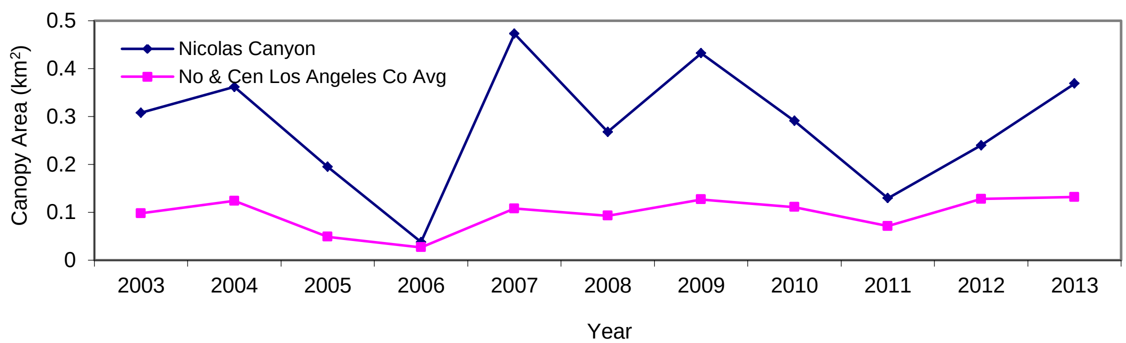


Figure 27. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Nicolas Canyon for the years shown.

El Pescador/La Piedra. Maps by Crandall (1912) indicated that the El Pescador/La Piedra kelp bed was 0.252 km^2 in 1911. By 1989, this bed was slightly larger in size than that observed by Crandall, and based on the total for the five beds in Bed 17, it was probably similar in size to that noted in 2003 (0.243 km^2) (Ecoscan 1990, MBC 2004a). By 2004, the canopy increased to 0.314 km^2 (its maximum size in the CRKSC surveys), but despite sharp peaks in growth in 2007 and 2009, it was reduced to 0.136 km^2 by 2011. It increased in 2012 and 2013, and by December 2013, it was similar in size to the bed measured in 2003. The El Pescador/La Piedra kelp bed is larger than the ABAPY, but its response has typically mirrored that of the regional beds (Figure 28).

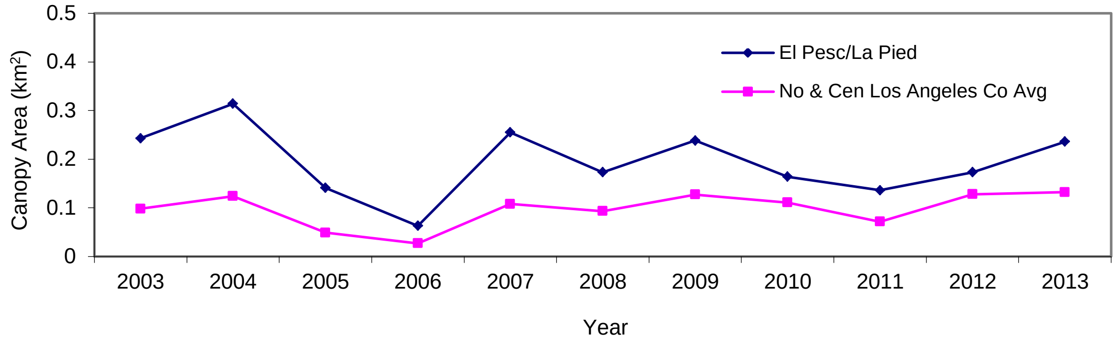


Figure 28. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off El Pescador/La Piedra for the years shown.

Lechuza. Crandall (1912) identified this bed and measured its surface canopy at 0.126 km^2. In 1983, a survey in the vicinity of Lechuza kelp bed by Patton and Harman (1983) found reef structure rising two to three meters above the surrounding sandy bottom, but no kelp was found (in the midst of a very strong El Niño). Visual inspection of Ecoscan (1990) images from 1989 suggest Lechuza kelp bed was present, but noticeably smaller than what was calculated in 2003 (0.105 km^2) or 2004 (0.104 km^2) (MBC 2004a, 2005a). All of the individual kelp beds in Bed 17 declined in 2006, and during that year, the canopy at Lechuza kelp was the smallest on record (0.022 km^2). In the last six years, however, the canopy size has fluctuated between 0.066 and 0.106 km^2. In 2013, Lechuza kelp bed reached its largest extent (0.154 km^2), exceeding that recorded in 1911. The Lechuza kelp bed size and its responses have been nearly identical to those of the average bed in the region until 2012 when it unexpectedly decreased while most beds in the region increased (Figure 29). Even though the ABAPY was similar in 2013 and 2012, the size of the Lechuza kelp bed more than doubled.

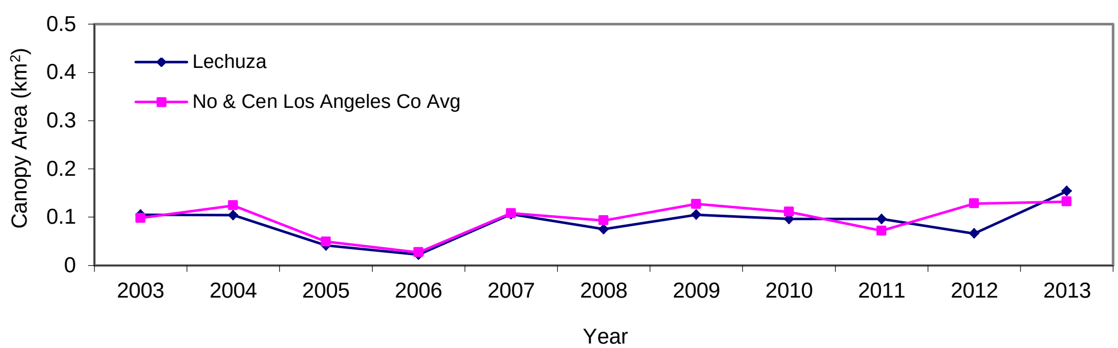


Figure 29. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Lechuza for the years shown.

POINT DUME TO MALIBU POINT

Point Dume. Point Dume demarks the western boundary of Fish and Wildlife Kelp Bed 16. In 1911, Point Dume kelp bed was a sizable kelp bed with an area totaling 0.686 km^2 (Crandall 1912). Since then, the kelp bed at Point Dume has decreased considerably in size. It appears from photographs taken during calm-water periods that much of the area's hard substrate may be inundated by sand. Very little reef structure is visible in any of the photos, suggesting that large movements of sediments occurred (or a large storm event swept through and eliminated kelp growing on sand) sometime between the regime shift of 1977 and 1989. In 1989, this kelp bed was much smaller than it was in 1911, although it was larger than the 0.012 km^2 noted in the first CRKSC survey of 2003 and the 0.029 km^2 noted in early 2004 (Table 4). Unlike some of the other more northern kelp beds of the Central Region, the Point Dume kelp bed grew larger in the December 2006 survey, and was measured to be 0.053 km^2. By June 2009, the Point Dume canopy totaled 0.104 km^2, the largest bed at this location since CRKSC monitoring began. In 2012, the bed increased to a 10-year maximum size (0.154 km^2), although it decreased by 27% in 2013. The Point Dume kelp bed was typically in synch with the ABAPY, and has been since 2006 (Figure 30).

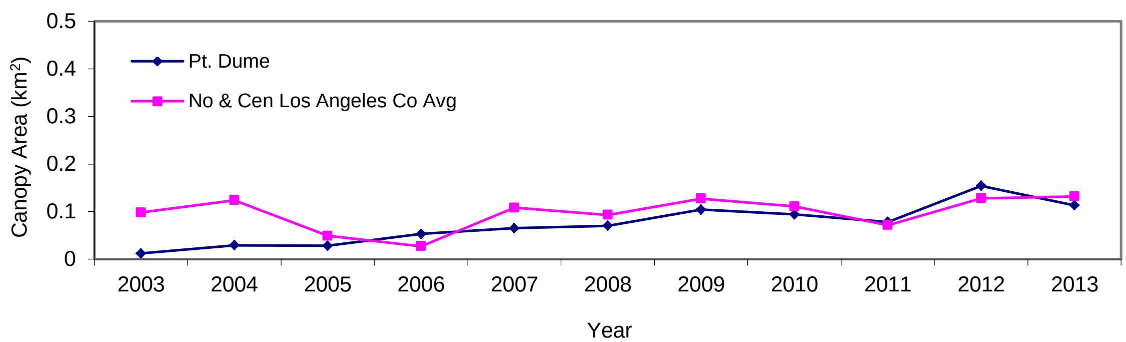


Figure 30. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Point Dume for the years shown.

Paradise Cove. Paradise Cove kelp bed was a very large bed in 1911, covering 1.37 km^2 (Crandall 1912). The spur and groove topography in this area provides ample attachment for kelp. Nonetheless, this bed declined considerably in size by 1967, a decrease that continued until the late 1970s (Table 2). While no areal measurements were made by MBC from the 1989 overflight surveys of Ecoscan (1990), the overflight images suggest that coverage in 1989 was less than during the first CRKSC survey in 2003. Coverage during 2003 was only 0.162 km^2, but it increased to 0.258 km^2 in 2004. Warm water and phytoplankton blooms combined in 2005 so that the greatest areal extent occurred in the 22 June survey; it was calculated at 0.035 km^2 (an 80% reduction in one year), and by 2006 it was only slightly larger (0.036 km^2). Bed size at Paradise Cove increased during each year from 2007 to 2010. However, the following year (2011), Paradise Cove reacted in concert with most of the other beds in the region and decreased in size by about 50% from the previous year. In 2012, the bed responded to good nutrient conditions during most of the year and had the largest canopy extent (0.346 km^2) in the 10 years of CRKSC monitoring. Canopy coverage decreased by 29% in 2013. The Paradise Cove kelp bed has been larger than average during most of the last decade, and has usually responded in relative concert with the ABAPY (Figure 31).

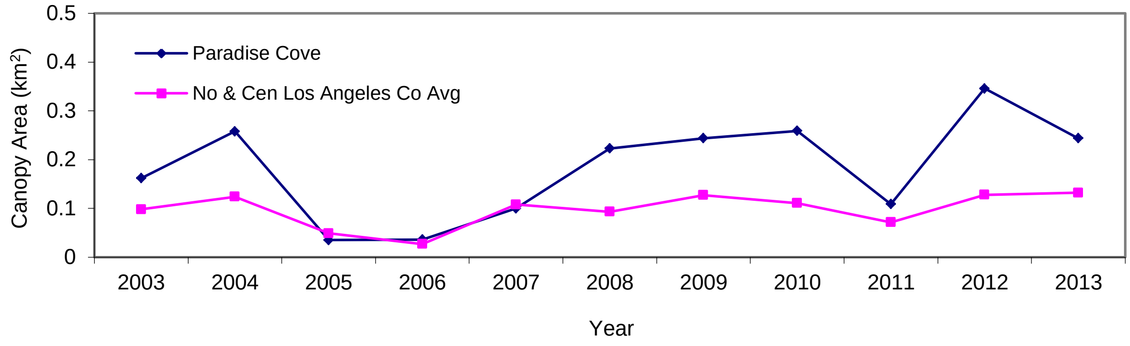


Figure 31. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Paradise Cove for the years shown.

Escondido Wash. Escondido Wash kelp bed is one of the denser beds and in 1911 it totaled 0.583 km^2 (Crandall 1912). Since then, Escondido Wash kelp bed has decreased in size, although not to the extent seen in many of the nearby kelp beds. From aerial surveys conducted in 1967, the total for the region was estimated to be about 75% of what Crandall (1912) recorded, indicating that the bed was probably substantially larger than seen in recent years. In a survey of the entire California coastline in 1989 by Ecoscan (1990), this kelp bed was noticeably smaller than in the CRKSC monitoring in 2003 (0.214 km^2) and 2004 (0.250 km^2) (MBC 2004a, 2005a). The 2005 maximum areal coverage was 0.078 km^2, a 69% reduction in surface canopy area from that seen in 2004. The surveys of the Escondido Wash kelp bed in 2006 did not record a canopy until a minor trace of kelp was noted in the December 2006 survey. With the advent of the La Niña in 2007, kelp rebounded strongly and areal coverage was 0.339 km^2 by late 2007. Bed size fluctuated through 2010, but like all of the other upcoast beds, canopy decreased considerably in 2011. By December 2011, canopy coverage was only 0.104 km^2, but in 2012, Escondido Wash kelp bed reacted very favorably to what appeared to be a better nutrient regime and increased to a size (0.248 km^2) similar to that observed in 2010. Canopy size decreased by only 2% in 2013. This bed is typically larger than the ABAPY, and generally mirrors the trends in the ABAPY (Figure 32).

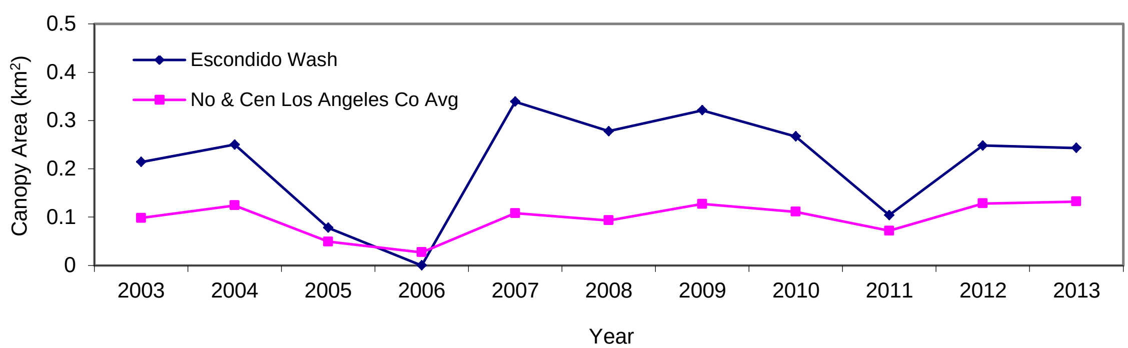


Figure 32. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Escondido Wash for the years shown.

Latigo Canyon. Crandall's (1912) maps were used to calculate the Latigo Canyon canopy coverage of 1911 (0.446 km^2) (Table 2). Aerial photographs of the bed in 1989 (Ecoscan 1990) indicate that this bed was much smaller than reported in Crandall (1912), and appeared to be considerably smaller than the size calculated in 2003 (0.125 km^2) or 2004 (0.161 km^2). In 2005, the bed attained a size of only 0.032 km^2, an 80% reduction from the previous year. The Latigo Canyon kelp bed continued to shrink, and measured only 0.007 km^2 during December 2006; however, by the end of 2007, the bed increased to 0.186 km^2. From 2007 to 2011, canopy size at Latigo Canyon fluctuated between 0.070 and 0.195 km^2. In 2012, the Latigo Canyon kelp bed grew considerably and attained its largest size (0.202 km^2) since the CRKSC monitoring began. The canopy at Latigo Canyon decreased by about one-third in 2013. The Latigo Canyon kelp bed is very near the ABAPY for the region, and has tracked closely during the 11 years of monitoring (Figure 33).

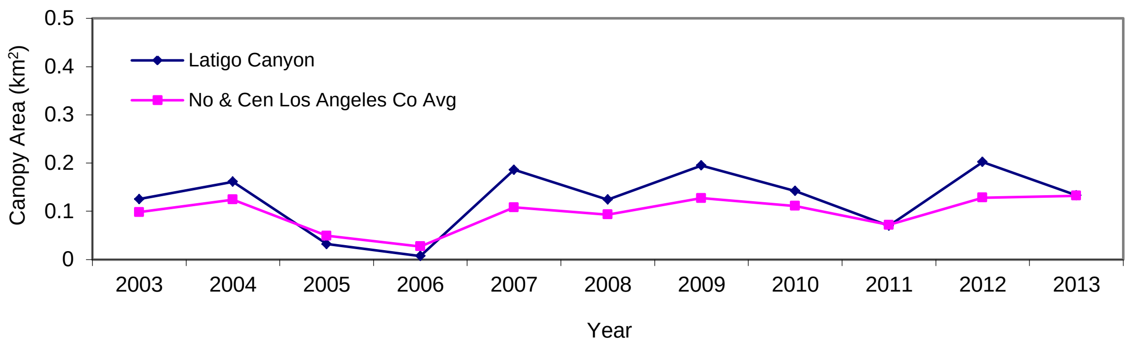


Figure 33. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Latigo Canyon for the years shown.

Puerco/Amarillo. Surface canopy at Puerco/Amarillo kelp bed totaled 0.343 km^2 in 1911 (Crandall 1912). Since then, the Puerco/Amarillo kelp bed has decreased in size. In 1989 this kelp bed was considerably larger than in 2003 (0.074 km^2) and 2004 (0.051 km^2) (Ecoscan 1990). The 2005 maximum areal coverage was 0.039 km^2; unlike its upcoast neighbors, it increased in 2006 to 0.055 km^2 and responded well to the La Niña in 2007, increasing to 0.095 km^2. Between 2006 and 2011, canopy size at Puerco/Amarillo kelp bed fluctuated between 0.06 and 0.13 km^2. Similar to other beds in this part of the Central Region, however, it was larger in December 2012 (0.153 km^2) than during any previous CRKSC survey. In 2013, canopy coverage at Puerco/Amarillo decreased by 31%. This bed typically trended with the ABAPY after 2007, although it responded differently than the ABAPY in 2004 and 2006 (Figure 34).

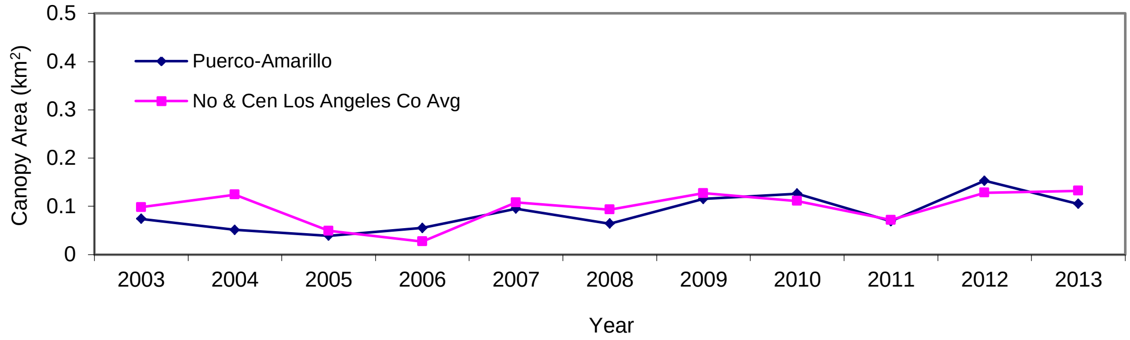


Figure 34. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Puerco/Amarillo for the years shown.

Malibu Point. Crandall (1912) did not record kelp off Malibu Point. The amount of surface kelp observed at this location by Ecoscan (1990) was similar to the size recorded from the 2003 CRKSC survey (0.011 km^2). The Malibu Point kelp bed maintained a canopy that ranged between 0.008 and 0.016 km^2 between 2003 and 2009. Ongoing kelp restoration projects apparently combined with favorable conditions, and by December 2010, canopy size at Malibu Point (0.066 km^2) was four times larger than in any previous survey. The canopy increased each of the next two years, and in 2012, the canopy size was 0.084 km^2, the largest extent of kelp observed since CRKSC surveys began. However, the Malibu Point kelp bed decreased in size by 29% in 2013. This kelp bed was smaller than the ABAPY during most years, and canopy size at this site has not correlated well with the ABAPY (Figure 35).

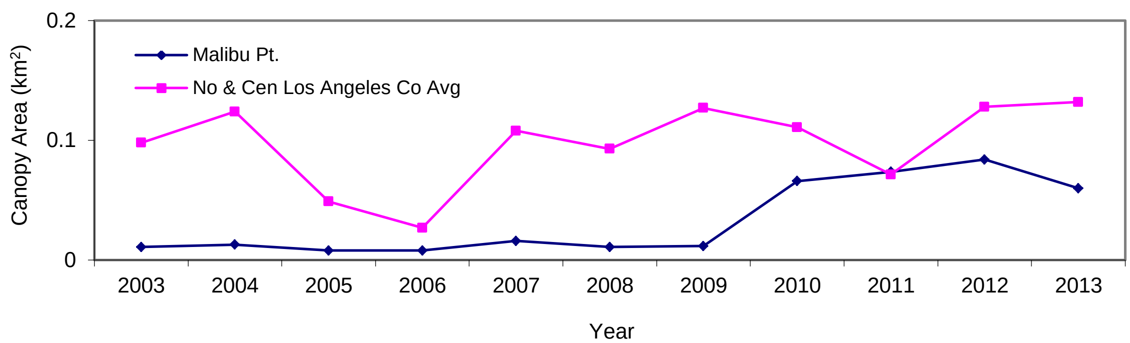


Figure 35. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Malibu Point for the years shown.

MALIBU POINT TO SANTA MONICA PIER

La Costa. Crandall (1912) included this kelp bed in his measurements; however, its location was farther downcoast than its present position. In 1911, La Costa kelp bed canopy coverage was only 0.021 km^2 (Crandall 1912). From all available reports, this kelp bed never came close to the same amount of coverage, at least not after 1955. No surface canopy was present in 1989 (Ecoscan 1990). In 2003, 0.001 km^2 of surface canopy was recorded and 0.002 km^2 was seen in 2004 (Table 4). No surface canopy was seen in any of the quarterly surveys from 2005 through 2008, but the bed reappeared in December 2009 with a canopy totaling 0.001 km^2. It remained the same size in 2010, but the La Costa kelp bed was not visible in any of the four surveys of 2011 (although a dark reef patch was visible in several survey photographs). In 2012, it was not present in the June or October surveys, but reappeared as a small bed (0.003 km^2) in December, the largest in 10 years of monitoring. In May 2013, canopy size was unchanged since 2012. Due to its relatively small size, the kelp bed at La Costa has not reacted in any discernable pattern since 2003 (Figure 36).

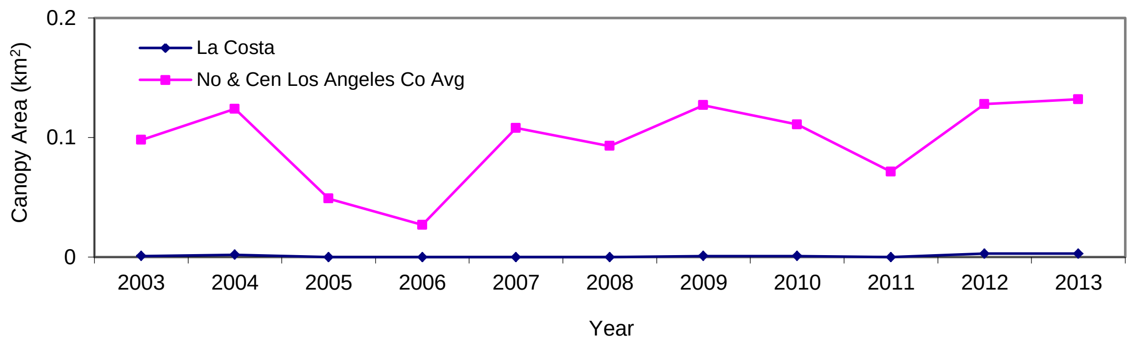


Figure 36. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off La Costa for the years shown.

Las Flores. The surface canopy of Las Flores kelp bed was small in 1911 (0.014 km^2; Crandall 1912), and inspection of the 1989 overflight data revealed that the kelp bed was similarly sized in 1989 (Ecoscan 1990). Canopy size in 2003 was 0.009 km^2; however, in 2004 the density of the canopy increased to a size that was 61% larger than in 1911 (0.023 km^2) (MBC 2004a, 2005a). This bed disappeared during the second and third quarterly surveys in 2004, and then reappeared during the fourth quarter (23 December) in fairly good condition. However, the largest areal extent of Las Flores kelp bed in 2005 was observed during the 15 March survey when it covered 0.004 km^2, an 83% reduction from that seen in 2004. Subsequently, the quarterly surveys of 2006 detected no canopy and the bed did not reappear until the October survey of 2007 (0.005 km^2). Between 2008 and 2011, bed size fluctuated between 0.001 and 0.008 km^2. By December 2012, the bed had grown larger than during any other survey of the CRKSC, and at 0.025 km^2, it was slightly larger than in 2004. Canopy size decreased by 12% in 2013. Compared to the ABAPY, since 2003 the kelp bed at Las Flores has generally not mirrored the ABAPY (due in part to its relatively small size) except for growth spikes in 2004 and 2012 (Figure 37).

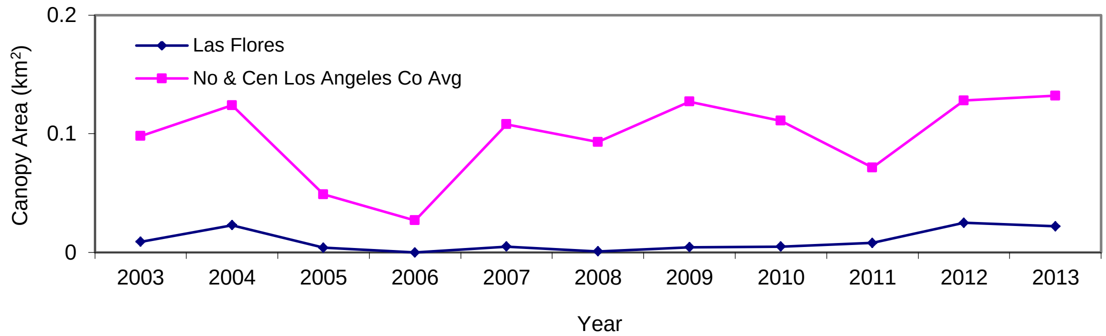


Figure 37. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Las Flores for the years shown.

Big Rock. Big Rock kelp was measured by Crandall (1912) to be 0.017 km^2, and the bed appeared to be similar in size in 1989 (Ecoscan 1990). Surface canopy in 2003 was 0.005 km^2, and in 2004 the bed increased to 0.014 km^2 (Table 4). From 2005 through 2008, canopy size ranged narrowly between 0.001 and 0.004 km^2. In 2006, it was the only bed with any canopy (0.001 km^2) in the region, and it was located just east of the Big Rock Beach headland. Canopy size increased each year from 2009 through 2012, and in December 2012 Big Rock kelp bed reach its largest size (0.018 km^2) since the inception of the CRKSC program. Canopy size decreased slightly (to 0.017 km^2) in 2013. Since 2003, the kelp bed at Big Rock has generally not mirrored the ABAPY (due in part to its relatively small size) except for growth spikes in 2004 and 2012 (Figure 38).

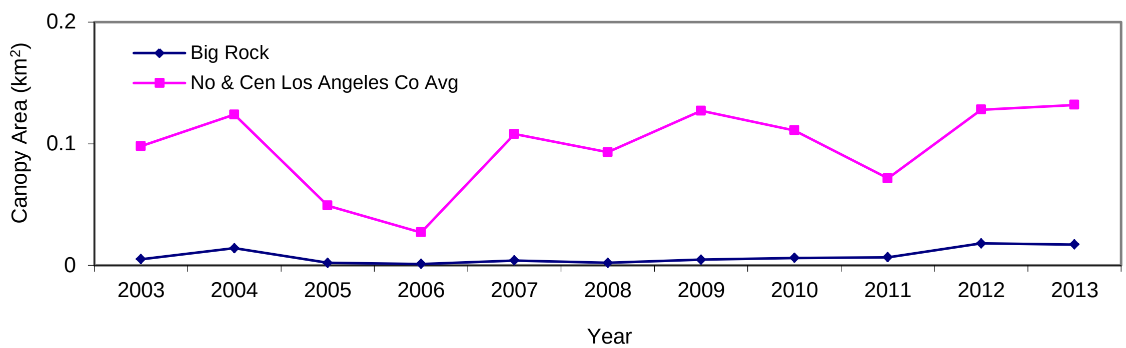


Figure 38. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Big Rock for the years shown.

Las Tunas. Las Tunas kelp bed was small in 1911 at 0.017 km^2 (Crandall 1912), and aerial surveys in 1989 indicated the kelp bed was approximately one-quarter of its historical size (Ecoscan 1990). By 2003, surface canopy of this kelp bed measured only 0.003 km^2 (Table 4). However, in 2004 Las Tunas kelp bed increased considerably to a size (0.018 km^2) similar to that observed by Crandall (1912). The greatest areal extent in 2005 was seen during the 15 March survey when the canopy of this bed measured 0.004 km^2. No kelp was seen in 2006; however, it reappeared by the December 2007 survey and measured 0.008 km^2. By the June 2009 survey, the bed increased to 0.019 km^2; it became smaller during the remainder of 2009, and bed size decreased during 2010 and 2011. In concert with the other beds in the region, Las Tunas increased substantially in 2012, and by the December survey canopy size reached 0.030 km^2, about double that recorded by Crandall in 1911. The Las Tunas kelp bed size decreased slightly (3%) in 2013. Las Tunas is a very small bed, and well below the ABAPY for the region, but has generally responded in the same direction of the ABAPY during most years (Figure 39).

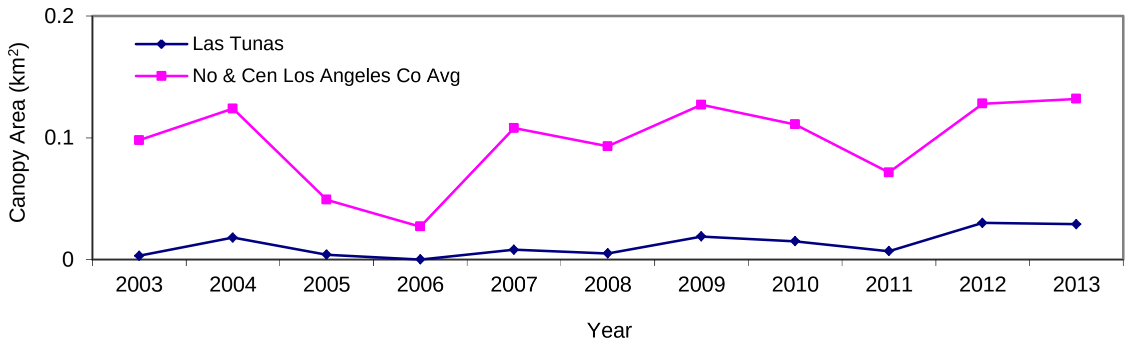


Figure 39. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Las Tunas for the years shown.

Topanga. Topanga kelp bed was surveyed by Crandall (1912); it was small, and its size was estimated to be 0.017 km^2. In 1989, this bed was reduced in size to approximately one-tenth of its historical extent (Ecoscan 1990). The bed was considerably smaller in 2003, measuring <0.001 km^2 (Table 4). This bed was absent for much of 2004, but then reappeared by the fourth quarterly survey with a canopy size of 0.002 km^2. In 2005, there was only a trace of surface canopy. No canopy was recorded at this location in 2006 and 2007, but it reappeared as a very small bed in 2008, and increased to 0.002 km^2 by June 2009. Thus, it was surprising to see the large increase in November and December 2010 to 0.052 km^2, three times larger than recorded by Crandall (1912) and 26 times larger than measured since 2003. Topanga kelp bed decreased in size by about 21% in 2011, increased by 17% in 2012, and decreased by 8% in 2013. Topanga is a relatively small bed, and well below the ABAPY for the region, and therefore its extent has generally not mirrored the ABAPY (Figure 40).

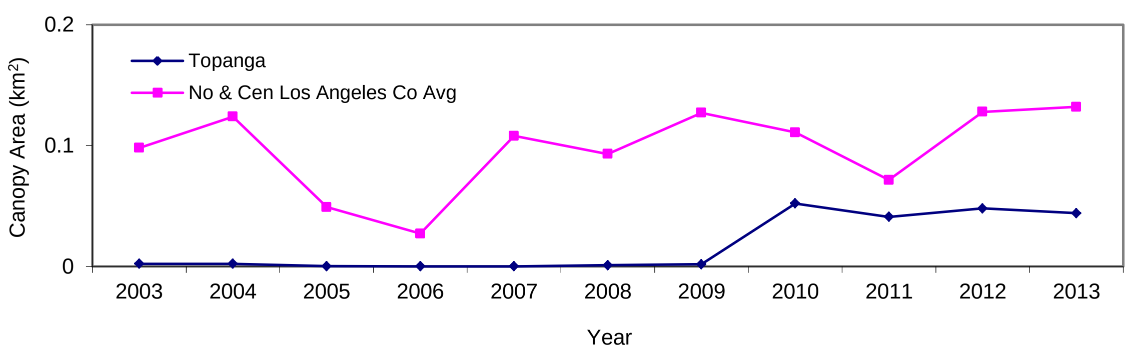


Figure 40. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Topanga for the years shown.

Sunset. In 1890 and in 1911, Sunset kelp bed was relatively large and measured 0.960 km^2 (U.S. Coast and Geodetic Survey 1890 and Crandall 1912). However, this bed was missing or very small by 1955, indicating major environmental changes had occurred offshore of Sunset during the preceding 44 years. This loss was either due to sand inundation of the reef, or because kelp may have grown on the sand and was extirpated by storm(s). In any case, no hard substrate is found at this locale, suggesting the discussed causative agents may have been responsible. By 1989, only a small fraction of the historical bed was observed (Ecoscan 1990). Sunset kelp bed has not been observed in any of the CRKSC surveys through 2012, but a small amount of kelp was noted on the submerged breakwater offshore of Santa Monica at the southern end of the bed from 2009 through 2013 (Table 9).

SANTA MONICA PIER TO REDONDO BEACH BREAKWATER SOUTHERN TIP

Santa Monica Pier to Redondo Beach Breakwater. Although no kelp was noted in 2003 or 2004 from the Santa Monica Pier to Marina del Rey Harbor, a small amount of kelp was noted along the breakwaters at Marina del Rey Harbor and King Harbor in April 2005 and at slightly higher concentrations in December 2006, particularly near the northern end and inside of the King Harbor breakwater. No kelp was seen between the two harbors along the Hyperion Treatment Plant outfall pipeline, offshore the Scattergood and El Segundo Generating Stations, Chevron Oil Refinery, Manhattan or Hermosa Beach, or the Redondo Beach Generating Station. Since at least 2005, kelp has been visible at both the Marina del Rey and King Harbor breakwaters during some portion of the year.

Redondo Beach Breakwater to Malaga Cove, Torrance. This stretch of coastline appears to have been unsuitable for kelp since the survey of Crandall (1912), implying that it continues to be sandy bottom with no substantial hard substrate. In 2013, no kelp was seen between King Harbor and Malaga Cove at the Palos Verdes Peninsula.

MALAGA COVE TO SAN PEDRO BREAKWATERS

The Palos Verdes kelp beds are typically quite large and have been more accessible to researchers than other areas, resulting in many more comprehensive surveys of this region (Table 11). It has been helpful to divide the two beds that Fish and Wildlife recognizes into four distinct kelp regions since they have at times responded differently to oceanographic conditions. Maps of the kelp beds at Palos Verdes Peninsula from 1890 (and possibly earlier) indicate that the kelp beds were large even then, but major fluctuations in extent of Palos Verdes kelp beds have occurred at least since 1911, when 9.124 km^2 of kelp was reported (Appendix B). Despite the region-wide decline of kelp beds since 1911, the extent of the decline in the Palos Verdes kelp forest over the first half of the 20^{th} century was unusual.

During a survey conducted in 1928, the kelp beds were larger (9.912 km^2) than reported by Crandall (1912). However, the status of the Palos Verdes kelp beds was unclear between the 1928 survey and initiation of the discharge of wastewater in 1937 from the Joint Water Pollution Control Plant (JWPCP) off White Point (IMR 1954). The first measurement of local kelp bed extent following initiation of the wastewater discharge was in 1945 when the canopy coverage of Palos Verdes kelp beds was 5.591 km^2. The subsequent decline and disappearance of kelp off Palos Verdes correlated with increasing mass emission of suspended solids from the JWPCP. A study appeared to indicate that particulate inputs from the discharge and increased water column turbidity were the likely mechanism by which the wastewater contributed to the loss of kelp (SWQCB 1964). Under this continued stress, the Palos Verdes kelp beds were virtually eliminated during a large El Niño in 1958–1959.

Kelp recovery and persistence was initiated by a sharp reduction in emission of suspended solids as the result of improved primary treatment, moving the outfall progressively further offshore, and the efforts of Dr. Wheeler North and others to reestablish the kelp in that region. By 1989, Palos Verdes kelp beds covered 2.0 km^2 early in the year and increased to 4.560 km^2 later in the year, stimulated by La Niña conditions (Wilson 1989, Ecoscan 1990). This amounted to a four-fold increase in kelp canopy since 1978 and, relative to the coverage reported in 1911, was consistent with kelp coverage found throughout the SCB (Tarpley and Glantz 1992). While surveys of Palos Verdes kelp beds during the La Niña were infrequent, North flew one flight in late April 2000 showing approximately 1.230 km^2 (no surveys were conducted in 2001). Several surveys were flown in 2002 with CDF&W reporting from 1.343 km^2 (Bedford, CDF&W 2004, pers. comm.) to 2.84 km^2 of kelp (Veisze et al. 2004). Table 2 presents representative survey results of 2.676 km^2 of kelp taken on 21 February 2002 since that particular survey provided information on all four sections of the Palos Verdes Peninsula. The varying estimates probably reflect the time of year the surveys were conducted and suggest the February 2002 survey did not represent the annual maximum canopy at Palos Verdes. The total of nearly 4.0 km^2 of kelp by June 2009 was the largest measurement of kelp at Palos Verdes in the 20 years since the 1989 survey total of about 4.5 km^2 of kelp.

Table 11. Historical record of kelp canopy coverage of the Palos Verdes Peninsula.

YEAR	Km^2	ACRES	HECTARES	NAUT MI^2 * ($N mi^2$)	COMMENT	SOURCE
2013	2.600	642.47	260.00	0.758	M	CRKSC IR Survey (4 Surveys)
2012	2.599	642.22	259.90	0.758	M	CRKSC IR Survey (4 Surveys)
2011	2.396	592.06	239.60	0.699	M	CRKSC IR Survey (4 Surveys)
2010	2.494	616.41	249.45	0.727	M	CRKSC IR Survey (4 Surveys)
2009	3.998	987.92	399.80	1.17	M	CRKSC IR Survey (4 Surveys)
2008	2.916	720.56	291.60	0.85	M	CRKSC IR Survey (3 Surveys)
2007	2.062	509.53	206.20	0.60	M	CRKSC IR Survey (4 Surveys)
2006	2.187	540.49	218.73	0.64	M	CRKSC IR Survey (4 Surveys)
2005	1.099	271.57	109.90	0.32	M	CRKSC IR Survey (4 Surveys)
2004	0.589	145.54	58.90	0.17	M	CRKSC IR Survey (4 Surveys)
2003	1.425	352.12	142.50	0.42	M	CRKSC IR Survey (4 Surveys)
2002	2.837	701.00	283.68	0.83	M	CF&G/Ocean Imaging (2 Surveys)
2000	1.230	303.94	123.00	0.36	M	W.J. North IR Survey (1 Survey)
1999	1.267	313.00	126.67	0.37	M	CF&G IR Survey (1 Survey)
1998	0.498	123.00	49.78	0.15	M	CF&G IR Survey (3 Surveys)
1997	1.048	259.00	104.81	0.31	M	CF&G IR Survey (2 Surveys)
1996	1.356	335.00	135.57	0.40	M	CF&G IR Survey (2 Surveys)
1995	1.493	369.00	149.33	0.44	M	CF&G IR Survey (2 Surveys)
1994	2.703	668.00	270.33	0.79	M	CF&G IR Survey (2 Surveys)
1993	1.214	300.00	121.41	0.35	M	CF&G IR Survey (1 Survey)
1992	1.731	427.70	173.08	0.50	M	CF&G IR Survey (3 Surveys)
1991	2.964	732.50	296.43	0.86	M	CF&G IR Survey (4 Surveys)
1990	3.641	899.60	364.06	1.06	M	CF&G IR Survey (4 Surveys)
1989	4.549	1124.20	454.95	1.33	M	CF&G IR Survey (2 Surveys)
1988	3.379	835.00	337.91	0.99	M	CF&G IR Survey (4 Surveys)
1987	4.242	1048.30	424.23	1.24	M	CF&G IR Survey (4 Surveys)
1986	3.097	765.20	309.67	0.90	M	CF&G IR Survey (4 Surveys)
1985	2.627	649.20	262.72	0.77	M	CF&G IR Survey (4 Surveys)
1984	2.861	707.00	286.11	0.83	M	CF&G IR Survey (4 Surveys)
1983	1.963	485.00	196.27	0.57	M	CF&G IR Survey (4 Surveys)
1982	2.871	709.40	287.08	0.84	M	CF&G IR Survey (4 Surveys)
1981	2.424	598.90	242.37	0.71	M	CF&G IR Survey (4 Surveys)
1980	2.397	592.40	239.74	0.70	M	CF&G IR Survey (4 Surveys)
1979	1.842	455.25	184.23	0.54	M	CF&G IR Survey (4 Surveys)
1978	1.205	297.80	120.52	0.35	M	CF&G IR Survey (4 Surveys)
1977	0.365	90.30	36.54	0.11	M	CF&G IR Survey (4 Surveys)
1976	0.262	64.80	26.22	0.08	M	CF&G IR Survey (4 Surveys)
1975	0.095	23.50	9.51	0.03	M	CF&G IR Survey (3 Surveys)
1974	0.015	3.70	1.50	0.00	M	CF&G IR Survey (2 Surveys)
1967	1.062	262.4	106.2	0.31	M	SAI (1 Survey)
1959†	0.034	8.48	3.43	0.01	M	SWQCB 1964
1958	0.171	42.38	17.15	0.05	M	SWQCB 1964
1957	0.446	110.18	44.59	0.13	M	SWQCB 1964
1955	0.823	203.41	82.32	0.24	M	SWQCB 1964
1953	1.509	372.92	150.92	0.44	M	SWQCB 1964
1947	3.601	889.93	360.14	1.05	M	SWQCB 1964
1945	5.591	1381.51	559.08	1.63	M	SWQCB 1964
1928	9.912	2449.42	991.25	2.89	M	SWQCB 1964
1911	9.124	2254.58	912.40	2.66	M	Crandall 1912

* Data in naut. mi^2 are from SWQCB (1964); 2003-2007 data includes Cabrillo; M = Measured
† 1959 value as reported by SWQCB (1964) is actually <0.01 N mi^2. This was changed to 0.01 N mi^2 (8.5 acres). 1911-1959 values were converted using 1 N mi^2 $(6076.13\ ft)^2$ = 36,919,368 ft^2 = 847.55 acres = 342.99 hectares = 3.43 km^2. Values from 1974 to present are maximum coverage for each year in the CF&G or CRKSC aerial surveys.

The Portuguese Bend landslide is an important local factor in limiting kelp forests on reefs along the southern face of Palos Verdes. This slide, that has been active since 1956, has contributed as much as 9.4 million metric tons of sediment to the nearshore waters (Kayen et al. 2002). Besides increasing water column turbidity with attendant effects on sea floor light availability, sediment from the slide buried many low-lying reefs that would otherwise support kelp beds (LACSD 2003). Kayen et al. (2002) compared bathymetry in the region to assess the magnitude of the historic accretion of sediment on these reefs. Comparing 1933 and 1976 bathymetric surveys, they found shoaling of the seafloor of greater than one meter between the 3- and 15-m isobaths within the depth range suitable for kelp bed formation.

Palos Verdes IV. The Palos Verdes kelp beds have the most complete record of all the beds in the Central Region because of surveys conducted by the CDF&W and monitoring efforts by Los Angeles County Sanitation Districts.. Along the entire Palos Verdes Peninsula, Crandall (1912) calculated kelp canopy coverage to be 9.124 km^2; about 6.174 km^2 of that occurred from Flat Rock at Malaga Cove to Point Vicente. In aerial photographs from 1928, the beds covered 9.912 km^2; however, by 1945, all beds along the Palos Verdes Peninsula declined dramatically in size (SWQCB 1964, Appendix B). By 1958, only a small remnant of the PV IV kelp bed was visible. Efforts by Dr. Wheeler North to restore the largely reduced Palos Verdes kelp beds commenced in the 1970s. By 1989, Fish and Wildlife Kelp Bed 14 recovered to 3.312 km^2 with the majority of that occurring in the PV IV kelp bed (Ecoscan 1990). Since 1989, areal extent of these beds has been much smaller. In 2002, approximately 1.4 km^2 of canopy coverage was observed over the entire Fish and Wildlife Kelp Bed 14.

In the PV IV kelp bed, 0.196 km^2 of kelp was seen in 2003 at the initiation of the CRKSC program. By 2004, this area increased to 0.245 km^2. The largest areal extent of PV IV kelp bed in 2005 occurred during the September survey when it exhibited 0.204 km^2 of canopy coverage (Table 4). In the first quarterly survey on 20 April 2006, kelp coverage at PV IV kelp bed increased to the largest areal extent (0.859 km^2) observed and measured since 2002. Responding favorably to the La Niña, the beds increased still further in 2007 (1.151 km^2) and increased greatly in size in 2008 to 1.839 km^2, a size not recorded since the Ecoscan survey of 1989; however, it was probably larger than this in 1990 and 1991 (Table 4), as the total for the four kelp beds of the Palos Verdes Peninsula exceeded that of 2008. Responding to a favorable nutrient regime, the PV IV beds increased again in March 2009 to 2.122 km^2 of kelp canopy (Table 4). The beds were reduced by the September and December 2009 surveys and the 2010 March survey, but by the August survey, the beds had increased again and reached their maximum extent in November 2010 with a coverage of 1.136 km^2. They stayed fairly large during the first two surveys of 2011, and increased slightly during the October and December 2011 survey to 1.139 km^2, virtually the same as in 2010. In 2012, the kelp beds were large in all four surveys, but the December survey depicted the beds at their greatest coverage of 1.337 km^2. In 2013, the PV IV beds decreased slightly (5%) compared to their 2012 extent. The PV IV kelp bed was typically much larger than the average kelp bed in the region (Figure 41). It is apparent from the ABAPY graph that 2003 through 2005 were poor years for growth throughout the region, particularly at Palos Verdes. It is equally clear from the ABAPY that the PV IV kelp bed responded similarly to other beds in the region, though generally with a sharper upward or downward trend.

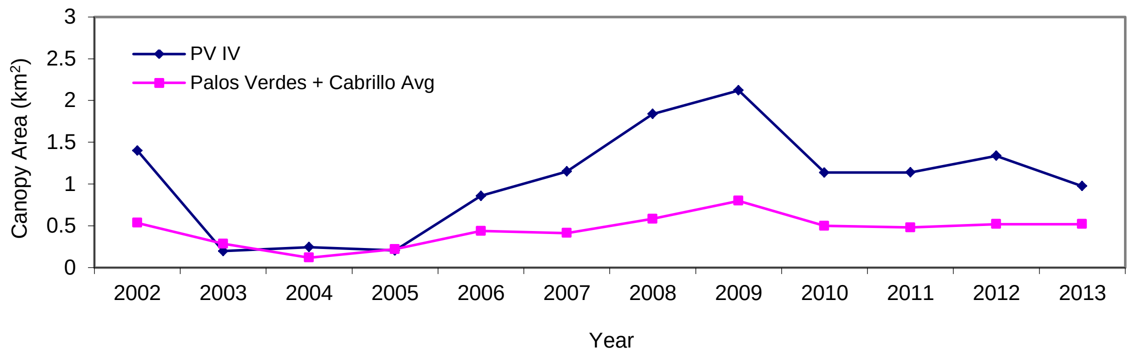


Figure 41. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV IV for the years shown.

Palos Verdes III. Palos Verdes III (PV III) kelp bed includes the area from Palos Verdes Point to Point Vicente. Since PV III kelp bed is physically connected to PV IV kelp bed, its areal coverage has historically tracked that of PV IV kelp bed, with the exception of periods of area-wide kelp canopy decline when Palos Verdes III kelp bed declined to an even greater extent than PV IV. In 2002, the canopy of PV III kelp bed measured 0.028 km^2. By 2003, the canopy increased considerably to 0.045 km^2, while in 2004 it remained similar in size at 0.040 km^2 (Table 4). The greatest areal extent in 2005 was 0.056 km^2, a 29% increase over the previous year. Canopy coverage increased even more the following year, especially within Lunada Bay, and by the December 2006 survey, canopy area totaled 0.135 km^2. The June 2007 survey total of 0.074 km^2 was the largest extent of the bed for the year indicating that conditions were not as favorable in 2007 for this section of the coastline. In 2008, conditions were highly favorable; PV III kelp bed increased greatly to 0.300 km^2, and in June of 2009, the bed totaled 0.570 km^2. In August 2010, in contrast to the reductions that occurred at PV IV, the canopy coverage at PV III increased to 0.624 km^2 indicating varying oceanographic regimes over a relatively short distance. Kelp coverage in 2010 was the greatest since 1989; however, as mentioned previously, it was probably larger than this from 1990 through 1991. The total kelp bed area of PV III decreased in this region during the first two surveys of 2011 and began to increase during the last two, but totaled just 0.452 km^2 in 2011. Conditions improved enough to nudge the canopy higher in 2012, and though the bed was large all year, it was marginally larger in December at 0.488 km^2. By September 2013, the bed was 3% larger than during the previous year. Prior to 2010, PV III was well below the ABAPY, but in 2010, the kelp bed outperformed the ABAPY. It has, however, generally corresponded to the ABAPY the last few years (Figure 42).

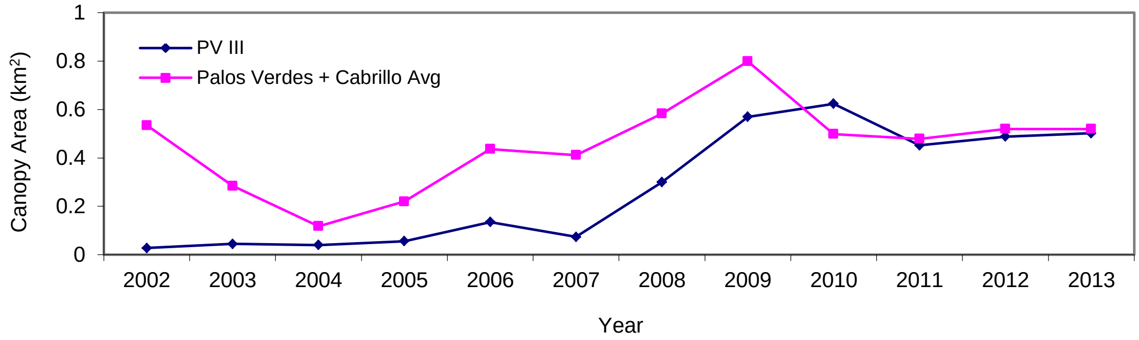


Figure 42. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV III for the years shown.

Palos Verdes II. Palos Verdes II (PV II) kelp bed includes the kelp from Point Vicente to Inspiration Point. Areal coverage of PV II was 0.059 km^2 in 2003 and 0.023 km^2 in 2004 (Table 4). In 2005, the greatest canopy coverage was measured at 0.034 km^2, but canopy coverage more than doubled by the December 2006 survey, and totaled 0.082 km^2. Unlike the other two beds in the Palos Verdes Peninsula, PV II decreased to 0.034 km^2 by the June 2007 survey and remained smaller during the two subsequent aerial surveys in 2007. Unlike the PV III and PV IV beds, canopy size at PV II increased for five consecutive years (2008 through 2012), and in December 2012 it covered 0.295 km^2, the largest total of any CRKSC survey. This was the largest total measured since 1989, though the beds were probably larger from 1989 to 1991 based on the total for the four bed areas (Table 11). In September 2013, the bed was 6% smaller than during 2012. PV II kelp bed was also much smaller than the ABAPY, and patterns of bed size were muted. However, with the exception of continued growth from 2009 through 2010, the bed has generally corresponded with the ABAPY (Figure 43).

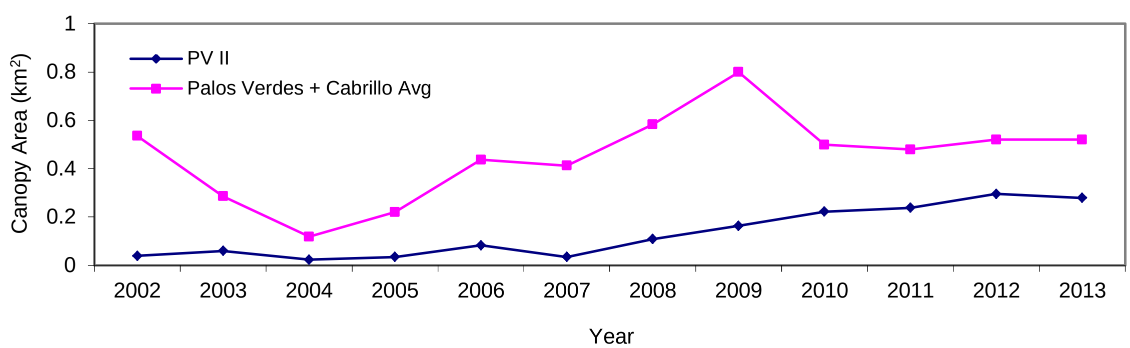


Figure 43. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV II for the years shown.

Palos Verdes I. Palos Verdes I (PV I) kelp bed includes the area from Inspiration Point to Point Fermin. In the 2003 and 2004 surveys, PV I kelp bed included sections of the Cabrillo kelp bed. Therefore, this exaggerated the size of PV I kelp bed in those years, and understated the actual size of Cabrillo kelp bed. This error was corrected in the 2005 report and is correctly reported in Table 4 and Appendix B. In 2005, all canopy west of Point Fermin was included as PV I kelp bed, and all canopy east of the point was included as Cabrillo kelp bed. The re-calculated areas for PV I kelp bed were 1.063 km^2 in 2003 and 0.211 km^2 in 2004 (Table 4). The greatest areal extent in 2005 was 0.702 km^2, a 140% increase over the previous year, and by December 2006, canopy coverage increased dramatically to 0.951 km^2. Despite this increase and the advent of the La Niña, kelp at PV I decreased in area to 0.703 km^2 by June 2007, with further decreases throughout the remainder of 2007. Although kelp coverage increased from what was observed in late 2007, it was still smaller in 2008 than observed in mid-year 2007, and covered an area of 0.608 km^2. Responding to nutrients in the early part of 2009, it increased to 0.980 km^2. The bed at PV I began to decrease after its high point in June 2009, and by August 2010, the bed was reduced to 0.389 km^2, the lowest canopy size at this bed since 2004. Although much smaller by the April 2011 survey, it increased by the December 2011 survey (0.465 km^2). It also responded unfavorably to the nutrient regime and atypically decreased (0.384 km^2) after the April 2012 survey. Unlike the other Palos Verdes kelp beds, PV I increased substantially (75%) in 2013, and the canopy coverage was the highest recorded since 2009. PV I kelp bed was considerably larger than the ABAPY during some years, but it size and growth patterns have corresponded to the ABAPY since 2008 (Figure 44).

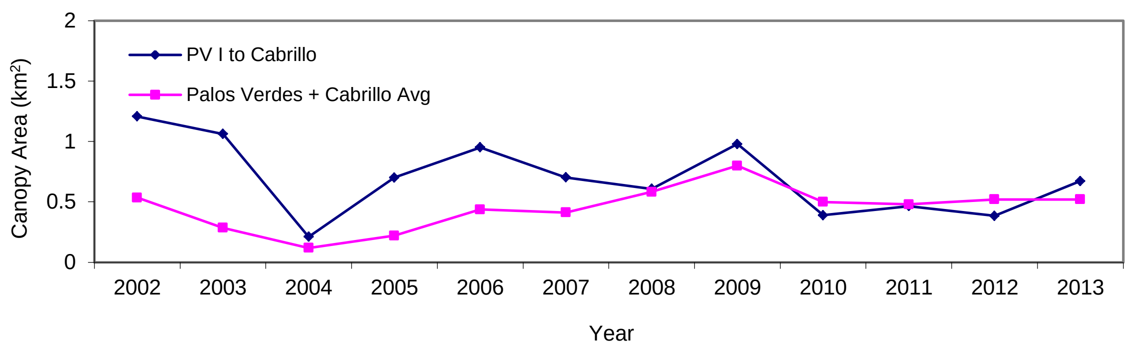


Figure 44. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV I for the years shown.

Cabrillo. The Cabrillo kelp bed includes the area east of Point Fermin up to and including the groin extending from the western end of the Port of Los Angeles breakwater. Cabrillo has consistently maintained a dense kelp bed since 1989, although kelp canopy declined markedly during the 1998 El Niño. As mentioned in the discussion of PV I kelp bed, the area calculated for Cabrillo kelp bed was re-measured in 2005 to include all area east of Point Fermin. The re-calculated areas for Cabrillo kelp bed were 0.062 km^2 in 2003 and 0.070 km^2 in 2004 (Table 4). The greatest areal extent in 2005 was 0.102 km^2, a 46% increase over the previous year. The December 2006 survey indicated canopy coverage was 0.161 km^2, much larger than previously recorded in CRKSC surveys. Despite the advent of a La Niña in 2007, canopy at Cabrillo decreased to 0.100 km^2 by June 2007, and further shrank throughout the remainder of 2007. Although kelp coverage increased from what was observed in late 2007, it was still smaller (0.060 km^2) in 2008 than observed in mid-year 2007, but covered an area of 0.163 km^2 by June 2009. By March 2010, the bed was much smaller but increased in areal extent by November (0.124 km^2). This trend continued in 2011, with the bed much smaller by April 2011, but it increased by August to a bed that was just slightly smaller than seen the previous year (0.103 km^2), and then decreased somewhat thereafter in the October and December surveys. It was equally large in both April and December 2012, but since the adjacent bed PV I was measured in April, the April data for the Cabrillo kelp bed (0.095 km^2)

were also used. In 2013, Cabrillo kelp bed increased in size by 83%, and the measured area was the highest recorded since 2003. The bed is relatively small, but with the exception of a downward decline in opposition to the ABAPY in 2008 and 2012, it has corresponded to the ABAPY (Figure 45).

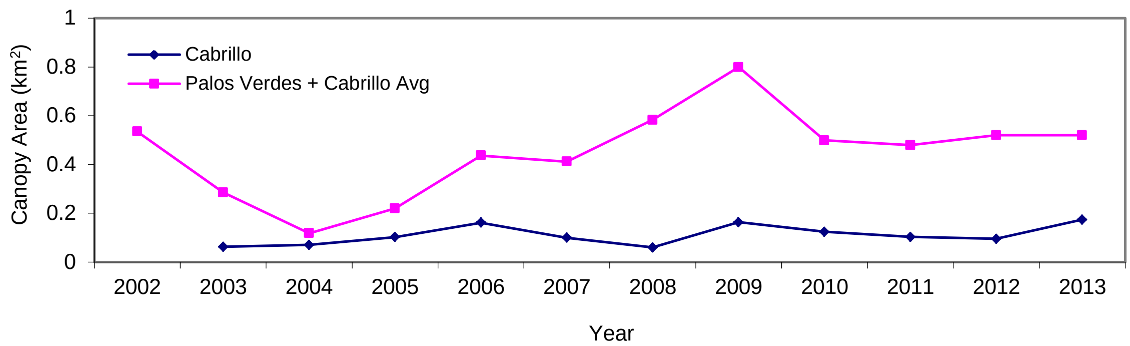


Figure 45. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off Cabrillo for the years shown.

POLA-POLB Breakwaters. A large amount of kelp exists along the Ports of Los Angeles and Long Beach breakwaters, on the armored edges of the outer harbors, and in some cases extending into the inner harbors. This kelp was not adequately considered in CRKSC reports before 2005, but has been measured on a yearly basis since. The existence of these beds was known for some time, but the extent was not thought to be great. In response to growing curiosity as to the extent of the kelp in the harbor complex, it was requested that the overflight photographs for the third quarterly survey in 2005 (28 September 2005) include the entire outer breakwater complex. Analysis revealed a narrow band of dense kelp (0.147 km^2) on both the inside and outside of the riprap. Only a small portion of the berths in the southern part of the port complex was included in the photographs, and it was suggested that the outer harbor be included in future overflights. Due to reports of kelp existing along a number of the inner breakwaters, the entire harbor was photographed and surveyed by biologists to determine whether the algae in the infrared photographs was giant kelp, feather boa kelp (*Egregia menziesii*), and/or *Sargassum* sp. The visual inspection of the growth along the breakwaters and within the confines of the harbors confirmed that the major portion was giant kelp (*M. pyrifera*). The more inclusive survey of the harbor complex in 2006 measured 0.494 km^2 of giant kelp on the inner and outer breakwaters (Table 4). The beds decreased in 2007 to 0.118 km^2, but increased during four of the subsequent five years to 0.495 km^2 (the highest since monitoring commenced) in 2012. Despite a 32% reduction in kelp coverage in 2013, total coverage in the harbor complex was still higher than the mean since 2005. With the exception of the three-year period of 2009–2011, the patterns of the POLA-POLB kelp have generally not corresponded to the ABAPY from Palos Verdes and Cabrillo (Figure 46). The coverage of the kelp in the port complex was also smaller than the ABAPY during most years, but the two have been relatively similar in size during the last three years.

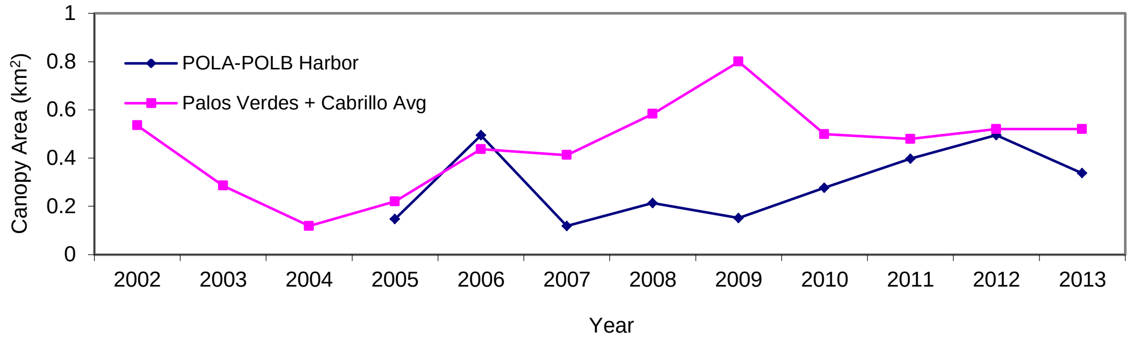


Figure 46. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off POLA-POLB Harbor for the years shown.

SAN PEDRO BREAKWATER LIGHTHOUSE TO LAGUNA BEACH

POLA and POLB

Although much of the area south from the Ports of Los Angeles and Long Beach breakwaters to the Newport/Irvine Coast is along a broad, flat alluvial fan from the San Bernardino Mountains, the area once supported several kelp beds. Rocky area existed off of San Pedro in the Horseshoe kelp area, and offshore of Huntington Beach in an area known as Huntington Flats.

Horseshoe Kelp. No giant kelp canopy has formed at the site of Horseshoe Kelp in more than 60 years.

Huntington Flats. No giant kelp canopy was apparent at Huntington Flats in 2013.

Huntington Flats to Newport Harbor. No kelp was observed from Huntington Flats to Newport Harbor, which includes the area offshore of the Huntington Beach Generating Station and Orange County Sanitation District outfalls. However, narrow bands of kelp were visible on the Newport Harbor jetties during the 2013 quarterly surveys.

NEWPORT BEACH TO ABALONE POINT, LAGUNA BEACH

Newport/Irvine Coast - Corona del Mar to Crystal Cove. Downcoast from Newport Harbor, giant kelp existed in a number of small beds (collectively called the Newport/Irvine Coast kelp bed) that covered 0.755 km^2 during Crandall's survey of 1911, but canopies covered only about 0.180 km^2 by 1970. Kelp beds persisted in the region (up to 0.220 km^2 in 1976) until the El Niño of 1982–1983, when they disappeared (North and MBC 2001). Due to kelp reforestation efforts in the late 1980s, they reappeared as very small beds until disappearing again in the early 1990s during a series of small El Niño events. Approximately one decade later, reforestation began in 2000 at sites near Arch Rock (off Corona del Mar) that was known to be a purple urchin (*Strongylocentrotus purpuratus*) barrens, and expanded to the southeast to Scotchman's Cove (a portion of Crystal Cove). Two other sites—Wheeler's Reef and the bed southeast of Rocky Point at Scotchman's Cove—displayed small canopies during early-2003. A dive survey was conducted at the restored Corona del Mar bed in 2003, and purple urchins were still prevalent, but kelp recruitment was so successful that drift algae was apparently sufficient to keep the urchins from moving and overwhelming the kelp recruits.

Neither of these two beds was visible during any of the aerial surveys of 2005, but the Newport/Irvine Coast kelp bed was the largest bed off Orange County in 2006 (0.023 km^2), including all the kelp beds south to La Jolla. It more than doubled in size in 2007 (to 0.054 km^2) and coverage was at 1983 levels. Kelp was growing at Cameo Shores and Whistler's Reef, and small beds were visible at both ends of Crystal Cove; by the end of 2008, the canopy size of the Newport/Irvine Coast kelp beds was 0.089 km^2. Canopy increased in June 2009 to 0.095 km^2, about 65% of the bed size recorded in 1980. In the March and December aerial surveys of 2010, the beds of this region were very robust. The Newport/Irvine Coast kelp bed in December 2010 was 0.161 km^2, which was the largest amount recorded since 1979 when 0.200 km^2 was recorded in that location (North and MBC 2001). By the December 2011 survey, the Newport/Irvine Coast kelp beds totaled 0.419 km^2. This was larger than the previous maximum (in the past 50 years) of 0.319 km^2 in 1989. Although, beds were very large in three of the four surveys in 2012, the beds were slightly larger during the April survey (0.395 km^2), and decreased slightly from 2011. Canopy coverage during December 2013 was the highest on record, and represented an 8% increase since 2012. Kelp restoration efforts from 1986 through 2009 revived these beds from their total extirpation in the early 1980s (MBC 2010c). The Newport/Irving Coast bed followed the ABAPY for other beds of the region until giant kelp was extirpated offshore of the Newport/Irvine Coast during the El Niño of 1982–1984 and did not return until about 1989 (due to restoration efforts). Kelp disappeared from this stretch of coast again, returned due to further restoration efforts in 2003, and has roughly followed the ABAPY since (figure 47).

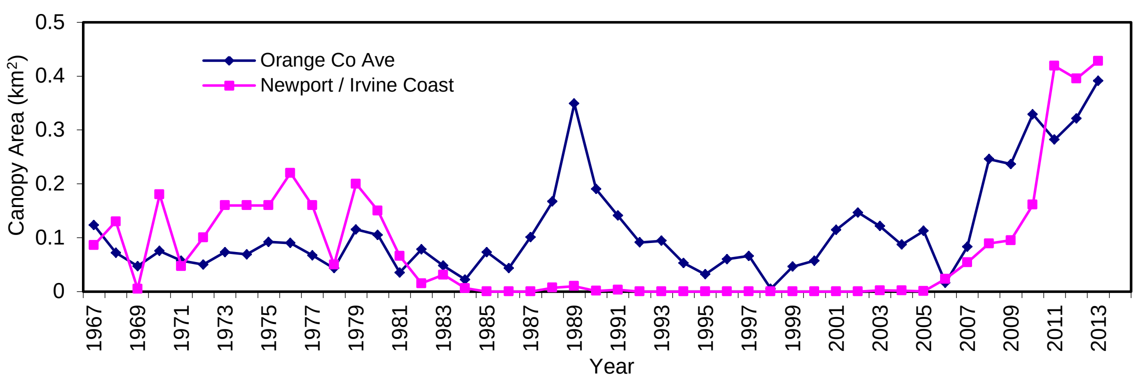


Figure 47. Comparisons between the average Orange County ABAPY and the canopy coverages of the kelp bed off the Newport/Irvine Coast for the years shown.

REGION NINE KELP SURVEYS

The Region Nine program identifies 24 individual kelp beds (although many are comprised of two or more distinct beds) either using local names or geographical references for the name. Looking at the performance of a single bed can elicit more meaningful information if we compare it to like beds in the region because there can be distinct differences between the beds of Orange and San Diego counties based on localized upwelling and oceanographic exposure. The combined RNKSC kelp canopy coverage has been well above average (6.959 km^2) during each of the last seven years (Figure 48). Each bed is also compared to the average for the beds in both Orange and San Diego County, excluding the very large beds of La Jolla (LJ) and Point Loma (PL), because these two beds tend to skew the data (Figure 49). As can be seen in Figure 48, strong upwelling events, such as those associated with La Niña, and warming events such as El Niño, cause sharp increases and decreases in kelp coverage. Comparison of individual beds to each sub-region further refines the ability to identify underperforming beds and determine possible reasons for anomalous results. It is important to conduct these comparisons because large declines and subsequent recoveries are common occurrences in the historical record (especially if we include all the quarterly surveys). Drastic reductions may simply be short-term fluctuations of little importance to the long-term welfare of the bed. If, however, the decline represents a persistent change or develops into a downward trend, more evaluation may be needed to clarify the cause(s).

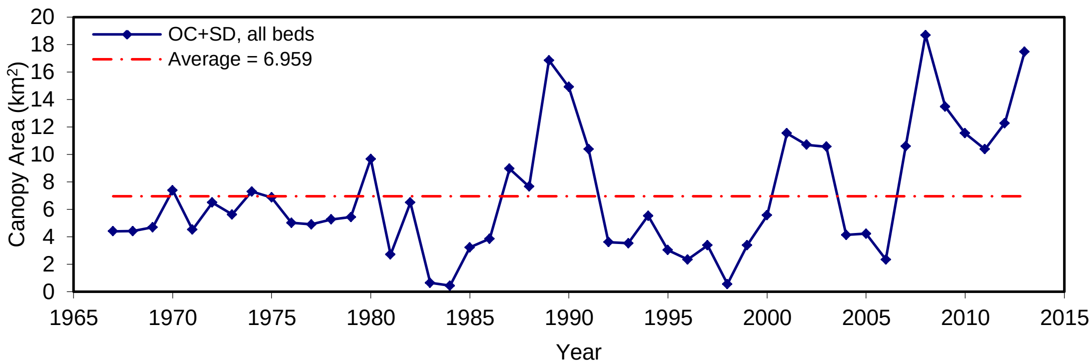


Figure 48. Combined canopy coverages of all kelp beds in Orange and San Diego Counties.

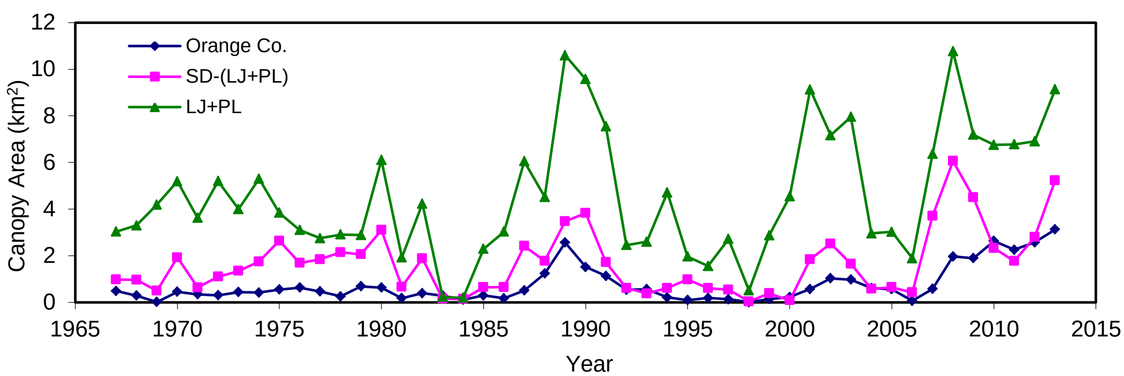


Figure 49. Diagram showings components of the Total Area graph partitioned into the kelp beds of: Orange County; San Diego County less La Jolla and Point Loma (SD-[LJ+PL]); and La Jolla plus Point Loma (LJ+PL).

NORTH LAGUNA BEACH TO CAPISTRANO BEACH

North Laguna Beach/South Laguna Beach. Kelp at this location appears prominently in a map from 1890 produced by T.C. Mendenhall for the US Coast and Geodetic Survey. However, by 1911, there was only a trace of kelp in the areas of North and South Laguna Beach, as Crandall (1912) did not record any kelp beds at this location (although he recorded many small beds along the coast). No available records have been found for the intervening years, but in 1955, kelp beds at this location totaled 0.680 km^2. Thereafter the beds declined and by 1967, they were listed as very small beds totaling only 0.005 km^2. By 1976, the beds began to increase in size and peaked in 1989 at 0.319 km^2 (Table 3). Giant kelp disappeared from North Laguna Beach in 1991 due to several small El Niños and a large influx of purple urchins. In South Laguna Beach, giant kelp persisted through 1993, but declined every year since 1989 and was last noted in the aerial survey of 1994.

Kelp was not seen during extensive diving surveys conducted prior to restoration activities in 2002. Following restoration efforts funded by several groups at sites clustered along a one-mile strip of coastline extending from Heisler Park to the offshore breaking reefs at Cress Street, and ranging in depth from 8 to 14 m, a small amount of kelp reappeared at South Laguna Beach in 2002, and a trace was observed at North Laguna Beach in 2003. These stayed small or disappeared (but persisted below the thermocline) over the next several years. No surface kelp was seen during the first two aerial surveys of 2007; however, diver surveys in March and May 2007 indicated that some areas were beginning to recover and several hundred giant kelp were found on the bottom (out of several thousand observed about 1.5 years earlier). As 2007 progressed, kelp densities began to increase at the restoration sites and many giant kelp of various sizes were found throughout the restoration area. This kelp persisted throughout 2007 and grew to a canopy of about 0.002 km^2 at North Laguna Beach and 0.025 km^2 at South Laguna Beach by the late December 2008 survey. The kelp beds continued to increase and totaled 0.063 km^2 by mid-2009. Conditions returned to near normal by the beginning of 2010, resulting in recovery of the canopies from losses in the latter half of 2009. By December 2010, canopy coverage was 0.191 km^2, indicating continued recovery following restoration efforts over an eight-year period (MBC 2010c). The Laguna Beach kelp beds increased to 0.368 km^2 in 2011 and to 0.406 km^2 in 2012. In 2013, the Laguna Beach kelp beds' size increased slightly (2%), although the two beds did not react similarly. The northern bed decreased by 26%, and the southern bed increased by 28%. Canopy in 2013 was larger than at any time in a continuous 47-year record, but not as large as the canopy coverage in 1955 of 0.680 km^2 (Table 3). The two Laguna Beach beds followed the fortunes of the ABAPY, and survived the El Niño of 1982–1984, but were extirpated in 1994. The Laguna Beach beds remained at zero in our measurements until about 2006 when the beds again reappeared as a result of restoration efforts and have since followed the mostly positive trend of the ABAPY (Figure 50).

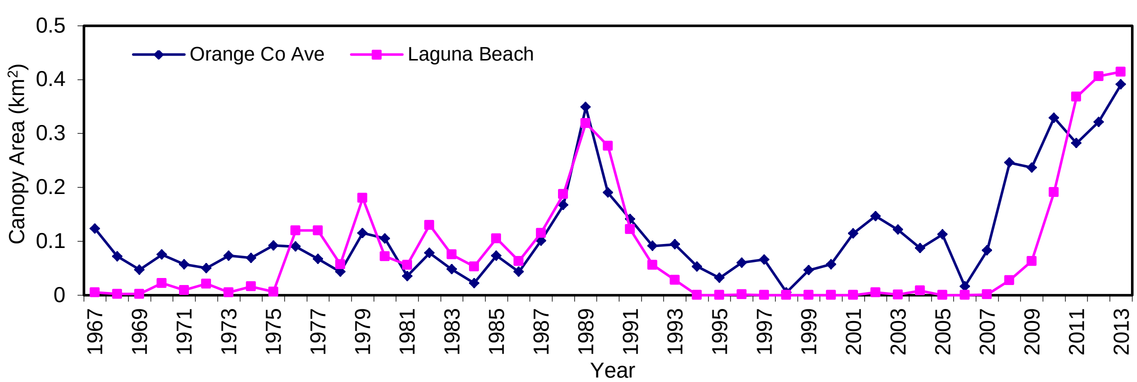


Figure 50. Comparisons between the average Orange County ABAPY with the history of Laguna Beach kelp (i.e., the sums of canopy coverages for North Laguna Beach plus South Laguna Beach kelp) for the years shown.

South Laguna. Giant kelp was not recorded at South Laguna in Crandall's 1911 survey. A record from 1955 suggests that as much as 2.02 km^2 of kelp coverage was present at Dana Point/Salt Creek and spilling into the South Laguna region. Based on that assessment, it was likely the bed was near 0.100 km^2 (twice what was recorded for this bed before 2013). By 1959, the two beds at Dana Point were only 0.180 km^2; indicating South Laguna was either not present or very small. No kelp was seen here in Dr. North's survey of the individual beds from 1967 to 1969, but kelp reappeared in 1970 and reached a total of 0.016 km^2 in 1976. The bed disappeared again in 1978 until a brief reappearance in 1983, and was again missing until 1988. By 1989, the bed was about 0.041 km^2, persisted in the area until 1994 and disappeared until 2000. It stayed for the next several years and although various kelp beds were visible at this location in early 2005, density of kelp decreased sharply and only scattered and tattered giant kelp were noted during the boat surveys through September 2005. A small amount of giant kelp was noted in early January 2006, but none was seen during subsequent aerial surveys and numerous fathometer searches throughout 2006. Small kelp beds were seen at the south end of South Laguna in early 2007, and they became much larger by the end of 2007.

Several surveys by boat in early 2008 documented a continuous strip of adult giant kelp in 12- to 15-m depths extending from Salt Creek upcoast about 0.5 km to well before Aliso Creek. By the end of 2008, the canopy measured 0.023 km^2 (Table 5). However, by March 2009, the bed canopy decreased to 0.017 km^2 and decreased thereafter until December. A dive survey in this region on 6 January 2010 indicated that the kelp bed appeared to have very healthy basal holdfasts with large sporophyll bundles and the bed was again increasing in size (Curtis 2010, pers. obs.). By December 2010, the bed increased to the size recorded two years earlier. A dive survey of the site on 28 December 2011 documented a very large canopy. Visibility was about five meters and kelp holdfasts on the bottom appeared healthy. Drift algae appeared sufficient on the bottom for the low number of urchins to stay immobile. The observation of a pink abalone at a depth of about 10 m indicated that the supply of drift algae was available for a sufficient period of time to foster its growth. The reduction in size of the canopy from the previous year (from 0.023 to 0.018 km^2) was not distinguishable. By the end of 2012, the bed was slightly smaller but virtually unchanged, with canopy coverage of 0.017 km^2. In 2013, however, the bed more than doubled in size, and reached its largest extent since 1989. The South Laguna kelp bed was smaller than the ABAPY during most years, and canopy size at this site has not correlated well with the ABAPY. However, the bed responded to relatively large stimuli such as the 1989–1990 La Niña, and since 2007 has usually trended in the same direction as the ABAPY (Figure 51).

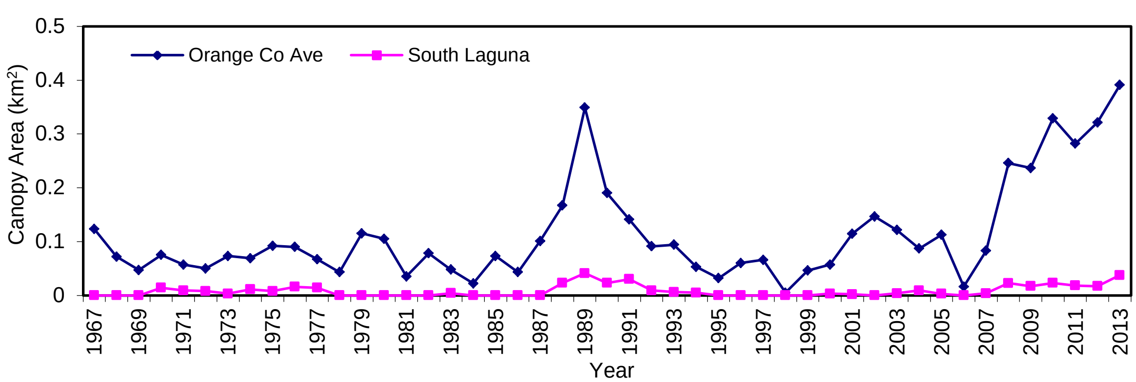


Figure 51. Comparisons between the average Orange County ABAPY and the canopy coverages of the kelp bed off South Laguna for the years shown.

Dana Point/Salt Creek. Kelp beds in the Dana Point/Salt Creek area were large in Crandall's 1911 survey, and totaled 1.166 km^2 (Table 3). They were even larger in 1955, when a survey covering the Dana Point/Salt Creek beds and the relatively small South Laguna bed totaled 2.02 km^2 of canopy coverage. Thereafter the beds declined to 0.240 km^2 in 1967, and stayed relatively small for the next two decades until coverage peaked at 0.878 km^2 in 1989. Coverage was about 0.2 to 0.5 km^2 through 1993, but declined thereafter, and was 0.1 km^2 or less through 1999. In 1999, however, the beds began recovering during a strong La Niña, and bed size increased through 2002. By the end of 2002, Dana Point/Salt Creek kelp covered an area of 0.432 km^2; canopy was extensive, and extended from the 11-m to the 20-m isobaths. The beds started waning in 2003, and disappeared in 2006.

By January 2006, surveys by vessel indicated that the area had a poorly defined canopy, but no canopy was visible during the first three aerial surveys of 2006 and only a trace was found during the December survey. Although no kelp was seen during the subsequent aerial surveys, a few kelp fronds were observed on the surface in late June and divers reported seeing a few adults, and more juvenile and sub-adults present on the bottom in a mid-July survey. Kelp beds at Dana Point/Salt Creek were not visible in the March 2007 aerial survey, but were found during dive surveys in March and May on the bottom where good recruitment of juveniles and sub-adults was recorded. During the June 2007 overflight, canopy formed and was becoming extensive, and by late December the canopy covering 0.302 km^2. The bed responded favorably in 2008, and during the December overflight, the canopy totaled 1.068 km^2 in area (almost matching the size Crandall reported in 1911). Although it was still a very large bed in the March and June 2009 aerial surveys, it lost canopy size from 2008 and was reduced to a bed covering 0.892 km^2 in the March 2009 survey. Dive surveys in March and June 2009 documented active recruitment on the outer edges of the kelp bed, although the inner bed appeared to be very mature kelp with a large number of stipes and very few juveniles present. Due to improving conditions in mid to late 2010, kelp canopy in the December survey increased (0.839 km^2) to a significant percentage (94%) of that seen in 2009. The bed was much reduced by the end of 2011 (covering 0.442 km^2), and lost kelp on both the outside (deeper) and inside (shallower) sections. A dive survey indicated there were many floating holdfasts, possibly the result of wave damage, but more likely the result of purple urchins that had weakened the holdfasts. The bed appeared to be about average during the first three surveys of 2012, but by the December survey, the bed strongly expanded with canopy coverage to 0.607 km^2. The canopy increased 38% in 2013, and canopy size was similar to that in 2009 and 2010. The beds at Dana Point/Salt Creek have been much larger than the ABAPY for much of the past decade (Figure 52). Canopy growth/reduction has usually corresponded with the ABAPY, although canopy decreases in 2009 and 2010 were out of synch with the Orange County average.

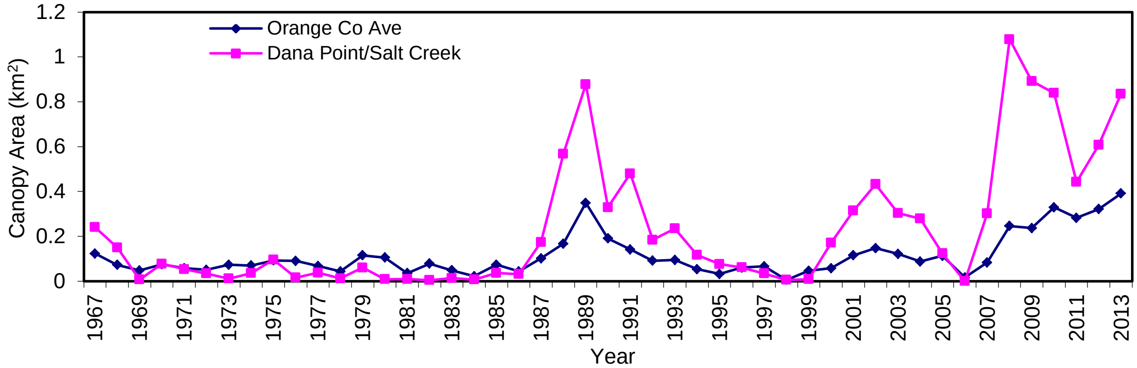


Figure 52. Comparisons between the average Orange County ABAPY and the canopy coverages at the Dana Point/Salt Creek kelp bed for the years shown.

Capistrano Beach. In 1911, Crandall mapped a bed at Capistrano Beach with a canopy coverage of 1.578 km^2. This total included a very large bed (0.755 km^2) offshore of Doheny Beach that was probably present in 1955 considering the very large size (almost the same as Crandall reported for the same area) for the Dana Point/Salt Creek and Capistrano kelp beds. By 1967, the beds at Capistrano Beach were small; the bed at Doheny had disappeared with the construction of Dana Point Harbor, and kelp covered only 0.080 km^2. The beds were small or absent until 1989, when canopy size increased to 0.233 km^2. The beds decreased to about one-half that size the next three years, diminished greatly in 1993, and were absent for the next seven years. Canopy re-formed in 2001, and in 2002, it totaled 0.118 km^2. The beds shrank in 2003, and were absent in 2005, but they formed anew and were relatively small in 2006 and 2007. Canopy size increased to 0.071 km^2 in 2008 and 2009, which was larger than in the previous five years, but still much smaller than observed from 1989–1992 when the canopy covered from 0.15 km^2 to 0.23 km^2 (North and MBC 2001). The kelp canopy appeared healthy in all surveys of 2010 and increased to 0.124 km^2. By the December 2011 overflight, the scattered kelp was measured at only 0.010 km^2, although it is likely that much of the canopy was below the surface because a survey conducted by vessel one week later indicated there were more dense canopies at Capistrano than appeared in the aerial photographs. Improved conditions by December 2012 resulted in a larger canopy (0.056 km^2), and in 2013 the bed size at Capistrano increased by 77%. The Capistrano Beach beds (combined with San Clemente beds) have responded in synch with the ABAPY, and typically to stimuli such as El Niño and La Niña events (Figure 53).

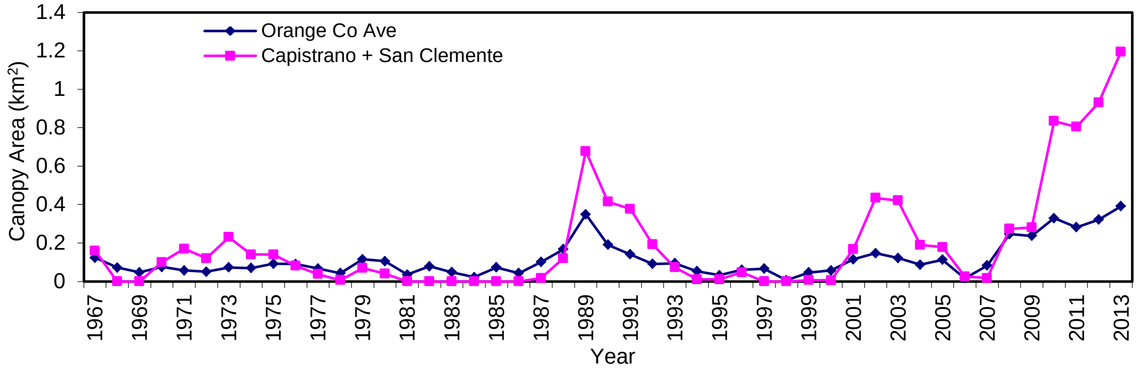


Figure 53. Comparisons between the average Orange County ABAPY and the canopy coverages at the Capistrano Beach plus San Clemente kelp beds for the years shown.

SAN CLEMENTE TO SAN ONOFRE

San Clemente. In 1911, the beds at San Clemente covered an area of 0.206 km^2 (Crandall 1912). The beds were very large in 1955 considering that the total for San Clemente, San Mateo Point, and San Onofre was 6.3 km^2; that was more than twice as large as Crandall reported for the three areas in 1911. San Clemente kelp beds were still larger than Crandall reported in 1959, but diminished to 0.010 km^2 by 1967. The beds were small or absent until 1988. From 1989 through 1991, canopy sizes at San Clemente were larger than what Crandall reported 80 years earlier, but they decreased substantially through 2000. Kelp disappeared with the advent of the 1997–98 El Niño, but emerged in 2001 with a canopy coverage of 0.124 km^2, and kelp increased again in 2003 to 0.352 km^2. In 2002, scattered giant kelp was noted throughout the region, but the largest change was the placement of approximately 50 small artificial reefs (each measuring 40 m x 40 m) offshore of San Clemente on barren sand at depths of about 12 to 15 m. Kelp immediately recruited to these reefs, and canopies in the shape of small squares were visible during most of the aerial surveys of 2002 and 2003. The beds appeared very productive during monthly boat surveys of the area. Each square reef canopy occupied an area of about 1,600 to 2,000 m^2, for a total of about 100,000 m^2 (0.10 km^2), resulting in the potential for approximately 30% more canopy coverage in the region. In spite of this additional substrate, poor nutrient conditions resulted in kelp declining by about 50% in 2004 and 2005, and by 90% in 2006 from that noted in 2003.

In 2006, the artificial reefs supported subsurface kelp, but the kelp appeared to be stressed as the blades were a pale yellow, indicating that nutrients were probably limiting growth. A small canopy inshore of the main reefs was observed in the December 2006 aerial photos, but the kelp bed was small through 2007. In 2008, the bed grew to 0.203 km^2. In early 2008, Southern California Edison (SCE) added additional reef material (covering 0.615 km^2 in total) and kelp recruited to the new reefs in late 2008. Kelp stayed fairly robust through both the March and June 2009 surveys, retreated in September, but recovered by December with 0.210 km^2 of kelp canopy. Kelp was beginning to be visible at the new SCE reefs, but much of the kelp was still below the surface by the end of 2009 (Table 5). Kelp covered the footprint of the new artificial reefs and reached a recorded high for the area of 0.710 km^2 in 2010; that was the highest canopy size for this bed since at least 1959. The aerial surveys of 2011 recorded a bed slightly larger (0.795 km^2) than observed the previous year and the vessel survey indicated the bed was extremely dense and the kelp tissues were a dark yellow, indicating nutrients were recently available. The bed was large in April 2012, decreased somewhat through the year, and then rebounded in December to 0.874 km^2. San Clemente kelp was 26% larger in 2013, the third consecutive year it increased in size. Kelp continues to fill in the areas among the reef modules. This bed probably benefits from its proximity to San Mateo Point and localized upwelling. The San Clemente beds (combined with the Capistrano Beach beds) have responded in synch with the ABAPY, and typically to stimuli such as El Niño and La Niña events (Figure 53).

San Mateo Point. San Mateo kelp bed was large in 1911, when it covered 1.235 km^2. Based on a total for several beds in the region, it was likely the bed remained fairly large during surveys of 1955 and 1959, but it was only about 0.057 km^2 by 1970. The bed was fairly large by 1980 (0.360 km^2) and was a large fraction of its 1911 size in 1989, when it covered 0.870 km^2. In 1990, however, it began a slow decline. After a major decrease in 1995, San Mateo kelp bed increased in 1996 and early 1997, but decreased through the remainder of the year and disappeared in 1998. No kelp beds were observed until a sparse canopy was seen in November and December 1999. The bed was sparse through 2002, but in 2003, the canopy size increased to 0.242 km^2. It diminished in 2004, but regained its 2003 size the following year (0.258 km^2). Kelp subsequently decreased and disappeared during the remainder of 2006. Field biologists observed small beds beginning to form by the end of 2006. The San Mateo kelp bed was still small in March 2007 and a large hole was observed in the middle of the kelp (this area had previously been an urchin barren), but the beds began to increase and dive surveys in April and May reported abundant kelp on the bottom (Moore 2007, pers. comm.). The canopy covered 0.201 km^2 by the end of 2007 and the stimulus of the La Niña in 2008 allowed the kelp bed to double in size (0.487 km^2) by the December 2008 survey, its largest size since 1989. Although 2009 appeared to be limited in nutrients, kelp canopy increased by the March 2009 survey to 0.545 km^2. During 2010, kelp canopy increased with each survey and totaled 0.583 km^2 by the late December 2010 survey, the largest area since 1989.

As noted previously, there is a perennial hole in the San Mateo kelp bed. Questions were raised about the nature of this hole (sand bottom, urchin barrens, etc.), so a dive survey was conducted in January 2010 to make observations. As North and Jones (1991) noted, below the hole is a rocky cobble and boulder reef that is elevated above the surrounding reef. North thought that sea urchin larvae preferentially recruited to this hillock. Diver observations indicated that it was a large sea urchin barren and both red and purple urchins were massed in a front (one to two meters wide) along the kelp bed, with 20 to 30 red urchins and 100 purple urchins per meter square. The urchins were actively eating giant kelp plants and expanding the hole. Although there were numerous scattered canopies and individual giant kelp observed during the vessel survey of 2011, the aerial survey recorded a canopy (0.203 km^2) that was 65% smaller than in 2010. The kelp bed was large in April, nearly disappeared by October, but it rebounded in December 2012 to cover an area of 0.216 km^2. Canopy size was virtually the same (0.219 km^2) in 2013. The San Mateo kelp bed typically responds to stimuli such as El Niño and La Niña events, and has closely followed the Orange County average (Figure 54).

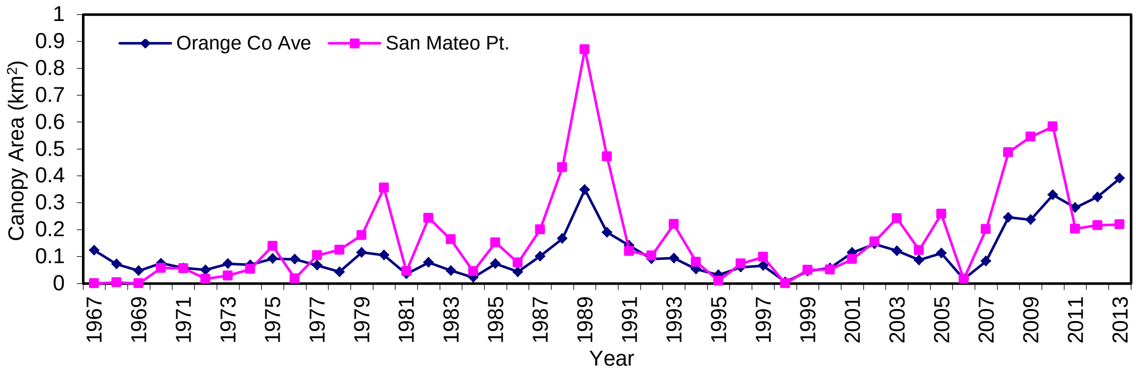


Figure 54. Comparisons between the average Orange County ABAPY and the canopy coverages at the San Mateo kelp bed for the years shown.

San Onofre. The kelp beds at San Onofre were relatively large (1.029 km^2) in 1911. Based on a total for two beds near San Onofre and another (Pendleton Artificial Reef [PAR], located about three kilometers downcoast) that has not had canopy since at least 1959, it was likely the beds remained fairly large during surveys of 1955 and 1959, but were absent from 1967 to 1971, and reappeared in 1972 as relatively small beds totaling about 0.094 km^2. The beds gained a respectable size (about 0.200 km^2 or more) from 1973 through 1976, shrank thereafter, and then increased in 1980 to 0.160 km^2. Bed size diminished to 0.045 km^2 through 1987; however, it increased nearly eight-fold in 1988, and doubled again in 1989. By 1990, the total canopy size was 0.763 km^2. During the next decade and a half, the beds were seldom larger than 0.100 km^2. In 2002, the beds were about 0.162 km^2, but by 2003, the beds decreased by about 33%, and still further in 2004, mostly due to the disappearance of the inshore bed and scattered beds north of the San Onofre Nuclear Generating Station (SONGS) Units 2 and 3 diffuser lines. Kelp canopies appeared healthy in the early part of 2005 and were larger than noted in December 2004. By July 2005 and through September, as would be expected in summer, the beds decreased greatly, and no canopy was present in 2006 (only a few beds persisted in Region Nine in 2006). No surface canopy was present during the remainder of 2006 through March 2007. A vessel survey indicated that small canopies were present and kelp was reported on bottom indicating recent recruitment; the beds were fairly robust (0.320 km^2) by December 2007.

In 2008, San Onofre kelp beds stayed relatively similar in size in the spring, waned in the summer, and recovered well in the fall and winter, resulting in a canopy size (0.476 km^2) that was the largest in almost two decades (since 1989). The kelp beds appeared in very good health during the March aerial survey even though canopy coverage decreased to a still robust 0.419 km^2. However, kelp coverage decreased during the two subsequent surveys, and then made a small recovery by December 2010 to 0.458 km^2. Scattered canopies were observed from the survey vessel in late December 2011 on the south side of the diffusers inshore and offshore of the 10-m depth curve, but by the December aerial survey, coverage decreased to 0.127 km^2. In 2012, San Onofre kelp was absent in the June and October survey, but again rebounded in winter and a small canopy was present in a few areas covering 0.191 km^2. In 2013, canopy was present during all four surveys, but the greatest extent (0.767 km^2) was recorded in December. Canopy size in 2013 represented a three-fold increase from 2012, and was the largest recorded by the RNKSC. Because of their location in a similar geographically area, San Mateo kelp has been used in several scientific studies as a control station for San Onofre kelp, and the two beds usually react similarly (Figure 55). The San Onofre kelp bed has also followed the ABAPY for San Diego County (Figure 56).

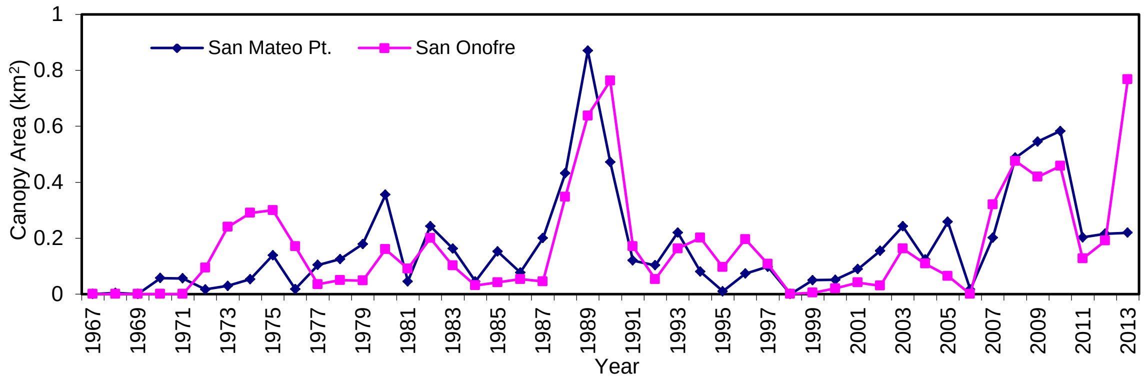


Figure 55. Comparison of histories of canopy coverages for the kelp beds off San Mateo Point and San Onofre. Operations at Unit 2 of the San Onofre Generating Station (SONGS) commenced in 1983. SONGS Unit 3 became operational in 1984.

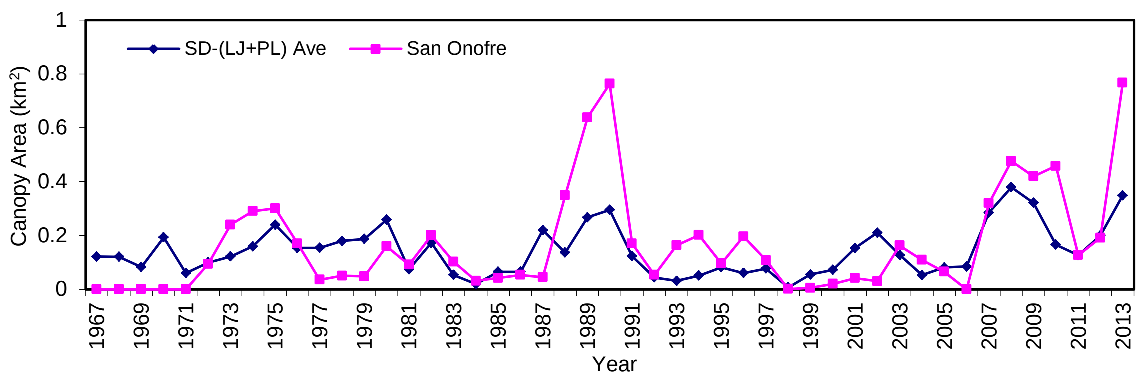


Figure 56. Comparisons between the average SD-(LJ+PL) ABAPY and the canopy coverages of the San Onofre kelp bed for the years shown.

HORNO CANYON TO SANTA MARGARITA RIVER

Horno Canyon. Horno Canyon kelp appeared as a small bed (0.172 km^2) upcoast of Barn kelp in Crandall's 1911 survey. Kelp was not recorded here again until 1988, when it emerged as a very small bed of 0.006 km^2, and it grew to 0.040 km^2 in 1992 before disappearing for the next seven years. In 2000, a small kelp canopy formed at Horno Canyon. Because conditions at Barn kelp were excellent from late 2000 through 2002, its proximity probably enhanced recruitment of kelp at this location. By 2003, the few giant kelp found scattered in the area had increased from the previous year, but did not form a canopy. No canopy was noted during boat or aerial surveys at Horno Canyon or at nearby PAR in 2005. Conditions began to deteriorate at nearby Barn kelp, indicating that nutrients were lacking. No kelp was found in 2006 or through most of 2007. During the December 2007 survey, small canopies formed and covered an area of 0.015 km^2. A few giant kelp were also seen at PAR during a vessel survey in December 2007. Kelp canopies at Horno Canyon in 2008 were the largest on record, and kelp covered an area of 0.083 km^2, indicating that kelp was responding to what appeared from the SSTs to be a favorable growing period. In 2009, kelp decreased to 0.018 km^2. A diving survey was conducted at PAR in January 2010. Large numbers of sea fans and urchins, but only two ragged and grazed kelp recruits, were found growing on isolated rocks. However, small kelp beds appeared by the December 2010 survey and resulted in a total canopy coverage of 0.081 km^2. No kelp was observed on the surface at PAR during any of the aerial or vessel surveys in 2010 or 2011. Horno Canyon in 2012 was again comprised of scattered kelp covering a large area, but it only amounted to 0.008 km^2. The kelp at Horno Canyon recovered in 2013, and coverage (0.125 km^2) was the highest on record since 1911. The Horno Canyon kelp beds are small and have been viable only during very large stimuli such as the La Niñas of 1989–1990, 2001, 2007–2008, and during the last four years (Figure 57).

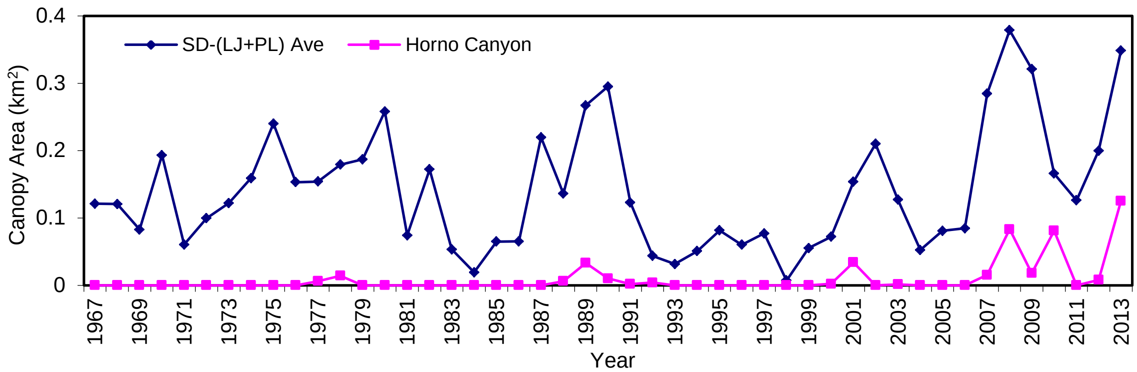


Figure 57. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Horno Canyon kelp bed for the years shown.

Barn Kelp. Barn kelp was a very large bed during Crandall's survey of 1911, covering an area of 2.435 km^2. It was next recorded in 1955 at 1.370 km^2, but by 1967, was composed of only small, scattered kelp that totaled 0.017 km^2. The bed stayed small until 1973 when its coverage increased to 0.120 km^2; subsequently it became slightly larger and stayed substantial in size through 1978. It disappeared from 1981–1987, then reappeared as a small bed in 1988. In 1989, it increased in size to 0.116 km^2 and was much larger in 1990 at 0.382 km^2. During most of the next decade, the bed vacillated in size between zero and 0.260 km^2, but like most beds in Region Nine, it was absent during the El Niño conditions in 1998. In 1999, the bed reappeared and grew to a size of 0.667 km^2 by 2002, the largest size recorded since 1955.

Thereafter, the bed began a decrease that accelerated with time from an apparent lack of nutrients in 2004, multiple factors in 2005, and again a lack of nutrients in 2006, resulting in the total loss of surface canopy. In 2007, Barn kelp recovered to a large fraction of its 2003 size. (0.466 km^2). By the December 2008 aerial survey, it increased to 0.858 km^2, presumably reacting to cooler waters and adequate nutrients. Barn kelp increased to 0.926 km^2 by the March 2009 survey, but decreased thereafter. The bed shrank in 2010, but was still a substantial kelp bed at 0.500 km^2. Extensive kelp canopy was observed during the vessel survey in 2011, but diver observations indicated that the kelp was being attacked by purple sea urchins and 57 eaten holdfasts were observed in a 20-minute survey. The divers also observed considerable numbers of new recruits indicating that the bed could make a resurgence. The aerial survey of December 2011 recorded a canopy that covered only a small fraction (about 20% = 0.095 km^2) of that observed in 2010. In 2012, the kelp bed was in poor shape in the early part of the year, disappeared by the October overflight, but returned as a substantial bed in December at 0.442 km^2. This year, the canopy size doubled, and total coverage (0.868 km^2) was similar to that recorded in 2008–2009. Other than for a severe downturn from 1980 to 1987, Barn kelp reacted similarly to the other beds in the San Diego region (Figure 58). For most of the past 25 years, Barn kelp has been larger than the ABAPY for the region.

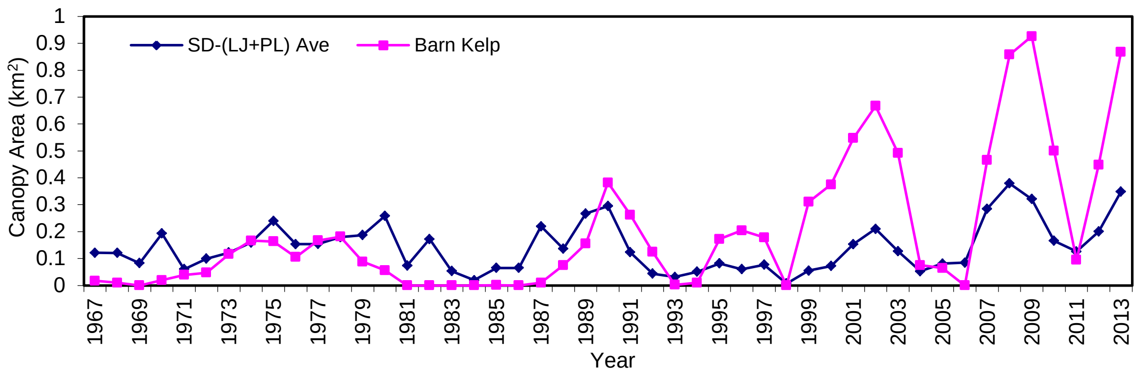


Figure 58. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of Barn Kelp for the years shown.

Santa Margarita. In 1911, Santa Margarita was the site of a substantial kelp bed that covered 0.858 km^2. Kelp disappeared here sometime before regular surveys began in 1967 by Dr. North. No kelp was seen during any of the vessel or aerial surveys until 1991, when a small bed covered an area of 0.049 km^2; it was much smaller in 1992, and disappeared in 1993. No canopy was observed at Santa Margarita for the next two decades, but a small kelp bed was visible during the December 2013 overflight. The size of the bed in 2013 (0.080 km^2) was 63% larger than in 1992, but was still small compared to the bed measured in 1911 (Tables 3 and 5).

NORTH CARLSBAD TO CARLSBAD STATE BEACH

North Carlsbad. The North Carlsbad kelp bed is comprised of several small beds that together covered 0.480 km^2 during Crandall's 1911 survey. Based on the total for the area covering North Carlsbad (which included the five beds north of it), it was probably about one-half that size in 1955 and 1959, and was further reduced by 1963. The beds increased to 0.120 km^2 by 1980 and to 0.165 km^2 by 1990. Between 1980–1995, kelp bed sizes ranged from 0 to about 0.100 km^2. In 1995, the canopy decreased to 0.008 km^2, and no canopy was visible the following two years. A remnant was visible in 1998, but it disappeared the following two years. A sparse canopy was visible during the vessel survey of November 2001. The bed continued to expand and it became denser in late 2002, indicating that environmental conditions continued to be favorable. A small but dense bed was seen in 2003 (totaling 0.053 km^2), but it soon began to thin and was much smaller by the March 2004 survey; it was not visible again until the December survey of 2004. A small bed was seen in early 2005, but it was absent during 2006. Diver observations in 2006 indicated numerous old holdfasts on the bottom, but only one small kelp recruit was noted during a 15-minute dive centered upon the coordinates of the last observed canopy. Apparently unfavorable environmental conditions (swells, turbidity, low nutrients, and persistent phytoplankton blooms) caused a decline in the bed through summer 2006. The bed was not observed during the first three aerial surveys of 2007, but a newly expansive kelp bed was visible in December 2007. This bed was larger than any bed measured at North Carlsbad since 2002. In 2008, the kelp bed was observed during the first survey, became smaller during the second, but resurged in December to 0.108 km^2, the largest recorded since 1990. By March 2009, the canopy size increased to 0.135 km^2, but declined throughout the remainder of the year, and for the next two years. This bed disappeared by the August 2011 aerial survey, but reappeared in both the October and December surveys as a small bed (0.017 km^2). The bed stayed small through October, but tripled in size by December 2012, and doubled in size by December 2013 to 0.125 km^2. The North Carlsbad and Agua Hedionda kelp beds tended to disappear or become very small during periods of intermediate-to-low nutrient availability, but reacted strongly to stimuli such as large La Niña events. The two beds combined followed the ABAPY fairly close, but were out of sync during 2011–2012 (Figure 59).

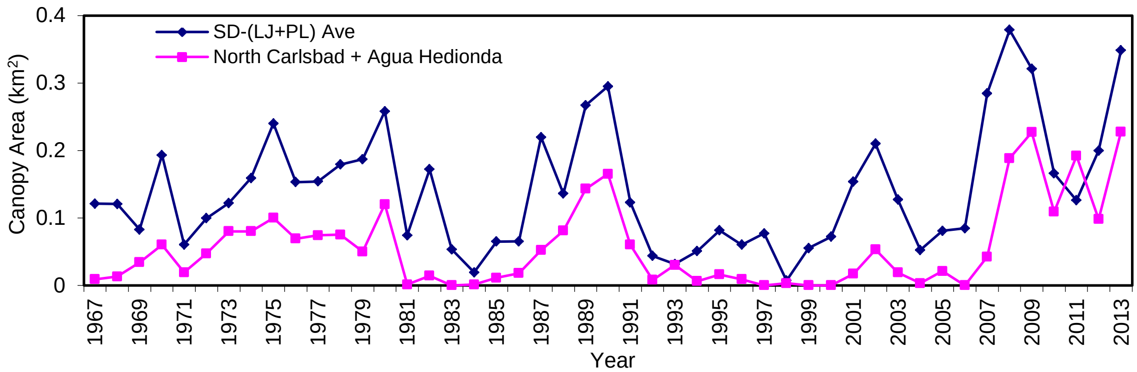


Figure 59. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the North Carlsbad plus Agua Hedionda kelp beds for the years shown.

Agua Hedionda. The kelp beds comprising Agua Hedionda kelp totaled 0.429 km^2 during Crandall's survey of 1911 (50% of a bed covering 0.858 km^2 in the vicinity of Agua Hedionda and Encina Power Plant). The bed was probably quite substantial in 1955 and 1959, but began to decline by 1963. No bed was recorded here from 1967 to 1969, but it reappeared as a very small bed (0.006 km^2) in 1970. It increased to 0.036 km^2 by 1975, and became larger in 1989 (0.047 km^2), but declined thereafter. After 1990, the kelp bed again became smaller and disappeared during the last few years of the century. The kelp bed off Agua Hedionda was substantial in size in the last aerial survey of 1996; however, subsequent surveys indicated that the increase in size of the kelp bed noted in late 1996 was arrested and the El Niño of 1997–1998 devastated the bed.

No kelp was observed at Agua Hedionda until a few giant kelp adults were noted in 2002. In 2003, this trace of kelp developed into a small but measurable bed (0.002 km^2). A trace of kelp was again observed in the aerial flight of March 2005. The kelp bed actually increased in 2005 to a greater total surface canopy than seen since 1996, but surface canopy disappeared in 2006. The kelp bed off Agua Hedionda was not observed during the 2006 aerial surveys; however, numerous sub-adult, juvenile, and recruiting kelp were found during a 15-minute dive survey in late 2006. This survey was conducted in the vicinity of the last known bed, indicating that kelp was poised to recover pending adequate nutrients and favorable environmental conditions. No kelp was observed in the region during the first three aerial surveys of 2007, but a relatively large bed (0.016 km^2) appeared in December 2007; this bed was larger than any bed recorded at that site since 1991. The sudden appearance of the bed indicated that the kelp was surviving below the thermocline (and this was reinforced by the youthful appearance of the fronds during a boat survey in late 2007. Kelp canopy at Agua Hedionda was smaller during the first three aerial surveys of 2008, but it was apparently doing well below the thermocline. When cool waters returned in late fall, the kelp bed increased greatly in size with canopy coverage of 0.080 km^2.

In 2009, the canopy grew through the March 10 survey to 0.092 km^2, but became progressively smaller during the next two surveys until finally responding to winter upwelling by regaining some canopy in December 2009. The large loss of canopy observed during the mid-to-latter part of 2009 reversed in 2010, but the canopy measured only 0.031 km^2 by the December 2010 aerial survey. No increase in kelp coverage and density occurred until the December 2011 survey when Agua Hedionda kelp covered 0.022 km^2. Kelp at this site was scattered and small during the first three aerial surveys in 2012, but on 28 December, there were two distinct patches of canopy measuring 0.046 km^2. During the follow-up vessel survey on 17 January 2013, the kelp blades were dark yellow (indicating recent nutrient availability) and about 75% of the fronds were mature. Biologists also observed that there was very little new kelp on the surface and apical growing tips were missing from about 50% of the fronds indicating the bed was stressed. However, like North Carlsbad, the Agua Hedionda bed more than doubled in 2013, and expanded to 0.102 km^2. The North Carlsbad and Agua Hedionda kelp beds tended to disappear or become very small during periods of intermediate-to-low nutrient availability, but reacted strongly to stimuli such as large La Niña events. The two bed combined followed the ABAPY fairly close, but were out of sync during 2011–2012 (Figure 59).

Encina Power Plant. The Encina Power Plant kelp canopy covered an estimated area of 0.429 km^2 during Crandall's survey of 1911 (50% of a bed covering 0.858 km^2 in the vicinity of Agua Hedionda and Encina Power Plant). The two beds south and three beds north of Encina Power Plant kelp were treated as a single bed in surveys in 1955 and 1959, the total area of which suggests this bed was probably substantial during these two surveys. A subsequent (combined) survey in 1963 suggested that the beds were beginning to decline. No kelp was recorded here in 1967, but it reappeared in 1970 as a very small bed with a canopy of 0.006 km^2. By 1975, it was much larger (0.144 km^2). It decreased in size (or disappeared) until 1988, when favorable conditions produced a canopy that covered 0.161 km^2. In 1989, the canopy size increased by 56% (0.251 km^2), and it was the largest on record. The Encina kelp bed decreased each of the next five years, and it disappeared in 1998 and 1999. It reappeared in 2000 (0.002 km^2), and grew each of the next three years to 0.178 km^2 in 2003. It was much larger than the few individual giant kelp observed in 2002 and was larger than it had been since the El Niño of 1997–1998.

In late March 2005, the Encina Power Plant kelp bed had decreased substantially and by the June survey was not visible, nor was it seen in September or the first survey of 2006. An aerial survey conducted in April 2005 by the Encina Power Plant for other required studies documented that the kelp bed increased from that measured in March 2005 (Weston 2005), indicative of the strong response the kelp bed can have to nutrient pulses. However, the loss of canopy by June 2005, caused apparently by a lack of nutrients, demonstrated how quickly the bed could deteriorate in their absence. Dive surveys conducted in the area offshore of the Encina Power Plant in spring 2005 recorded much lower densities (about one-third less) of kelp on the bottom as compared to that recorded in 2004 (Weston 2005).

The Encina Power Plant kelp bed was not visible during any surveys of 2006. A vessel survey in late July 2006 did not observe any surface canopy, but substantial numbers of sub-adult, juvenile, and recruiting kelp were noted on the bottom. Temperatures during summer 2006 were well above average, and there was no surface kelp during the September and

December 2006 surveys. The bed was also absent during the first three aerial surveys of 2007, but it returned in December 2007 as a relatively large bed covering an area of 0.081 km^2. There were scattered canopies at Encina during June 2008, and by the December 2008 survey, the bed covered an area of 0.306 km^2. In March 2009, the canopy size was reduced to 0.215 km^2, and the bed disappeared entirely in September, but it reemerged in December 2009. By then it was almost as large as noted in March, suggesting nutrients were available.

The bed was large in August 2010 and only slightly larger in the December 2010 survey (0.176 km^2), and it attained a large percentage (81%) of its 2009 size. The Encina Power Plant kelp bed was observed in three distinct patches over a large area in 2011, but coverage decreased to 0.084 km^2. It was relatively small throughout the first three surveys of 2012, but reacted to the presence of nutrients by December 2012 by growing to a total of 0.216 km^2. The Encina bed increased another 63% in 2013 to 0.352 km^2, the largest area recorded since 1911. The Encina Power Plant kelp bed mirrored the other beds in the San Diego region, and its size is similar to the ABAPY (Figure 60).

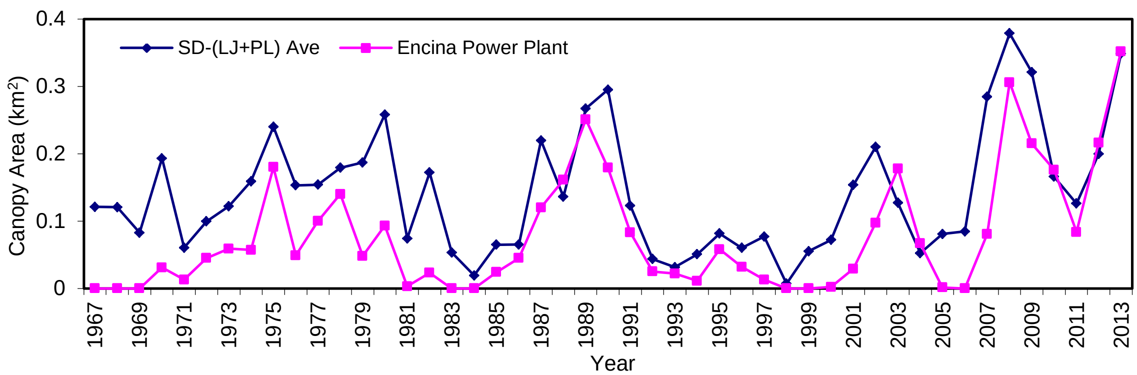


Figure 60. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Encina Power Plant kelp bed for the years shown.

Carlsbad State Beach. This bed was comprised of many mid-sized canopies during Crandall's survey of 1911, and they covered a combined area of 0.499 km^2. It was part of a much larger bed that extended southward from Carlsbad State Beach to Encinitas (Table 1). As mentioned previously (as part of a large area measurement covering the three beds south and two beds north of this bed), this bed was probably quite substantial in 1955 and 1959, but declined by 1963 and for most of the next decade. The bed was not recorded again until an aerial survey in 1967 when small canopies covering an area of only 0.032 km^2 were observed. The kelp bed increased to 0.200 km^2 by 1975, but disappeared during the 1983–1984 El Niño. It emerged in 1985, but was never larger than 0.081 km^2 during the subsequent 12 years, and canopy was not visible from 1997–1999.

During the fall survey of 2000, a trace of kelp was observed and small canopies were visible by winter. A sparse giant kelp bed was present in 2001, and it became denser in 2002, but the bed began to deteriorate after the beginning of the year and did not maintain the canopy gains from a more productive 2002. Only a trace of kelp was observed in 2003 and 2004, and no kelp was observed during any of the aerial surveys of 2005–2006. Carlsbad State Beach kelp bed reappeared as small canopies (0.064 km^2) with young kelp fronds in late 2007. By the December 2008 survey, the kelp bed was larger (totaling 0.121 km^2) than it had been since 1990. A slight increase in canopy size was recorded in early 2009 (0.127 km^2)

suggesting nutrients were available in late December 2008 through March 2009, and a large canopy developed by the December 2009 survey. That canopy was reduced by the late December 2010 survey to an area of 0.069 km^2. In 2011, the kelp bed at Carlsbad State Beach lost canopy during the first three surveys, and increased by the 21 December survey, but to a canopy coverage of only 0.024 km^2. During the vessel survey one week later, it was noted as scattered kelp with only one large patch measuring 100 m by 150 m in area. By December 2012, conditions improved and the kelp coverage increased to 0.058 km^2. The Carlsbad bed made considerable gains in 2013, increasing three-fold to 0.178 km^2. This bed grew/shrank similarly to the other beds in the San Diego region through about 1977. It acted in opposition to the ABAPY in 1978–1979, but while muted, corresponded to the ABAPY during the last three decades (Figure 61).

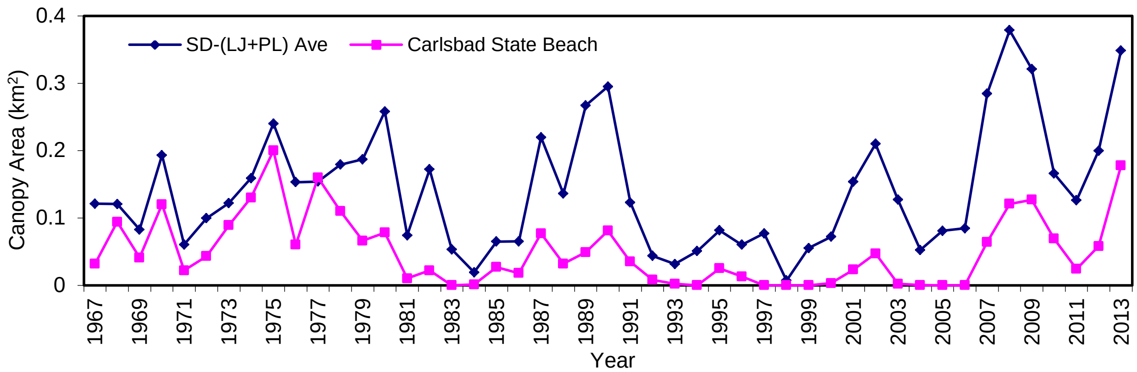


Figure 61. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Carlsbad State Beach kelp bed for the years shown.

LEUCADIA TO TORREY PINES

Leucadia. The Leucadia kelp beds were referred to as the North, Central, and South Leucadia kelp beds because of distinct breaks in the beds in 1911 (Crandall 1912). The beds covered an estimated area of 1.996 km^2 during 1911, and Leucadia was a portion of a much larger bed that spanned from Carlsbad State Beach to Encinitas (Table 1). Based on the total for several beds in the region, this bed was probably quite substantial in 1955 and 1959, but declined by 1963. By 1967 Leucadia kelp covered 0.240 km^2, was twice that size by 1975 (0.500 km^2), and was larger still by 1980 (0.670 km^2). The beds all but disappeared during the 1983–1984 El Niño, but canopy appeared again 1985. The canopy areas from 1985–1991 ranged from 0.070 to 0.426 km^2, but declined through 1994 to 0.010 km^2. Kelp disappeared from aerial surveys during 1998 but apparently survived below the thermocline, as the beds reappeared in early 1999. In the October 2000 survey, beds were observed in all three locations off of Leucadia, and their size increased slightly by the December survey. The three beds continued to increase in 2001 and 2002, with total surface canopy coverage of 0.334 km^2 in 2002. In 2003, the three main beds offshore of Leucadia appeared much smaller, which is common during the aftermath of the winter when light is limited, but atypically continued to decrease in overall canopy area throughout 2003. This decrease continued and the beds were reduced by the end of 2004 (0.048 km^2).

The beds of Leucadia appeared to be growing during the first two aerial surveys of 2005, with all three beds improving by June. However, none of the beds was visible during the September or end-of-the-year overflights and they remained small in 2006. During the first three aerial surveys of 2007, kelp did not appear to be developing well, and no surface canopy was apparent in October. However, during a vessel survey in mid-December 2007, kelp appeared to be very healthy with young, dark-yellow blades signifying adequate nutrients, ultimately resulting in canopies that covered 0.233 km^2 in December 2007. The beds of Leucadia reacted well to nutrient pulses in the early part of 2008, and by the first aerial survey in May 2008, the beds were maintaining their 2007 size; they decreased during summer, but by late fall, they increased to their largest size (0.421 km^2) since 1989. With nutrients available in early 2009, the beds increased slightly to 0.429 km^2 by the March survey.

The beds were alternately large and small during the first three surveys of 2010. The northern portion of the Leucadia kelp bed was very poor during the first two aerial surveys, and did not increase significantly until the December survey; the central and south Leucadia beds were larger than the northern bed in April, but they still increased only slightly by the December survey. Ultimately, the beds were the largest during the December 2010 survey with a canopy total of 0.215 km^2. The vessel survey noted very murky water conditions with reduced visibility, while clearer water was present at neighboring beds; no cause for the turbidity was observed. The three beds of Leucadia all decreased by the end of 2011, and measured only 0.119 km^2. The beds were small or absent until the December 2012 survey, when canopy coverage (0.232 km^2) exceeded that of the previous year. In 2013, Leucadia kelp bed increased to its highest coverage in the last 30 years (0.541 km^2). The North bed (off Batiquitos Lagoon) tripled in size, the Central bed doubled, and the South bed increased in size by 47% compared to 2012. The Leucadia kelp beds have mirrored the other beds in the San Diego region, but the separation between Leucadia and the ABAPY has been muted since 1983 (Figure 62).

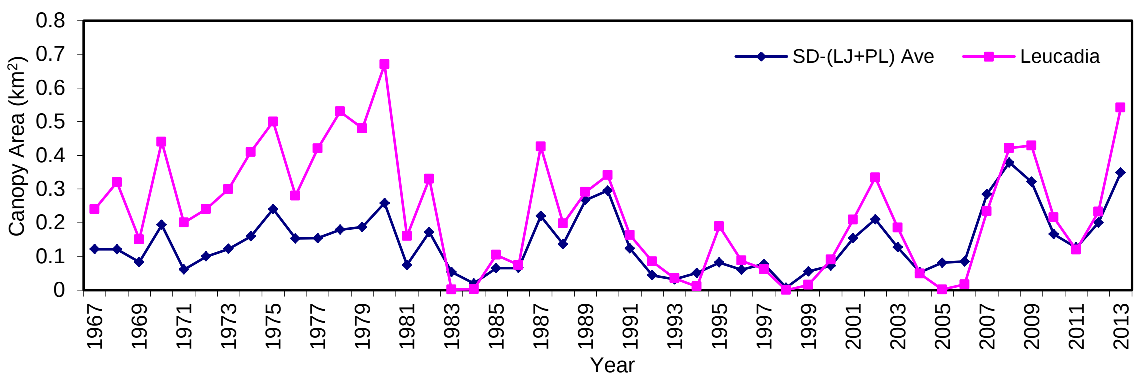


Figure 62. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Leucadia kelp bed for the years shown.

Encinitas. Encinitas kelp bed covered 0.832 km^2 during Crandall's 1911 surveys (it was part of a much larger bed that spanned from Carlsbad State Beach southward to Encinitas). Two surveys conducted in 1955 and 1959 combined these beds, with large totals that suggest the bed at Encinitas was probably present and substantial during those two surveys. A survey conducted in 1963 (that also combined these beds) determined the total area was much smaller, suggesting that Encinitas kelp bed was in decline at that time. This bed was not recorded as a single bed again until North's surveys of 1967 (North and Jones 1991), when it covered 0.065 km^2. By 1970, the canopies grew to 0.173 km^2 and by 1980, the bed covered

0.228 km^2. It disappeared at the onset of the 1983–1984 El Niño, but emerged as a small bed in 1984.

The bed size was variable, but increased through 1990, when it reached its former size. Like some of the other beds in Fish and Wildlife Bed Number 5, canopy size at Encinitas decreased through 1997, and by 1998, it was gone. The kelp bed offshore of Encinitas formed a small canopy in 1999, and its size increased through 2002. By December 2002, the canopy was considerably larger and there was an uninterrupted expanse of kelp offshore of Encinitas. Canopy size decreased to 0.05 km^2 by 2003, and continued declining in 2004. During the first two surveys of 2005, kelp coverage in this region increased, but it diminished during the last half of the year and there was only a trace of kelp by January 2006. This whole region was subjected to intense phytoplankton blooms during much of 2006 and this (combined with a weak nutrient regime) severely impacted the kelp. Only a trace of kelp was observed during the first survey of 2006 and kelp was not visible during the next two surveys, but there were very small canopies by the December 2006 overflight.

Kelp canopies were thin and appeared very small during the first three surveys of 2007, but formed a substantial bed by December 2007 and covered an area of 0.205 km^2. The kelp bed offshore of Encinitas increased by the December 2008 overflight to 0.346 km^2, a size not recorded since the 1911 survey (except for possibly 1955–1959). The kelp bed again decreased to its 2007 size by the March 2009 survey (0.205 km^2) and continued a downward trend until nutrients returned by the December 2009 survey resulting in a larger canopy. Although maintaining almost the same canopy size since December 2009, the Encinitas kelp bed was reduced by the end of 2010 to 0.128 km^2. In 2011, the Encinitas bed covered a very large area, and unlike the other beds upcoast, it did not decrease greatly. In 2012, it remained a healthy kelp bed during most of the year (even though it decreased somewhat in October) and reacted very favorably to end-of-year nutrient pulses to increase in size to 0.260 km^2. The vessel survey noted that the kelp color was a dark yellow that typically indicates that nutrients were prevalent. It also noted that about 75% of the fronds were mature and about four to six meters long on the surface. In 2013, Encinitas kelp bed lost 11% of its canopy size from 2012. Biologists noted in December 2013 that tissue color was medium- to dark-yellow, 50% of the fronds were mature, and frond length was five to six meters. The size of this bed has mirrored the other beds in the San Diego region (Figure 63). For unknown reasons, Encinitas kelp shrank slightly in 2013 while most beds in Region Nine grew. However, canopy size of Encinitas kelp bed was still the fourth highest recorded in the last 50 years.

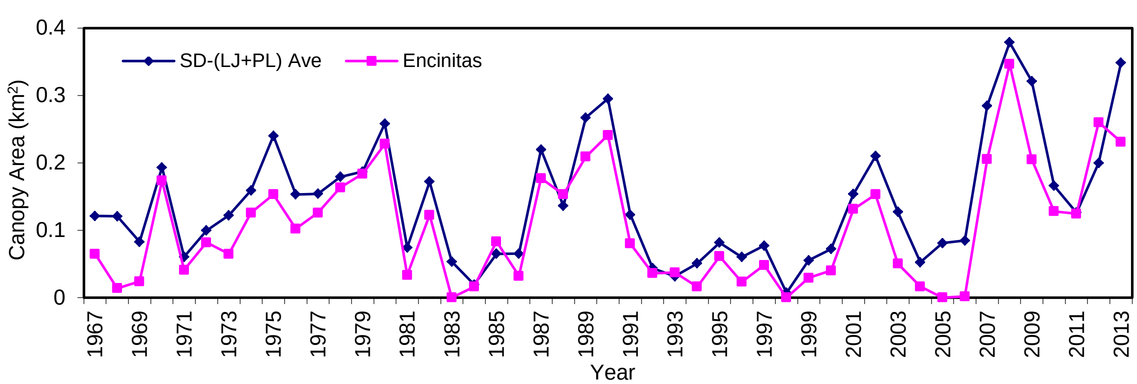


Figure 63. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Encinitas kelp bed for the years shown.

Cardiff and Solana Beach. Crandall did not record a kelp bed in this region in 1911. Because these two beds are typically quite large during RNKSC surveys, it suggests that unknown environmental factors probably were responsible for their absence more than 100 years ago. According to Cameron (1915), seafarers reported the kelp beds were in poor condition during Crandall's survey in 1911. Because of their close proximity and an almost arbitrary demarcation line between the two, they are treated together here. However, they are large enough that the north and south end of the beds can respond differently to environmental signals. These two large beds were not recorded until 1955, but that total (0.340 km^2) included not only Solana Beach, but also Del Mar kelp, as did a total of 0.400 km^2 recorded in 1959, and 0.160 km^2 recorded in 1963. In 1967, individual bed estimates were 0.125 km^2 for Cardiff and 0.290 km^2 for the Solana Beach bed. By 1975, the individual total coverage was 0.125 km^2 for Cardiff and 0.290 km^2 for Solana Beach, and by 1980 Cardiff increased in area to 0.442 km^2 and Solana Beach to 0.690 km^2.

Following several poor years, including the El Niño of 1983–1984, kelp increased at Cardiff to 0.575 km^2 and at Solana Beach to 0.488 km^2 in 1989. Kelp beds in both locations subsequently shrank and were relatively small through 1999. By the end of 1999, substantial numbers of scattered giant kelp were found throughout the offshore areas of Cardiff and Solana Beach, with several large canopies observed in both areas in December.

In 2000, kelp beds were large and appeared healthy, and were more than double the size documented in 1999. Both kelp beds continued to expand in 2002 (0.405 km^2 offshore of Cardiff and 0.488 km^2 offshore of Solana Beach), but the beds declined by 50% in 2003, and canopy size decreased by another 80–90% in 2004. The March and June aerial surveys of 2005 recorded substantial increases in canopy in the south at Solana Beach from that observed in December 2004, but the more northern Cardiff kelp bed was not observed. By the end of 2005, there was still no canopy at Cardiff, while the Solana Beach bed increased to 0.093 km^2. In April 2006, there was a slight amount of kelp in the Cardiff bed, but only a trace at Solana Beach and no kelp was observed at either bed in June. A survey by vessel in late July 2006 did not record any kelp on the surface, but a diver survey recorded substantial numbers of sub-adult, juvenile, and recruiting kelp on bottom. In addition, four adult pink abalone (*Haliotis corrugata*), an herbivore that feeds on kelp, ranging in size from 14 to 18 cm in length, were observed in a 15-minute dive survey indicating that kelp canopy was sufficient for a period of time to support these herbivores. Apparently, kelp remained below the thermocline and survived unfavorable environmental conditions (swells, turbidity, and low nutrients) that caused a decline in the adult kelp populations for most of the year. By December 2006, small canopies formed at both sites. Both beds were larger (but still below average) in early 2007; they disappeared by the October 2007 survey, but again reappeared as very substantial kelp beds in December 2007 (0.286 km^2 offshore of Cardiff and 0.457 km^2 offshore of Solana Beach). These bed sizes were larger than those recorded since 2002.

Both beds increased in canopy coverage by the June 2008 aerial survey, with Cardiff appearing substantially larger, and Solana Beach somewhat larger. By the December 2008 survey, the total canopy coverage at Cardiff was 0.484 km^2 (largest bed size since 1989) and 0.823 km^2 offshore of Solana Beach (its largest recorded size). As can be seen in the RNKSC record, substantial beds can disappear as they did in 2006 and reappear two years later in 2008 as very large beds, which could explain why Crandall reported no beds here in 1911. Cardiff increased in early 2009 to 0.520 km^2, while Solana Beach decreased to 0.505 km^2 by March. Both beds decreased during the next two surveys and rebounded to healthy but smaller beds by December 2009. The two beds decreased in 2010, along with most of the other beds in this region, to about one-half of their combined sizes in 2009: 0.213 km^2 at Cardiff and 0.318 km^2 at Solana Beach.

In 2011, both the Cardiff and Solana Beach kelp beds did not appear to be affected by the declines in coverage in the north and far surpassed the performance of those beds: Cardiff increased to 0.395 km^2 and Solana Beach grew to 0.504 km^2. Canopies were noted as very large during the vessel survey in December 2011, and kelp tissues were dark yellow indicating recently adequate nutrients. Surface frond lengths were long (five to seven meters) and about 70 to 90% of them were mature. In 2012, Cardiff kelp bed grew and Solana Beach kelp shrank, but the combined coverage of the two was nearly identical to that of the previous year. In 2013, Cardiff kelp shrank and Solana Beach kelp bed grew, and the combined coverage of the two was 33% larger than in 2012. Combined, these two beds are much larger than the ABAPY in the San Diego Region. Changes in Cardiff/Solana Beach kelp bed sizes have mirrored the other beds in the San Diego region, although the magnitude of the changes was generally greater because of the relatively large size of these two beds (Figure 64).

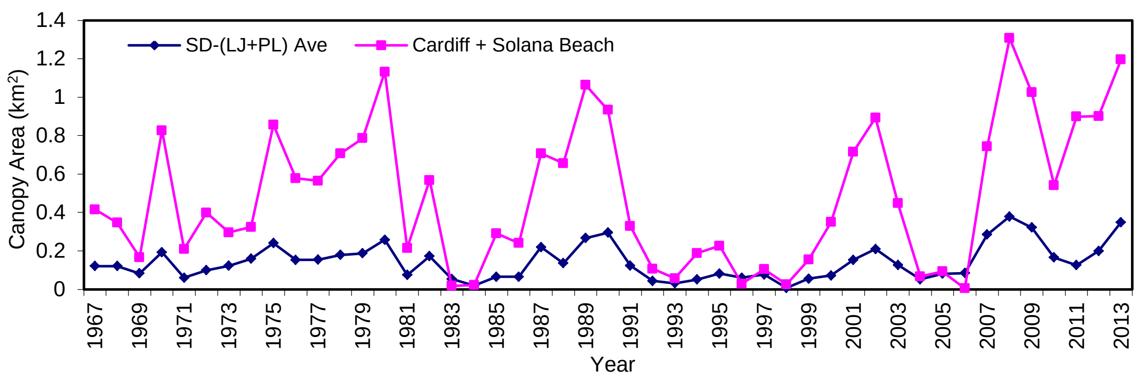


Figure 64. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Cardiff and Solana Beach kelp beds for the years shown.

Del Mar. Del Mar kelp bed was 0.823 km^2 during Crandall's survey of 1911. Rosenthal et al. (1975) characterized this kelp forest during their study done between 1967 and 1973. Plants in this stand occur on mixed sandstone and siltstone bottoms, with large areas of sand and silt among the rock, and the kelp is isolated by surrounding sand. The depth of this low-relief reef is between 14 and 20 m. The understory vegetation beneath the giant kelp canopy at Del Mar was relatively sparse, with only a few Southern palm kelp *Pterygophora californica,* the large leafy brown alga *Laminaria farlowii,* and a few foliose browns and reds occurring. Most of the bottom was covered with encrusting red algae.

Although this kelp bed was measured in 1955, 1959, and 1963, its area was combined with those from both Cardiff and Solana Beach. The first individual record after 1911 was in North's 1967 survey when canopy coverage totaled 0.190 km^2 (North and MBC 2001). It was a small bed for a few years thereafter and then was similarly large in 1974 to 1980, reaching a canopy size of 0.310 km^2 in 1979. The bed disappeared during the 1983–1984 El Niño, and was relatively small until 1989, when it responded favorably to a La Niña, but was small (<0.100 km^2) through 1995. Canopy at Del Mar kelp bed disappeared in 1996 and 1997. Only small kelp canopies were present along Del Mar by June of 1998, and these too disappeared and were not seen during overflights throughout 1999.

By the October 2000 survey, a trace of kelp appeared, and small canopies formed by December. Small kelp canopies at Del Mar were present in the April overflight of 2001, but they did not increase substantially throughout the remainder of the year. The Del Mar bed more than doubled in size between 2001 and 2002, beginning as small canopies that were observed in the April 2002 aerial survey and becoming somewhat larger (but still very small) by the December 2002 survey (0.035 km^2). In 2003, the bed was only about one-third of its largest extent noted during the previous two decades; it disappeared by the first aerial survey of 2004 and was not recorded during any of the subsequent aerial surveys of that year. Del Mar kelp bed was not observed during any of the aerial surveys of 2005 and 2006, and was not observed during a vessel search in the area in late July 2006. The bed reappeared in 2007, and after an absence of three years, canopy size was larger than any size recorded since 1995. Almost all of the kelp fronds were dark yellow and young, indicating that adequate nutrients were recently available.

The bed at Del Mar was present during the survey of June 2008, and by December 2008, it covered an area of 0.057 km^2. Del Mar kelp bed was reduced by March 2009, but was substantial in June. Kelp was below the thermocline in September and reappeared in December as a bed with canopy coverage of 0.044 km^2. Although it was a small bed, its size in 2010 (0.038 km^2) was similar to that in 2009. It grew in 2011 to a much larger bed (0.074 km^2) than it had been since 1990. It was found in two distinct patches with scattered kelp between the two, suggesting that favorable conditions could foster the bed to reach the size observed in 1989. In 2012, the bed reacted similarly to Solana Beach to the north and La Jolla to the south by shrinking considerably in size, suggesting nutrients were not adequate through the year. In 2013, however, Del Mar kelp bed doubled in size. This kelp bed typically has mirrored the other beds in the San Diego region, although it reacted opposite the ABAPY during 2011–2012. Its size has usually been much smaller than that of the ABAPY since 1983 (Figure 65).

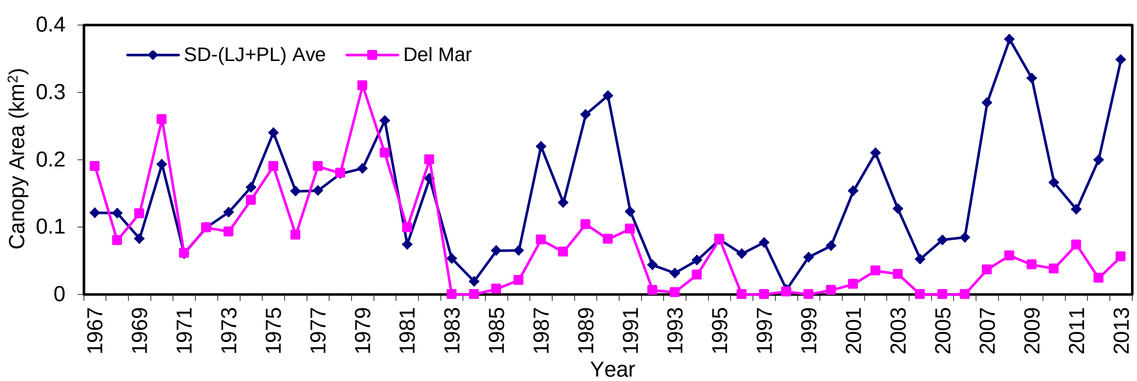


Figure 65. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Del Mar kelp bed for the years shown.

Torrey Pines. Torrey Pines kelp bed appeared in our records as a small trace of kelp during La Niña conditions in 1988 and 1989. It reappeared in 2006 as a measurable canopy (0.010 km^2) with scattered giant kelp about 1.5 km north of Scripps Pier and another concentration about 3.5 km north (MBC 2007b). Another concentration of scattered giant kelp was found about 1.5 km north of that position (5 km north of the pier). By 2007, no kelp was observed at this site, but a small amount was observed in 2008 and 2009 about 3.5 km upcoast of

Scripps Pier. That kelp was present in approximately the same location in 2010, but it disappeared in 2011. In 2011, the kelp bed appeared about 6.3 km upcoast of Scripps Pier and it was substantial at 0.031 km^2, it was almost the same size in 2012 at a coverage of 0.034 km^2, and it was in the same location. A vessel survey indicated the bed was situated in depths of about 10 to 12 m and measuring about 50 m by 200 m in a longshore direction. The bed had medium density, the blades were dark yellow, and the fronds were noted as being about 50% mature and 25% young. Horizontal frond length was four to five meters, but only about 20% of the visible apical meristem tips were viable. One giant kelp plant was also observed in 2012 at the artificial reef about 2.5 km north of the pier. In 2013, Torrey Pines kelp bed was measured at its largest extent (0.081 km^2). During a dive survey in December 2013, kelp was growing at depths of 7 to 11 m, 70% of the fronds were classified as young, and tissues were dark yellow.

LA JOLLA

La Jolla. La Jolla kelp bed was composed of two main canopies that were large (7.889 km^2) when Crandall measured them in 1911. The canopy coverage was similar in magnitude in 1934 (8.161 km^2) and 1941 (7.847 km^2), but it suffered a reversal during the next 14 years, and by 1955 it only covered an area of 1.660 km^2. In a survey conducted in 1959, the beds were almost as large as observed in 1911, at 6.490 km^2, but by the time North began surveying in 1967, they were reduced to very “small” beds (for La Jolla) covering only 0.330 km^2 (North and MBC 2001). Over the next 13 years (to 1980), canopy size ranged between 0.290 and 1.900 km^2 and averaged about 0.800 km^2. The beds were very small during the El Niño of 1983–1984 (covering 0.032 and 0.034 km^2, respectively). The beds rebounded in 1987 and by 1989 the kelp at La Jolla increased to 4.755 km^2, a significant fraction (60%) of the size seen in 1911. The kelp at La Jolla decreased in size during most of the ensuing nine years, and canopy size reached a 14-year low (0.215 km^2) during the El Niño in 1998.

La Jolla kelp rapidly increased in size during the La Niña of 1999–2000. The kelp beds were very large in the April 2000 aerial survey and appeared to be reclaiming canopy in the shallow portions that disappeared in 1998. In 2001, kelp was dense, extensive, and healthy and growing beyond the 25-m depth contour on the north edge of the bed, and out to 29 m on the offshore edge. The beds stayed large through 2002 and for most of 2003 (reaching 3.444 km^2), before decreasing each of the next three years (to 0.117 km^2 in 2006). By the September 2006 survey, only a trace of kelp was visible from the air, and by December 2006, any recovery was limited. In December 2006, divers failed to locate any kelp on bottom in relatively shallow water (25 m) in a previously dense portion of the bed. Kelp appeared stressed during the first three aerial surveys of 2007, and individual kelp were common, but no coherent canopy was present by late July 2007. However, by the December 2007 survey, canopy size grew to 2.750 km^2.

The La Jolla kelp bed continued to grow and by the December 2008 aerial survey it was at its largest size (4.145 km^2) since 1989. Nutrient conditions by March 2009 were apparently not adequate, or there were losses from powerful storms that occurred in mid-February 2009; canopy coverage decreased to 2.274 km^2 by March and the bed was small throughout the remainder of 2009. Both portions of La Jolla kelp peaked during the August 2010 survey, reaching 2.776 km^2 (larger than in 2009), but decreased drastically by the December survey. By the April 2011 survey, neither the northern nor southern section of the La Jolla Kelp bed was showing much canopy; canopy increased by the August and October surveys, but the total size was still below average. By the 21 December 2011 survey, the bed increased to 2.565 km^2.

In 2012, the aerial surveys documented distinct differences in the northern and southern portions of La Jolla, with the northernmost portion recorded as very poor in the aerial surveys and the southernmost portion recorded as average to slightly below average during the first two surveys. Clouds prevented an October view of the bed, but based on the other beds in the region classified as "well below average" to "below average", they probably did not fare well. However, by December 2012, the bed sizes began to increase (especially in the southern portion) but only to 1.569 km^2, a loss of almost 1.0 km^2 since the previous year. The vessel survey about two weeks later confirmed that nutrients were present as the surface fronds were a dark yellow. In 2013, La Jolla kelp canopy coverage increased by 159% to cover more than 4 km^2. This year was only the fourth time since 1941 that kelp coverage has exceeded that amount. During an inspection in December 2013, the kelp was growing as deep as 26 m, tissues were dark yellow, 80% of the fronds were mature, and frond length was six to eight meters.

The La Jolla kelp bed has usually mirrored that of the ABAPY (based on the La Jolla and Point Loma kelp bed averages), except for a few aberrant years such as 1970, 1993, 2002, and 2012 (when the ABAPY was opposite that of La Jolla). This suggests that overall; they are affected by the same oceanographic regime, but that small differences in bathymetry and currents can still make profound differences to kelp beds that otherwise appear very closely related (Figure 66).

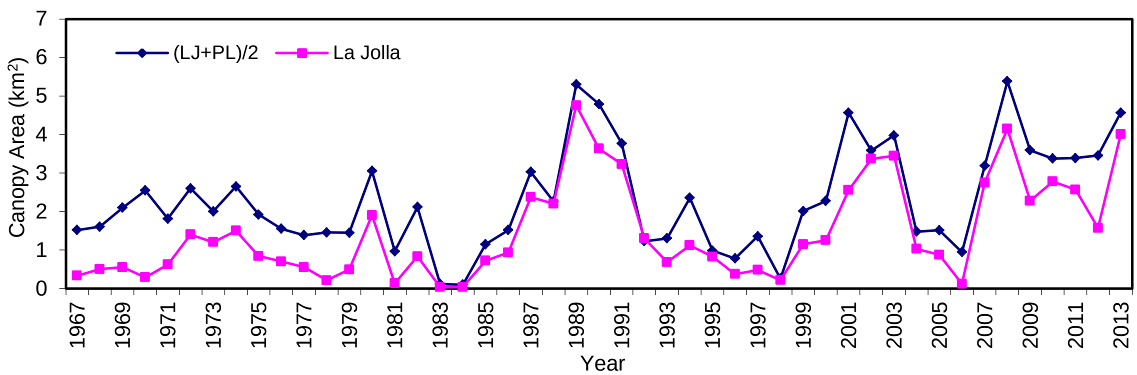


Figure 66. Comparisons between the (LJ+PL)/2 ABAPY and canopy coverages of the La Jolla kelp bed for the years shown.

POINT LOMA TO IMPERIAL BEACH

Point Loma. The Point Loma kelp bed is composed of many, usually contiguous kelp canopies ranging from depths of 5 m to over 30 m during good nutrient years. These beds were very large in 1911 during Crandall's survey, and they covered a linear distance of almost "eight nautical miles" and an area of 18.523 km^2 (Table 1, North and Jones 1991). Crandall's survey total matched the amount recorded during a survey conducted in 1857, indicating that Crandall's perimeter measurements (other than the inability to see gaps in coverage) were probably accurate (Table 1, SWQCB 1964, Neushul 1981, Appendix B). The canopy coverage was smaller, but still very large in 1934 (11.465 km^2) and in 1941 (8.286 km^2), but waned considerably over the next 14 years, and by 1955 the canopies covered an area of only 1.990 km^2. In a survey conducted in 1959, the beds were much smaller than observed in 1955, but by the time North (North and MBC 2001) began surveying in 1967, they covered 2.700 km^2, and grew to 4.990 km^2 by 1970.

By 1980, the beds at Point Loma covered 4.2 km^2, nearly disappeared during the 1983–1984 El Niño, but covered almost 6 km^2 by 1989. Following a low point with canopies covering less than 0.3 km^2 during the El Niño of 1997–1998, the peak canopy expanse at Point Loma (since 1941) of 6.6 km^2 was recorded in 2001 following the La Niña of 1999–2000. Kelp canopies grew well in 2001 during an exceptionally clear-water period of intense upwelling. After the peak in 2001, the kelp bed dissipated and was noticeably smaller during all of the 2002 surveys; it retreated from deeper depths, but still covered much of the same area. It was, however, more diffuse and scattered holes were apparent along the entire length of the bed. After losing about 40% of its size in 2002, the kelp bed increased in 2003 (covering 4.509 km^2). In early 2004, the bed at Point Loma shrank again and by December 2004, it was less than one-half the size noted in 2003. The Point Loma kelp bed lost a large amount of surface canopy, but the loss was mostly confined to the deeper areas. From 2004 through 2006, Point Loma kelp was about 2 km^2.

It appeared to be much reduced during the first three aerial surveys of 2007, but Point Loma kelp nearly doubled in size (3.616 km^2) by the end of 2007. The kelp bed was much larger by June 2008, decreased somewhat during the summer, and by December 2008, it rebounded to its largest size (6.623 km^2) since 1941. Point Loma kelp canopy decreased by 26% in 2009 and in synch with La Jolla kelp bed, this bed also peaked in August 2010 with a total canopy coverage of 3.977 km^2; however, it declined precipitously throughout the remainder of 2010. Point Loma kelp had smaller canopies in April 2011; however, by the August aerial survey small improvements were noted in the canopies (with better recovery in the southern portion), and by October the northern portion improved. By the December 2011 survey, the northern portion of the bed exceeded the gains noted in the southern portion and the bed covered an area of 4.212 km^2. Responding to nutrient pulses that appeared to affect the northern portion of Point Loma more than the southern part (based on the quarterly surveys), the bed was 5.340 km^2 in December 2012. By that time, Upper Point Loma appeared well above the average while Lower Point Loma was above average, and the difference likely resulted from variations in the local oceanographic regime. In 2013, Point Loma canopy decreased by 4%, but it was still larger than recorded in 9 out of the last 11 RNKSC survey years. The Point Loma kelp bed canopy sizes have mirrored the ABAPY (based on the La Jolla and Point Loma kelp bed averages) (Figure 67).

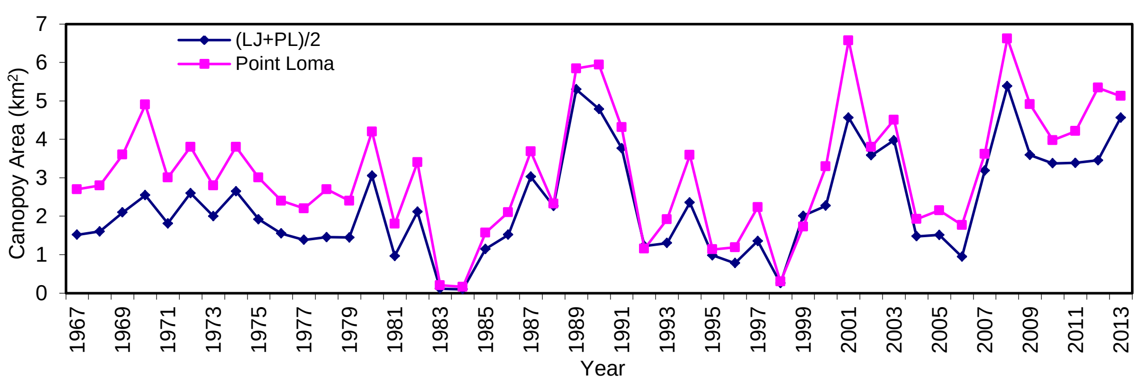


Figure 67. Comparisons between the (LJ+PL)/2 ABAPY and canopy coverages of the Point Loma kelp bed for the years shown.

IMPERIAL BEACH TO BAJA CALIFORNIA, MEXICO BORDER

Imperial Beach. The Imperial Beach kelp bed canopies covered 0.984 km^2 during Crandall's survey of 1911; however, they were not observed during surveys from 1967 to 1980. This area was the focus of restoration efforts by North in the mid-1960s and the 1970s; urchins dominated the substrate and consumed the kelp, and Dr. Wheeler North's considerable efforts in this area met with repeated failure as urchins overwhelmed the canopies. Ultimately, these efforts culminated in the appearance of a relatively large kelp bed (0.350 km^2) in 1980, although it was only about one-third the size noted by Crandall in his 1911 survey. Imperial Beach kelp bed did not survive the El Niño of 1983 –1984, but it appeared in 1985 as a small bed.

Imperial Beach kelp bed persisted through 1990, and its peak coverage (0.727 km^2) in 1987 was atypical compared to every other bed in Region Nine, which did not peak until the 1989 La Niña. After 1991, Imperial Beach kelp was relatively small until it disappeared in 1998, but it reformed as a single small bed in 1999 and 2000, and was farther south than its previous location off of the Imperial Beach Pier. By late September 2005, the beds at Imperial Beach were larger (0.400 km^2) than they had been since 1990; but, in the final survey for the year, they were greatly reduced in size.

The Imperial Beach kelp beds have responded differently than most of the other beds in the region during much of the past two decades. The Imperial Beach kelp bed canopies increased significantly in 2005 and 2006 while most other beds in the region decreased greatly from lack of nutrients, persistent phytoplankton blooms, and large swells. By the December 2006 survey, the kelp beds were very robust and regained the size (0.400 km^2) recorded in 2005. The beds did not appear to be reacting favorably to environmental conditions during the first three aerial surveys of 2007, but by the December survey, the canopy size significantly increased (1.493 km^2), far larger than Crandall (considered the baseline) recorded in 1911. The Imperial Beach kelp bed canopies increased in size by the June 2008 aerial survey, and by the December 2008 survey were extending farther south than noted in 2007. Canopy area in December 2008 (1.895 km^2) was larger than in 2007. However, the extremely large kelp canopy did not last, and by March 2009 only 0.862 km^2 was recorded (which was almost as large as Crandall recorded in 1911). This bed became progressively smaller in 2009 and disappeared between the 17 December 2009 and 28 March 2010 surveys.

The almost entire loss of this bed by the end of 2010 (canopy of only 0.004 km^2) is not explained but indicates that a major disruption occurred earlier in the year. Sea urchin grazing and storms were implicated in previous losses of Imperial Beach kelp bed; however, a diving survey that would have elicited information on urchin status was not conducted until the end of 2010. Examination of the wave record from the CDIP Point Loma South station offshore of Imperial Beach suggest that large swells may have been the cause of, or at least contributed to, the loss. Wave heights in late December 2010 and January 2011 reached three to four meters on several occasions. This included a one-week period in January with sustained swells exceeding three meters (MBC 2011b). It is very likely that these sustained swells negatively affected the kelp found on the cobble bottom. The bed was represented only by kelp remnants in the August and November surveys, and was not much greater by the 31 December 2010 aerial survey.

The bed was not observed during the April or August 2011 surveys, but reappeared in October as two separate kelp patches that were small (0.152 km^2) but considerably larger than noted in 2010. By the December survey, the beds decreased again. Interestingly, the vessel survey in December 2011 determined that one small canopy in deeper water (18 m) was actually comprised almost exclusively of Elkhorn kelp. In 2012, the kelp was scattered over a wide area, but was mostly congregated in three disparate locations and totaled 0.333 km^2. Biologists observed dark yellow blades, and about 80% mature fronds, with 50% of the apical meristem tips (scimitars) viable. A subsequent dive was conducted on one of the deeper kelp patches. The bottom was characterized by medium to large cobble and the kelp bed was a mixture of giant kelp and Elkhorn kelp. Urchin density was low, and only a few invertebrates and fishes were noted in the kelp bed despite excellent (four to five meters) visibility. This bed grew by almost 60% in 2013, and was still concentrated in three disparate patches. In December 2013, divers noted that 90% of the fronds were young, with lengths of three to four meters, and tissues were medium-yellow at the surface, but medium- to dark-brown in midwater. Kelp was growing in water as deep as 18 m off the Imperial Beach Pier, and multiple subsurface kelp plants were observed at this location.

Except for the period from 1967 to 1979 (when it was missing), the Imperial Beach kelp bed generally followed the ABAPY. In 2013, the Imperial Beach kelp bed followed the San Diego region kelp bed ABAPY (Figure 68).

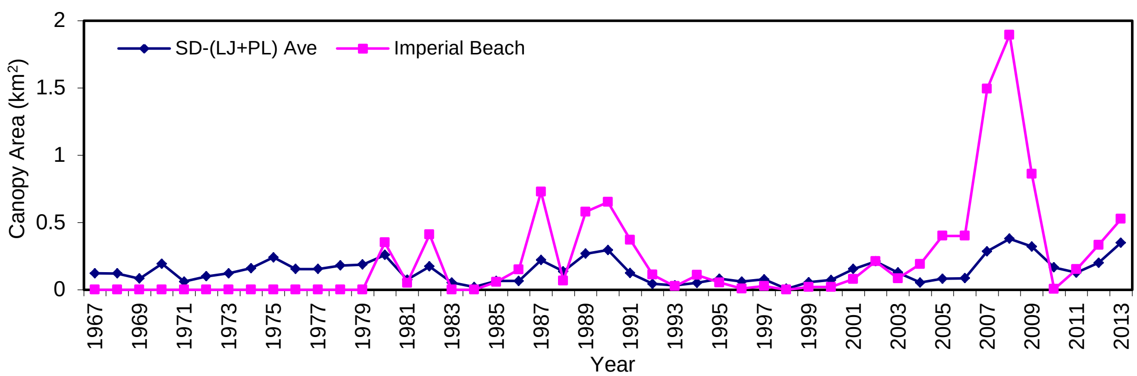


Figure 68. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Imperial Beach kelp bed for the years shown.

UPDATE TO THE PRESENT

One aerial survey for 2014 has been conducted (on 7 April). Based on a preliminary review of the data, kelp coverage declined throughout southern California. The daily pattern in temperature change tracked closely between the northern and southern automated sampling stations through May 2014 (the latest data available) (Figures 10 and 11). Surface temperatures were well above average throughout southern California during January and February, but there was an influx of colder water in March 2014. This drop in temperature was less pronounced at Point Loma, where temperatures stayed above average through May. By April, however, temperatures at most locations were back above average, and by May temperatures at all locations exceeded historical norms. At this early stage, it is unclear how the Central Region and Region Nine kelp beds will fare in 2014. At the time of this writing (7 June 2014), El Niño neutral conditions persist at the equator, but the probability for El Niño to develop will increase throughout the summer, and most models predict El Niño will develop by fall.

DISCUSSION

Overall Size

Total canopy size within the 50 kelp beds monitored as part of the CRKSC and RNKSC programs was above average in 2013. Canopy cover off Ventura to San Diego County increased 29% from the previous year.

Spatial Trends

There were major differences in the growth/contraction of kelp beds between the two regions. Kelp coverage in the CRKSC stayed about the same in 2013 (1% reduction), whereas coverage in Region Nine increased substantially (by 44%). Within each region, there were also major spatial differences in gains/losses. The beds farthest upcoast—from Deer Creek to Lechuza—all gained canopy, and two of those beds doubled in size. However, 11 of the 12 beds between Point Dume and Sunset lost canopy in the last year. The average change in size from 2012 was about -14%. The angle of the coastline from Point Dume to Santa Monica Bay is slightly different from that in other areas of Region Nine, and this affects the exposure to waves. Currents and water quality characteristics at Point Dume can vary on small scales. On 9 June 2014, the Regional Ocean Model System calculated temperatures were 2.2°C warmer immediately upcoast of Point Dume than downcoast, and currents were flowing in opposite directions (north-northeast just upcoast from Point Dume, and southwest just downcoast from the Point). The differences in bed performance could be related to these differences in flow regimes and water quality. The upcoast part of the Palos Verdes beds also fared poorly, and decreased in size by about 27%. The PV II and PV III beds were similar in size compared to last year, while the PV IV and Cabrillo beds increased substantially (>75%). A similar pattern was observed during 2005.

Within Region Nine, kelp appeared offshore the Santa Margarita River mouth for the first time in 22 years, and only a few kelp beds decreased in size since last year: North Laguna Beach, Encinitas, and Point Loma. These losses were fairly minor (-4% to -26%), and despite reductions, these three beds were still considered to be large compared to canopies recorded in the last few decades.

Temporal Trends

From Newport Beach to the Imperial Beach, almost all of the kelp beds were at their minimum size in summer (July), and reached their maximum extent in winter (December). Point Loma kelp bed, however, was at its largest size in fall (September); it was also one of three beds that shrank in 2013. From Ventura to Newport Beach, the majority of the kelp beds were also at their greatest size in December. The kelp growing on breakwaters at Ventura Harbor, Channel Islands Harbor, and Port Hueneme, and the Palos Verdes and Cabrillo beds, showed the most canopy in fall. Most of the beds from Point Dume downcoast to Sunset were at their maximum extent in spring (May); most of these beds also lost canopy in 2013.

Oceanographic Processes

Temperatures during the first three months of 2013 were mostly below average, and even though they increased to above the norm from March through May, there were several influxes of cold water from Point Dume to the SIO Pier (but not at Point Loma). The upwelling index (from 33°N latitude 119°W longitude) indicated strong upwelling in February, March, and April compared to the 66-year average since 1946. This could explain why most of southern California's kelp beds had above-average canopy coverage in May 2013.

The SSTs throughout the region increased in May and June, and upwelling was reduced. Strong cold-water pulses were evident in both regions from June through September. One of the most notable events that occurred in 2013 was the region-wide drop in temperature in July and August. Temperatures throughout southern California were below average to well below average during a period that is usually not conducive to kelp growth. Even though the upwelling index calculated normal upwelling in July and August, there were multiple cold-water events during these months. In September, temperatures returned to average (and above average) for the remainder of the year.

During the 2013–2014 nutrient season (beginning in July and ending in June the following year), the NQ values in the Central Region were low, ranging from 4 to 13 (20 to 30 is about average). The NQ values in Region Nine were similarly low (ranging from 7 to 12). In the Central Region, NQ values at all locations were the lowest since the CRKSC was formed (2003), and in Region Nine, NQ values were also well below average, but similar to those recorded in 2004–5 and 2009–10. Despite the low calculated values, Wells et al. (2013) reported above-average upwelling in the California Current System, and through mid-2013 they reported the highest upwelling recorded, although there were unidentified regional differences, and upwelling relaxed in summer and fall. Throughout the California Current, nitrate concentrations were well above average in spring 2013. Even though the NQ values were low at Newport Beach, all of the beds between Newport and San Onofre gained canopy except one: North Laguna Beach. Santa Margarita kelp bed appeared for the first time in more than 20 years, suggesting favorable environmental conditions. Despite lower-than-average NQ values in southern California in the last half of 2013, nearly all of the kelp canopies in Region Nine increased in 2013.

The NQ values have historically been calculated for each "indexed year", which spans from July through June of the following year. The logic in this time span is the historical availability of nutrients, which coincided with colder temperatures during winter and spring (i.e., December through May/June) (North and MBC 2001). The NQ values for calendar years from 2010–2013 were calculated for multiple sites in both regions. In the Central Region, NQ values at all locations (except Santa Monica Pier) were lower in 2013 than they were in

2010, 2011, and 2012. At Santa Monica Pier, the 2013 NQ of 33 was higher than the NQ from 2012 (27) and 2010 (31). In Region IX, NQ values at San Clemente and the SIO Pier were slightly higher in 2013 than they were in 2012; the NQ value at Point Loma South was lower in 2013 than in 2012.

Even though the temperature patterns were fairly similar across southern California, and NQ values were regionally low, some distinct SST patterns have developed over the last few years. At Point Dume, the number of days >16–20°C has increased above the 20-year mean since 2011 (Table 12). Likewise the number of days <13–14°C has declined substantially. At Newport Beach, the number of days >16–18°C increased in 2013, but so did the number of days <14°C. Lastly, at Scripps Pier, the number of days with SST below 13–14°C during the last three years has been well above the long-term mean, which could explain the protracted kelp growth. Conversely, the number of days with SSTs above 16°C has been at or below the long-term mean.

Table 12. Days above or below specific temperatures at three locations in southern California: 2011, 2012, 2013, and the 20-year mean. Red cells indicate years above the long-term mean (16–20°C) and blue cells below the long-term mean (13–14°C).

	Mean (1993-2012)	2011	2012	2013
Point Dume				
>20°C	9	0	**58**	**18**
>18°C	59	**65**	**111**	**132**
>16°C	147	**163**	**211**	**214**
<14°C	87	**89**	54	59
<13°C	35	29	23	7
Newport Pier				
>20°C	31	5	22	31
>18°C	102	63	**113**	**114**
>16°C	196	159	195	**221**
<14°C	60	56	56	**64**
<13°C	22	7	17	11
SIO Pier				
>20°C	71	13	29	61
>18°C	135	46	115	**136**
>16°C	210	128	190	191
<14°C	14	**72**	**51**	**53**
<13°C	1	**10**	**13**	**8**

The pattern in mean SST has also differed along the coast. During the last three years, annual mean SSTs at Point Dume exceeded the 20-year mean each year, and they were substantially higher during the 2012–2013 (Table 13). However, temperatures were only slightly higher than the long-term mean at Newport Beach, and lower than the long-term mean at SIO Pier.

Table 13. Comparison of (1) mean temperature from 1993–2012, and (2) annual mean temperature during 2011, 2012, and 2013 at three location in southern California. Cells in red are higher than the long-term mean, and those in blue are lower.

	Mean SST (°C; 1993-2012)	2011 Annual Mean SST (°C)	2012 Annual Mean SST (°C)	2013 Annual Mean SST (°C)
Point Dume	**15.6**	15.7	16.8	16.8
Newport	**16.5**	15.9	16.6	16.7
SIO Pier	**17.6**	15.7	16.6	17.0

La Niña conditions persisted in the Pacific Ocean through half of 2010 and most of 2011, and dissipated in early 2012. During this period, most of the kelp beds in the region achieved larger-than-average canopies. Despite a return to ENSO neutral conditions in 2012 and 2013, kelp coverage was higher than average, particularly in Region Nine. In light of recent studies suggesting that all of southern California has been subjected to a marine environment relatively depleted in nutrients since 1977, the respite from El Niño conditions has benefited the kelp beds.

Other environmental factors appeared from the data to have had minimal effects on the kelp beds of both regions during 2013. Annual rainfall in 2013 was the lowest on record, so effects from runoff (turbidity) were likely negligible. It is unknown if the reappearance of kelp off the Santa Margarita River mouth resulted (partially or in whole) from the low rainfall the last few years. A berm formed across the river mouth in 2013, so potential sediment flow into the nearshore zone (and turbidity) was at least partially interrupted at that location. Point Loma was one of three beds in Region Nine to wane in 2013. It is not known if kelp is being harvested from Point Loma kelp bed, but Kelp Bed Number 3 was leased from the state in 2012.

The wave climate was relatively mild in 2013, with very few waves approaching or exceeding the four-meter range from the west, where one would expect to see damage from breaking waves. None of the periods of intense swell lasted long enough to impart any lasting damage to the kelp beds. There were algal blooms reported in the fall in Del Mar and La Jolla; however, these beds increased considerably despite any effects to water clarity.

CONCLUSION

Kelp bed performance varied by region in 2013. Beds from Deer Creek downcoast to Lechuza all grew, and coverage in that stretch of coast was the highest since 2004. Eleven of the twelve beds from Point Dume downcoast to Topanga shrank, however. Most of these beds are relatively small, and the losses were modest. Results at Palos Verdes were mixed. The Newport/Irvine Coast kelp beds were larger than the maximum in the past 50 years. Almost all of the kelp beds in Region Nine gained canopy in 2013, and the regional coverage was the second highest since the 1930s.

Most areas in the region were subjected to similarly large temperature fluctuations synoptically, and responses by kelp beds differed among areas. However, the dramatic decreases in temperature (likely from upwelling) that occurred between San Diego and Newport Beach were not observed at Point Dume. This illustrates that oceanographic conditions throughout the Central Region and Region Nine can differ, and this is reflected by variable kelp bed growth.

Results from 2013 were consistent with those from past kelp consortium surveys, and oceanographic conditions controlled the fate of the Central Region and Region Nine kelp beds. Variations in bed growth (or decline), sometimes within relatively small distances, were likely related to variations in bathymetry, current flow, nutrient availability, etc. There was no apparent correlation between kelp bed growth, or lack thereof, with the various discharges in the region, and there was no evidence to suggest any perceptible influence of the various dischargers on the persistence of the region's giant kelp beds.

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PERSONAL COMMUNICATIONS

Bedford, D. 2004. Dennis Bedford is a marine biologist, working for the Department of Fish and Game, coordinating photographic overflights of the kelp beds of northern California and the offshore islands. Los Alamitos, California.

Curtis, M. 2003, 2010. Mike Curtis is a marine biologist working on kelp ecosystems for MBC Applied Environmental Sciences in Costa Mesa, California.

Elwany, H. 2007. Dr. Hany Elwani is the founder of Coastal Environments and is a scientist working on sediment transport in the Southern California Bight.

Moore, R. 2007, 2010. Robert Moore is a biologist working on kelp ecosystems for MBC Applied Environmental Sciences.

Morris, K. 1995. 16 March 1995. Kevin Morris fishes both freshwater and salt. He is a respected fisherman among his peers and has written numerous articles for fishing magazines. He reported that in several trips in April and May (remembers month because kelp bass were just beginning to spawn) of 1987 and 1988 that he would see two or three giant kelp per trip just below the surface while fishing in 60 to 80 ft depths in different areas of Horseshoe Kelp banks. This is consistent with records of kelp growing on the submerged oil island riprap at the mouth of Huntington Harbor during this same period.

North, W. 2000. Dr. Wheeler North was a well-published and respected kelp ecologist with California Institute of Technology. Dr. North passed away in 2002.

Pondella, D.J. 2012. Presentation to OCMPAC Symposium.

Shipe, R. 2006. Dr. Rebecca Shipe is an Assistant Professor in the Department of Ecology and Evolutionary Biology at the University of California, Los Angeles. Her expertise is phytoplankton ecology and physiology, particularly in southern California coastal zones. Throughout 2005 and 2006, Dr. Shipe investigated the distribution of phytoplankton species within Santa Monica Bay and their relationship to coastal processes.

Simonin, E. 1994. 25 May 1994. Edward Simonin is a retired high school principal from the Long Beach area. Mr. Simonin fished the Horseshoe Kelp area with his father on their boat the Moonstone in the late 1920s and 1930s. Mr. Simonin is still fishing off of the boat the Moonstone IV and has continued to fish the Horseshoe Kelp area frequently since the late 1920s.

Wilson, K. 1986. Ken Wilson is a California Department of Fish and Game Biologist who previously worked on the kelp beds of Southern California for the Department on the Nearshore Sport Fish Habitat Enhancement Project.

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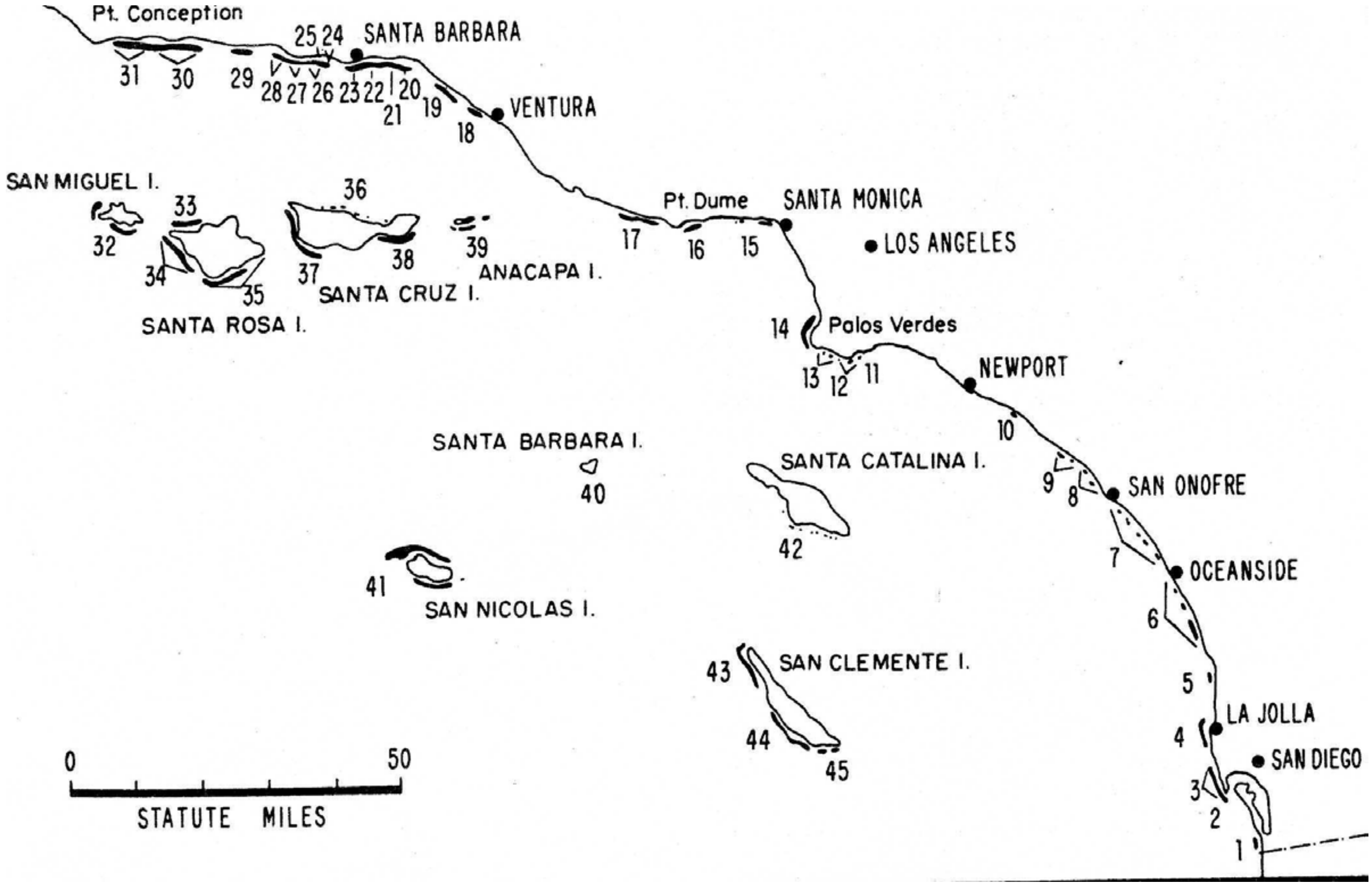
APPENDIX A

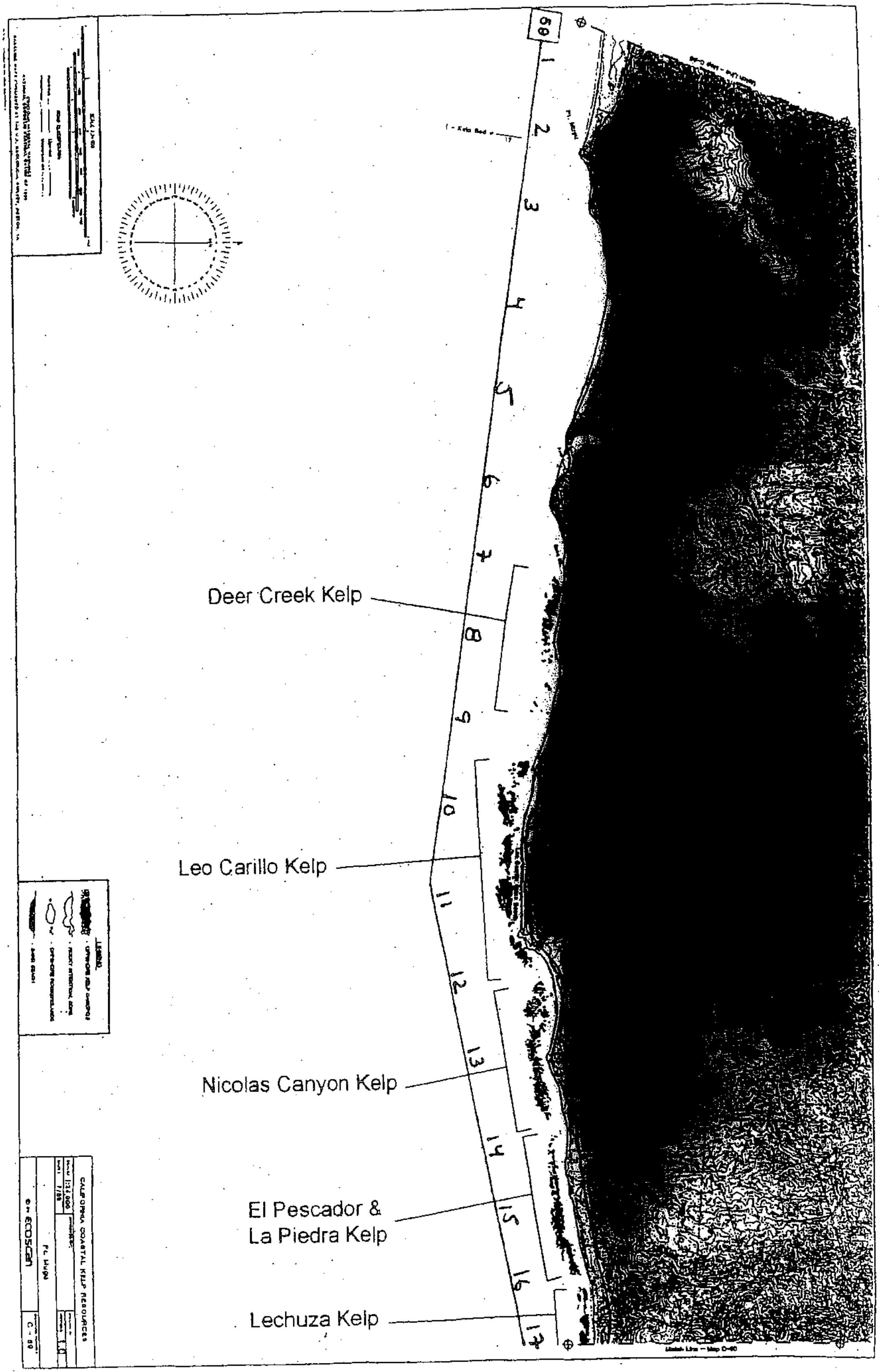
Kelp Canopy Maps

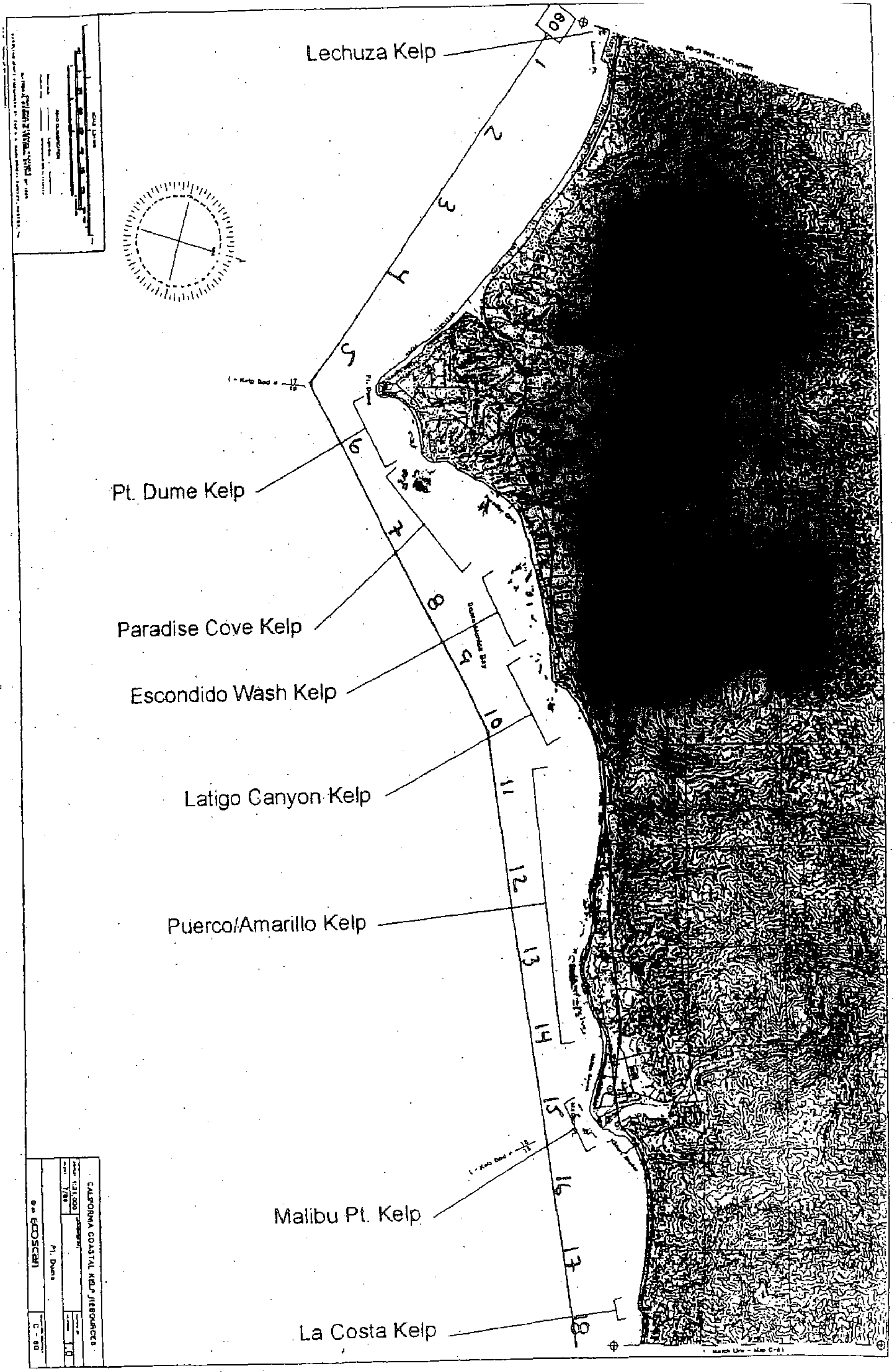


Fish and Game designated kelp bed numbers in the Southern California Bight.

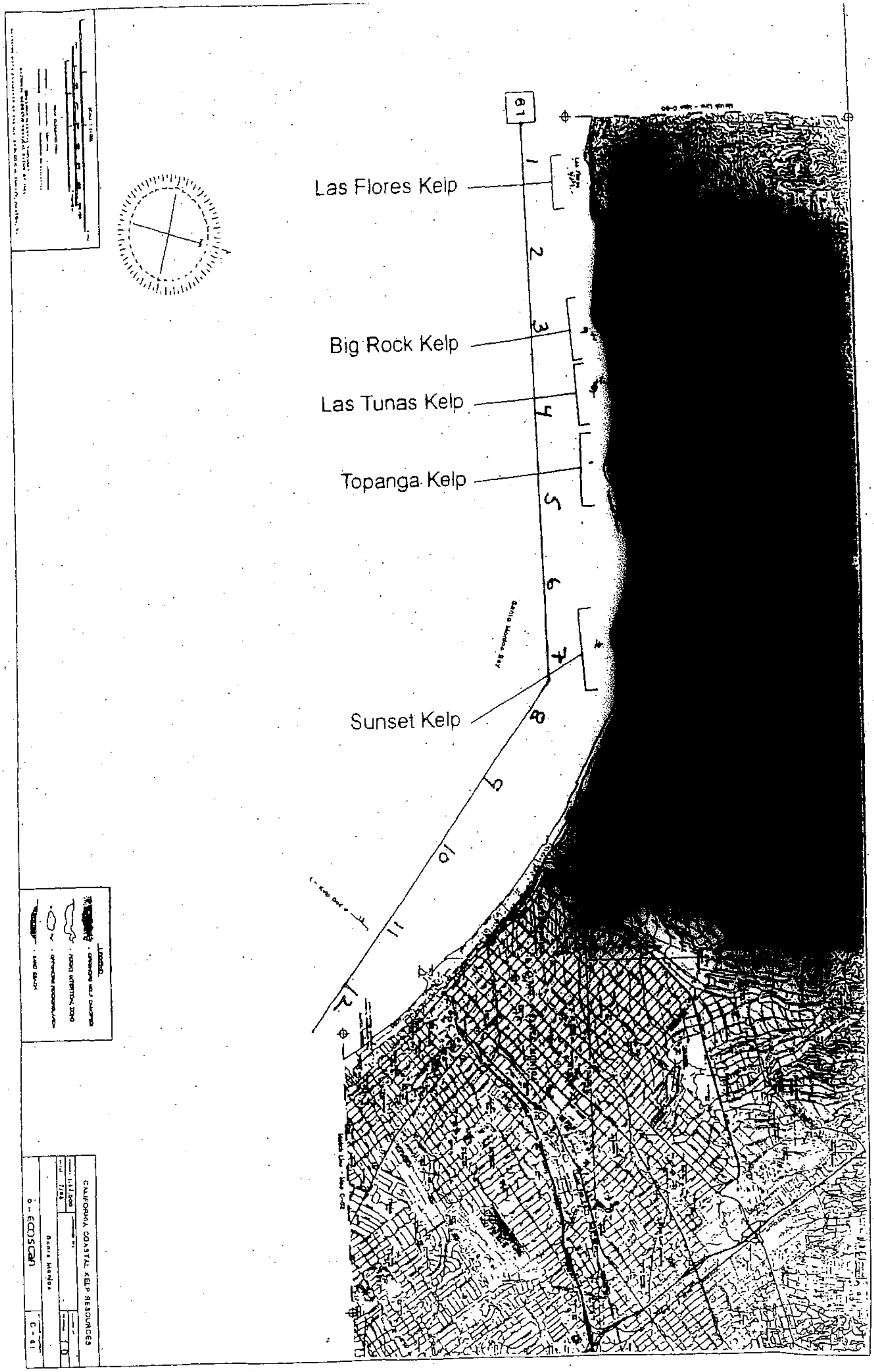
Kelp Slide Atlas

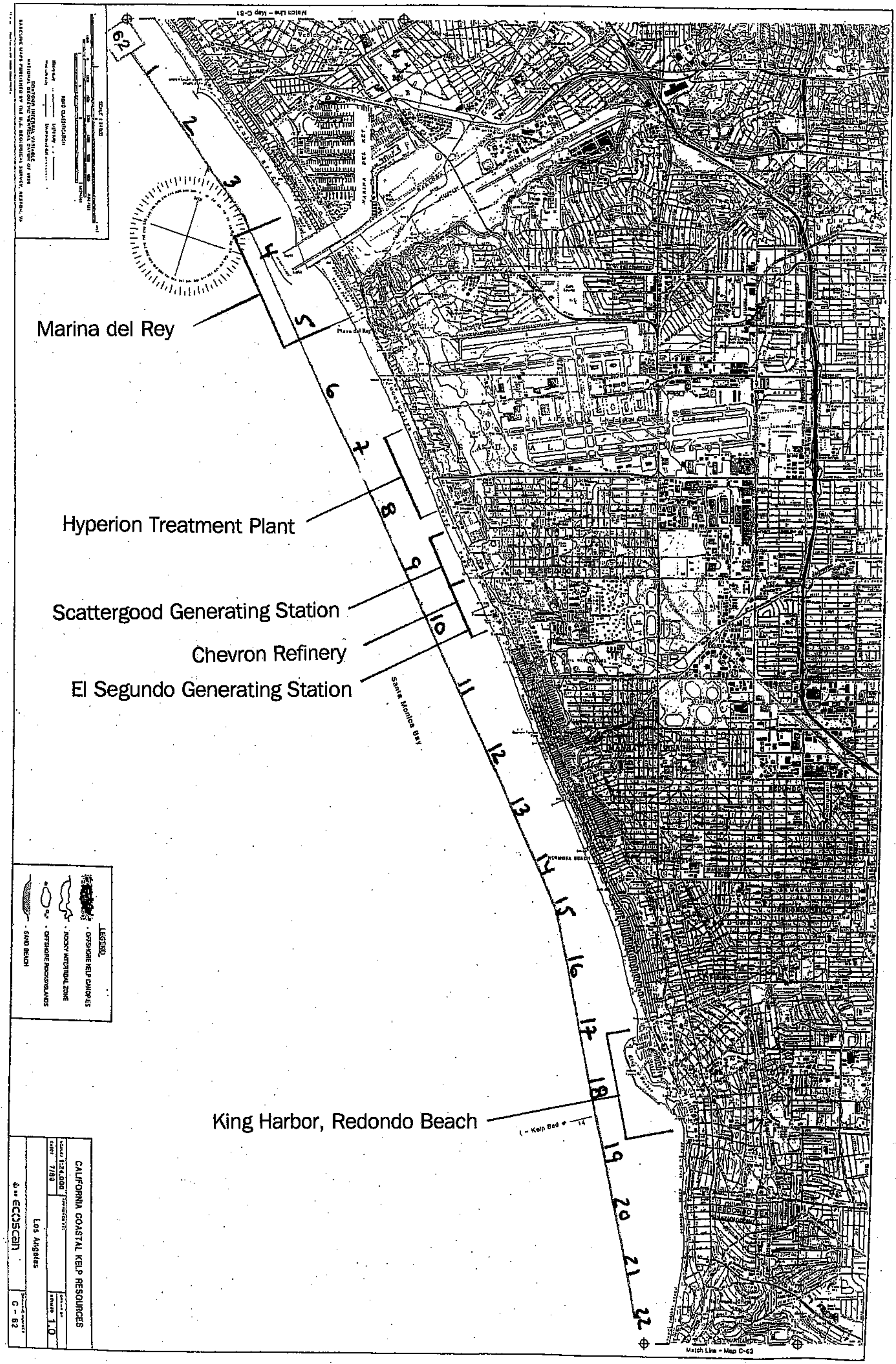
Kelp Bed	Map No.	Shot Nos
Ventura Harbor	57	1 - 4
Channel Islands Harbor	58	1 - 6
Port Hueneme	58	7 - 10
Deer Creek	59	5 - 9
Leo Carillo	59	9 -12
Nicolas Canyon	59	12 - 14
El Pescador/La Piedra	59	14 - 16
Lechuza Kelp	59, 60	16, 1, 2
Point Dume	60	4 - 7
Paradise Cove	60	6 - 8
Escondido Wash	60	7 - 10
Latigo canyon	60	9 - 11
Puerco/Amarillo	60	11 - 14
Malibu Pt.	60	14 - 16
La Costa	60	17 - 18
Las Flores	61	1 - 2
Big Rock	61	2 - 4
Las Tunas	61	3 - 5
Topanga	61	4 - 6
Sunset	61	6 - 11
Marina Del Rey	62	4,5
Redondo Breakwater	62	16 - 18
Malaga Cove - PV Point (IV)	63	1 - 7
PV Point - Point Vicente (III)	63	7 - 11
Point Vicente - Inspiration Point (II)	63	11 - 18
Inspiration Point - Point Fermin (I)	63	18 - 25
Cabrillo	63	25 - 28
LB/LA Harbor and Breakwaters	63, 64	28 - 51, 1 - 32
Horseshoe Kelp	63	
Huntington Flats	64	39 - 43
Newport Harbor	65	15 - 18
Corona Del Mar	65, 66	17 - 20, 1 - 3
North Laguna Beach	66	4 - 6
So. Laguna Beach	66	7 - 10
South Laguna	66	11 - 13
Salt Creek-Dana Point	66	13 - 16
Dana Marina *	66	17
Capistrano Beach	67	1 - 6
San Clemente	67	6 - 9
San Mateo Point	67	10 - 12
San Onofre	67	13 - 19
Pendleton Reefs*	68	2, 3
Horno Canyon	68	3 - 5
Barn Kelp	68	6 - 9
Santa Margarita	68	13 - 15
Oceanside Harbor*	68	16 - 17
North Carlsbad	69	3, 4
Agua Hedionda	69	4, 5
Encina Power Plant	69	6 - 8
Carlsbad State Beach	69	8 - 10
North Leucadia	69	10, 11
Central Leucadia	69	12
South Leucadia	69	13
Encinitas	69, 70	14, 1
Cardiff	70	2, 3
Solana Beach	70	3 - 5
Del Mar	70	7 - 9
Torrey Pines Park*	70	10 - 13
La Jolla Upper	71	1 - 8
La Jolla Lower	71	8 - 15
Point Loma Upper	71	20 - 29
Point Loma Lower	71	29 - 40
Imperial Beach	72	12 - 15


Deer Creek Kelp
Leo Carillo Kelp
Nicolas Canyon Kelp
El Pescador &
La Piedra Kelp
Lechuza Kelp
CALIFORNIA COASTAL KELP RESOURCES

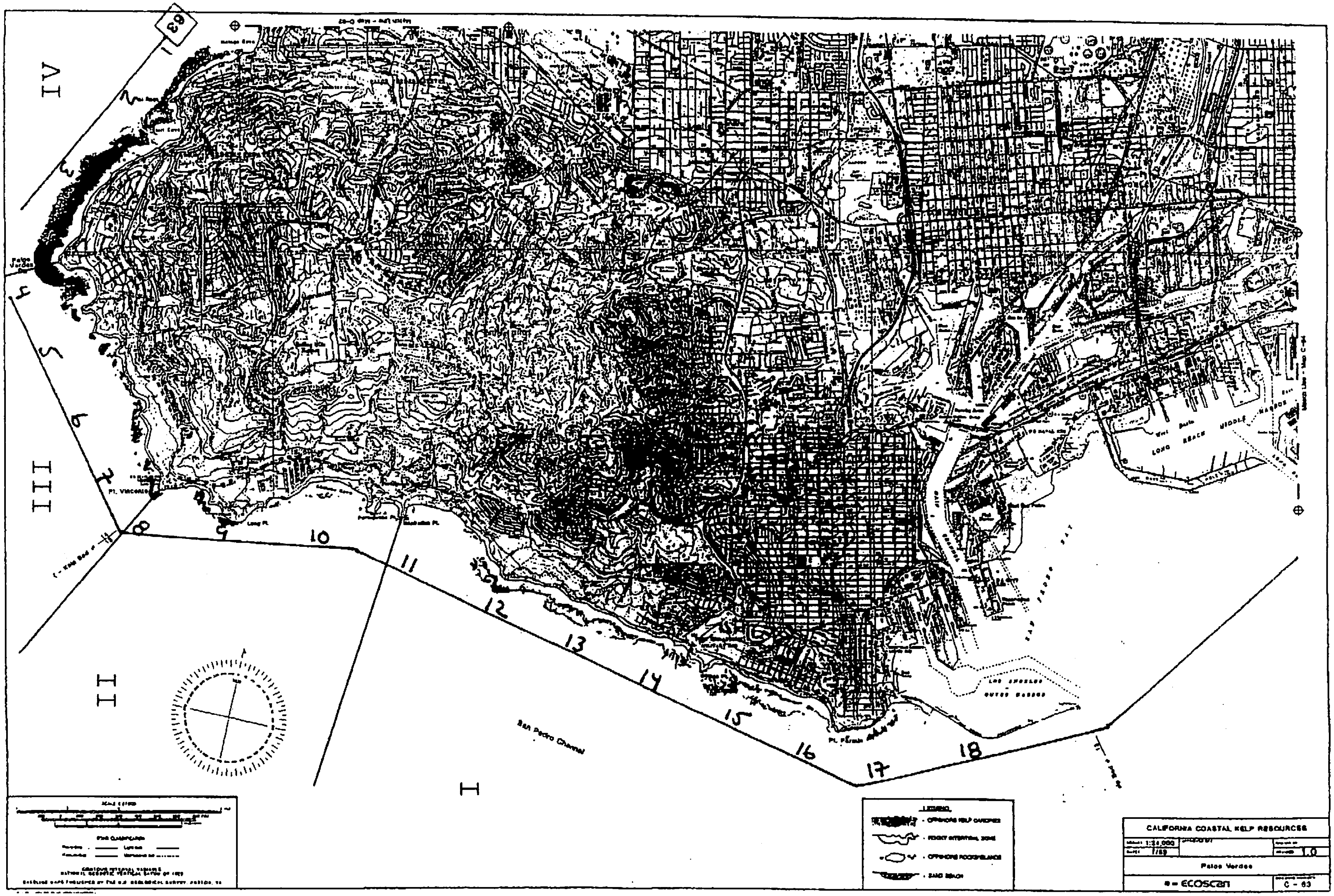


Lechuza Kelp
Pt. Dume Kelp
Paradise Cove Kelp
Escondido Wash Kelp
Latigo Canyon Kelp
Puerco/Amarillo Kelp
Malibu Pt. Kelp
La Costa Kelp
CALIFORNIA COASTAL KELP RESOURCES
Pt. Dume
ECOSCAN
C - 80

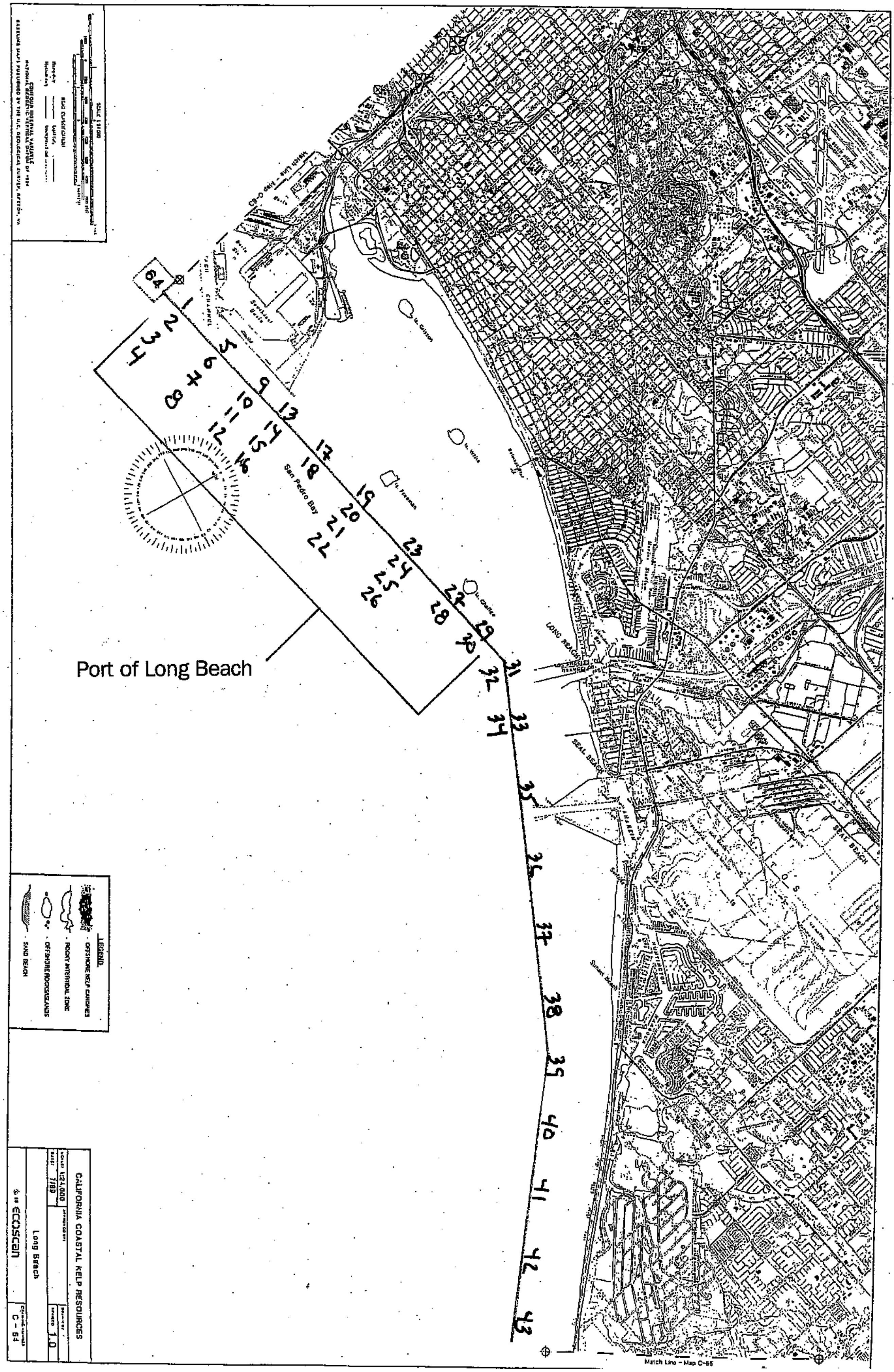

61
Las Flores Kelp
Big Rock Kelp
Las Tunas Kelp
Topanga Kelp
Sunset Kelp
CALIFORNIA COASTAL KELP RESOURCES



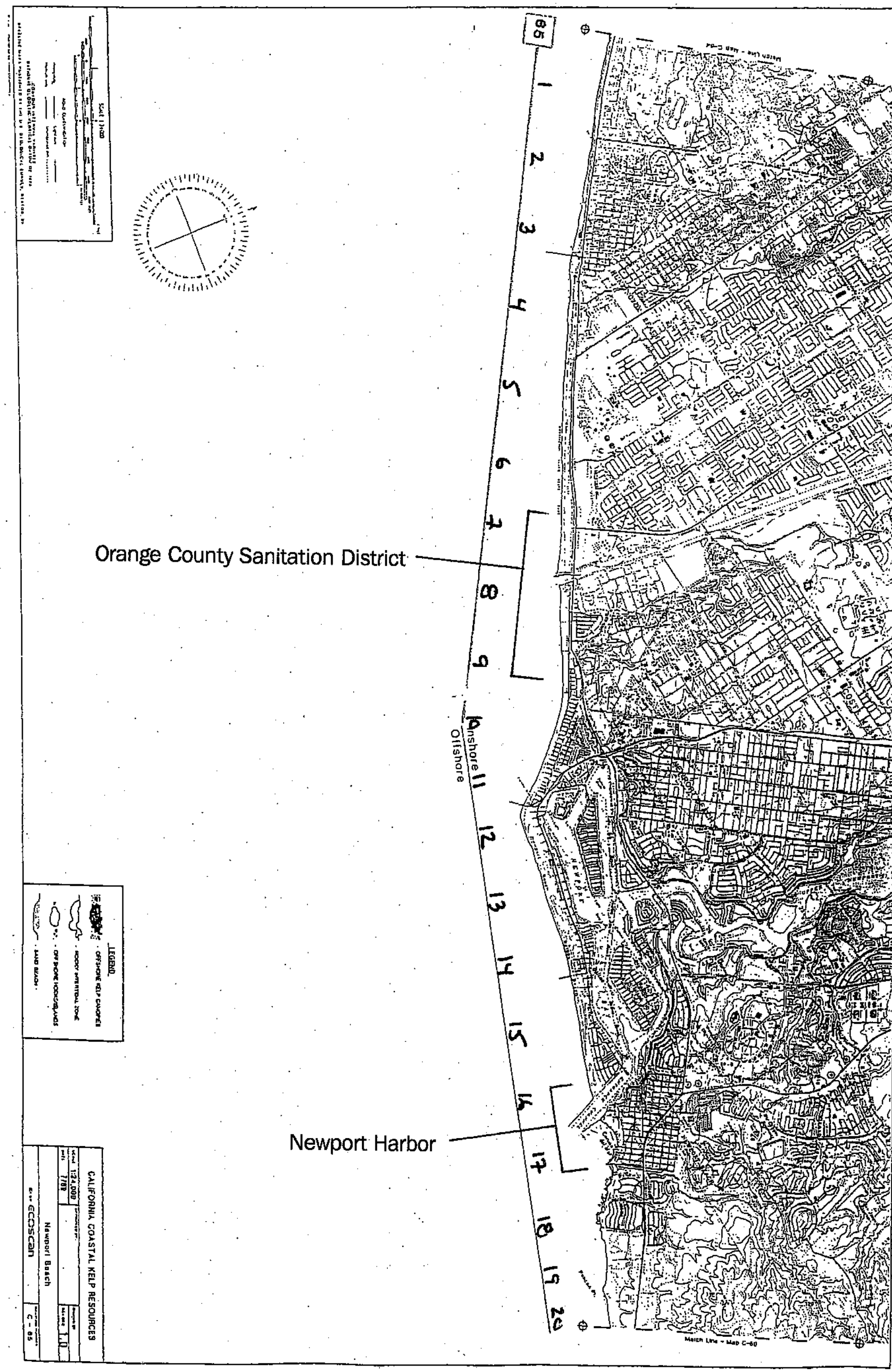
Marina del Rey
Hyperion Treatment Plant
Scattergood Generating Station
Chevron Refinery
El Segundo Generating Station
King Harbor, Redondo Beach
Santa Monica Bay
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
Los Angeles
C - 62
Match Line - Map C-61
Match Line - Map C-63



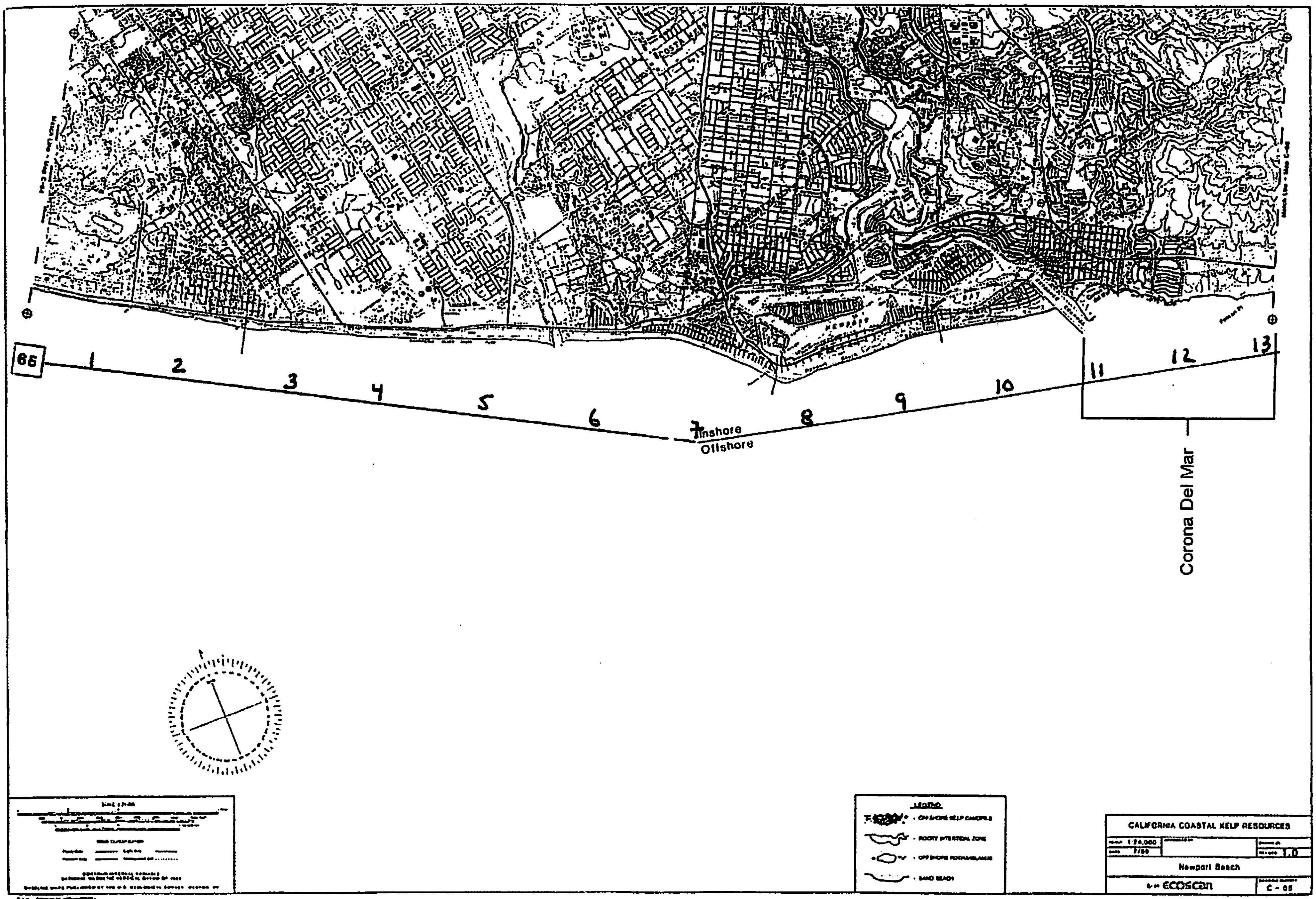
IV
III
II
I
63
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Palos Verdes
Pt. Vicente
Long Pt.
Pt. Fermin
San Pedro Channel
LOS ANGELES
OUTER HARBOR
SAN PEDRO BAY
LONG BEACH MIDDLE HARBOR
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Palos Verdes
ECOSCAN
C - 63



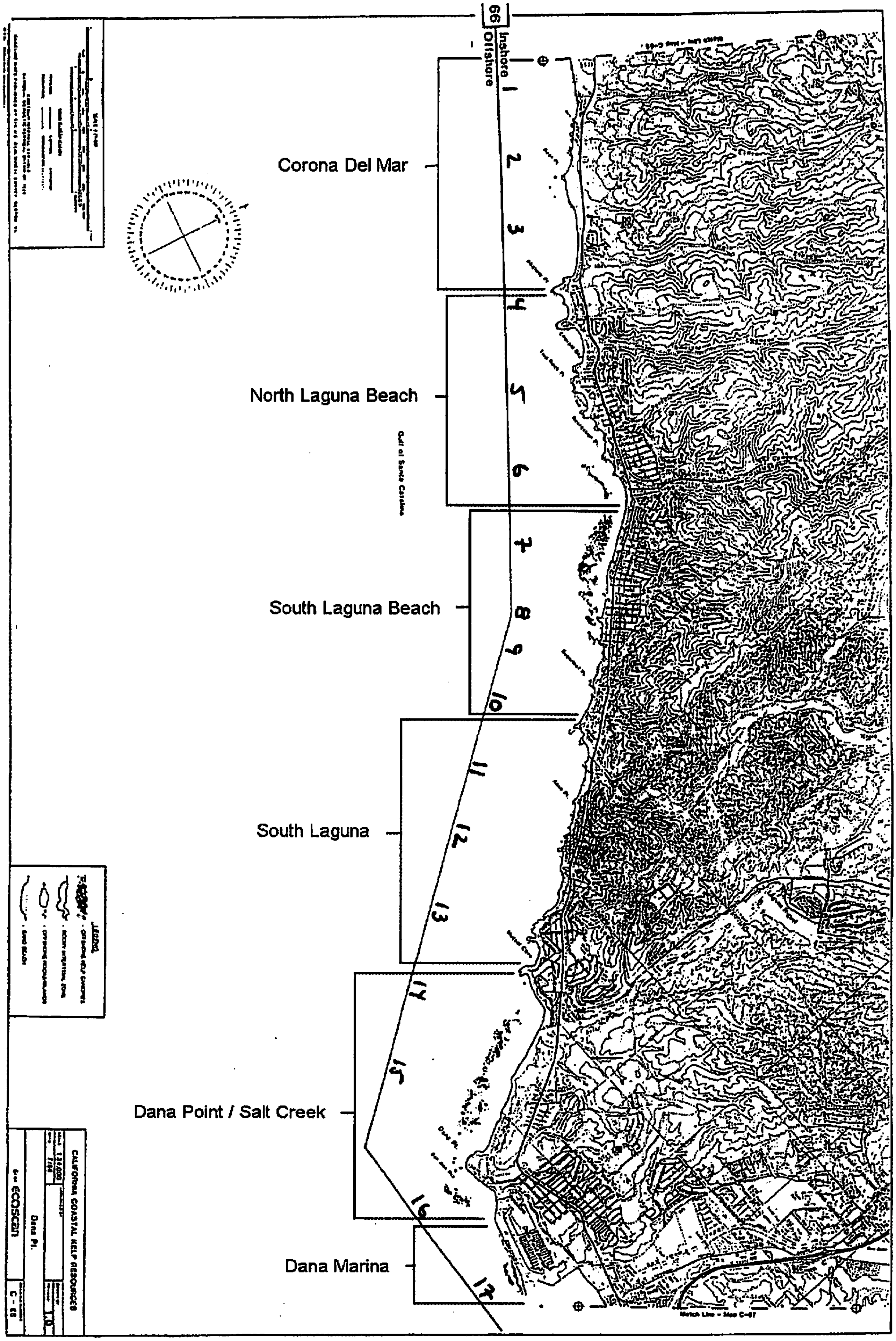
CALIFORNIA COASTAL KELP RESOURCES
Long Beach
C - 64
ecoscan
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
San Pedro Bay
Port of Long Beach
Match Line - Map C-65



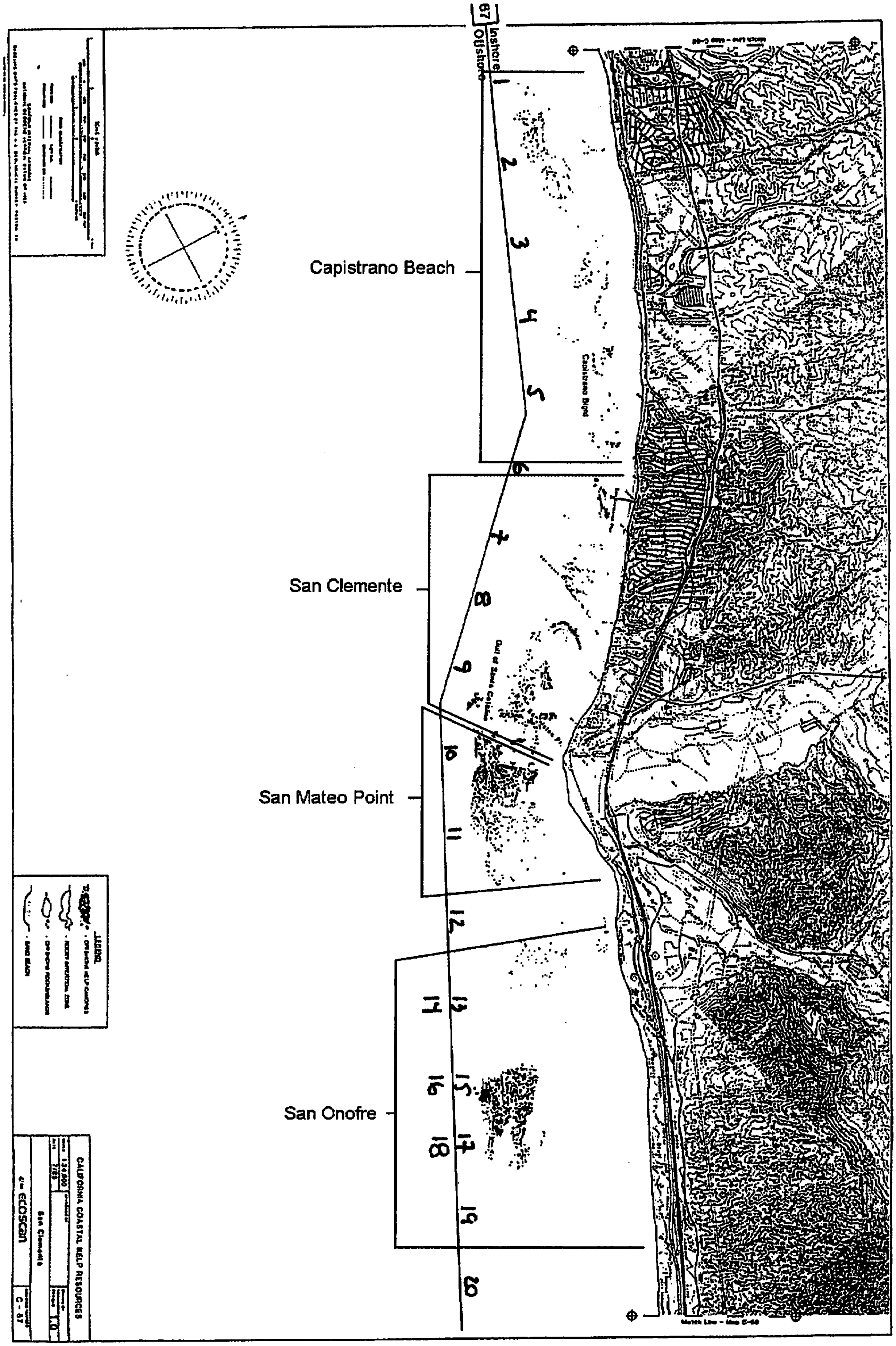
Orange County Sanitation District
Newport Harbor
Inshore
Offshore
CALIFORNIA COASTAL KELP RESOURCES
Newport Beach
ecoscan
C - 65



65
1
2
3
4
5
6
7
Inshore
Offshore
8
9
10
11
12
13
Corona Del Mar
LEGEND
OFF SHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFF SHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Newport Beach
ECOSCAN
C - 65



99
Inshore
Offshore
Corona Del Mar
North Laguna Beach
South Laguna Beach
South Laguna
Dana Point / Salt Creek
Dana Marina
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17



67
Inshore
Offshore
Capistrano Beach
San Clemente
San Mateo Point
San Onofre
1
2
3
4
5
6
7
8
9
10
11
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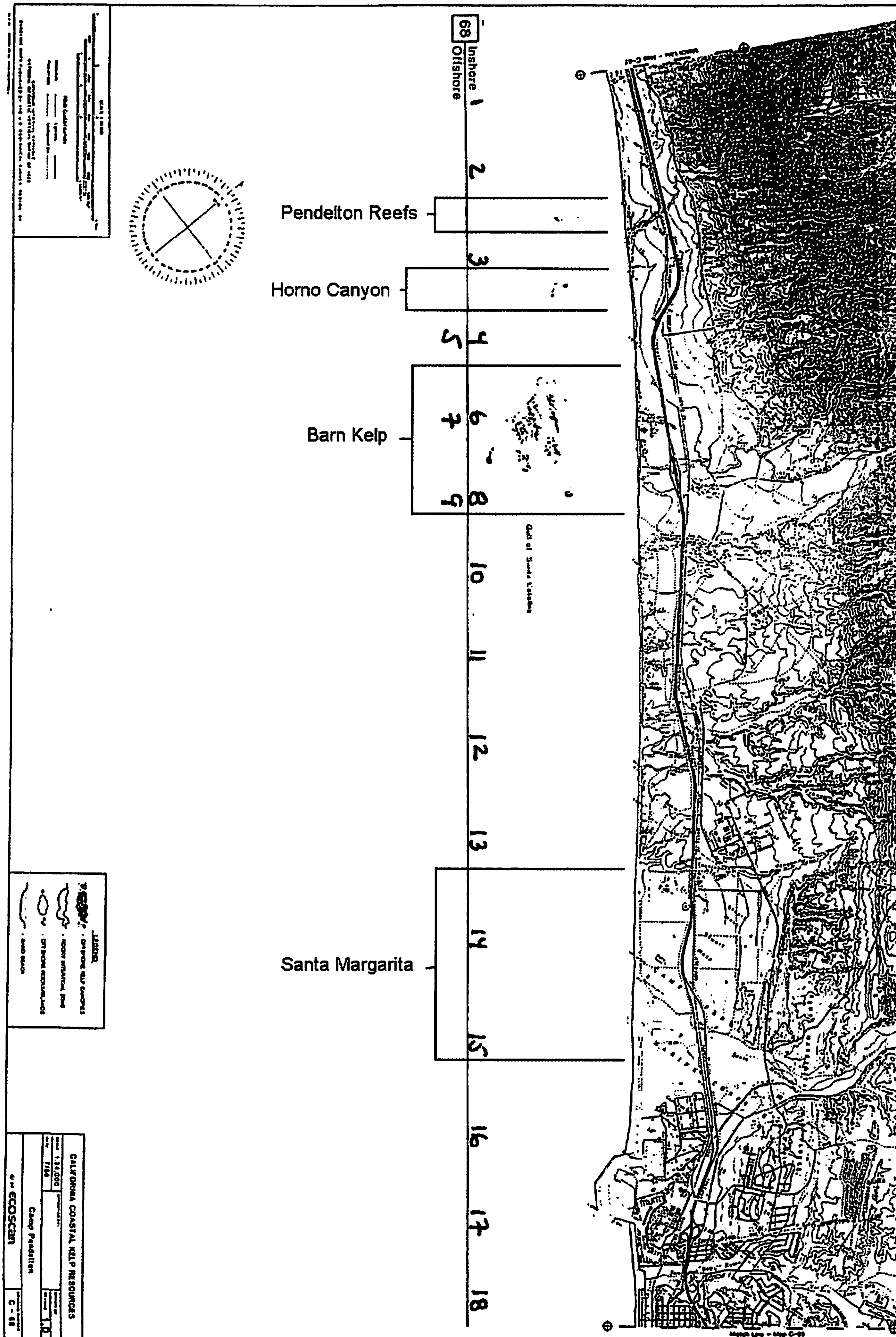
17
18
19
20
Capistrano Bight
CALIFORNIA COASTAL KELP RESOURCES
San Clemente
ECOSCAN
C - 67



Pendelton Reefs
Horno Canyon
Barn Kelp
Santa Margarita
68
Inshore
Offshore
1
2
3
4
5
6
7
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9
10
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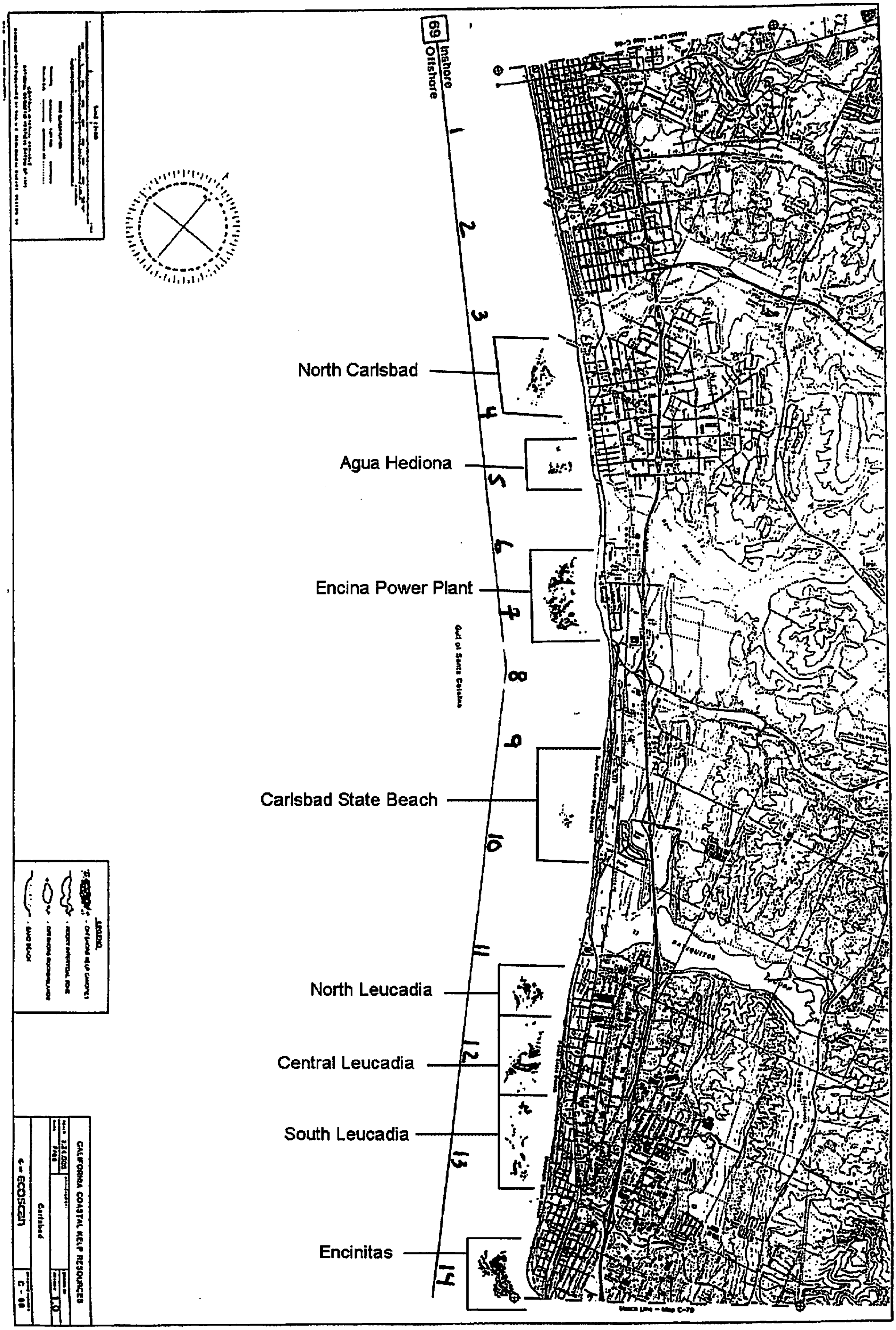
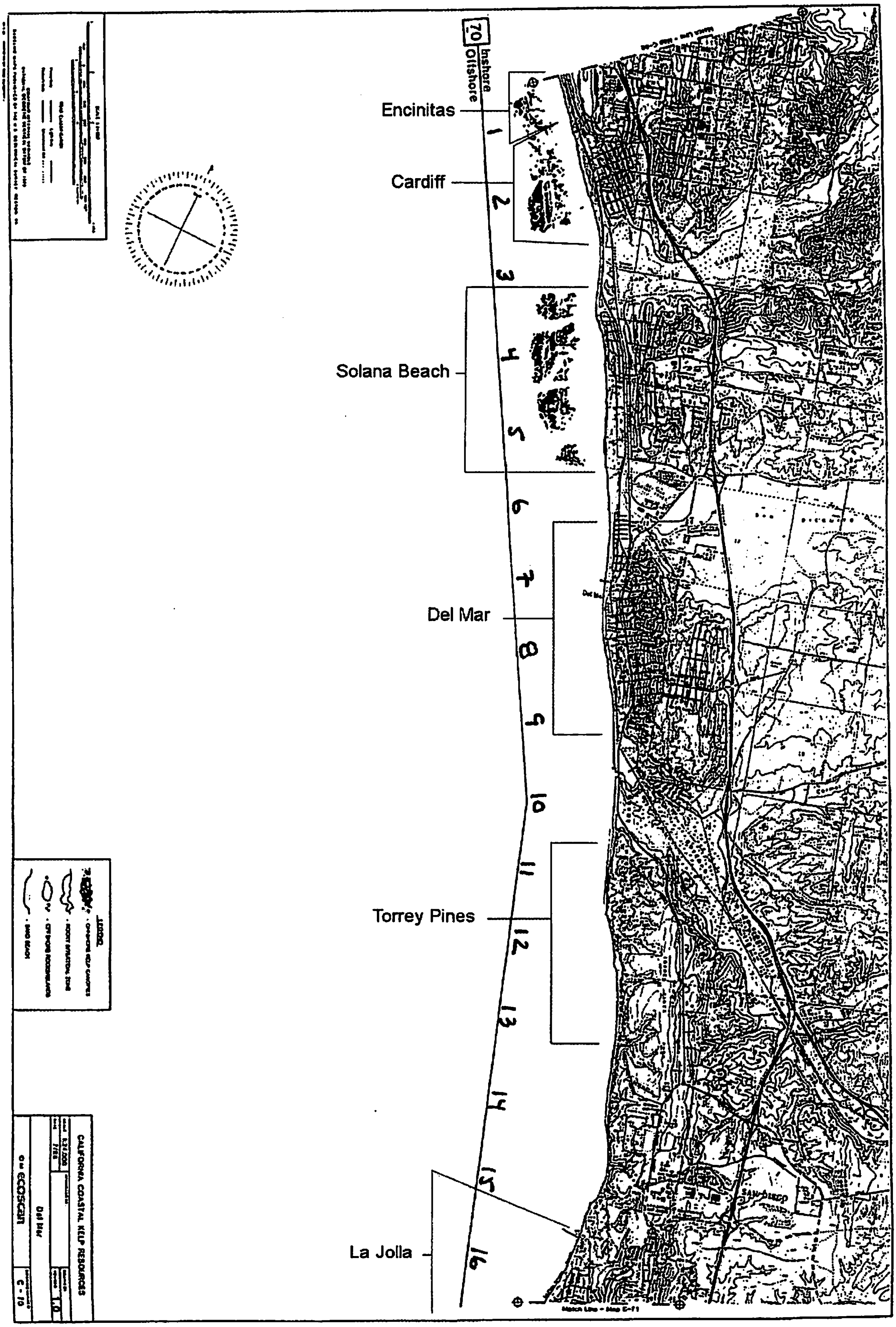
16
17
18
CALIFORNIA COASTAL KELP RESOURCES
Camp Pendelton
ecoscan
C-68



69
Inshore
Offshore
1
2
3
North Carlsbad
4
Agua Hediona
5
6
Encina Power Plant
7
8
9
Carlsbad State Beach
10
11
North Leucadia
12
Central Leucadia
South Leucadia
13
Encinitas
14
CALIFORNIA COASTAL KELP RESOURCES
Carlsbad



70
Inshore
Offshore
Encinitas
Cardiff
Solana Beach
Del Mar
Torrey Pines
La Jolla
1
2
3
4
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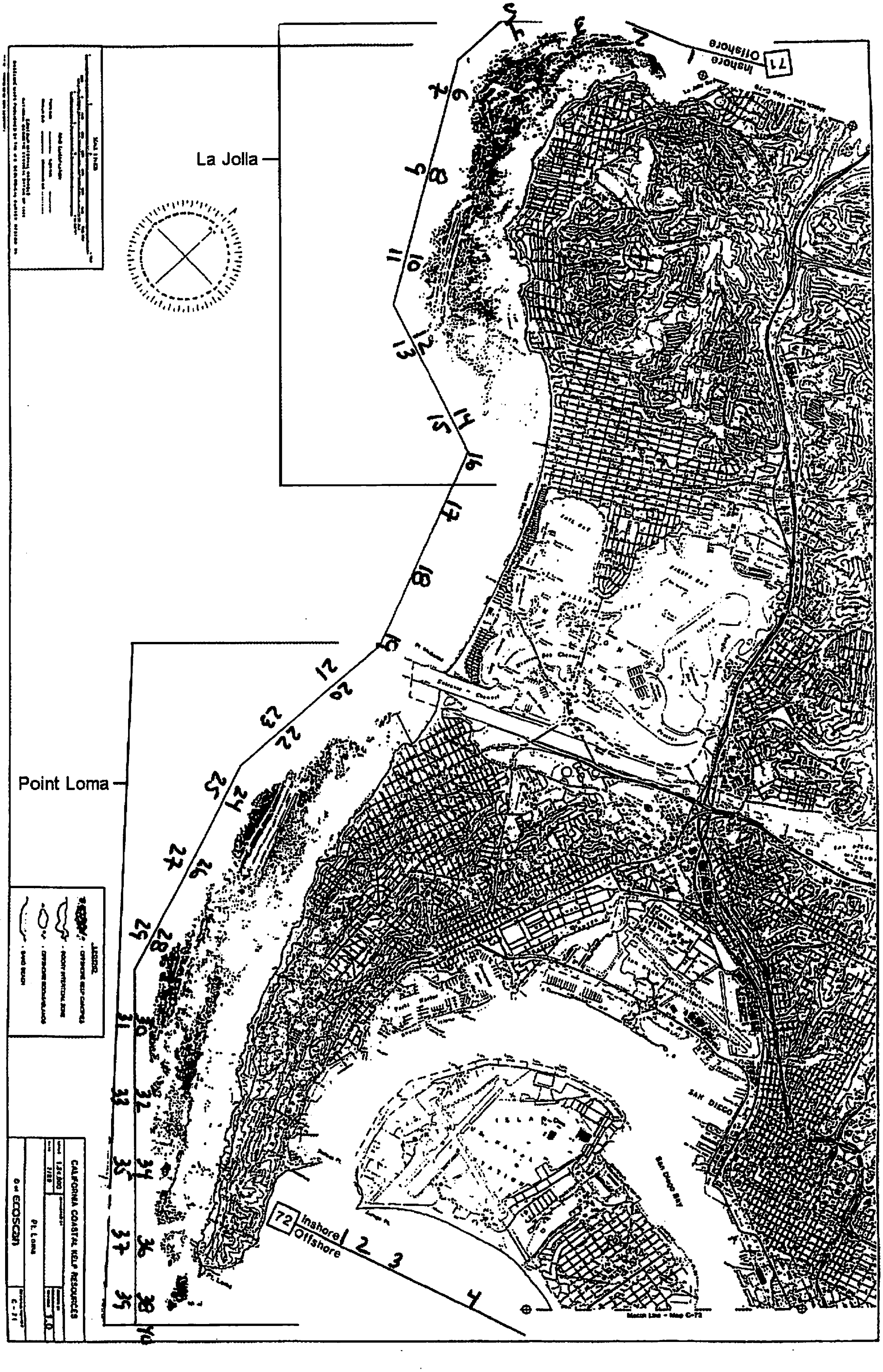
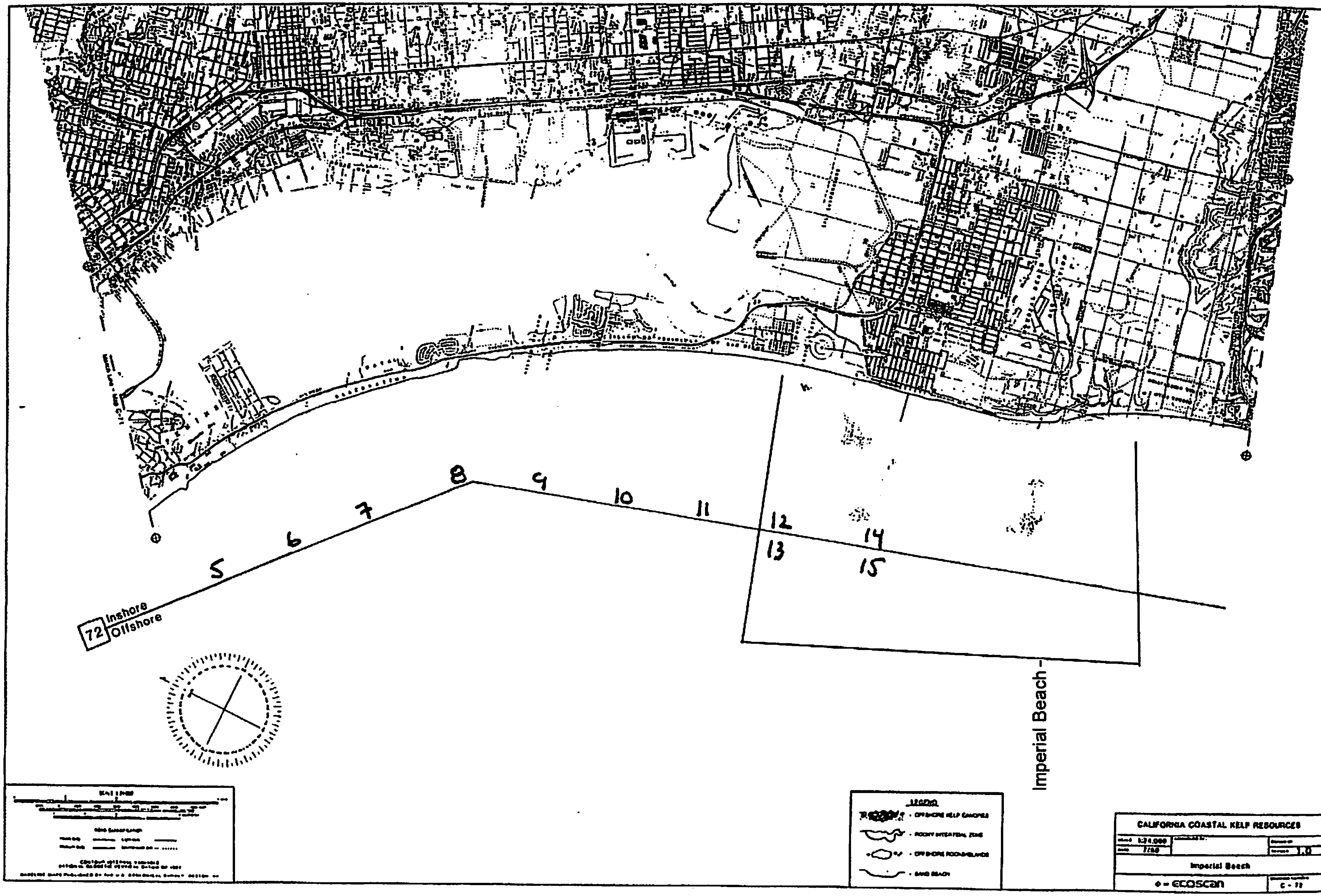
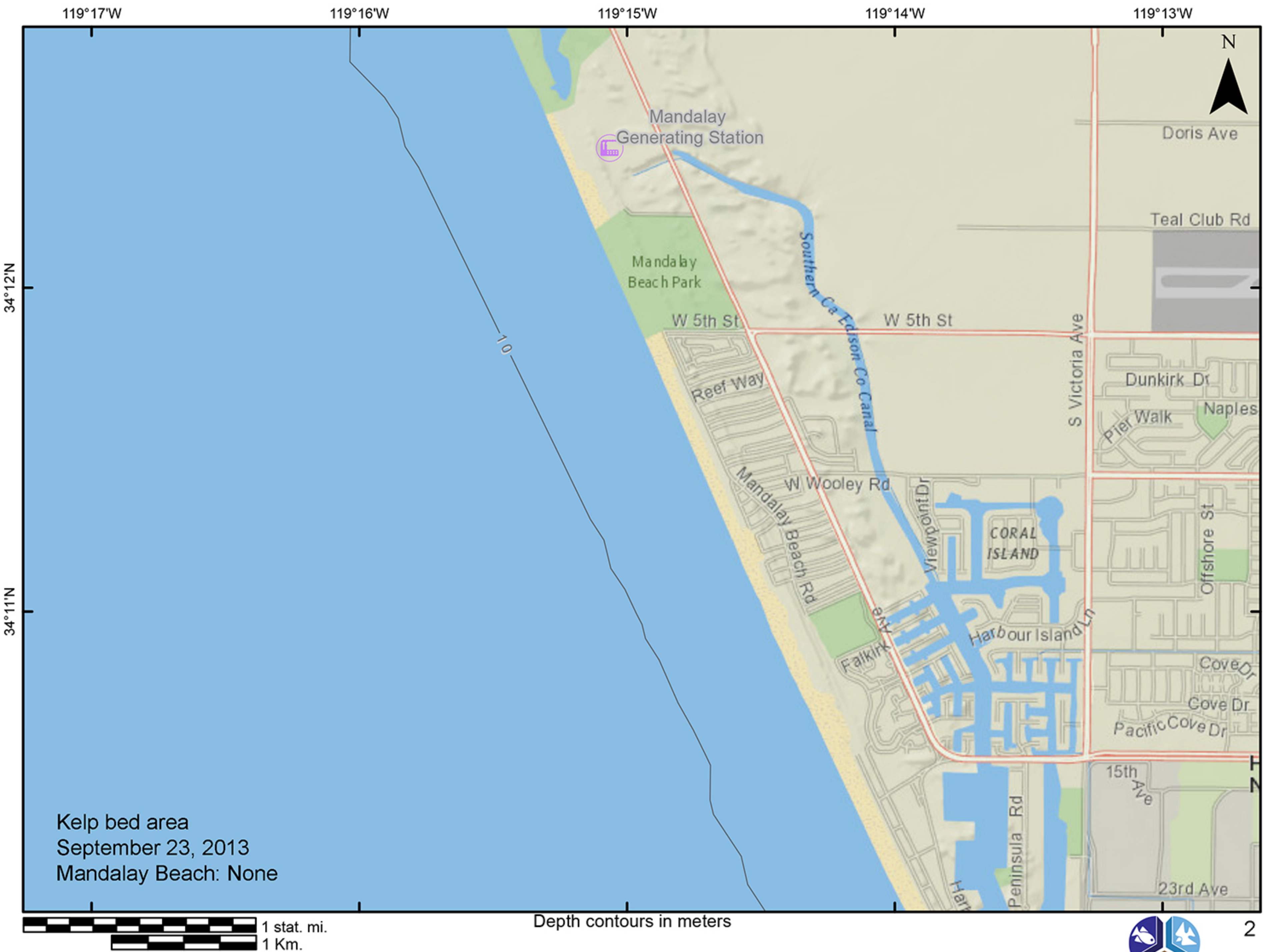
16
CALIFORNIA COASTAL KELP RESOURCES
Del Mar
ecoscan
C - 10


La Jolla
Point Loma
71 Inshore Offshore
72 Inshore Offshore
SAN DIEGO
San Diego Bay

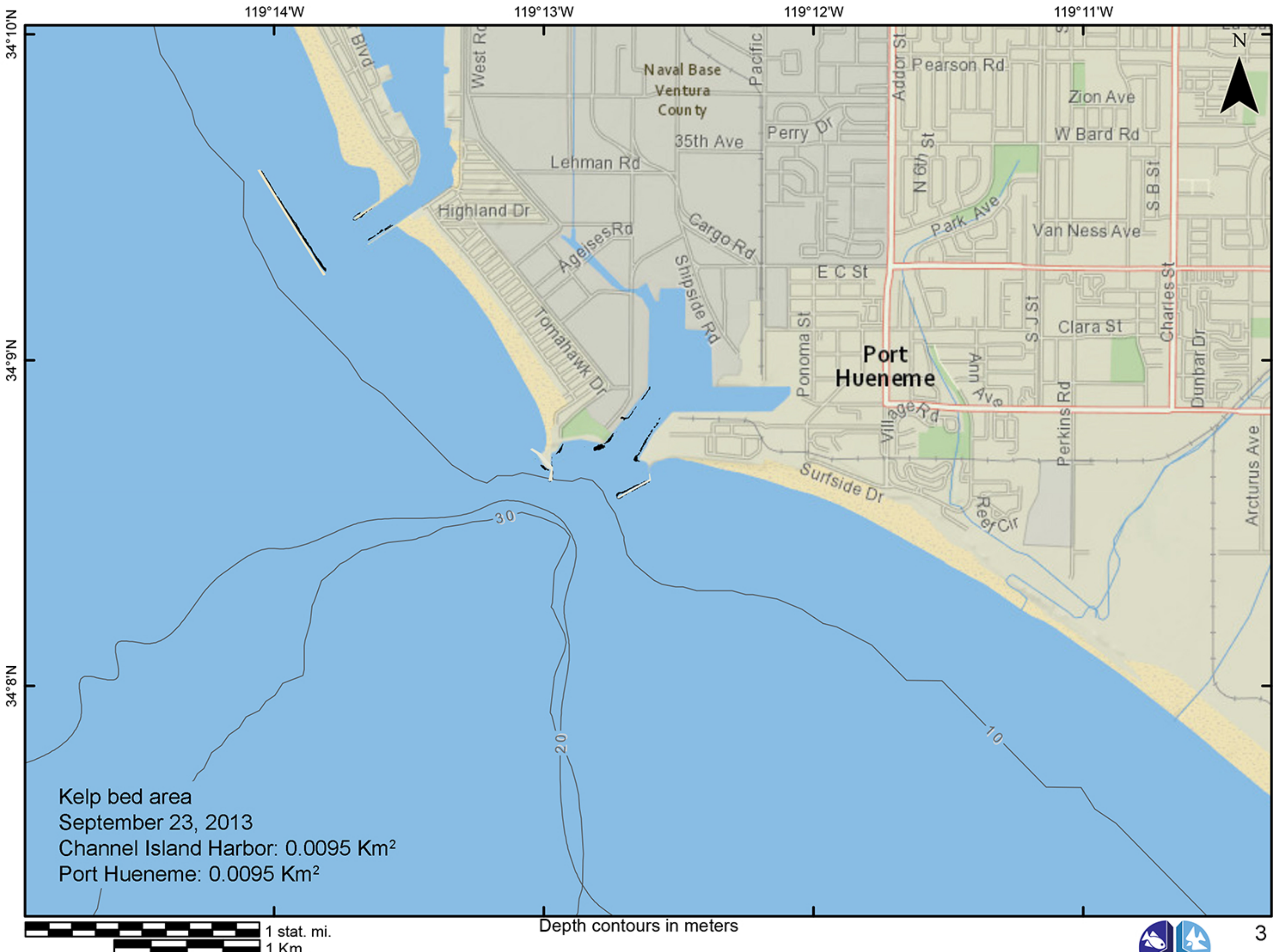


72 Inshore
Offshore
5
6
7
8
9
10
11
12
13
14
15
Imperial Beach
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Imperial Beach
ECOSCAN

119°18'W
119°17'W
119°16'W
119°15'W
119°14'W
34°15'N
34°14'N
N
10
Pierpont Blvd
Channel Dr
101
E Main St
Seahorse Ave
Bayshore Ave
Beachmont St
Arundell Barranca
Transport St
Donlon St
Goodyear Ave
Eastman Ave
Navigator Dr
Spinnaker Dr
Olivas Park Dr
Olivas Links
Santa
Mcgrath State Beach
Kelp bed area
September 23, 2013
Ventura Marina Kelp: 0.0072 Km²
Depth contours in meters
1 stat. mi.
1 Km.

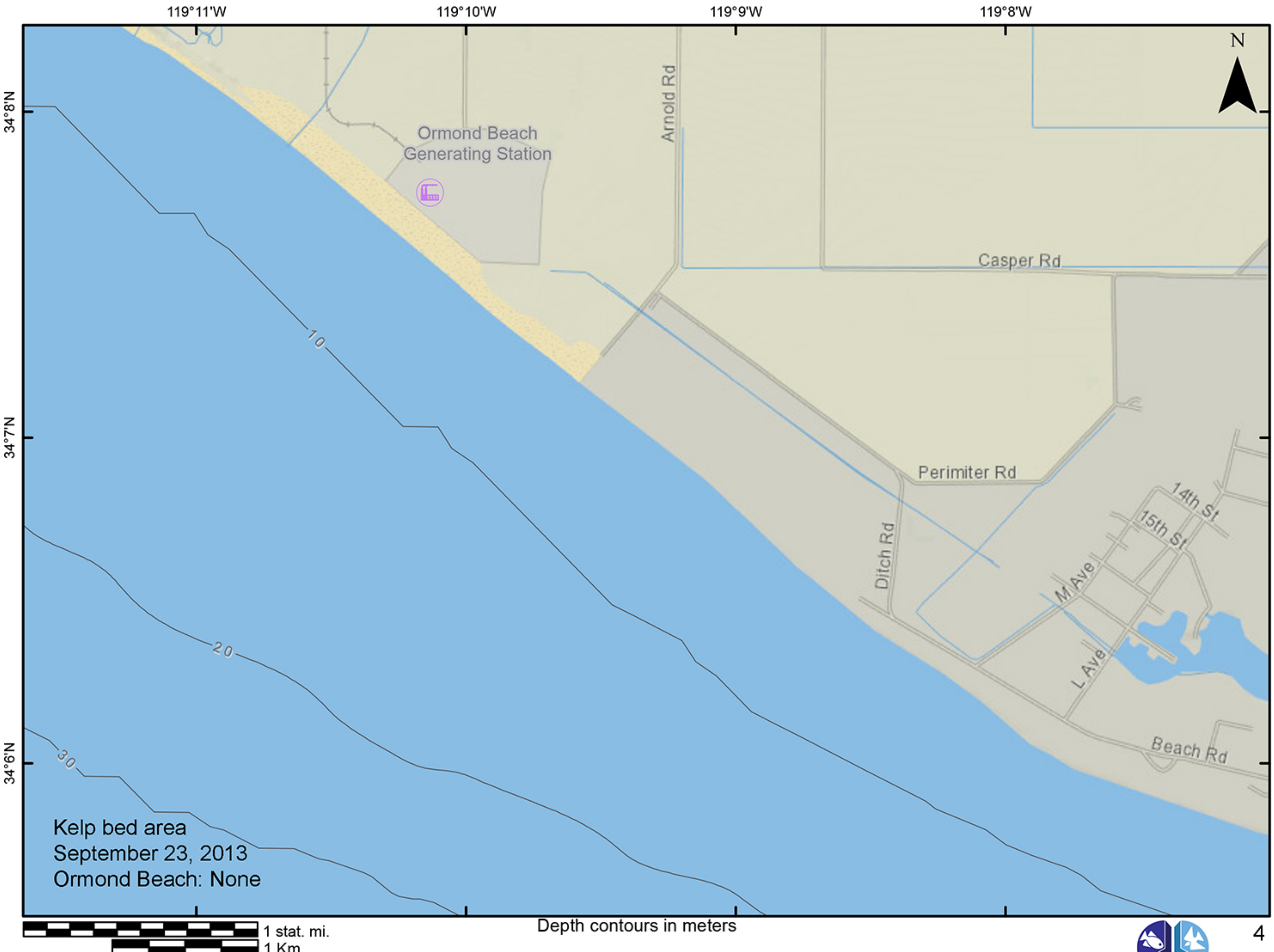

119°17'W
119°16'W
119°15'W
119°14'W
119°13'W
34°12'N
34°11'N
N
Mandalay
Generating Station
Doris Ave
Teal Club Rd
Southern Ca Edison Co Canal
Mandalay
Beach Park
W 5th St
W 5th St
S Victoria Ave
10
Reef Way
Dunkirk Dr
Pier Walk
Naples
Mandalay Beach Rd
W Wooley Rd
Viewpoint Dr
CORAL
ISLAND
Offshore St
Falkirk Ave
Harbour Island Ln
Cove Dr
Cove Dr
Pacific Cove Dr
15th Ave
Peninsula Rd
23rd Ave
Kelp bed area
September 23, 2013
Mandalay Beach: None
1 stat. mi.
1 Km.
Depth contours in meters

MBC

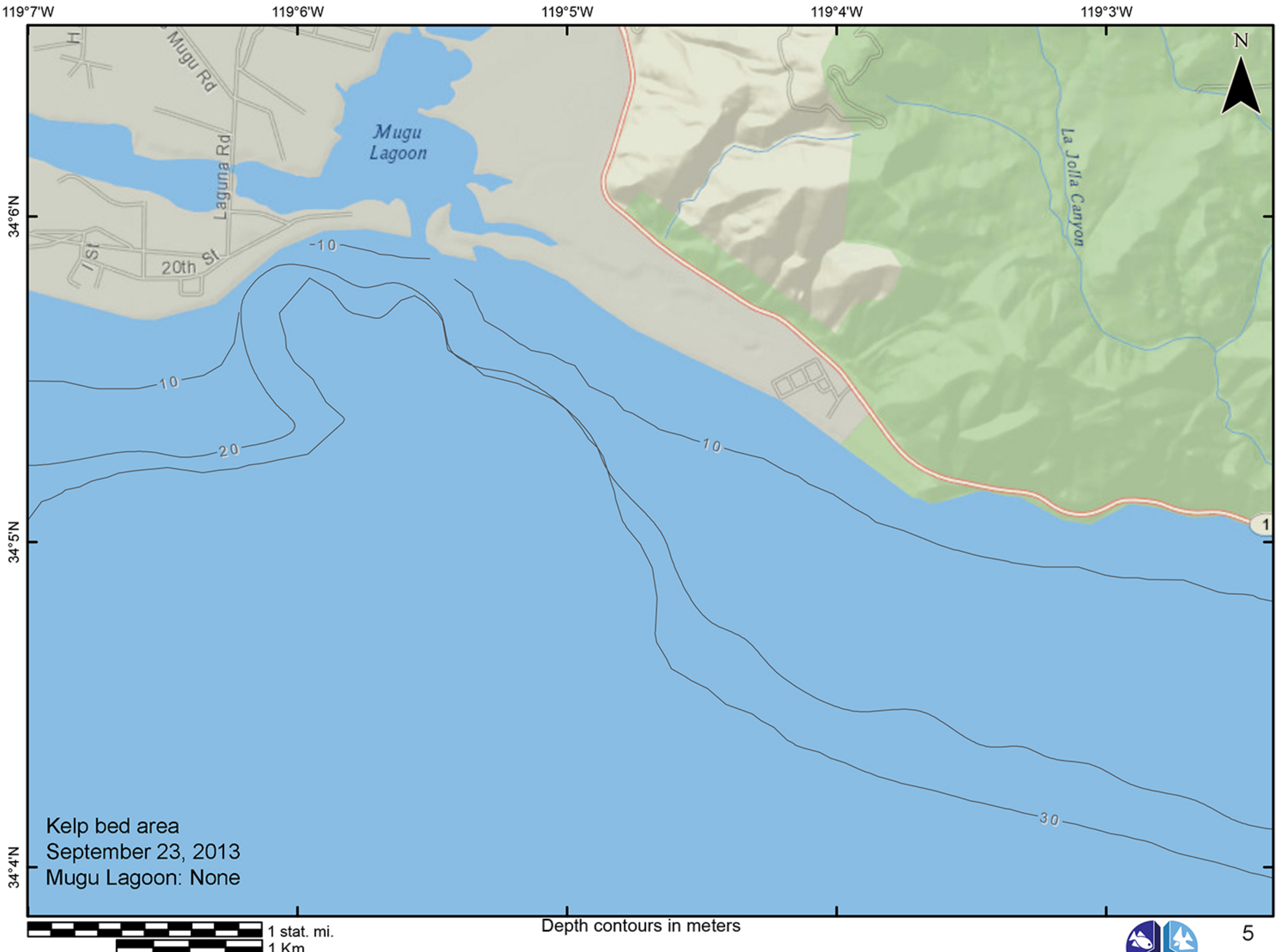


Depth contours in meters

MBC

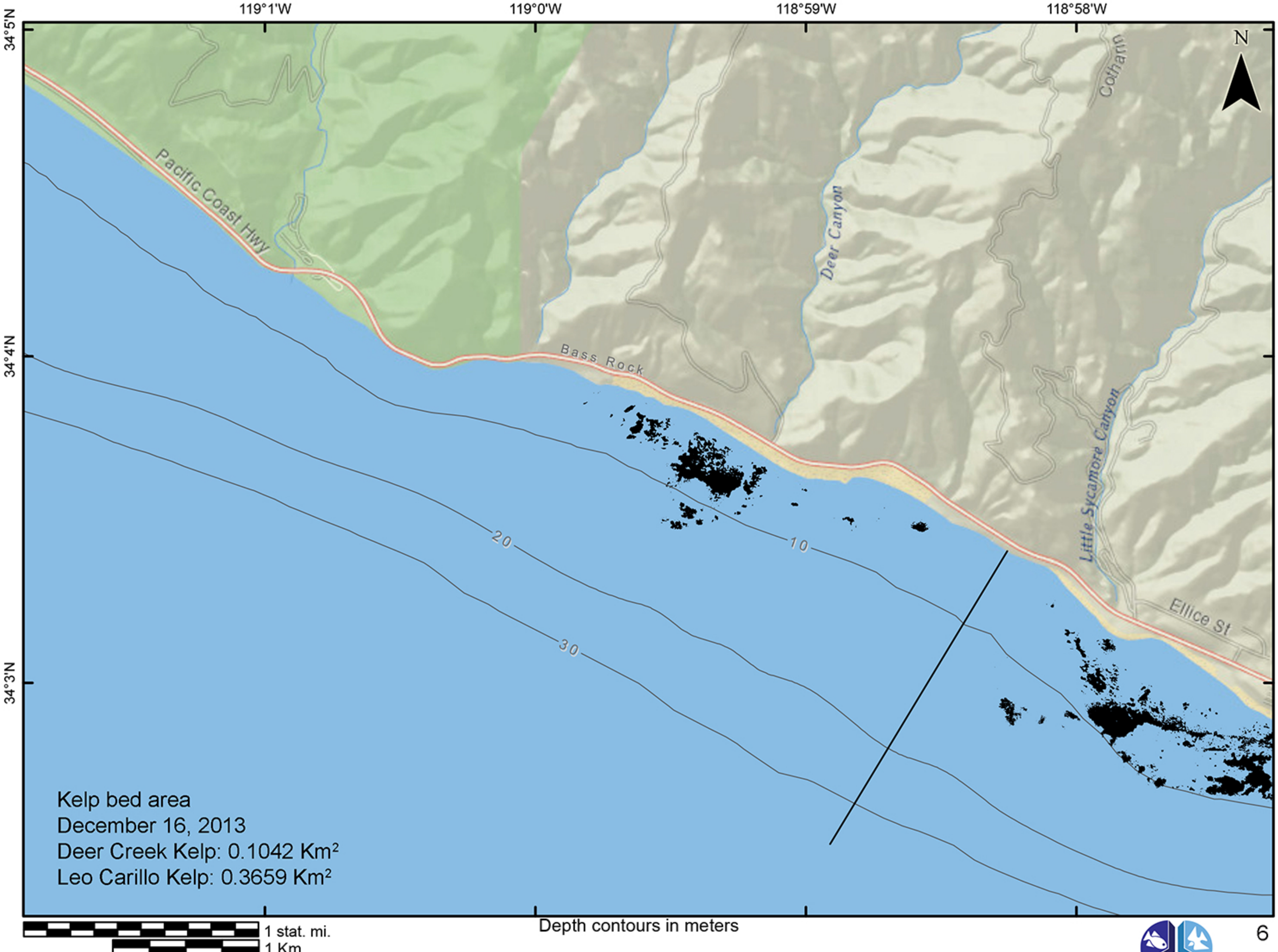


119°11'W
119°10'W
119°9'W
119°8'W
34°8'N
34°7'N
34°6'N
N
Ormond Beach
Generating Station
Arnold Rd
Casper Rd
Perimiter Rd
Ditch Rd
14th St
15th St
M Ave
L Ave
Beach Rd
10
20
30
Kelp bed area
September 23, 2013
Ormond Beach: None
1 stat. mi.
1 Km.
Depth contours in meters



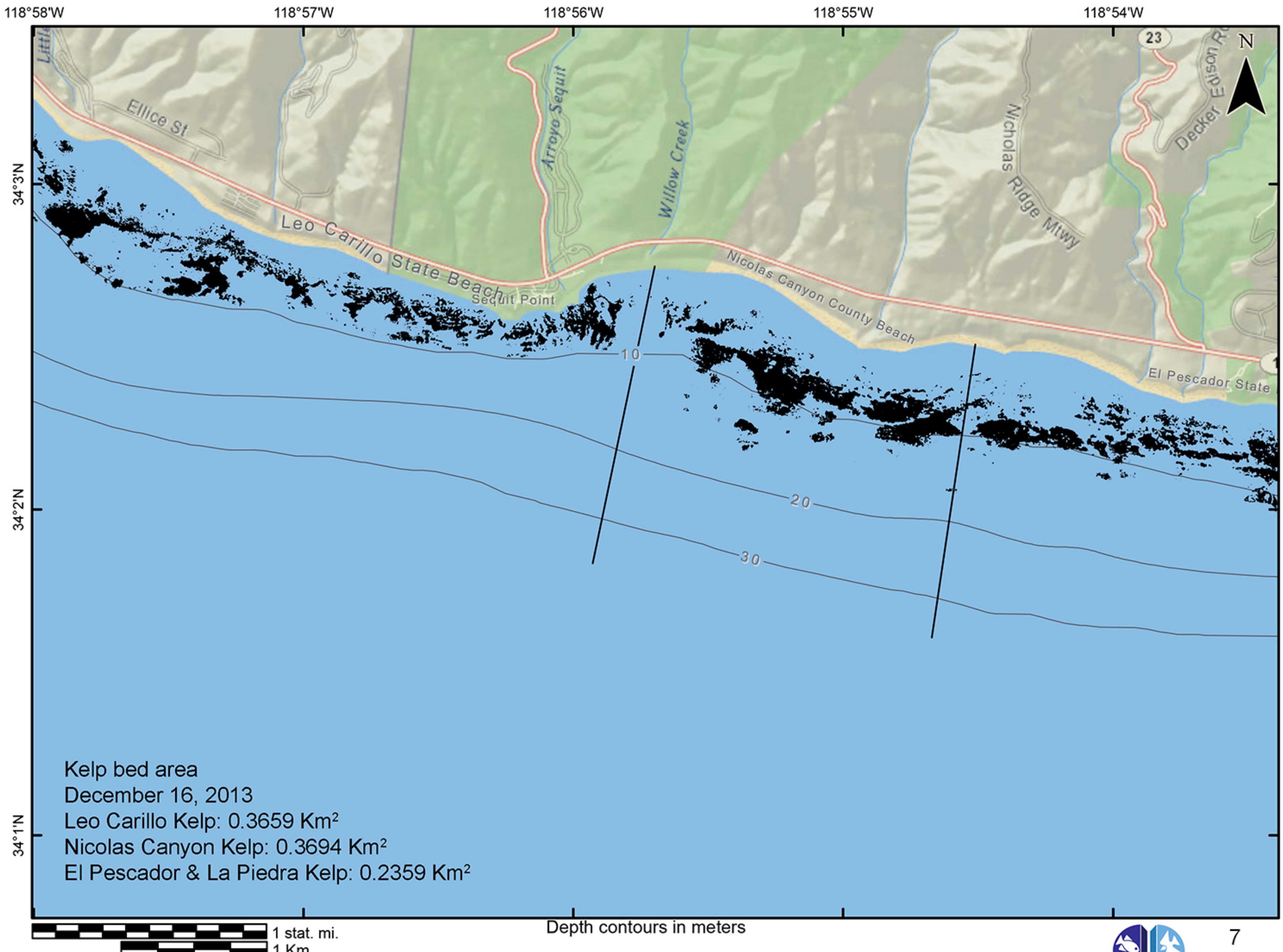
119°7'W
119°6'W
119°5'W
119°4'W
119°3'W
34°6'N
34°5'N
34°4'N
N
Mugu Rd
Laguna Rd
Mugu Lagoon
La Jolla Canyon
20th St
1st
1
10
20
30
-10
Kelp bed area
September 23, 2013
Mugu Lagoon: None
1 stat. mi.
1 Km.
Depth contours in meters

MBC



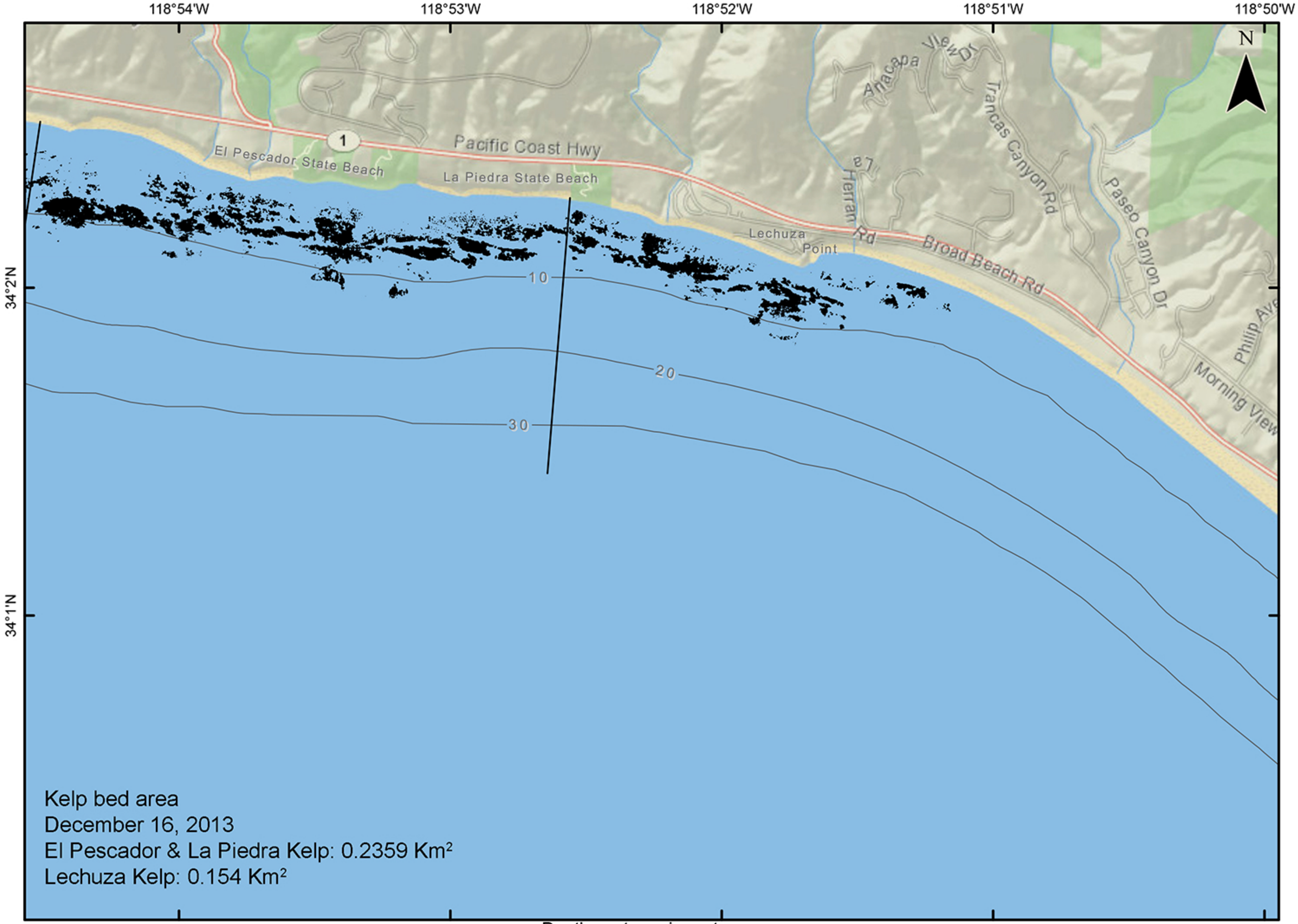
Depth contours in meters

MBC



Depth contours in meters

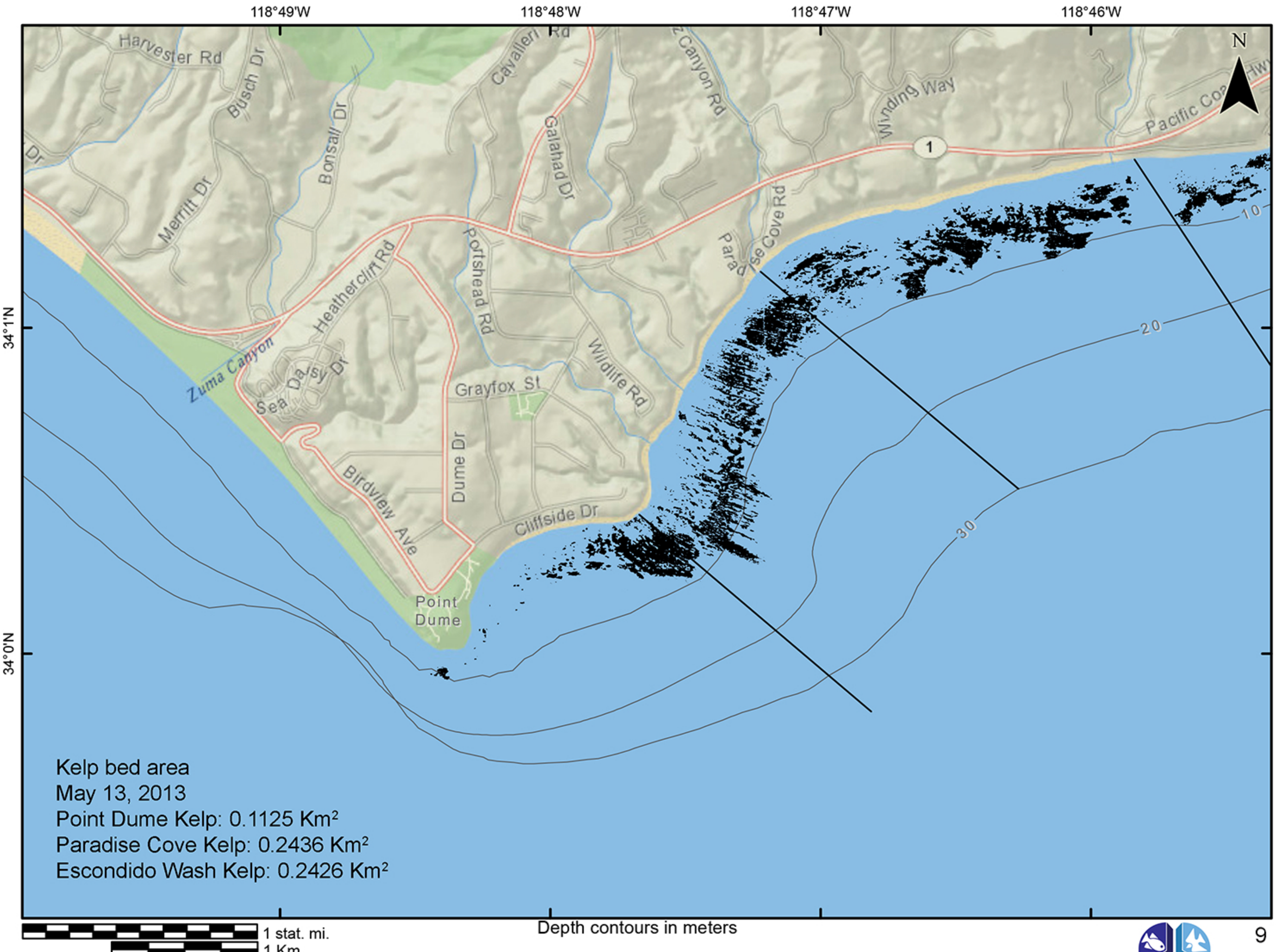
MBC



1 stat. mi.
1 Km.

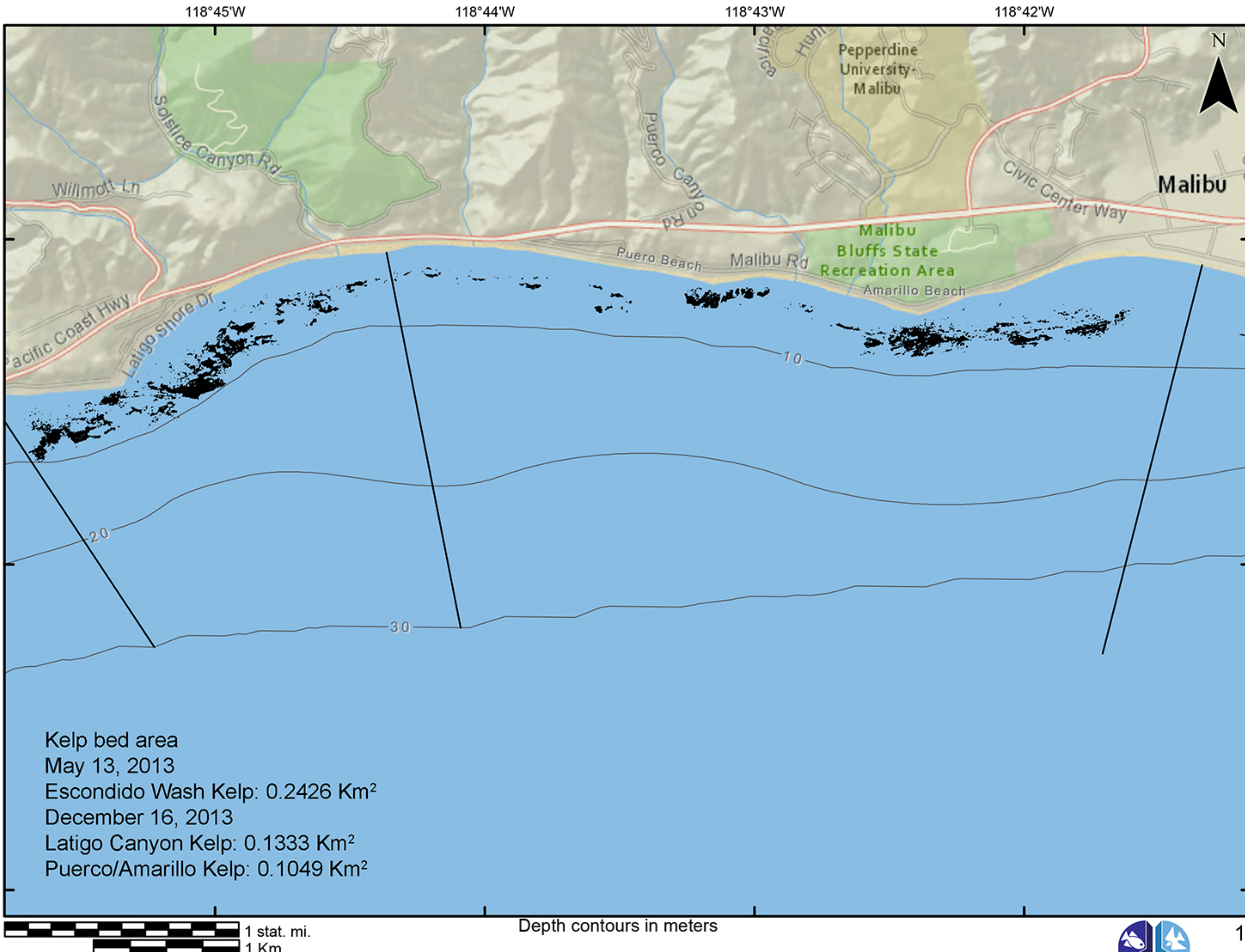
Depth contours in meters

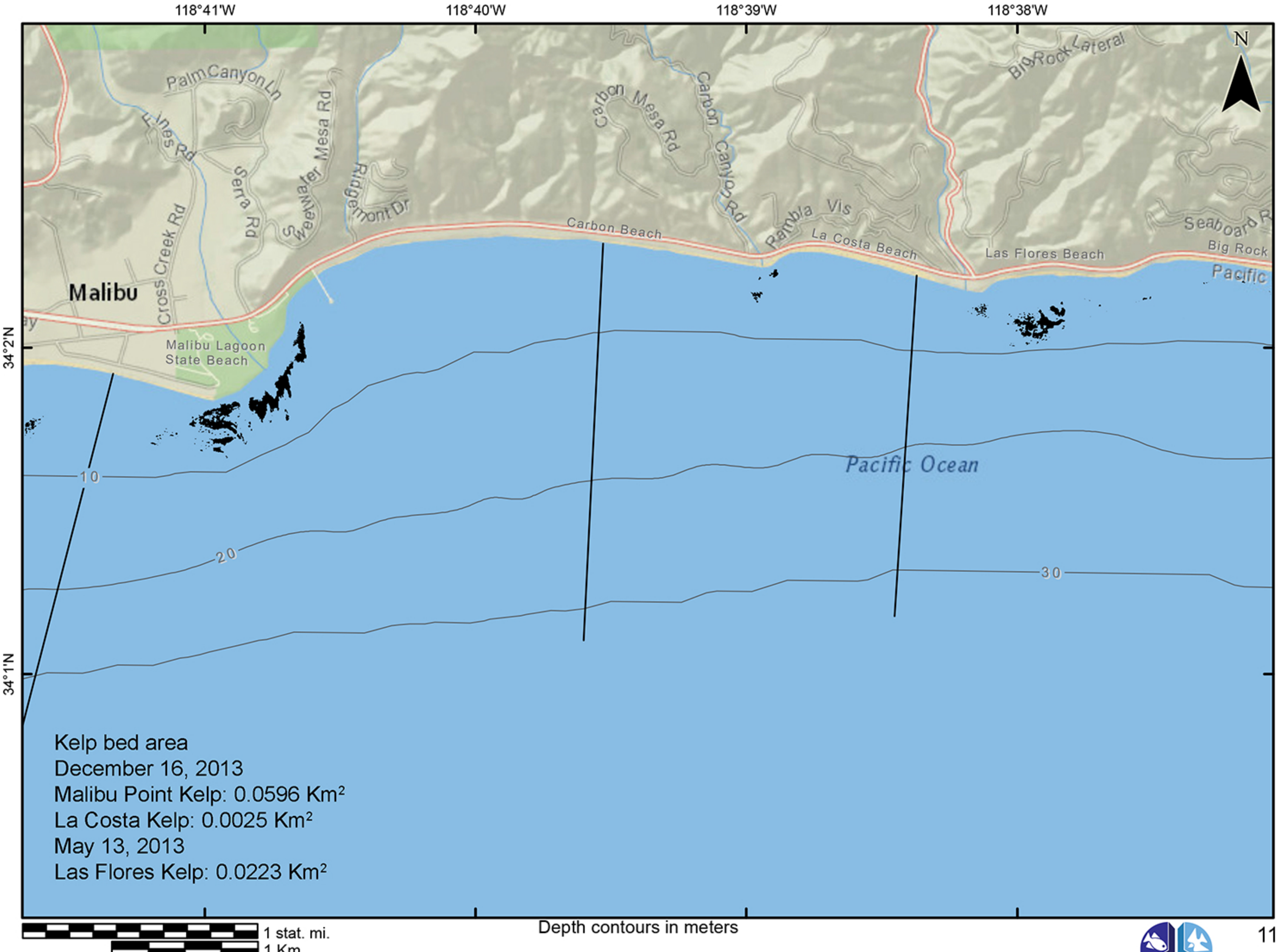
MBC

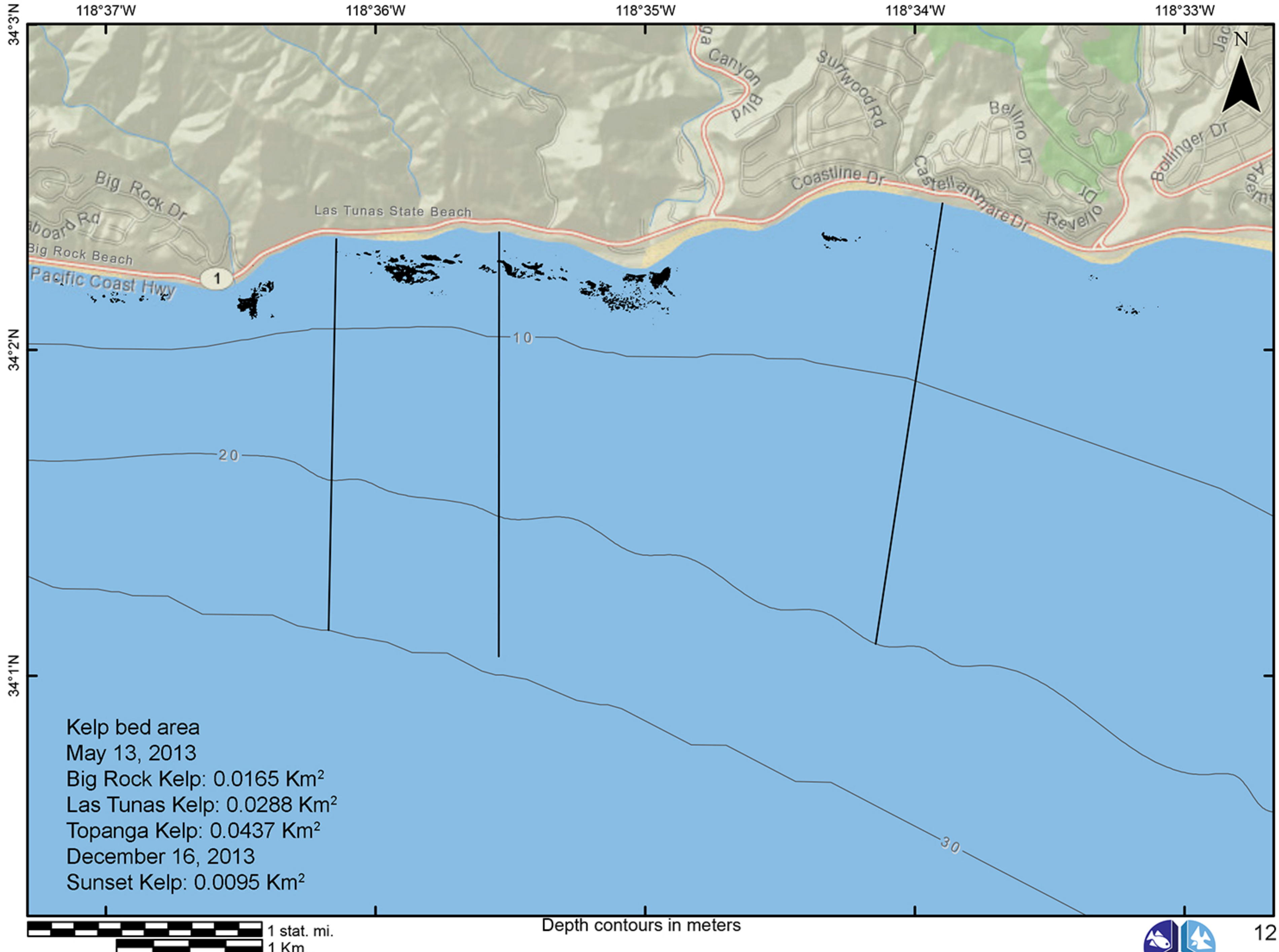


118°49'W
118°48'W
118°47'W
118°46'W
34°1'N
34°0'N
N
Harvester Rd
Busch Dr
Bonsall Dr
Cavalleri Rd
Galahad Dr
Canyon Rd
Winding Way
Pacific Coast Hwy
1
Merritt Dr
Heathercliff Rd
Portshead Rd
Paradise Cove Rd
Zuma Canyon
Sea Daisy Dr
Grayfox St
Wildlife Rd
Dume Dr
Birdview Ave
Cliffside Dr
Point Dume
10
20
30
Kelp bed area
May 13, 2013
Point Dume Kelp: 0.1125 Km²
Paradise Cove Kelp: 0.2436 Km²
Escondido Wash Kelp: 0.2426 Km²
1 stat. mi.
1 Km.
Depth contours in meters

MBC

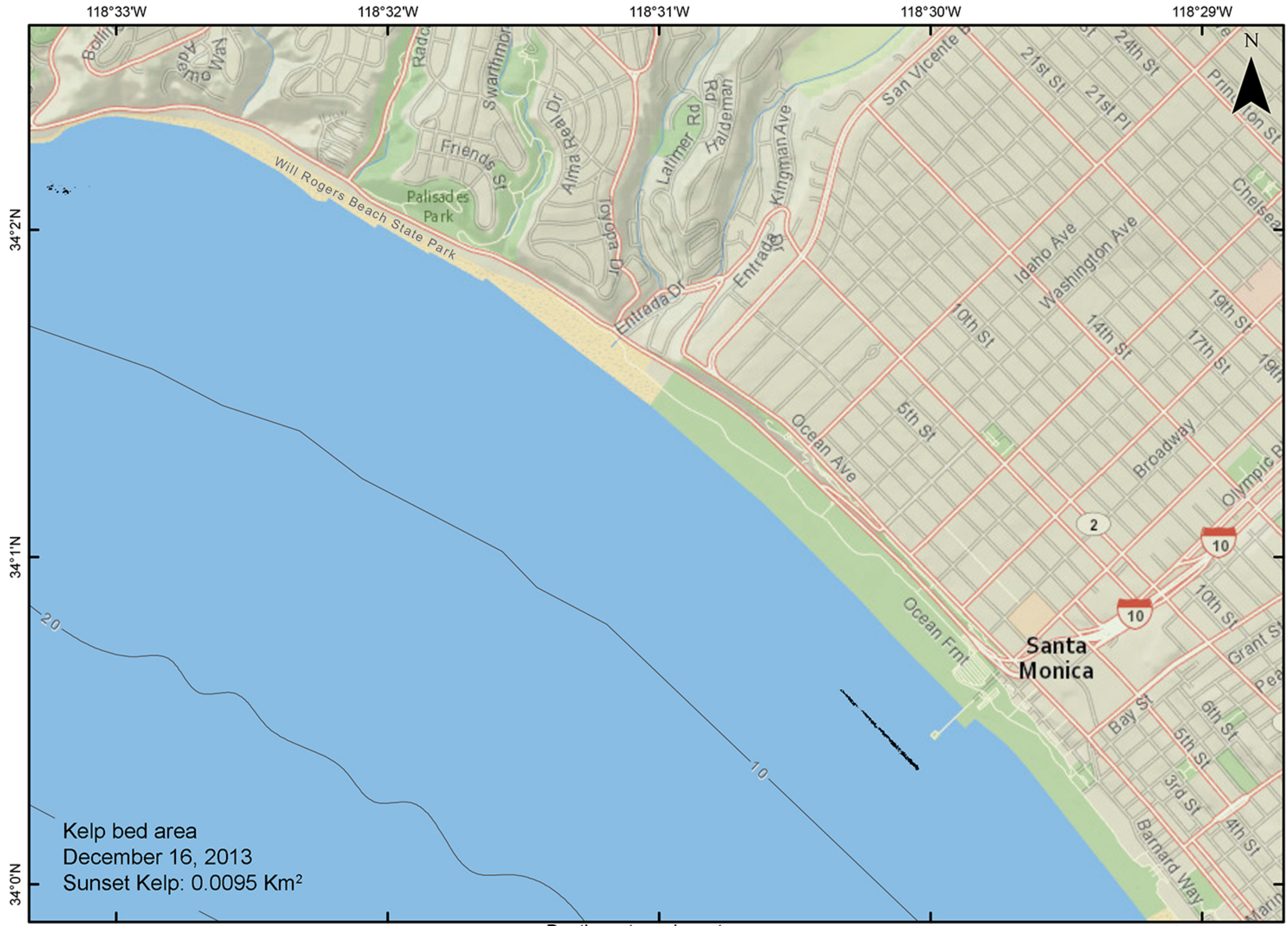

118°45'W
118°44'W
118°43'W
118°42'W
34°2'N
34°1'N
34°0'N
N
Pepperdine University-Malibu
Malibu
Solstice Canyon Rd
Willmott Ln
Puerco Canyon Rd
Civic Center Way
Malibu Bluffs State Recreation Area
Puero Beach
Malibu Rd
Amarillo Beach
Pacific Coast Hwy
Latigo Shore Dr
10
20
30
Kelp bed area
May 13, 2013
Escondido Wash Kelp: 0.2426 Km²
December 16, 2013
Latigo Canyon Kelp: 0.1333 Km²
Puerco/Amarillo Kelp: 0.1049 Km²
1 stat. mi.
1 Km.
Depth contours in meters


118°41'W
118°40'W
118°39'W
118°38'W
34°2'N
34°1'N
N
Palm Canyon Ln
Serra Rd
Sweetwater Mesa Rd
Ridgemont Dr
Carbon Mesa Rd
Carbon Canyon Rd
Big Rock Lateral
Rambla Vis
Carbon Beach
La Costa Beach
Las Flores Beach
Seaboard Rd
Big Rock
Pacific
Cross Creek Rd
Malibu
Malibu Lagoon State Beach
Pacific Ocean
10
20
30
Kelp bed area
December 16, 2013
Malibu Point Kelp: 0.0596 Km²
La Costa Kelp: 0.0025 Km²
May 13, 2013
Las Flores Kelp: 0.0223 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC



118°37'W
118°36'W
118°35'W
118°34'W
118°33'W
34°3'N
34°2'N
34°1'N
N
Canyon
Blvd
Surfwood Rd
Bellino Dr
Bollinger Dr
Big Rock Dr
Las Tunas State Beach
Coastline Dr
Castellammare Dr
Revello Dr
Big Rock Beach
Pacific Coast Hwy
1
10
20
30
Kelp bed area
May 13, 2013
Big Rock Kelp: 0.0165 Km²
Las Tunas Kelp: 0.0288 Km²
Topanga Kelp: 0.0437 Km²
December 16, 2013
Sunset Kelp: 0.0095 Km²
1 stat. mi.
1 Km.
Depth contours in meters

MBC



Depth contours in meters

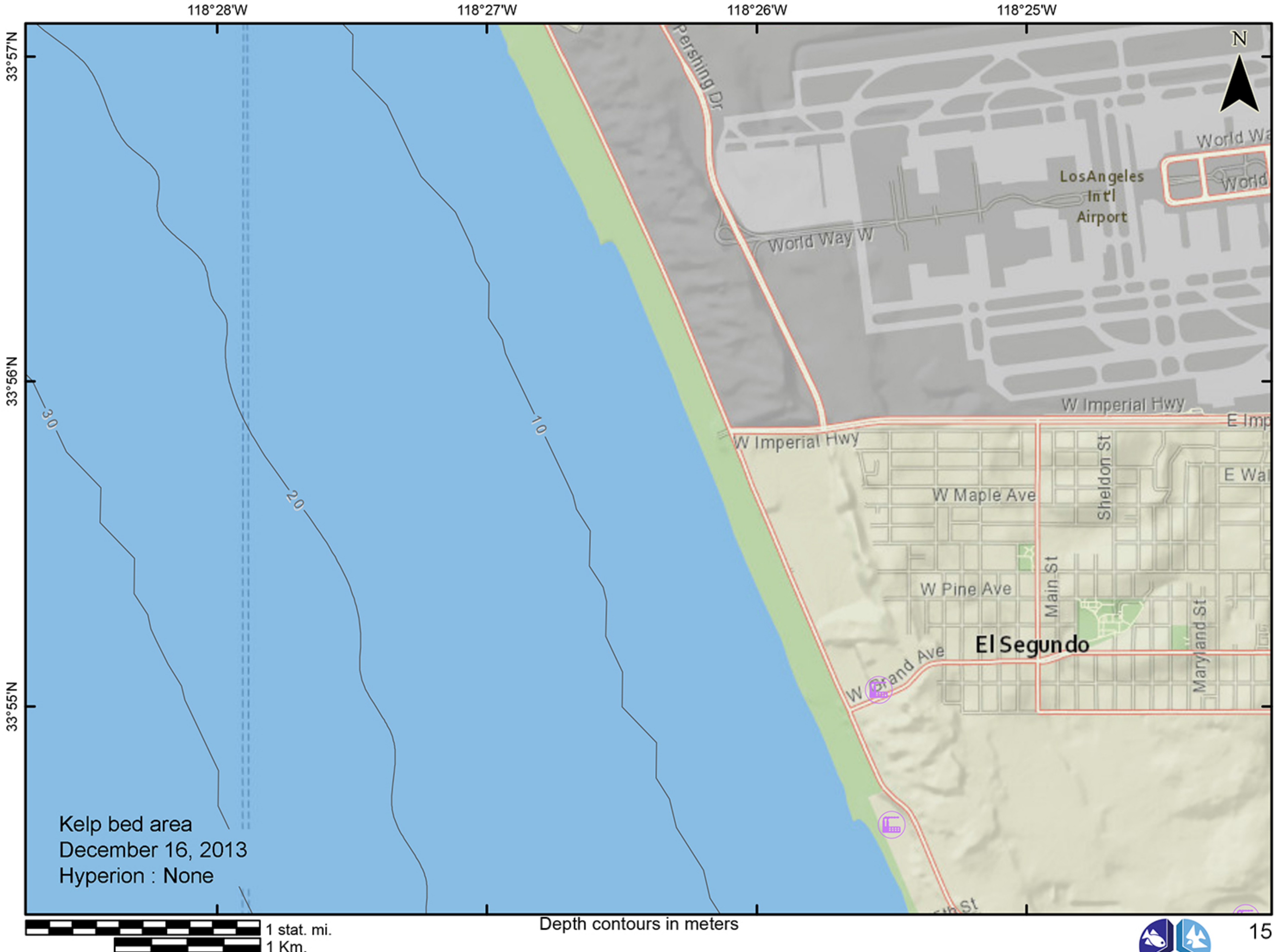
1 stat. mi.
1 Km.

Kelp bed area
December 16, 2013
Marina Del Rey Kelp: 0.0115 Km²

1 stat. mi.
1 Km.

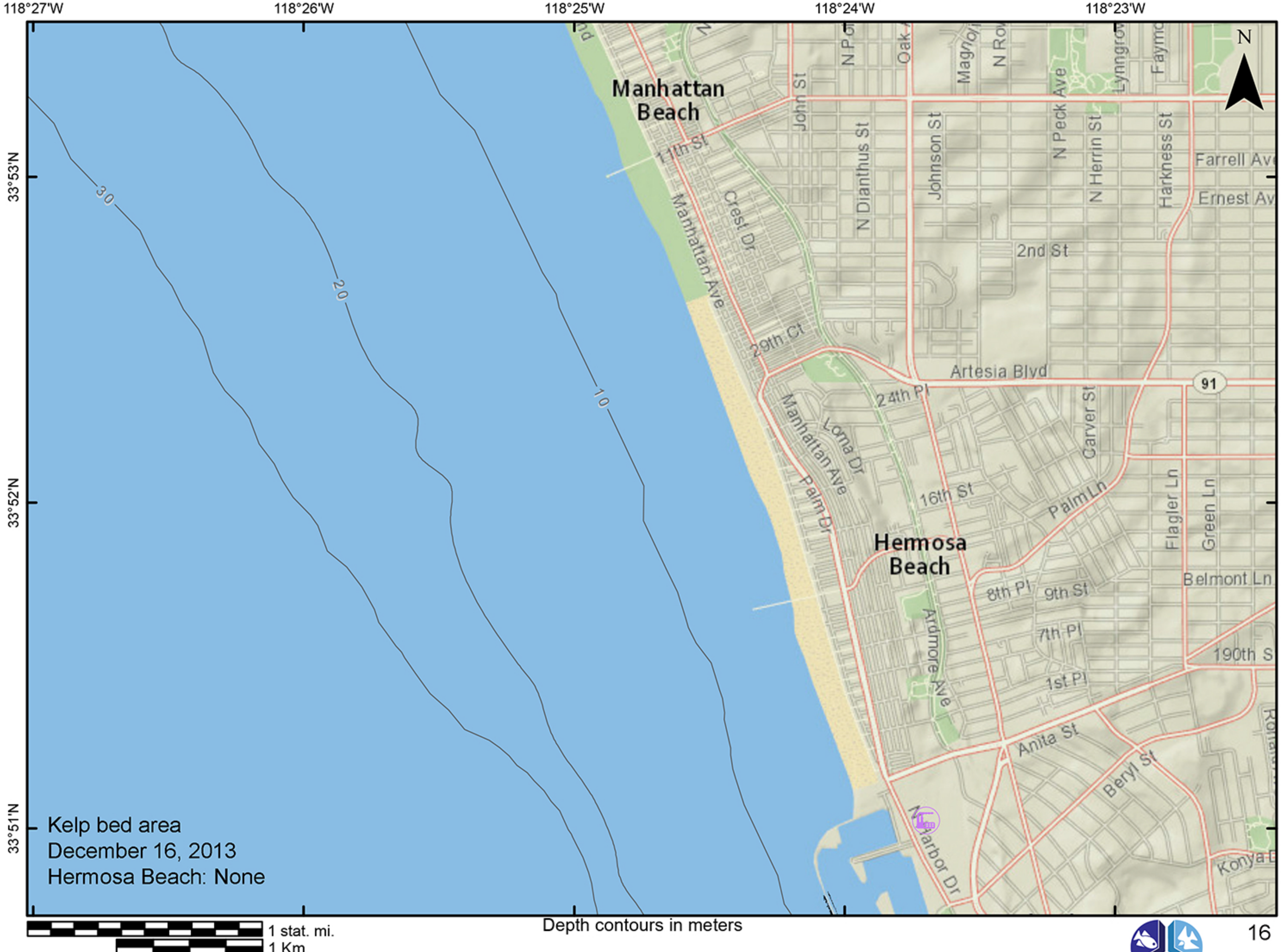
Depth contours in meters

MBC



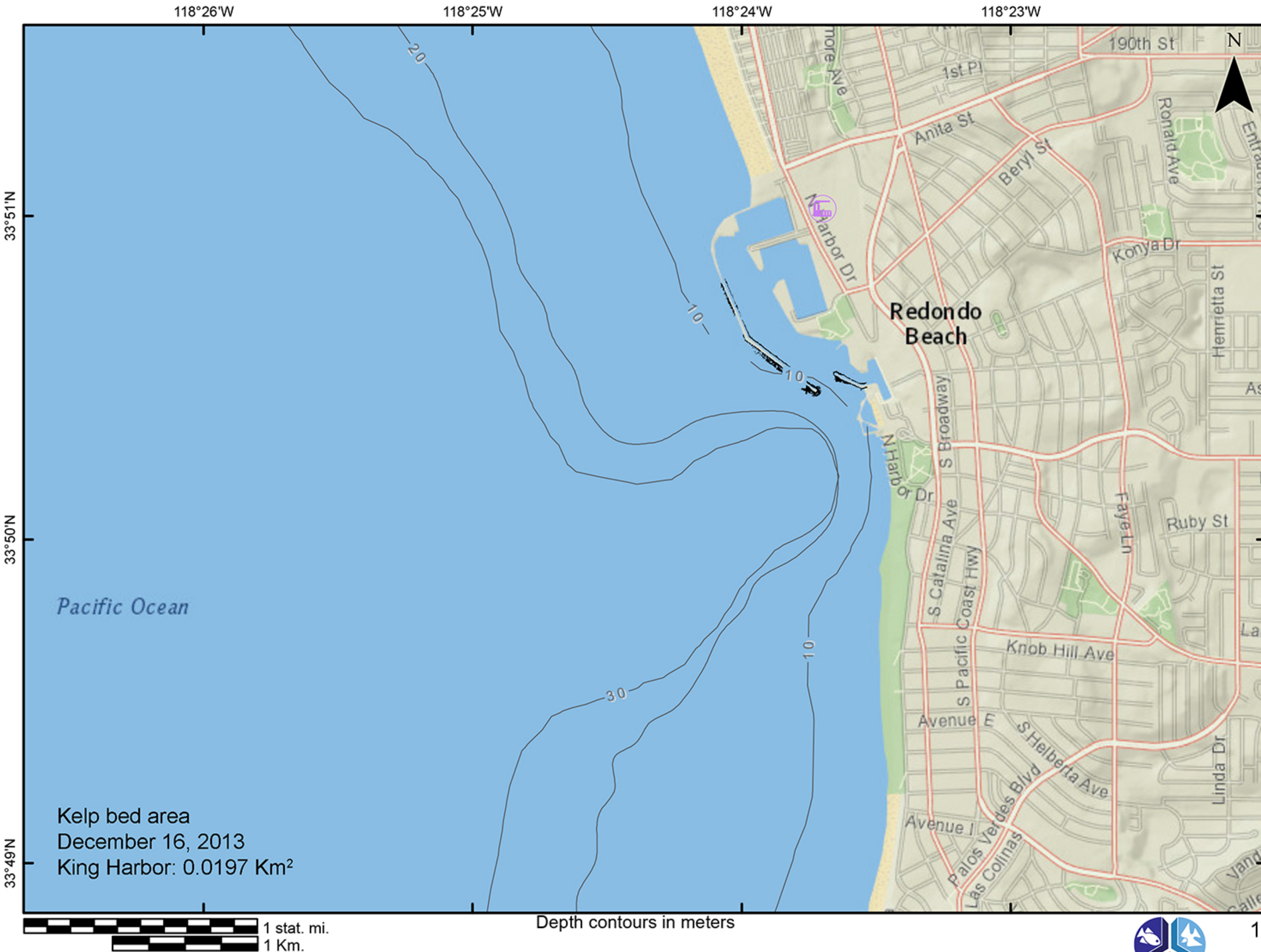
Depth contours in meters

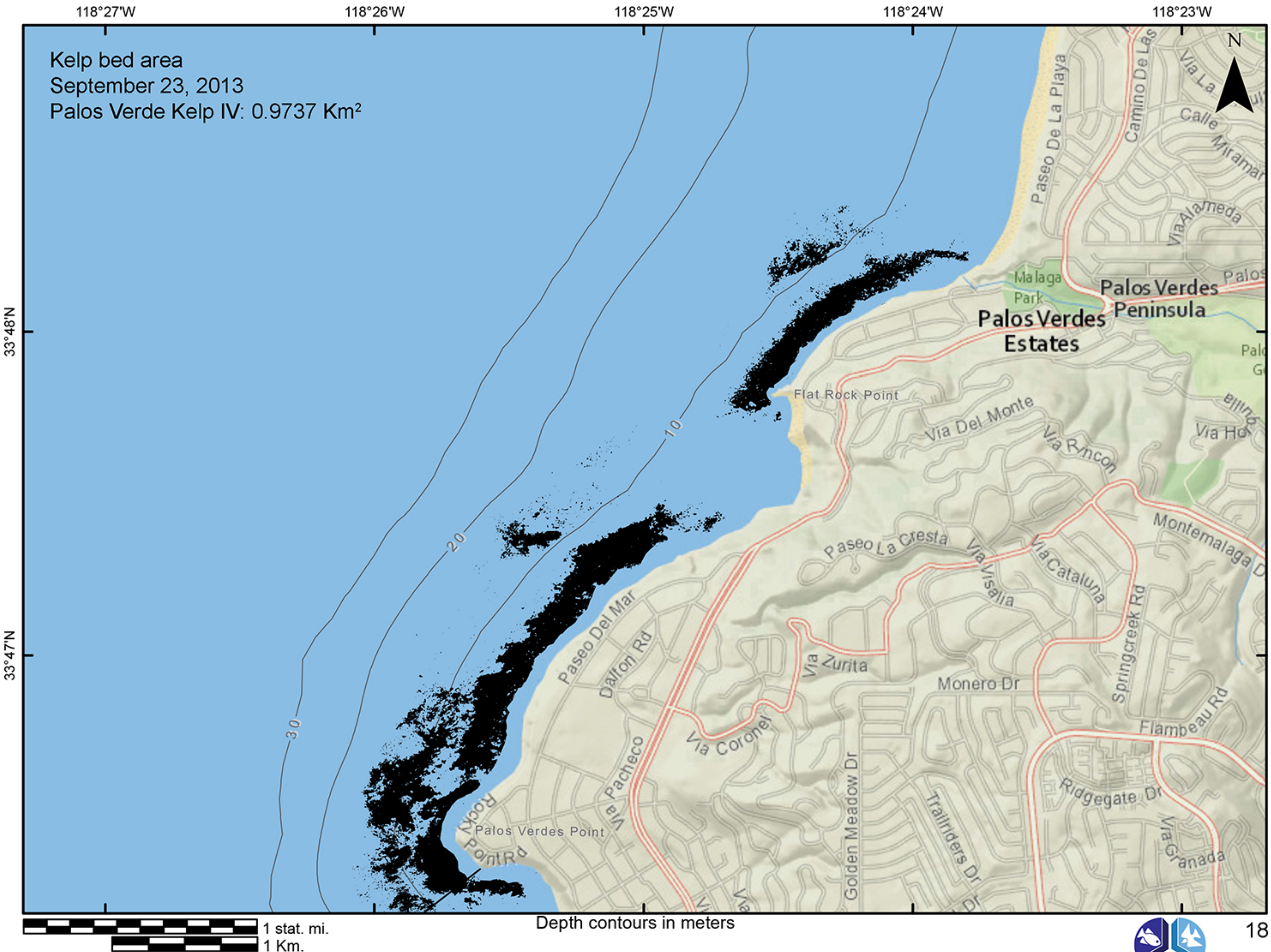
MBC



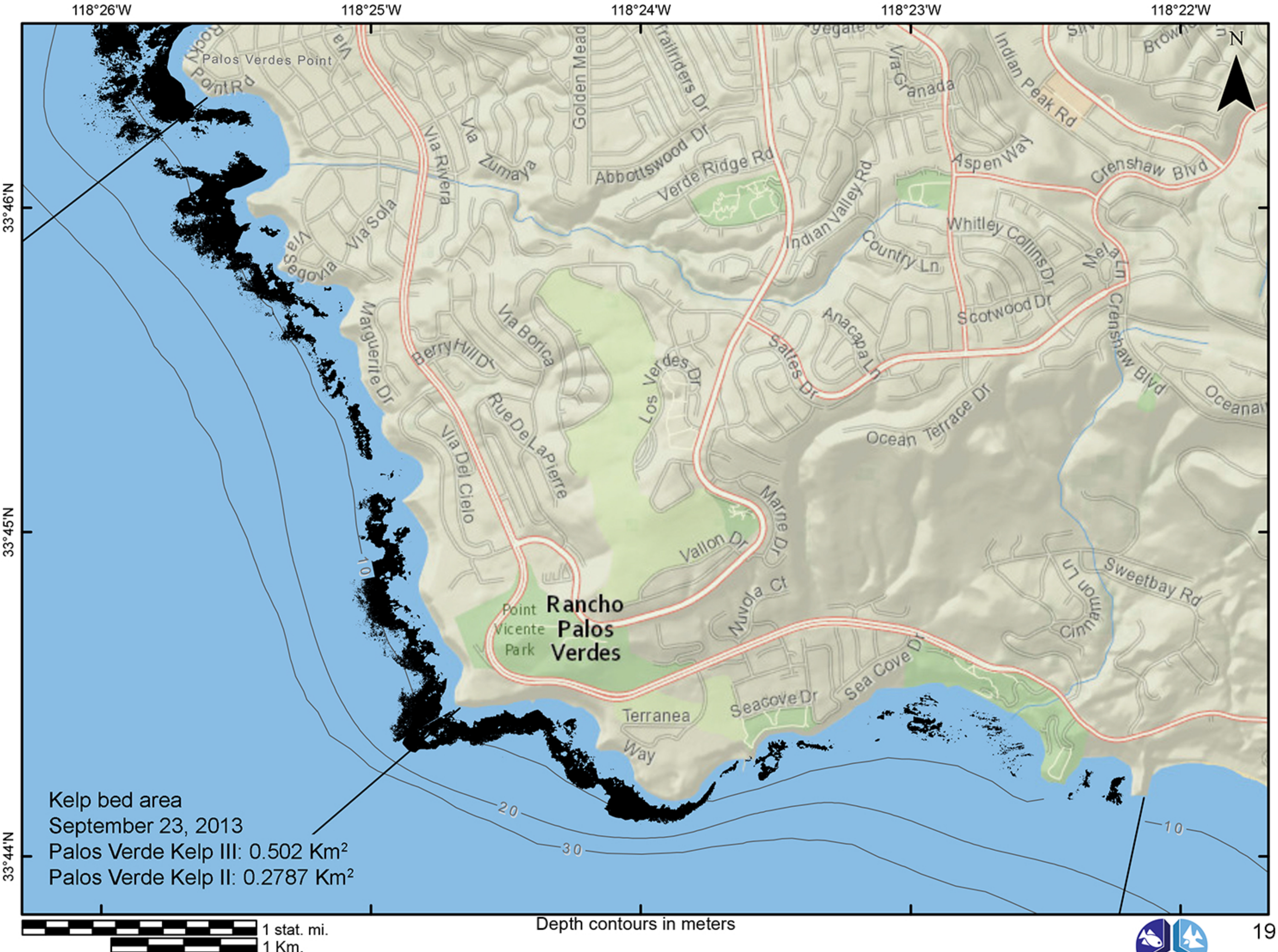
Depth contours in meters

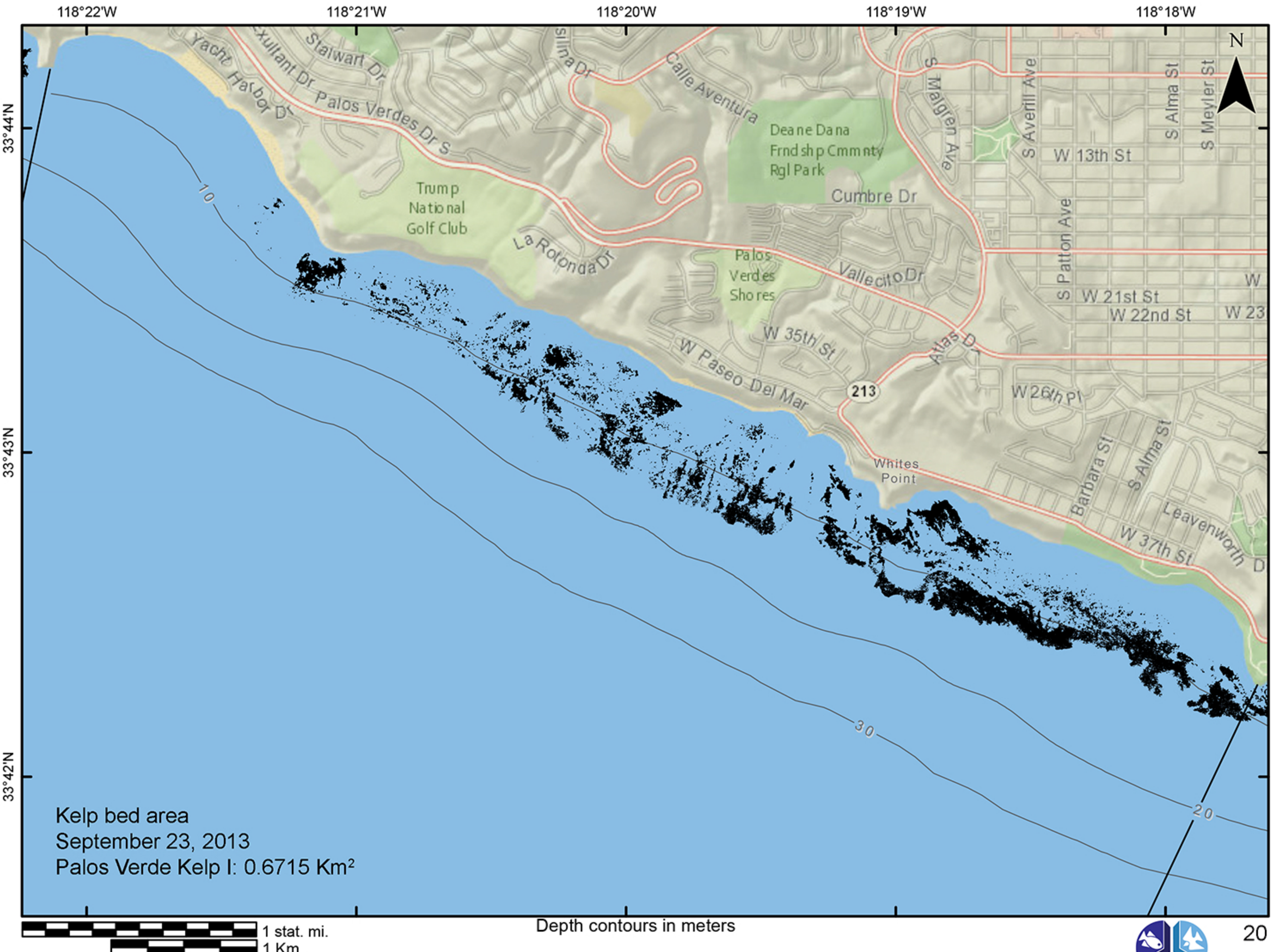
MBC


118°26'W
118°25'W
118°24'W
118°23'W
33°51'N
33°50'N
33°49'N
N
190th St
1st Pl
Anita St
Beryl St
Ronald Ave
Konya Dr
N Harbor Dr
Redondo Beach
Henrietta St
S Broadway
S Catalina Ave
S Pacific Coast Hwy
Faye Ln
Ruby St
Knob Hill Ave
Avenue E
S Helberta Ave
Palos Verdes Blvd
Avenue I
Las Colinas
Linda Dr
Pacific Ocean
20
10
30
Kelp bed area
December 16, 2013
King Harbor: 0.0197 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

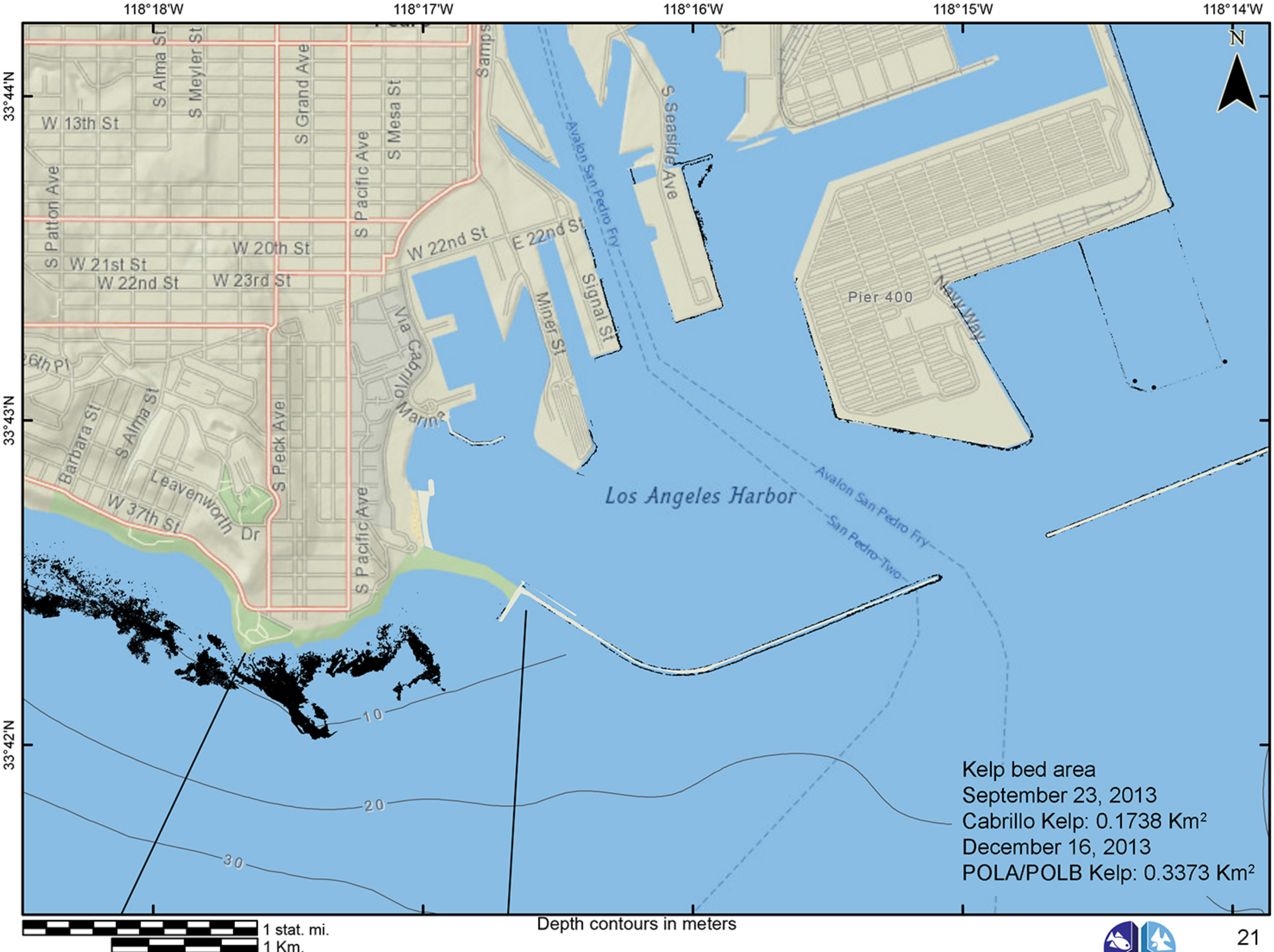


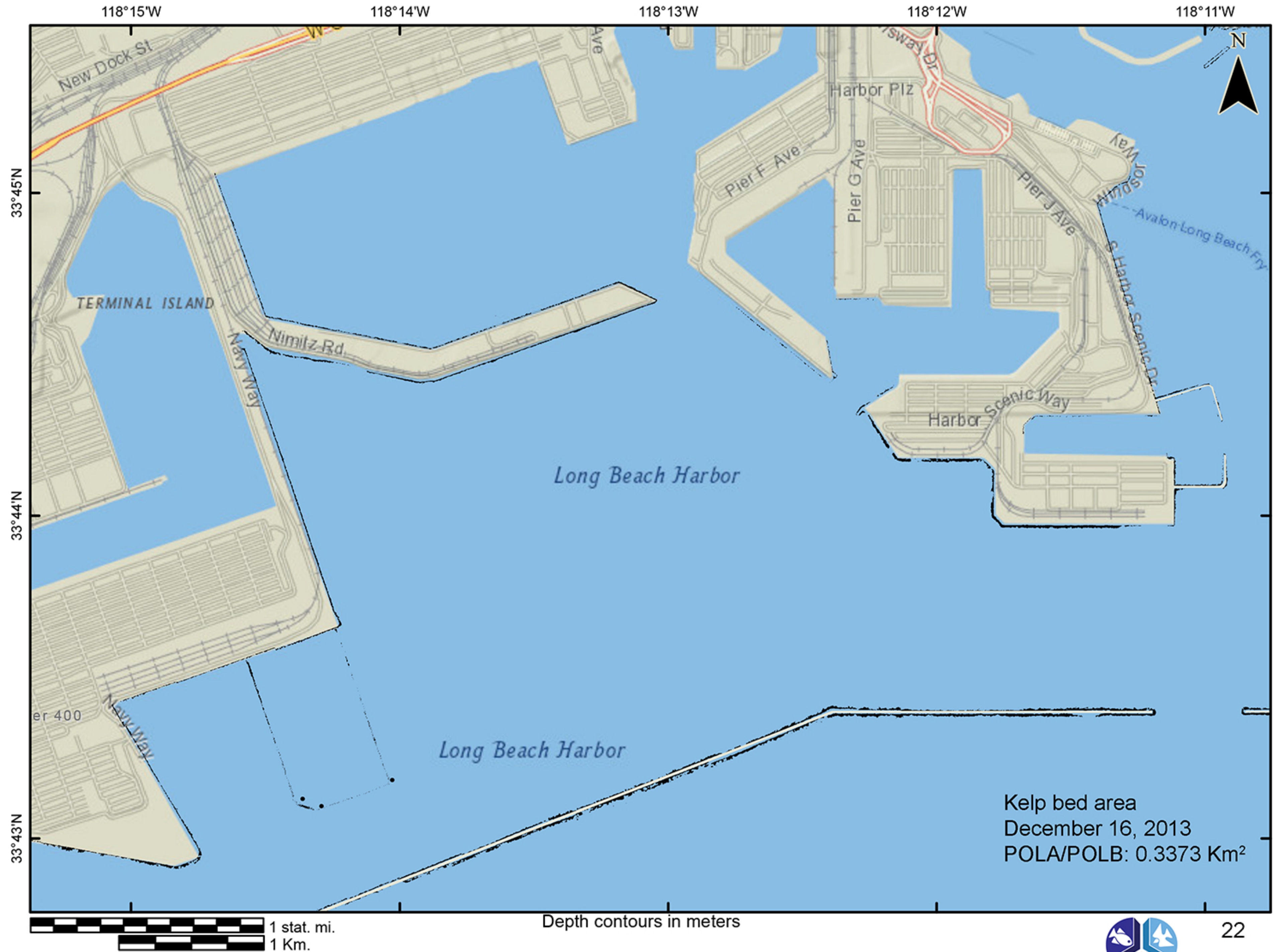
118°27'W
118°26'W
118°25'W
118°24'W
118°23'W
33°48'N
33°47'N
Kelp bed area
September 23, 2013
Palos Verde Kelp IV: 0.9737 Km²
N
10
20
30
Flat Rock Point
Palos Verdes Estates
Palos Verdes Peninsula
Malaga Park
Paseo De La Playa
Via Del Monte
Via Rincon
Paseo La Cresta
Via Visalia
Via Cataluna
Montemalaga Dr
Springcreek Rd
Paseo Del Mar
Dalton Rd
Via Zurita
Monero Dr
Flambeau Rd
Via Coronel
Via Pacheco
Golden Meadow Dr
Trailriders Dr
Ridgegate Dr
Via Granada
Palos Verdes Point
Rocky Point Rd
1 stat. mi.
1 Km.
Depth contours in meters


118°26'W
118°25'W
118°24'W
118°23'W
118°22'W
33°46'N
33°45'N
33°44'N
N
Palos Verdes Point
Rocky Point Rd
Via Rivera
Via Zumaya
Golden Meadow
Trailriders Dr
Abbottswood Dr
Verde Ridge Rd
Indian Valley Rd
Via Granada
Indian Peak Rd
Aspen Way
Crenshaw Blvd
Via Sola
Via Segovia
Whitley Collins Dr
Country Ln
Mela Ln
Scotwood Dr
Anacapa Ln
Saffes Dr
Marguerite Dr
Berry Hill Dr
Via Borica
Los Verdes Dr
Rue De La Pierre
Via Del Cielo
Ocean Terrace Dr
Oceanaire
Marne Dr
Vallon Dr
Sweetbay Rd
Cinnamon Ln
Muvola Ct
Point Vicente Park
Rancho Palos Verdes
Sea Cove Dr
Seacove Dr
Terranea Way
10
20
30
Kelp bed area
September 23, 2013
Palos Verde Kelp III: 0.502 Km²
Palos Verde Kelp II: 0.2787 Km²
1 stat. mi.
1 Km.
Depth contours in meters

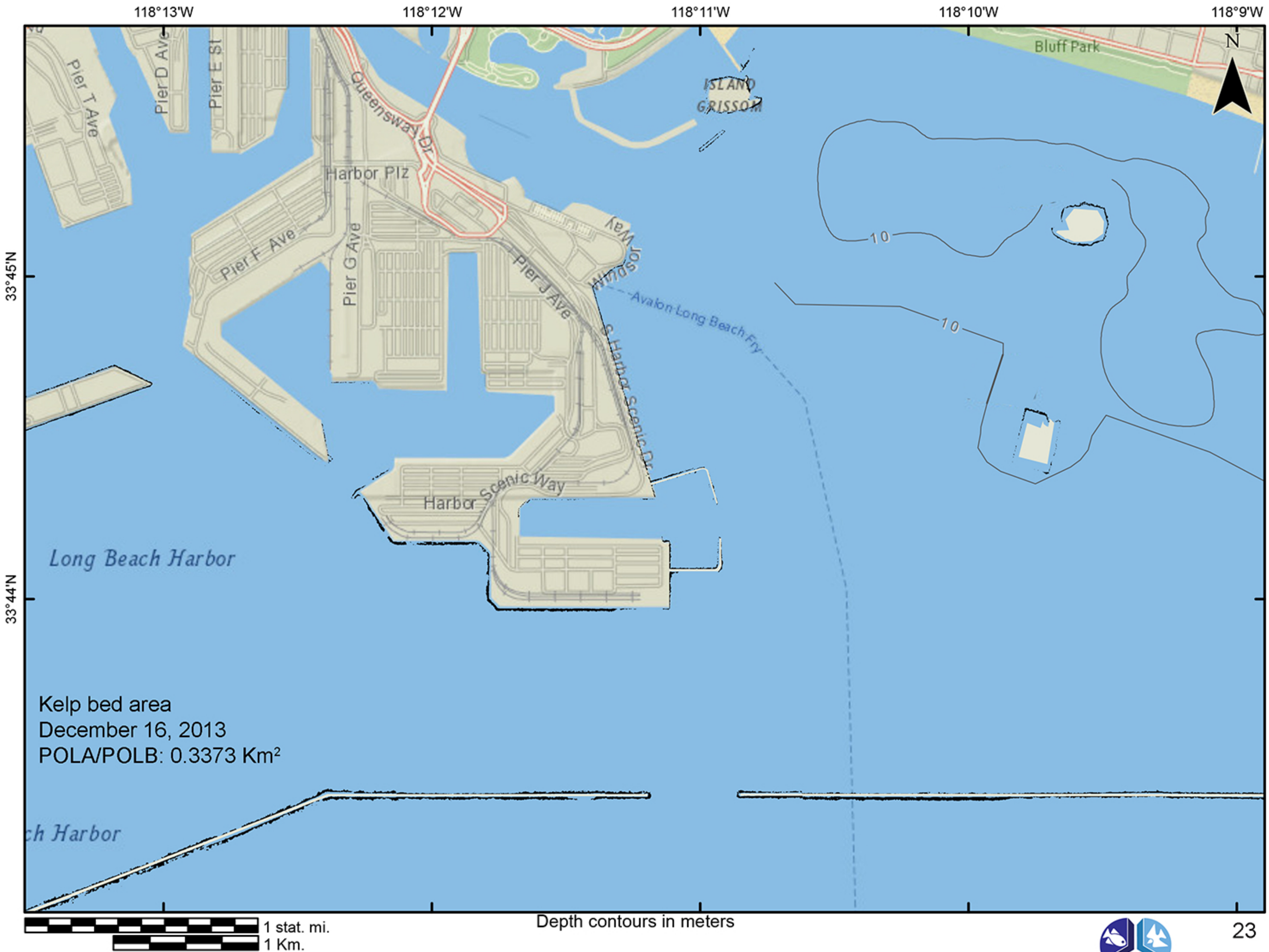


Depth contours in meters


118°18'W
118°17'W
118°16'W
118°15'W
118°14'W
33°44'N
33°43'N
33°42'N
N
W 13th St
S Alma St
S Meyler St
S Grand Ave
S Mesa St
S Pacific Ave
S Patton Ave
W 20th St
W 21st St
W 22nd St
W 23rd St
E 22nd St
Miner St
Signal St
S Seaside Ave
Avalon San Pedro Fry
Pier 400
Navy Way
Via Cabrillo Marina
Barbara St
S Alma St
S Peck Ave
Leavenworth Dr
W 37th St
S Pacific Ave
Los Angeles Harbor
Avalon San Pedro Fry
San Pedro Two
10
20
30
Kelp bed area
September 23, 2013
Cabrillo Kelp: 0.1738 Km²
December 16, 2013
POLA/POLB Kelp: 0.3373 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC



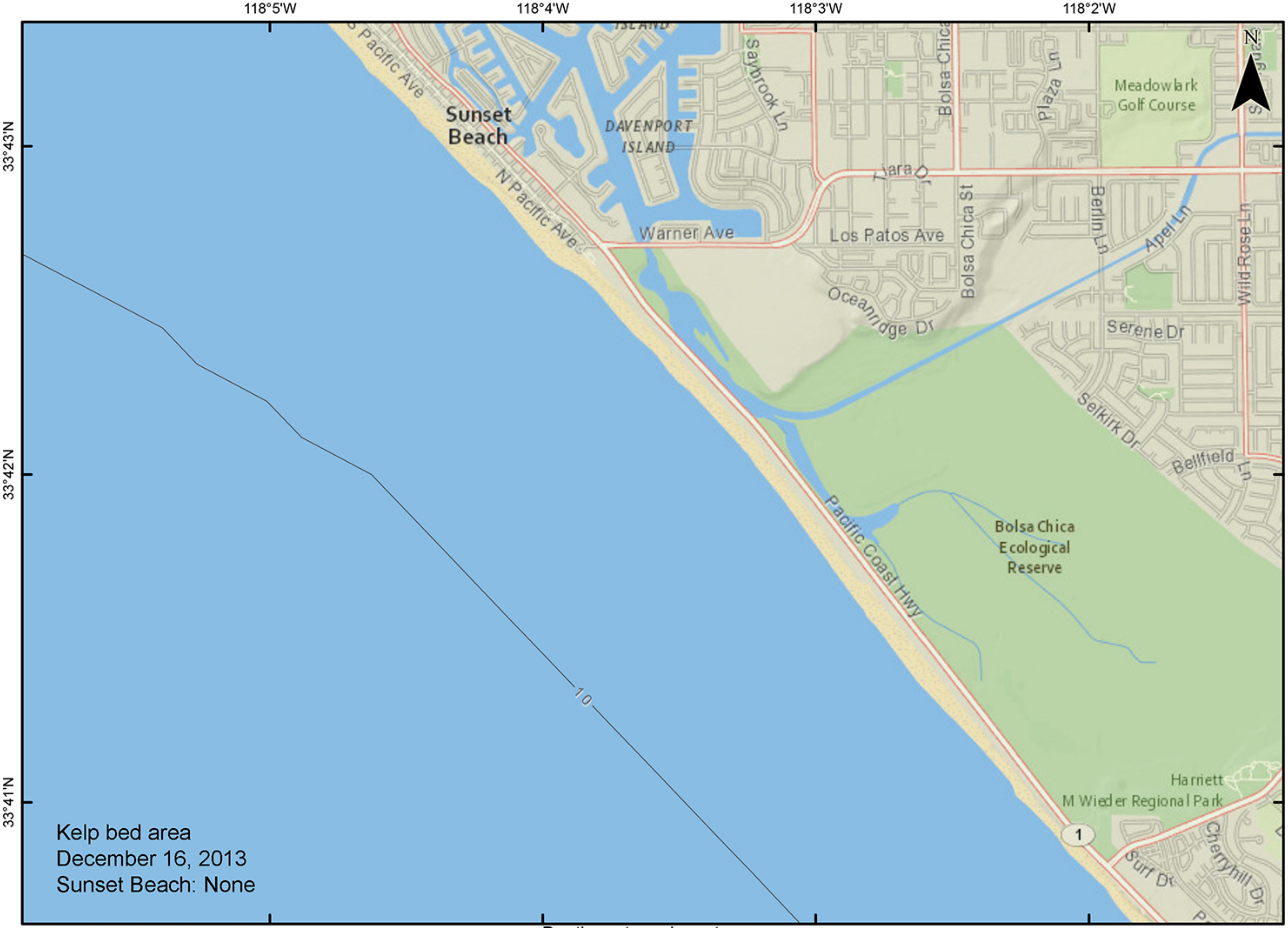
118°15'W
118°14'W
118°13'W
118°12'W
118°11'W
33°45'N
33°44'N
33°43'N
N
New Dock St
Harbor Plz
Pier F Ave
Pier G Ave
Pier J Ave
Windsor Way
Avalon Long Beach Fry
S Harbor Scenic Dr
Harbor Scenic Way
TERMINAL ISLAND
Nimitz Rd
Navy Way
Long Beach Harbor
Long Beach Harbor
Kelp bed area
December 16, 2013
POLA/POLB: 0.3373 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


118°13'W
118°12'W
118°11'W
118°10'W
118°9'W
33°45'N
33°44'N
Pier D Ave
Pier E St
Pier T Ave
Queensway Dr
Harbor Plz
Pier F Ave
Pier G Ave
Pier J Ave
Windsor Way
S Harbor Scenic Dr
Harbor Scenic Way
Avalon Long Beach Fry
ISLAND GRISSOM
Bluff Park
N
10
10
Long Beach Harbor
ch Harbor
Kelp bed area
December 16, 2013
POLA/POLB: 0.3373 Km²
1 stat. mi.
1 Km.
Depth contours in meters

MBC


118°9'W
118°8'W
118°7'W
118°6'W
118°5'W
33°45'N
33°44'N
33°43'N
N
2nd Street
NAPLES ISLAND
Lido Ln
E Ocean Blvd
61st Pl
66th Pl
Anaheim Bay
E Marina Dr
N Marina Dr
LOS ANGELES
ORANGE
Gum Grove Park
Seal Beach Blvd
Hussey Rd
Bolsa Ave
Pelorus Ave
Seal Beach
2nd St
Ocean Ave
Landing Ave
Electric Ave
Seal Way
Huntington Harbor
Pacific Ocean
ISLAND CHAFFEE
10
Surfside
S Pacific
Kelp bed area
December 16, 2013
POLA/POLB: 0.3373 Km²
1 stat. mi.
1 Km.
Depth contours in meters

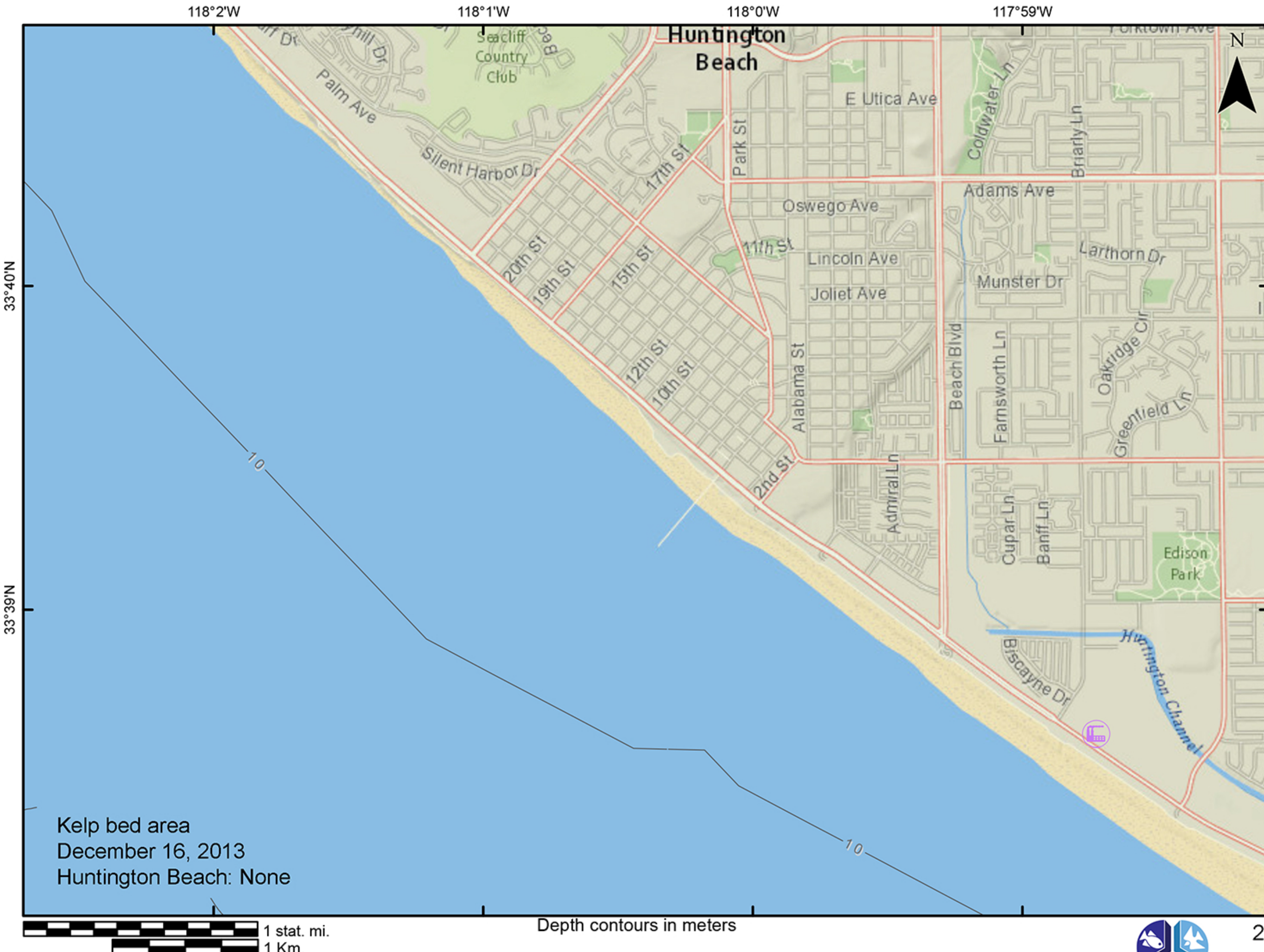
MBC



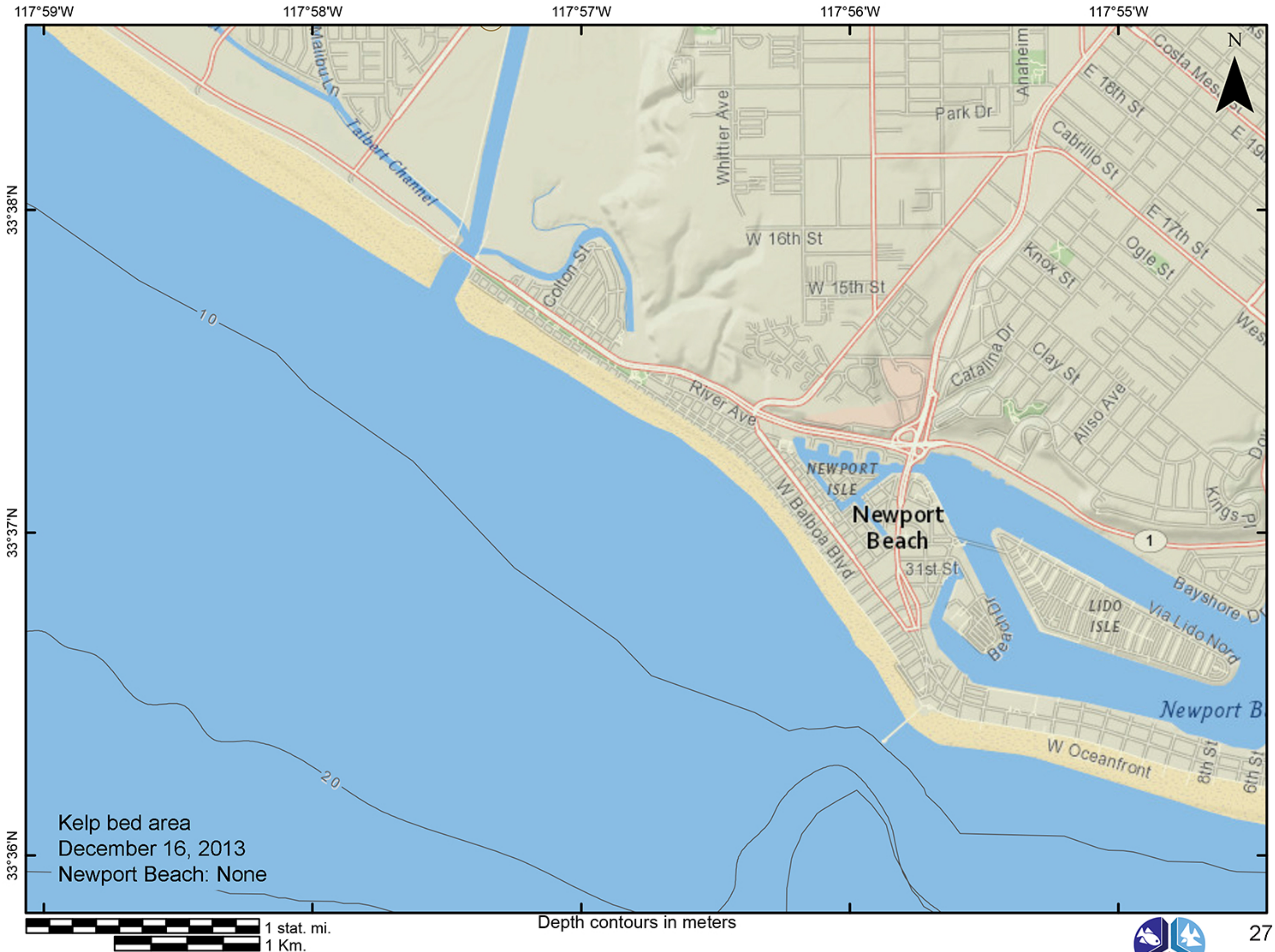
1 stat. mi.
1 Km.

Depth contours in meters

MBC

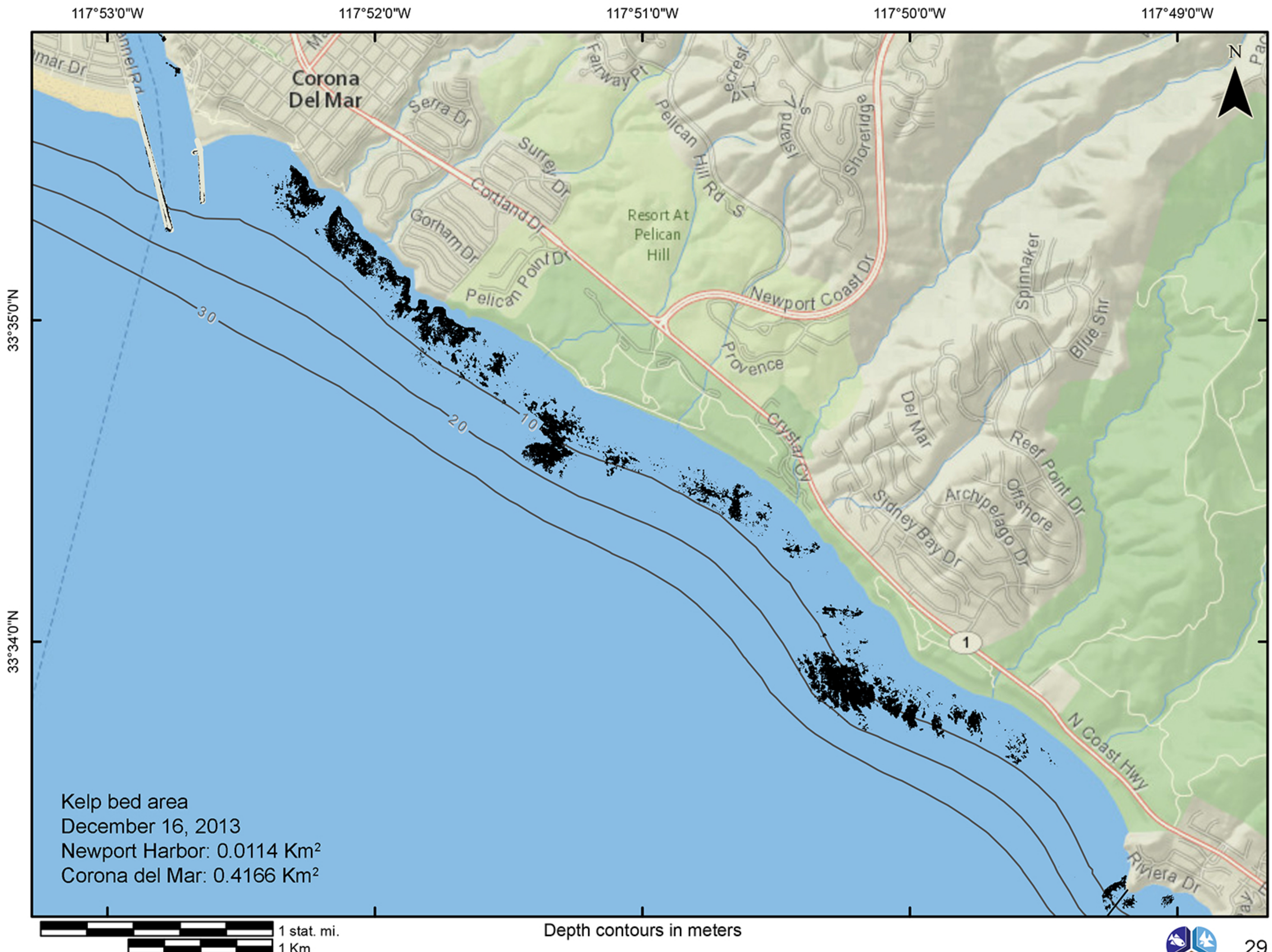


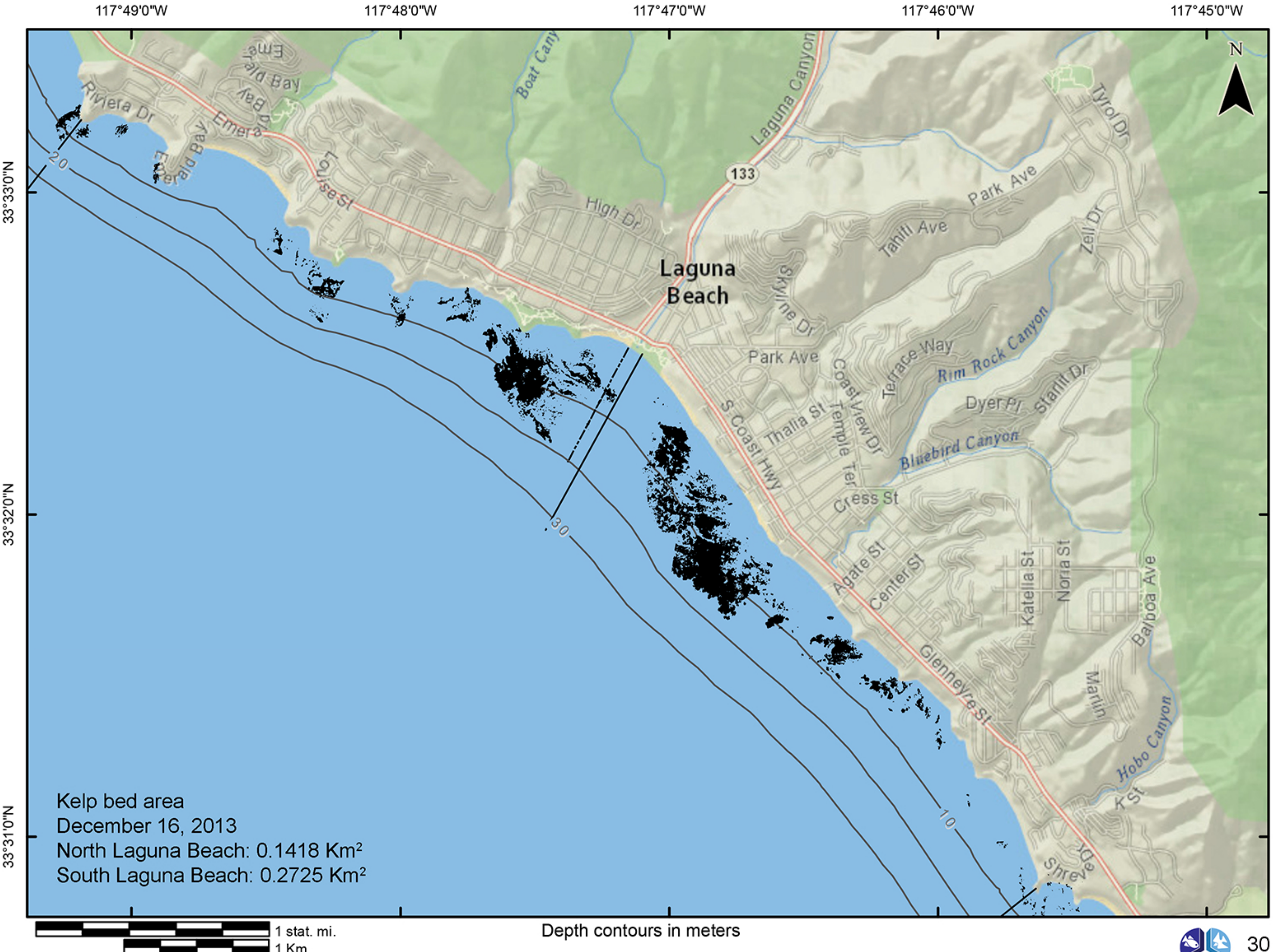
Depth contours in meters

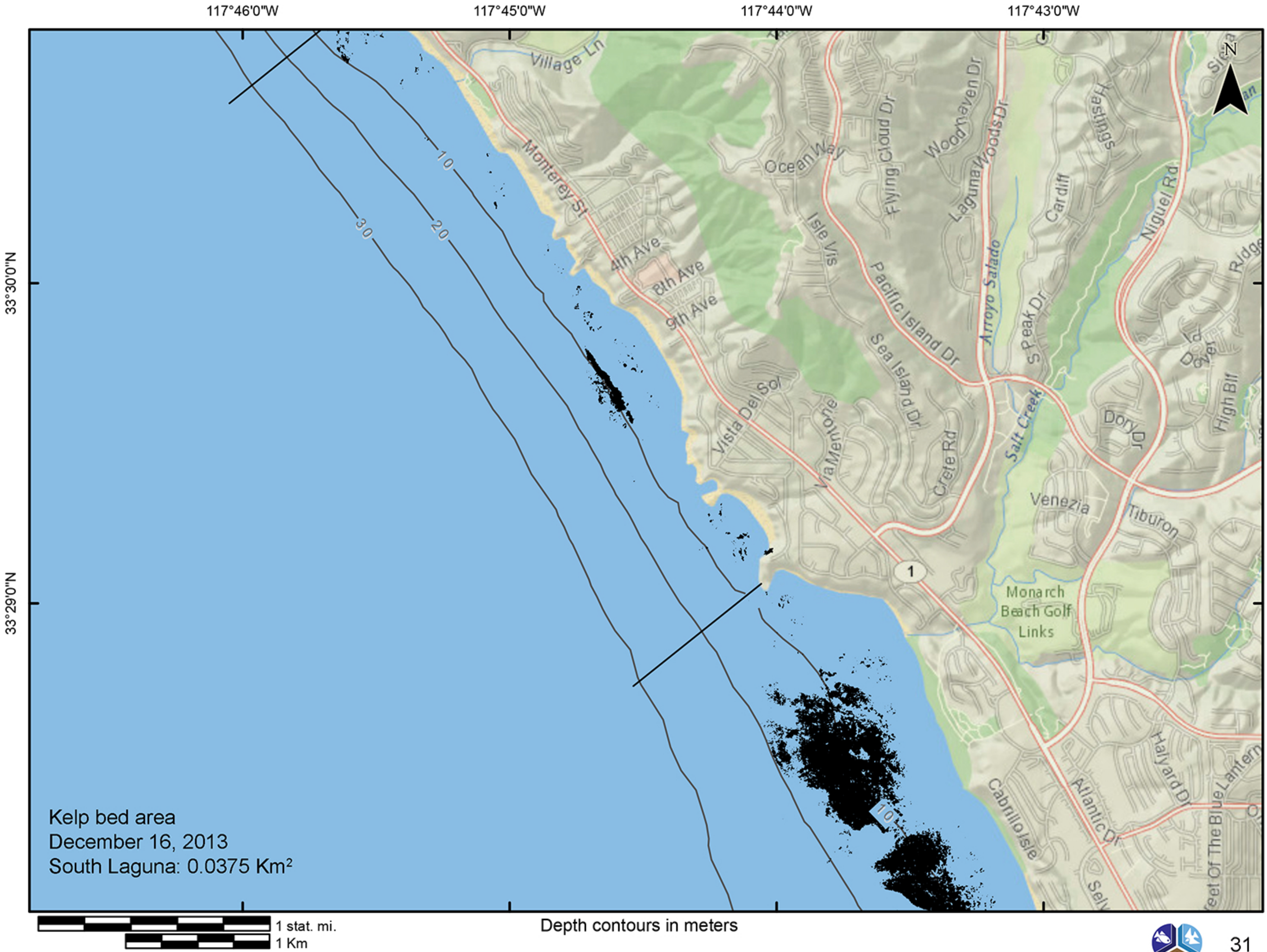


Depth contours in meters


117°56'W
117°55'W
117°54'W
117°53'W
117°52'W
33°37'N
33°36'N
33°35'N
N
Newport Beach
Corona Del Mar
NEWPORT ISLE
LIDO ISLE
LINDA ISLE
HARBOR ISLAND
BAY ISLE
BALBOA ISLAND
Fashion Island
Newport Beach Country Club
Newport Bay
Pacific Ocean
W Balboa Blvd
31st St
Via Lido Nord
Bayshore Dr
Bayside Dr
Dolphin Ter
Pearl Ave
W Oceanfront
E Oceanfront
E Bay Ave
8th St
6th St
A St
F St
Miramar Dr
Channel Rd
Newport Center Dr
Ocean Vis
Avocado Ave
Crown Dr
Sea Ln
Iris Ave
Marguerite Ave
Kings Pl
Liberty
1
10
20
30
Kelp bed area
December 16, 2013
Newport Harbor: 0.0114 Km²
1 stat. mi.
1 Km.
Depth contours in meters


117°53'0"W
117°52'0"W
117°51'0"W
117°50'0"W
117°49'0"W
33°35'0"N
33°34'0"N
N
Corona
Del Mar
Serra Dr
Surrey Dr
Cortland Dr
Gorham Dr
Pelican Point Dr
Fairway Pt
Pelican Hill Rd S
Resort At
Pelican
Hill
Shoreridge
Newport Coast Dr
Provence
Crystal Cv
Del Mar
Spinnaker
Blue Shr
Reef Point Dr
Offshore
Archipelago Dr
Sidney Bay Dr
1
N Coast Hwy
Riviera Dr
30
20
10
Kelp bed area
December 16, 2013
Newport Harbor: 0.0114 Km²
Corona del Mar: 0.4166 Km²
1 stat. mi.
1 Km
Depth contours in meters

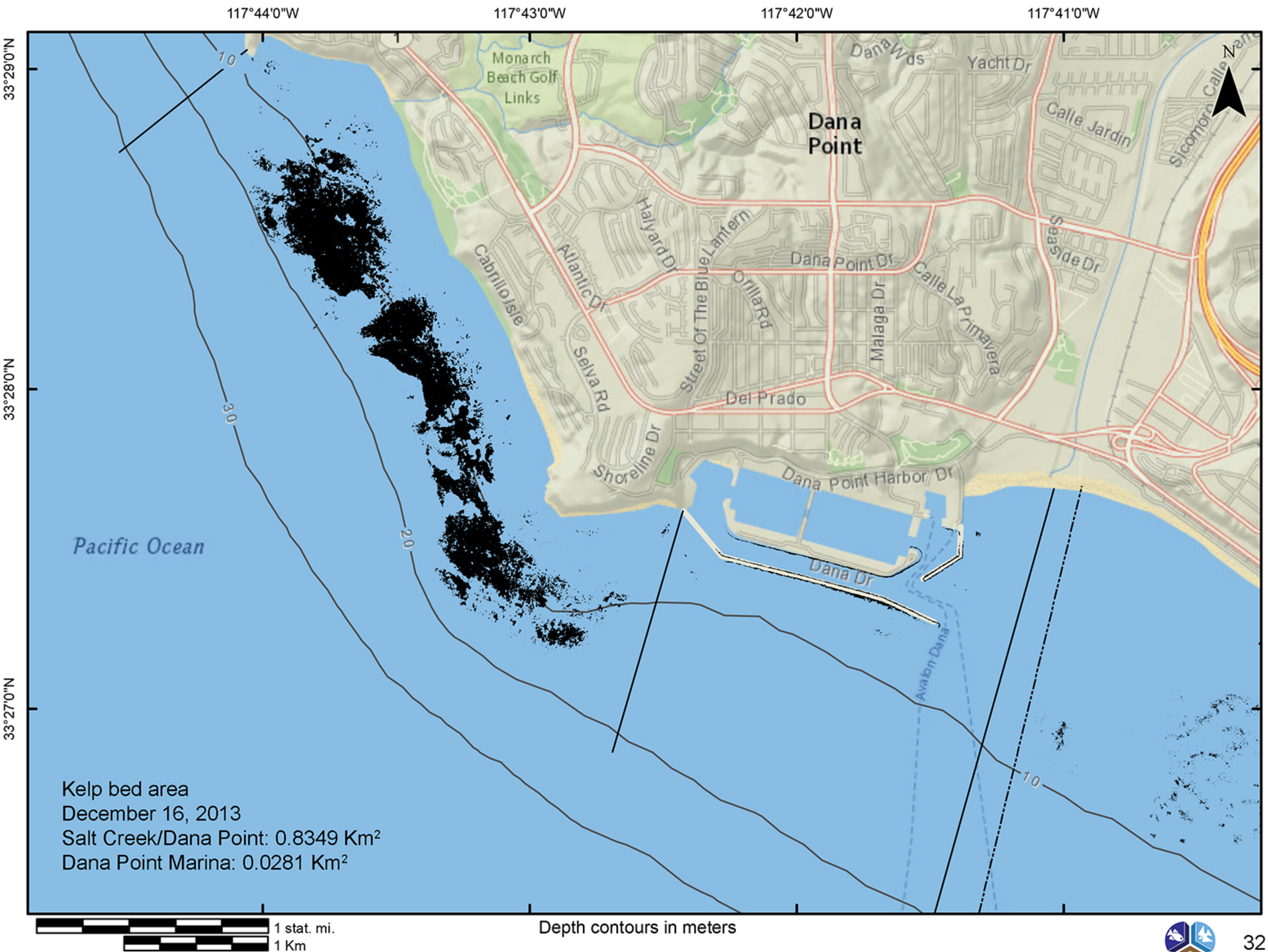

117°49'0"W
117°48'0"W
117°47'0"W
117°46'0"W
117°45'0"W
33°33'0"N
33°32'0"N
33°31'0"N
N
Laguna
Beach
20
30
10
Kelp bed area
December 16, 2013
North Laguna Beach: 0.1418 Km²
South Laguna Beach: 0.2725 Km²
1 stat. mi.
1 Km
Depth contours in meters

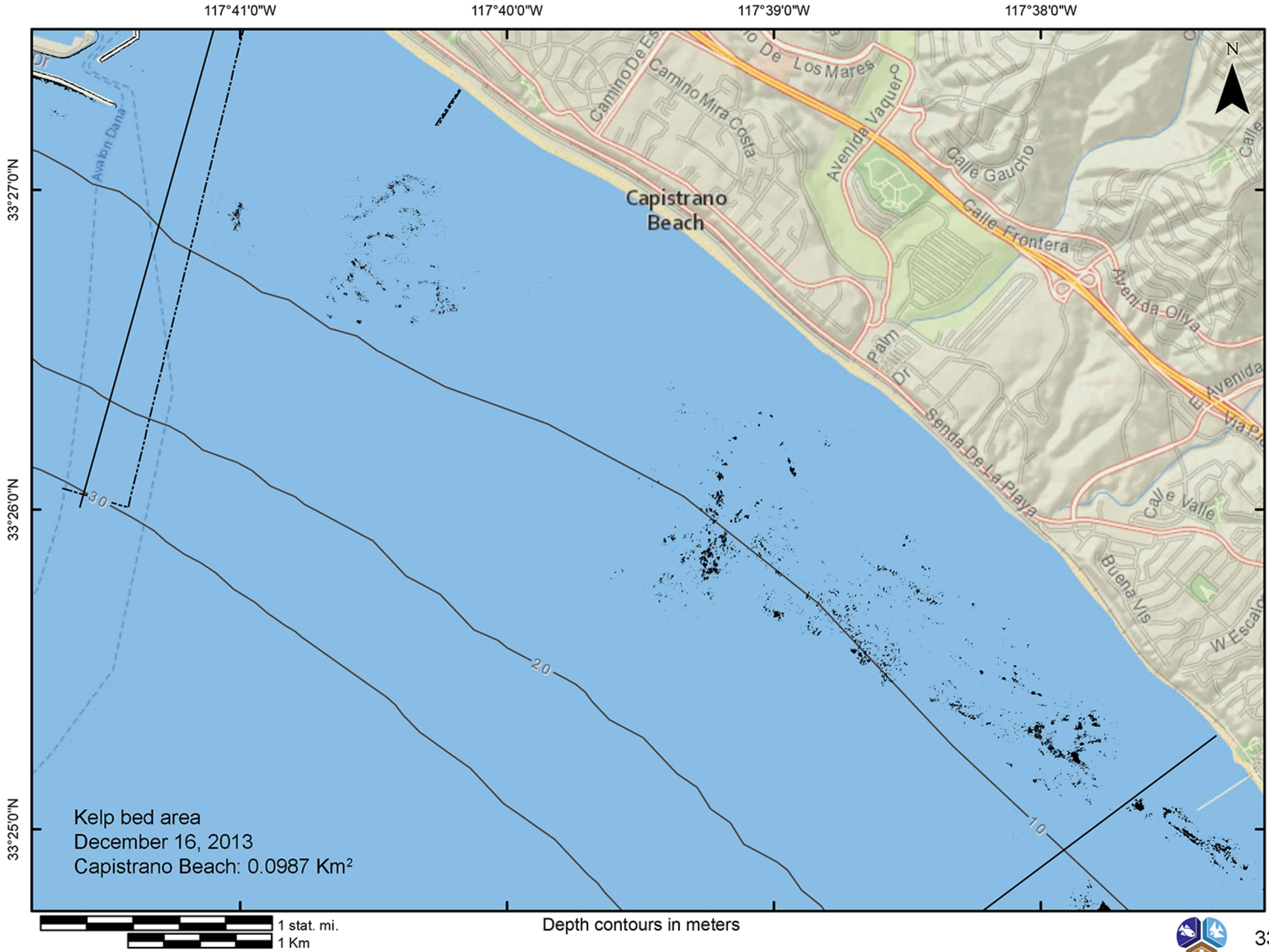


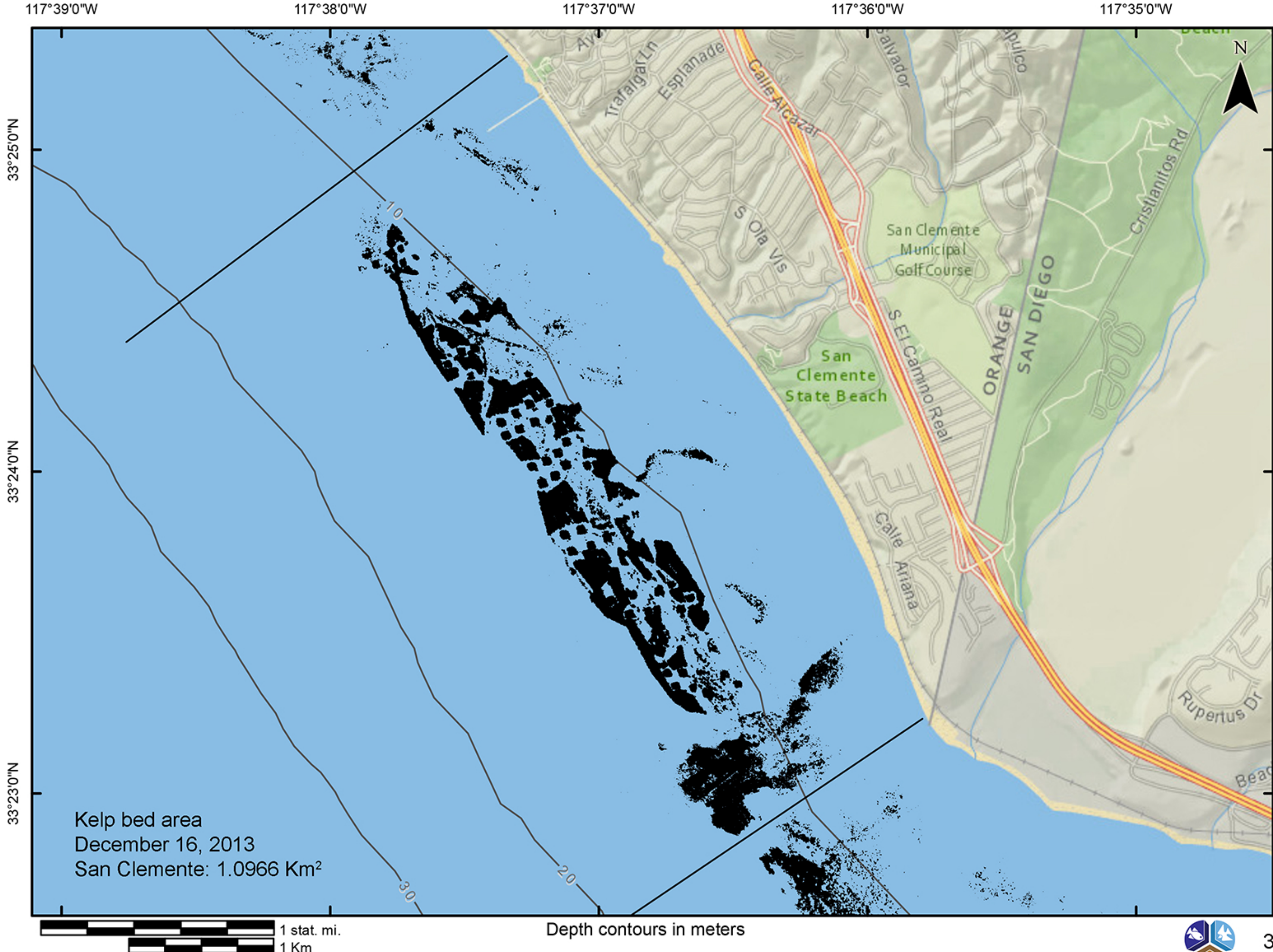
Kelp bed area
December 16, 2013
South Laguna: 0.0375 Km²

Depth contours in meters

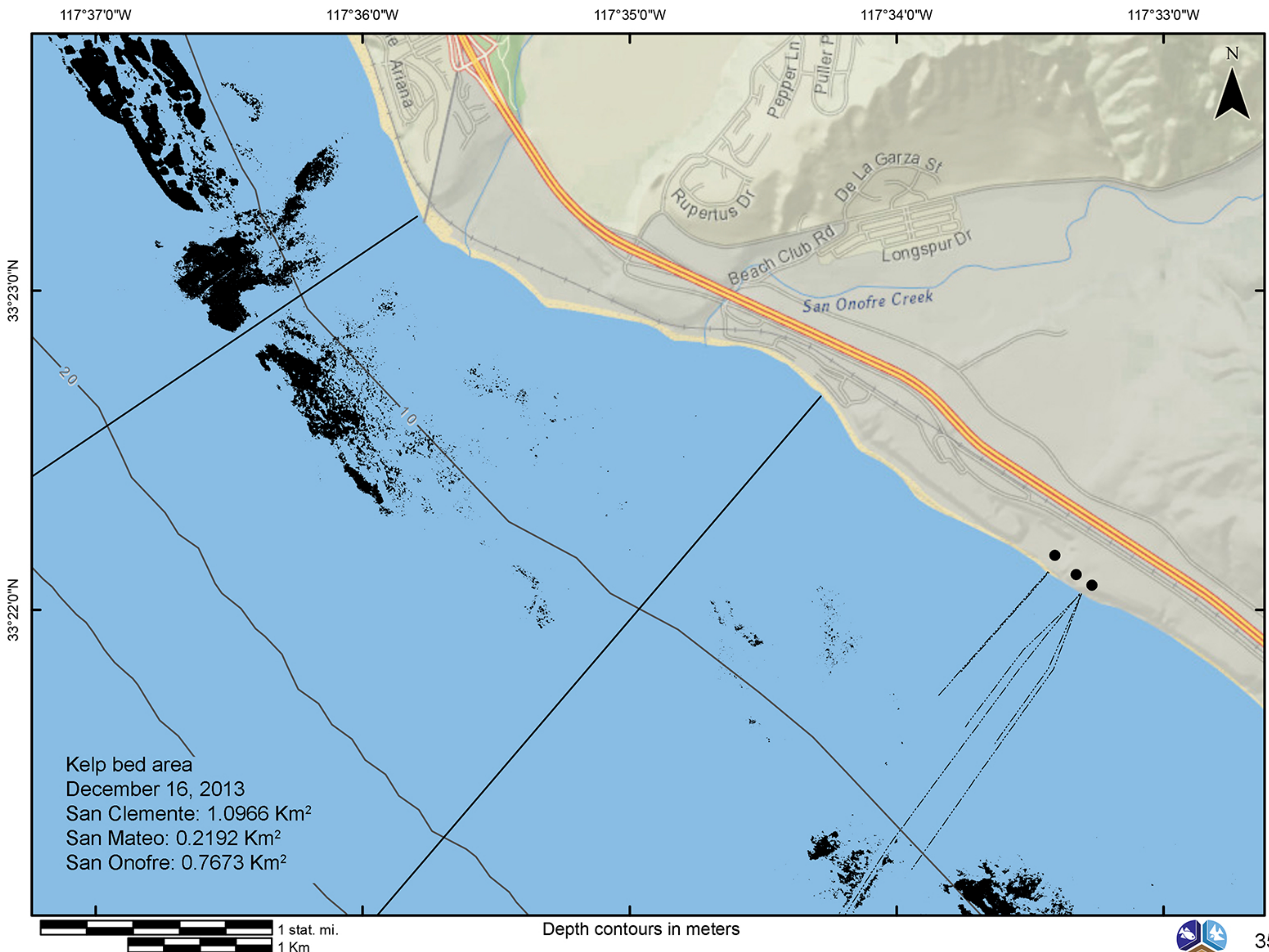
MBC


117°44'0"W
117°43'0"W
117°42'0"W
117°41'0"W
33°29'0"N
33°28'0"N
33°27'0"N
Monarch Beach Golf Links
Dana Point
Pacific Ocean
Kelp bed area
December 16, 2013
Salt Creek/Dana Point: 0.8349 Km²
Dana Point Marina: 0.0281 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

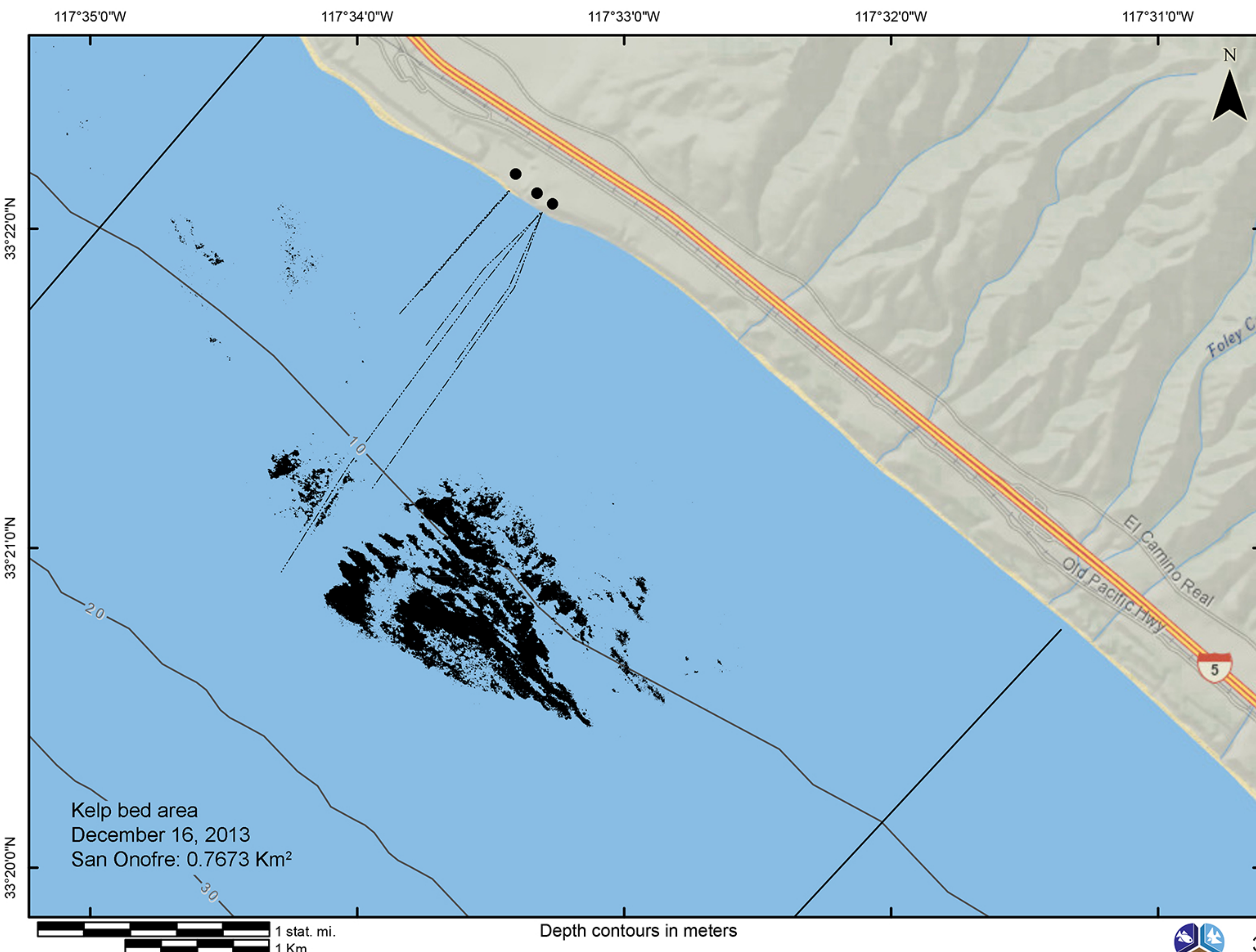

117°41'0"W
117°40'0"W
117°39'0"W
117°38'0"W
33°27'0"N
33°26'0"N
33°25'0"N
N
Capistrano Beach
Camino De Los Mares
Camino Mira Costa
Avenida Vaquero
Calle Gaucho
Calle Frontera
Avenida Oliva
Palm Dr
Senda De La Playa
Calle Valle
Buena Vis
W Escalo
Avalon Dana
30
20
10
Kelp bed area
December 16, 2013
Capistrano Beach: 0.0987 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC



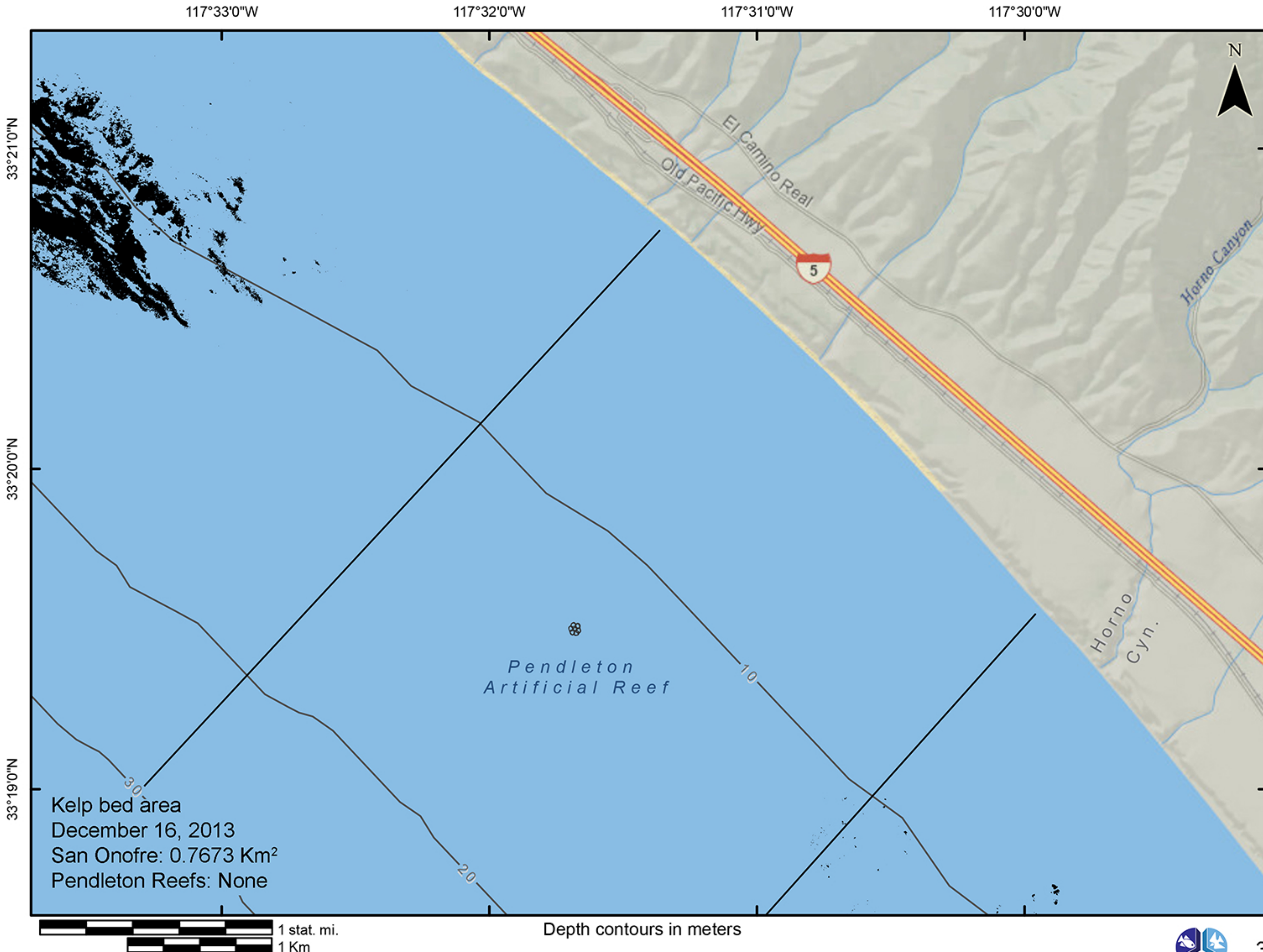
117°39'0"W
117°38'0"W
117°37'0"W
117°36'0"W
117°35'0"W
33°25'0"N
33°24'0"N
33°23'0"N
N
Trafalgar Ln
Esplanade
Calle Alcazar
Salvador
S Ola Vis
San Clemente Municipal Golf Course
S El Camino Real
ORANGE
SAN DIEGO
Cristianitos Rd
San Clemente State Beach
Calle Ariana
Rupertus Dr
10
20
30
Kelp bed area
December 16, 2013
San Clemente: 1.0966 Km²
1 stat. mi.
1 Km
Depth contours in meters

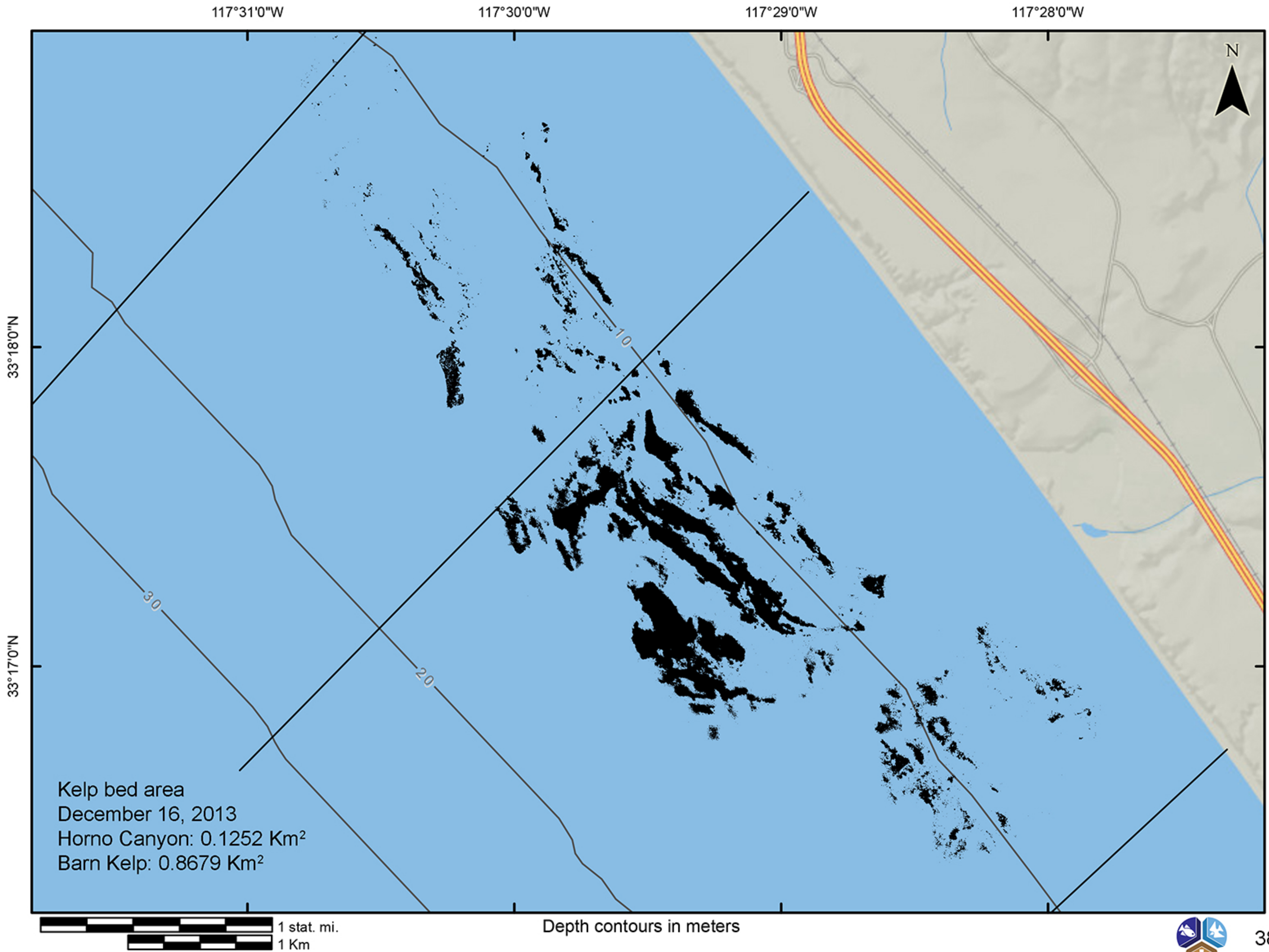


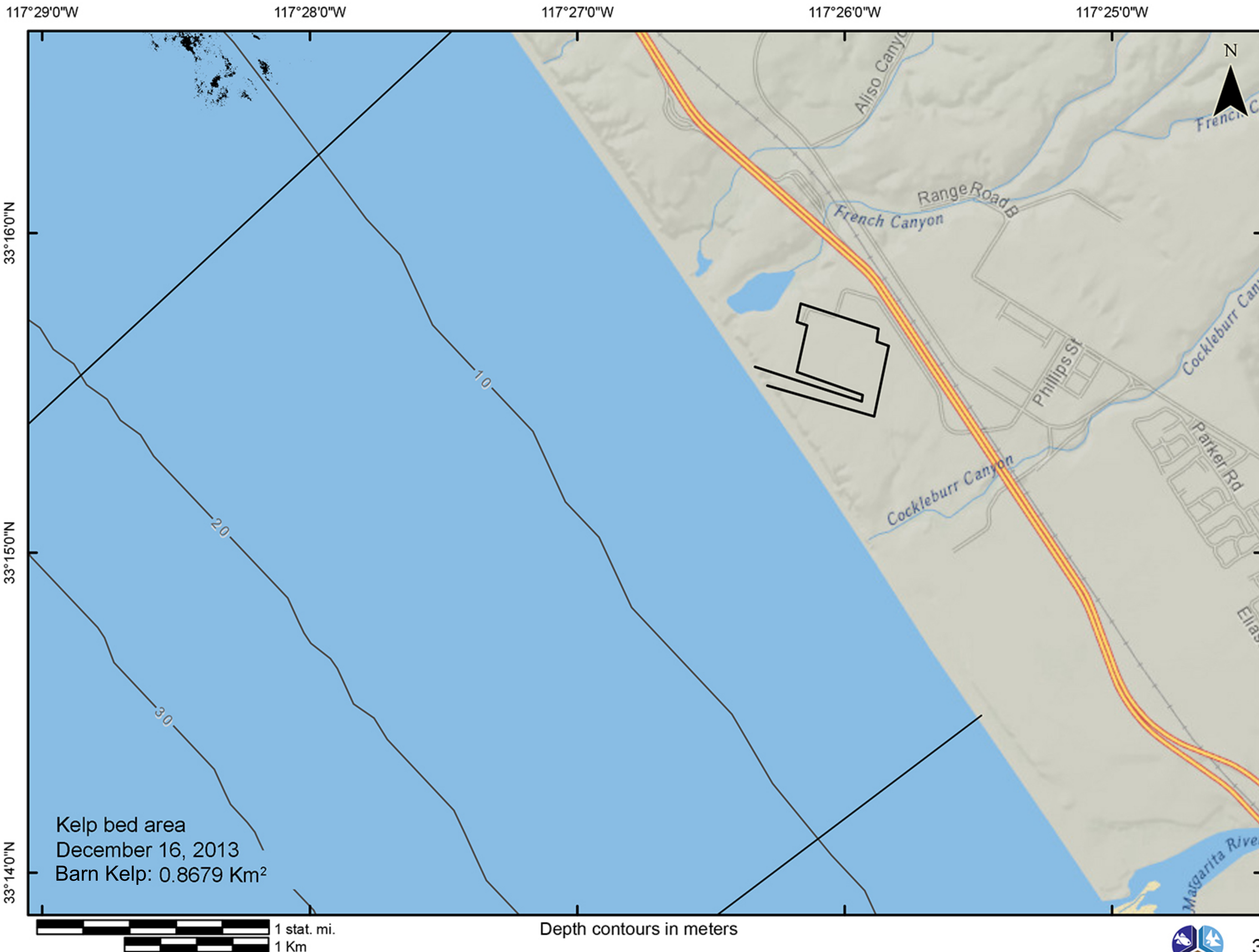
117°37'0"W
117°36'0"W
117°35'0"W
117°34'0"W
117°33'0"W
33°23'0"N
33°22'0"N
N
Ariana
Pepper Ln
Puller
De La Garza St
Rupertus Dr
Beach Club Rd
Longspur Dr
San Onofre Creek
20
10
Kelp bed area
December 16, 2013
San Clemente: 1.0966 Km²
San Mateo: 0.2192 Km²
San Onofre: 0.7673 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

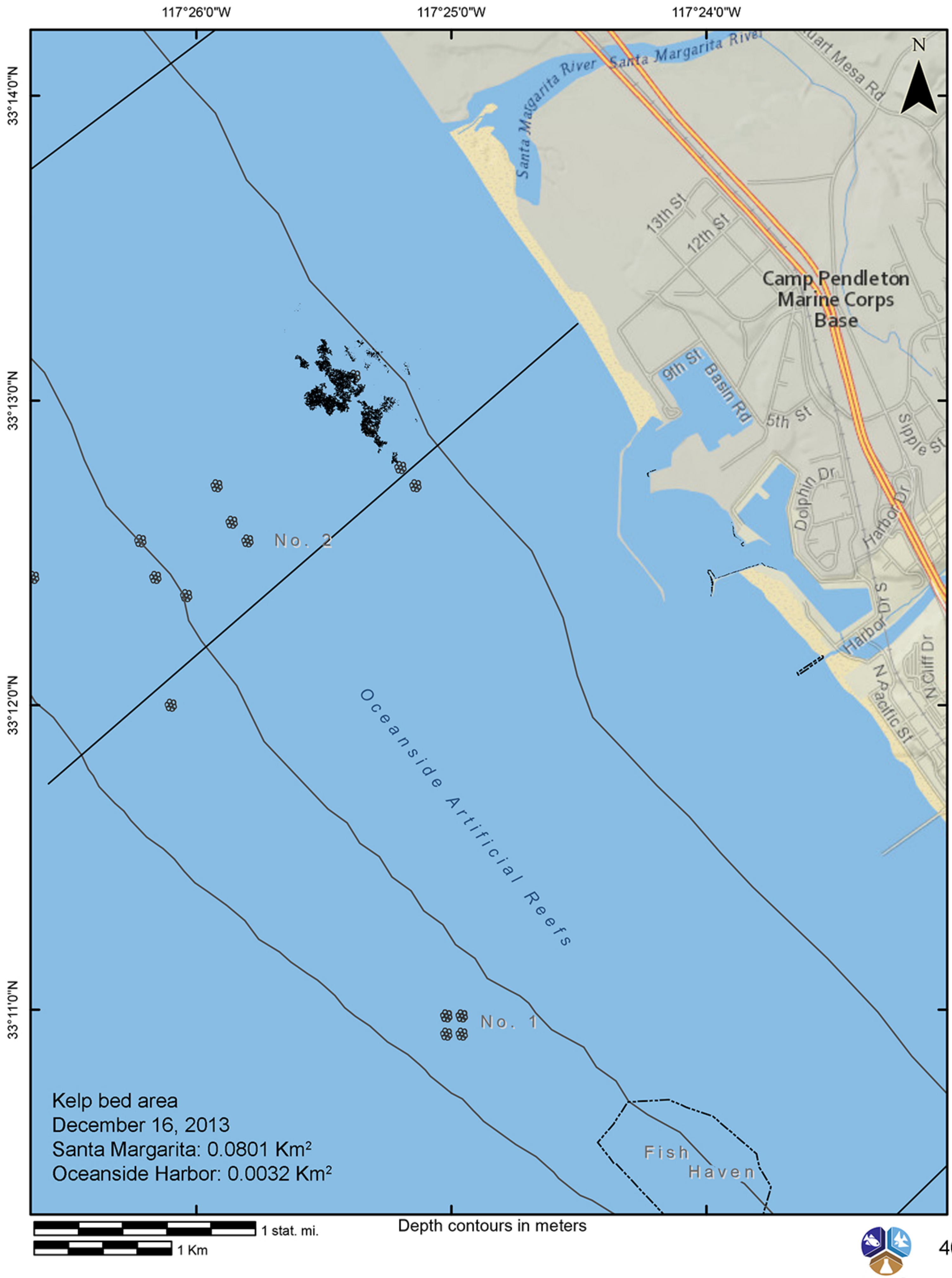

117°35'0"W
117°34'0"W
117°33'0"W
117°32'0"W
117°31'0"W
33°22'0"N
33°21'0"N
33°20'0"N
N
Foley Ca
El Camino Real
Old Pacific Hwy
5
10
20
30
Kelp bed area
December 16, 2013
San Onofre: 0.7673 Km²
1 stat. mi.
1 Km
Depth contours in meters

MBC


117°33'0"W
117°32'0"W
117°31'0"W
117°30'0"W
33°21'0"N
33°20'0"N
33°19'0"N
N
El Camino Real
Old Pacific Hwy
5
Horno Canyon
Horno Cyn.
Pendleton Artificial Reef
10
20
30
Kelp bed area
December 16, 2013
San Onofre: 0.7673 Km²
Pendleton Reefs: None
1 stat. mi.
1 Km
Depth contours in meters


117°31'0"W
117°30'0"W
117°29'0"W
117°28'0"W
33°18'0"N
33°17'0"N
N
10
20
30
Kelp bed area
December 16, 2013
Horno Canyon: 0.1252 Km²
Barn Kelp: 0.8679 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°29'0"W
117°28'0"W
117°27'0"W
117°26'0"W
117°25'0"W
33°16'0"N
33°15'0"N
33°14'0"N
N
Aliso Canyo
French C
Range Road B
French Canyon
Cockleburr Cany
Phillips St
Parker Rd
Cockleburr Canyon
Elias
Margarita River
10
20
30
Kelp bed area
December 16, 2013
Barn Kelp: 0.8679 Km²
1 stat. mi.
1 Km
Depth contours in meters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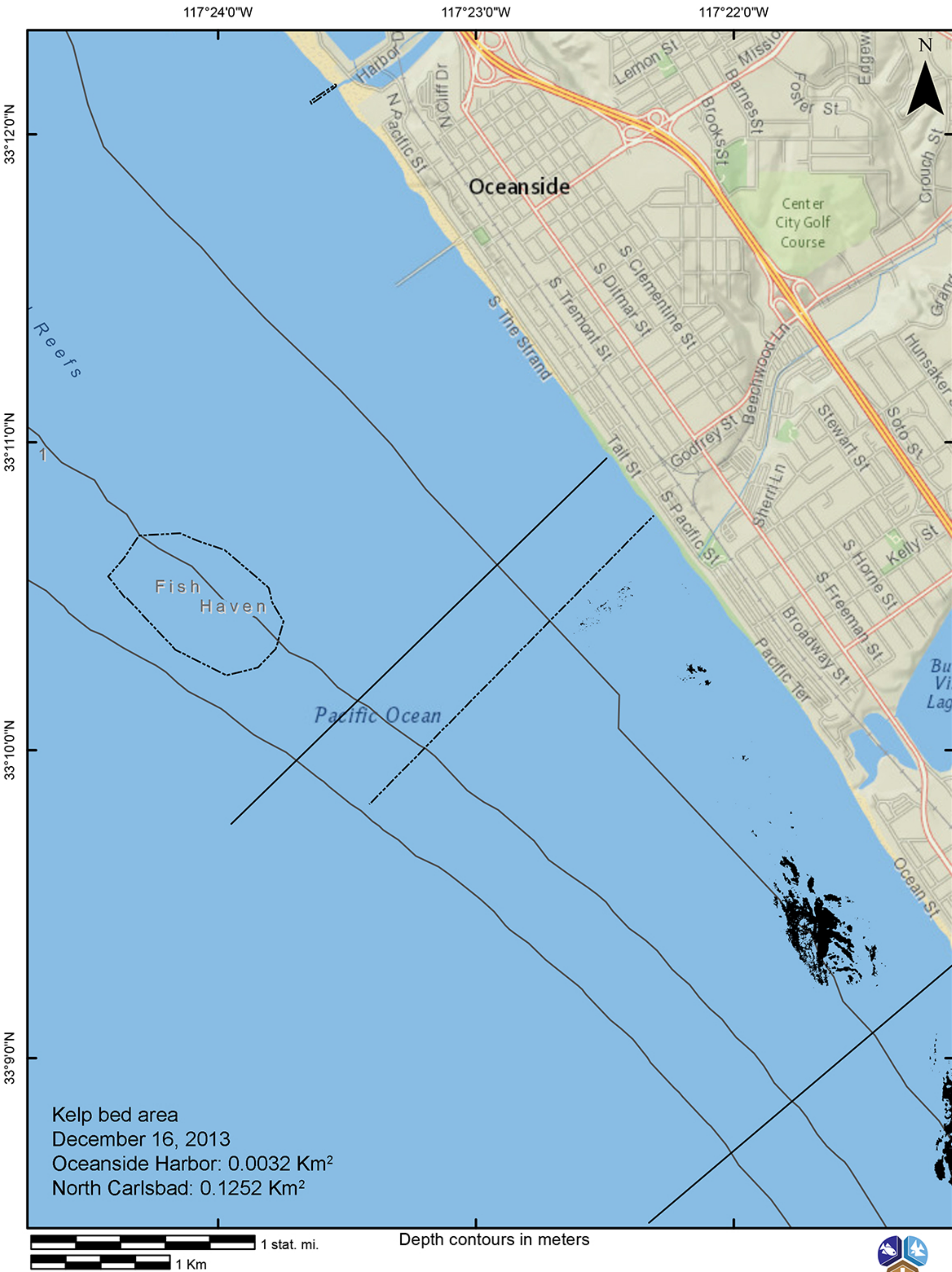
33°13'0"N
33°12'0"N
33°11'0"N
N
Santa Margarita River
Santa Margarita River
Santa Margarita River
Stuart Mesa Rd
13th St
12th St
Camp Pendleton Marine Corps Base
9th St
Basin Rd
5th St
Sipple St
Dolphin Dr
Harbor Dr
Harbor Dr S
Harbor Dr
N Cliff Dr
N Pacific St
No. 2
Oceanside Artificial Reefs
No. 1
Fish Haven
Kelp bed area
December 16, 2013
Santa Margarita: 0.0801 Km²
Oceanside Harbor: 0.0032 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC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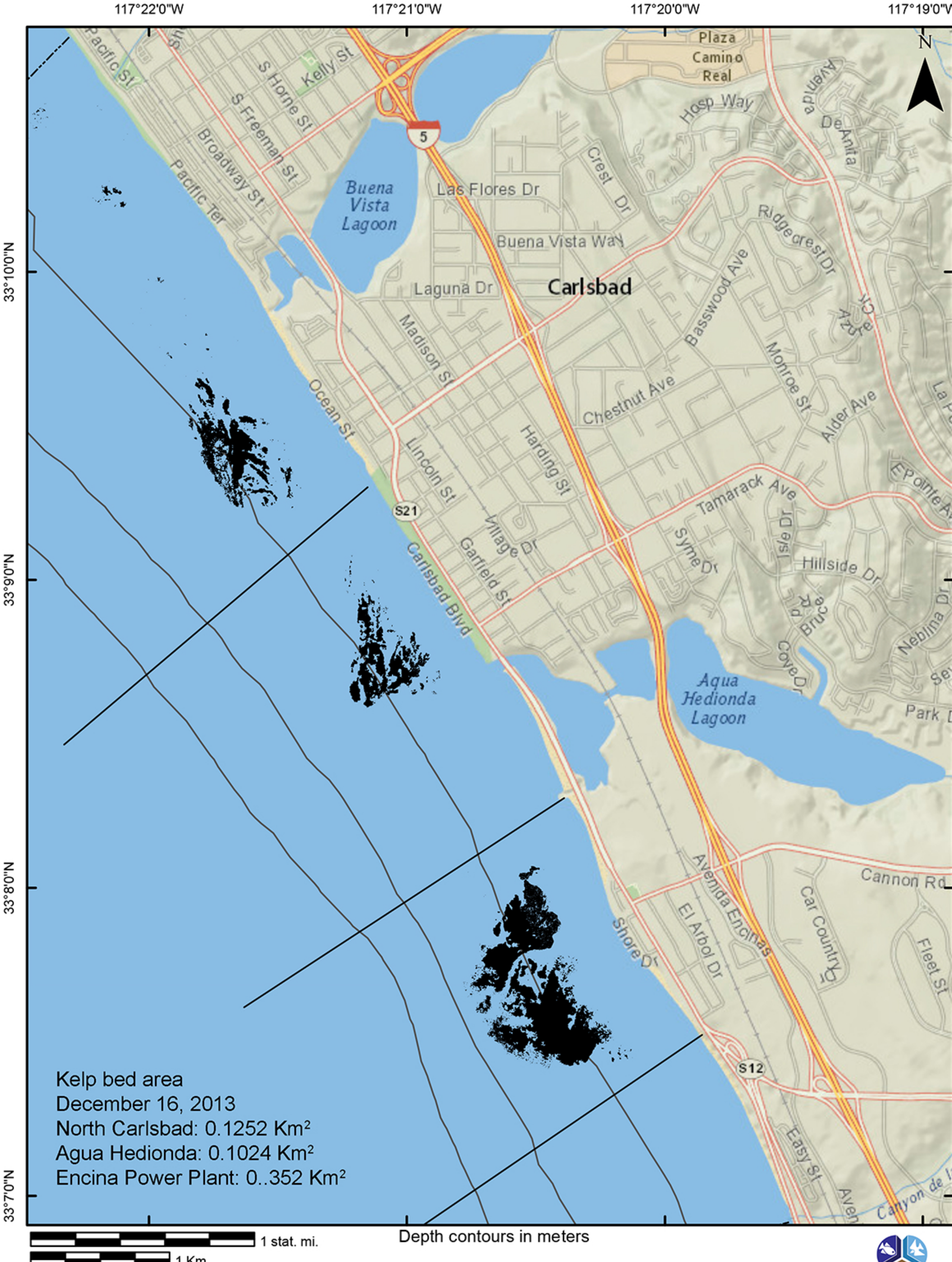
Oceanside
Center City Golf Course
Pacific Ocean
Fish Haven
Reefs
Kelp bed area
December 16, 2013
Oceanside Harbor: 0.0032 Km²
North Carlsbad: 0.1252 Km²
1 stat. mi.
1 Km
Depth contours in meters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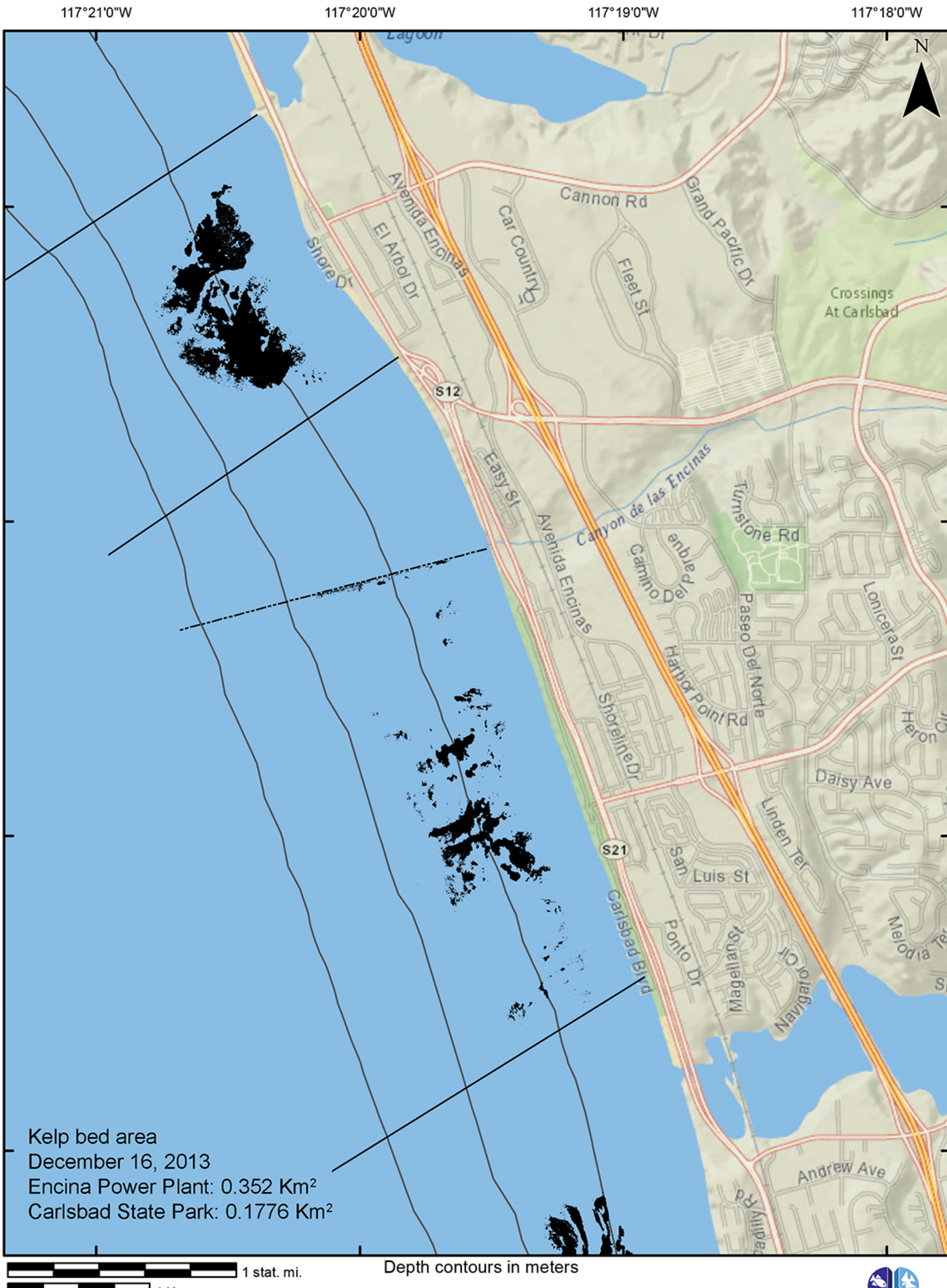
117°20'0"W
117°19'0"W
33°10'0"N
33°9'0"N
33°8'0"N
33°7'0"N
N
Plaza Camino Real
Buena Vista Lagoon
Carlsbad
Agua Hedionda Lagoon
Pacific St
Kelly St
S Horne St
S Freeman St
Broadway St
Pacific Ter
Hosp Way
Avenida De Anita
Las Flores Dr
Crest Dr
Ridgecrest Dr
Buena Vista Way
Laguna Dr
Basswood Ave
Madison St
Ocean St
Chestnut Ave
Monroe St
Alder Ave
Lincoln St
Harding St
Tamarack Ave
S21
Village Dr
Garfield St
Carlsbad Blvd
Syme Dr
Isle Dr
Hillside Dr
Bruce Rd
Cove Dr
Neblina Dr
Park Dr
Cannon Rd
Avenida Encinas
El Arbol Dr
Car Country Dr
Fleet St
Shore Dr
S12
Easy St
Kelp bed area
December 16, 2013
North Carlsbad: 0.1252 Km²
Agua Hedionda: 0.1024 Km²
Encina Power Plant: 0..352 Km²
1 stat. mi.
1 Km
Depth contours in meters

MBC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117°18'0"W
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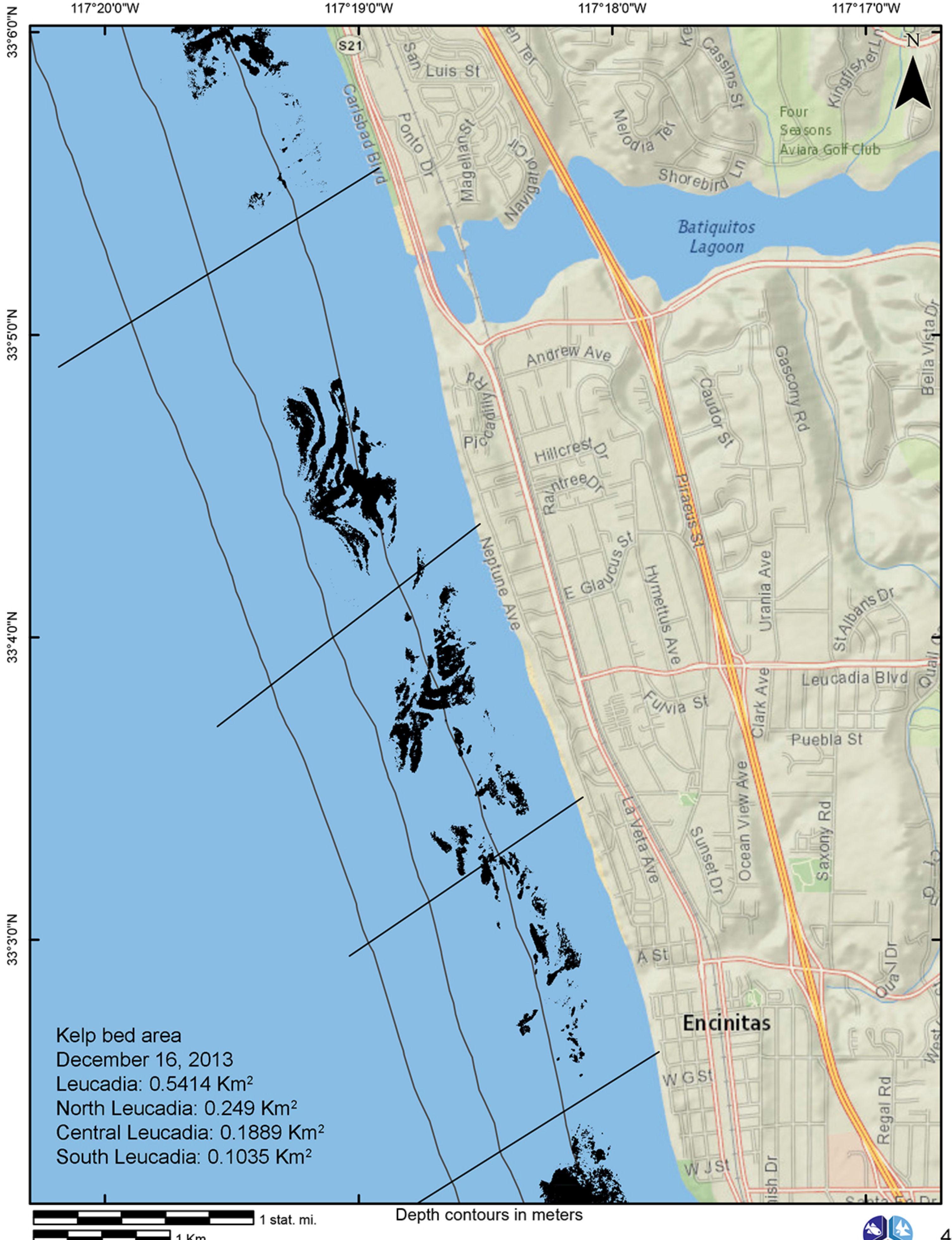
33°7'0"N
33°6'0"N
33°5'0"N
N
Lagoon
Cannon Rd
Grand Pacific Dr
Car Country Dr
Fleet St
Avenida Encinas
El Arbol Dr
Shore Dr
Crossings At Carlsbad
S12
Easy St
Canyon de las Encinas
Turnstone Rd
Camino Del Parque
Paseo Del Norte
Lonicera St
Harbor Point Rd
Shoreline Dr
Heron Cir
Daisy Ave
S21
Linden Ter
San Luis St
Carlsbad Blvd
Ponto Dr
Magellan St
Navigator Cir
Melodia Ter
Andrew Ave
Kelp bed area
December 16, 2013
Encina Power Plant: 0.352 Km²
Carlsbad State Park: 0.1776 Km²
1 stat. mi.
1 Km
Depth contours in meters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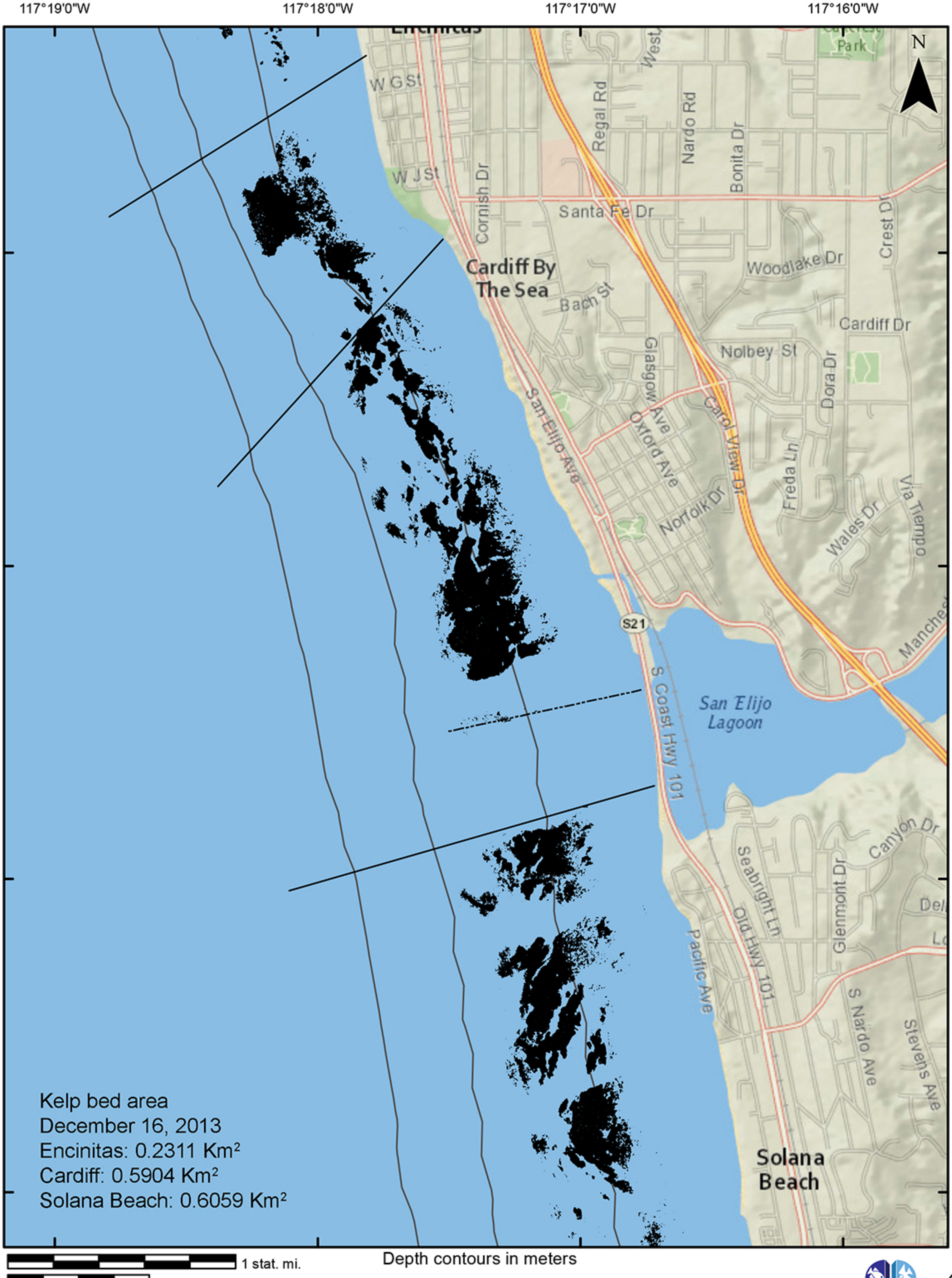
33°5'0"N
33°4'0"N
33°3'0"N
N
S21
San Luis St
Carlsbad Blvd
Ponto Dr
Magellan St
Navigator Cir
Cassins St
Melodia Ter
Shorebird Ln
Kingfisher Ln
Four Seasons Aviara Golf Club
Batiquitos Lagoon
Andrew Ave
Piccadilly Rd
Caudor St
Gascony Rd
Bella Vista Dr
Hillcrest Dr
Raintree Dr
Piraeus St
Neptune Ave
E Glaucus St
Hymettus Ave
Urania Ave
St Albans Dr
Leucadia Blvd
Fulvia St
Clark Ave
Puebla St
La Veta Ave
Sunset Dr
Ocean View Ave
Saxony Rd
A St
Encinitas
W G St
W J St
Regal Rd
Kelp bed area
December 16, 2013
Leucadia: 0.5414 Km²
North Leucadia: 0.249 Km²
Central Leucadia: 0.1889 Km²
South Leucadia: 0.1035 Km²
1 stat. mi.
1 Km
Depth contours in meters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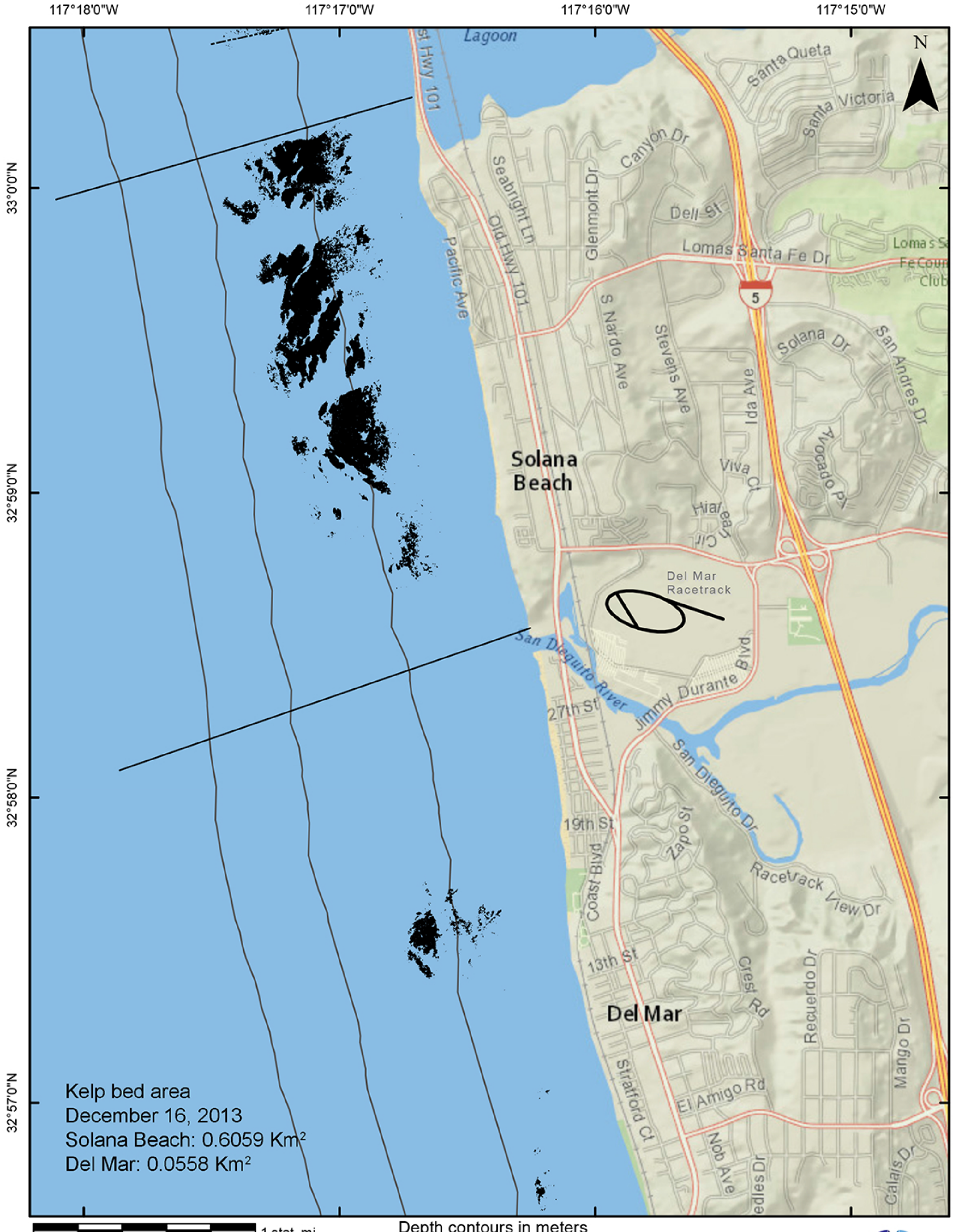
117°17'0"W
117°16'0"W
33°2'0"N
33°1'0"N
33°0'0"N
32°59'0"N
N
Encinitas
Cardiff By The Sea
San Elijo Lagoon
Solana Beach
W G St
W J St
Cornish Dr
Regal Rd
Nardo Rd
Bonita Dr
Santa Fe Dr
Crest Dr
Woodlake Dr
Bach St
Cardiff Dr
Nolbey St
Glasgow Ave
Oxford Ave
Carol View Dr
Dora Dr
San Elijo Ave
Freda Ln
Norfolk Dr
Wales Dr
Via Tiempo
S21
S Coast Hwy 101
Seabright Ln
Glenmont Dr
Canyon Dr
Old Hwy 101
Pacific Ave
S Nardo Ave
Stevens Ave
Park
Kelp bed area
December 16, 2013
Encinitas: 0.2311 Km²
Cardiff: 0.5904 Km²
Solana Beach: 0.6059 Km²
1 stat. mi.
1 Km
Depth contours in meters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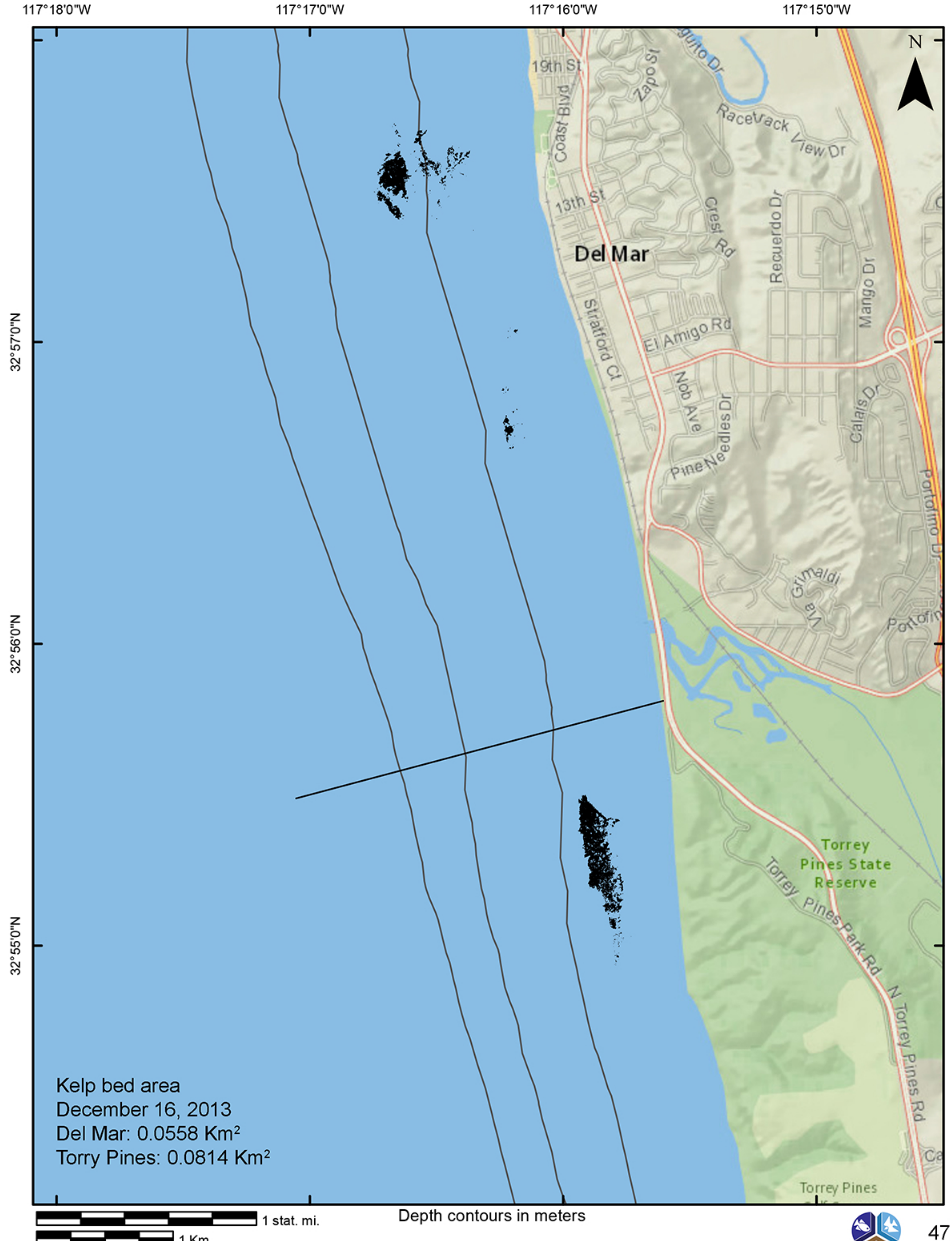
32°57'0"N
N
Lagoon
Solana Beach
Del Mar
Del Mar Racetrack
San Dieguito River
Kelp bed area
December 16, 2013
Solana Beach: 0.6059 Km²
Del Mar: 0.0558 Km²
1 stat. mi.
1 Km
Depth contours in meters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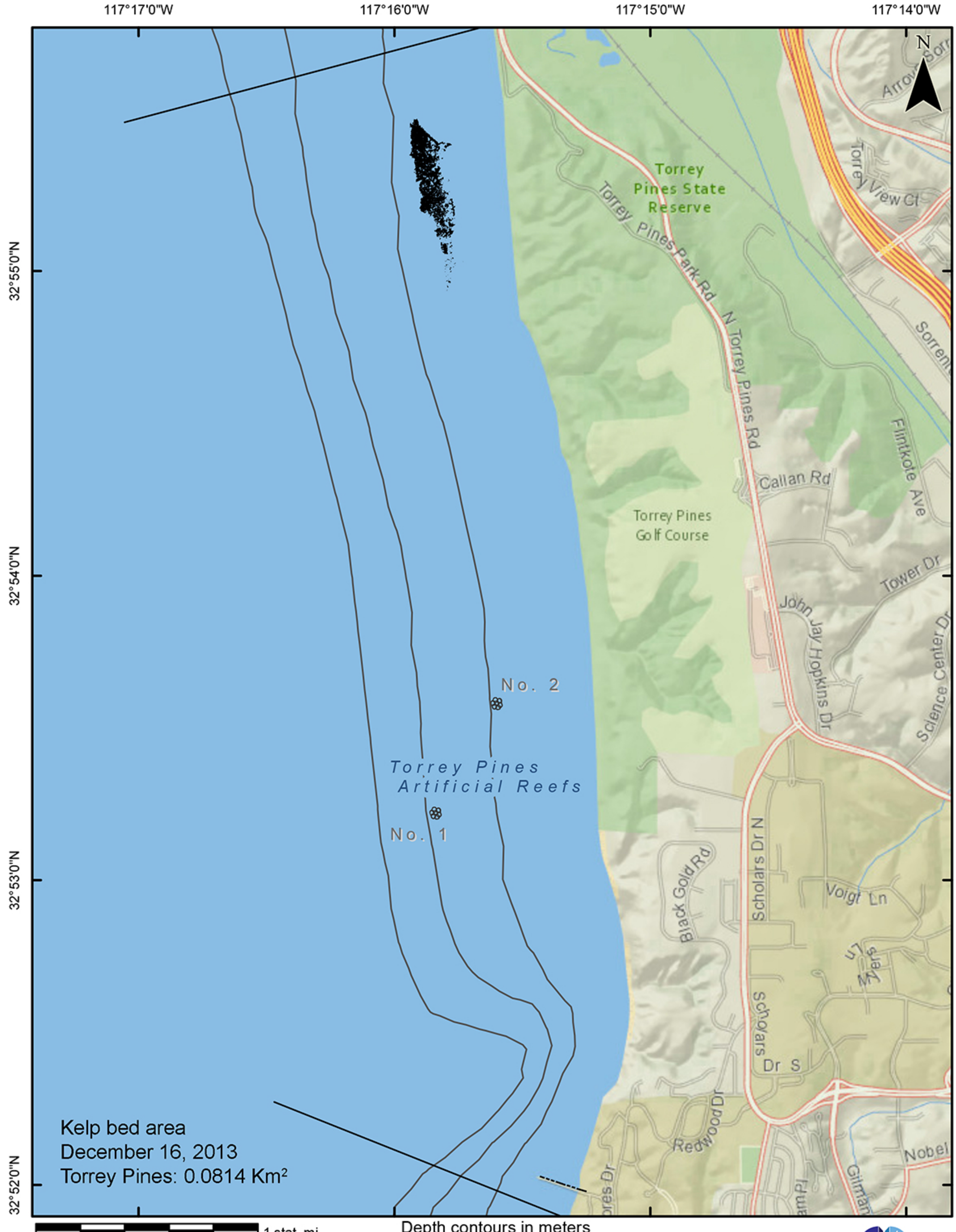
117°15'0"W
N
32°57'0"N
32°56'0"N
32°55'0"N
19th St
Zapo St
Coast Blvd
Racetrack View Dr
13th St
Del Mar
Crest Rd
Recuerdo Dr
Mango Dr
Stratford Ct
El Amigo Rd
Nob Ave
Pine Needles Dr
Calais Dr
Via Grimaldi
Torrey Pines State Reserve
Torrey Pines Park Rd
N Torrey Pines Rd
Torrey Pines
Kelp bed area
December 16, 2013
Del Mar: 0.0558 Km²
Torry Pines: 0.0814 Km²
1 stat. mi.
1 Km
Depth contours in meters

MBC



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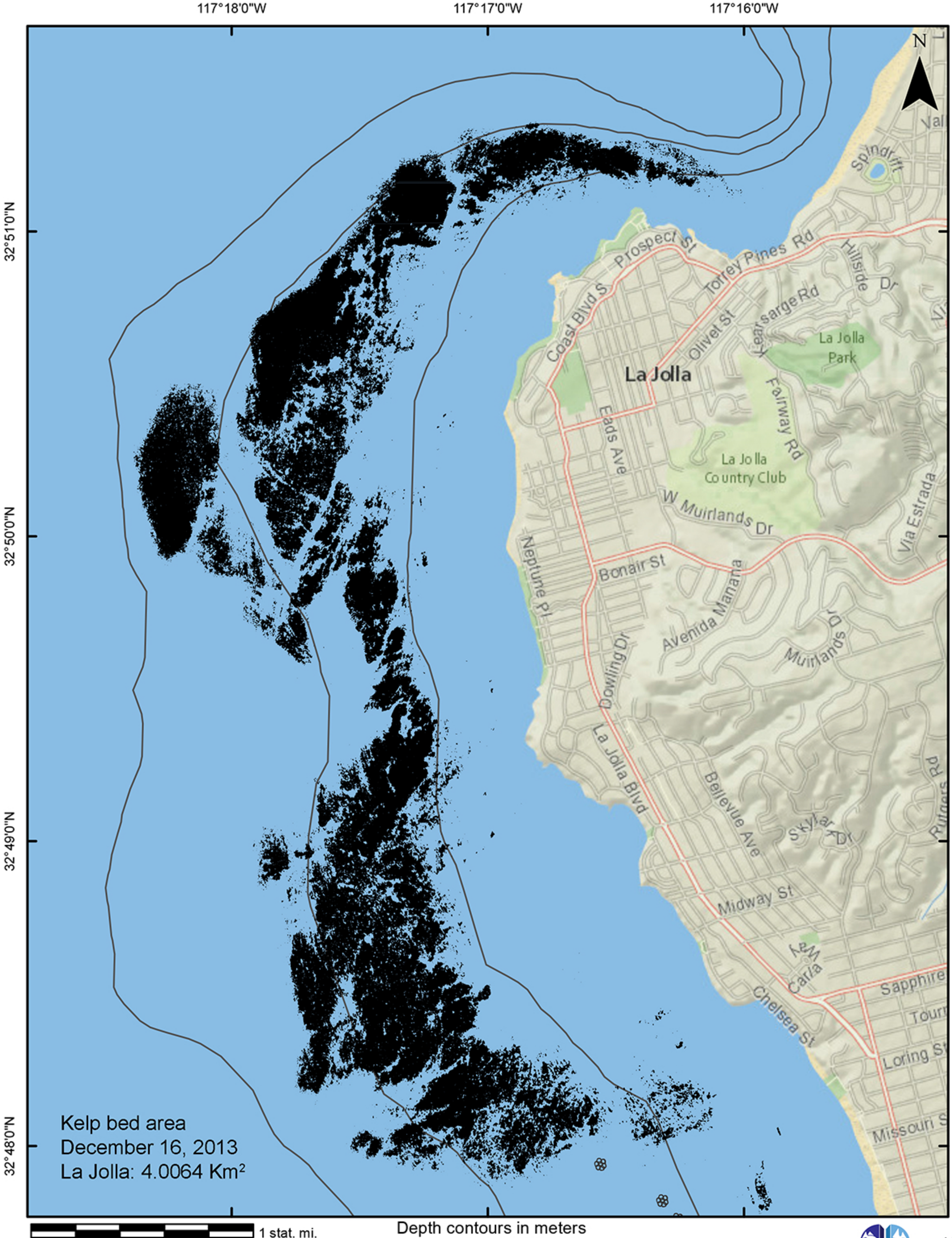
117°16'0"W
117°15'0"W
117°14'0"W
32°55'0"N
32°54'0"N
32°53'0"N
32°52'0"N
N
Torrey Pines State Reserve
Torrey Pines Park Rd
N Torrey Pines Rd
Torrey Pines Golf Course
Callan Rd
Flintkote Ave
Tower Dr
John Jay Hopkins Dr
Science Center Dr
Torrey View Ct
No. 2
Torrey Pines Artificial Reefs
No. 1
Black Gold Rd
Scholars Dr N
Voigt Ln
Scholars Dr S
Redwood Dr
Nobel
Kelp bed area
December 16, 2013
Torrey Pines: 0.0814 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC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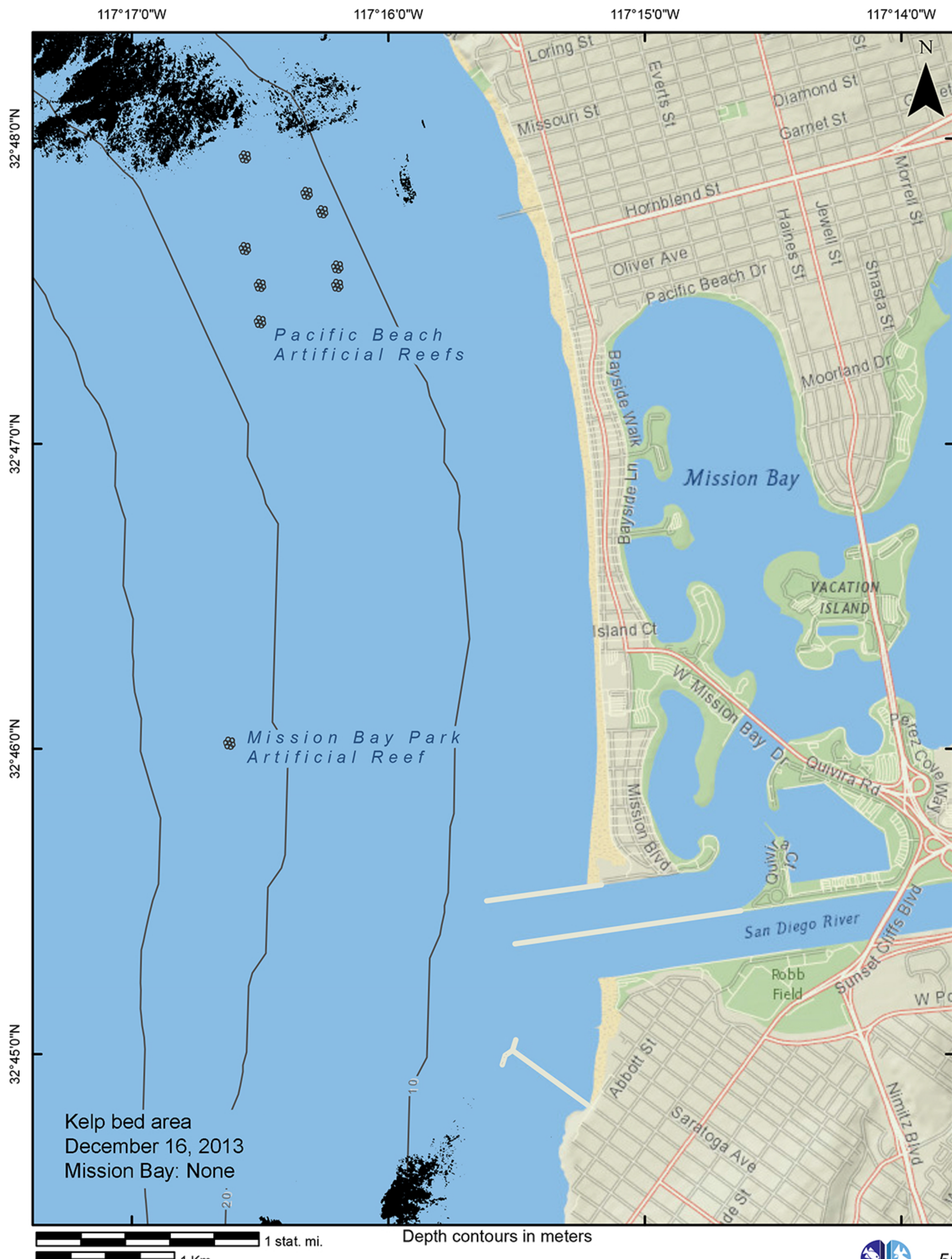
32°51'0"N
32°50'0"N
32°49'0"N
32°48'0"N
N
Kelp bed area
December 16, 2013
La Jolla: 4.0064 Km²
La Jolla
La Jolla Park
La Jolla Country Club
Prospect St
Torrey Pines Rd
Hillside Dr
Kearsarge Rd
Olivet St
Coast Blvd S
Spindrift
Fairway Rd
Eads Ave
W Muirlands Dr
Via Estrada
Neptune Pl
Bonair St
Avenida Manana
Muirlands Dr
Dowling Dr
La Jolla Blvd
Bellevue Ave
Skylark Dr
Midway St
Carla Way
Chelsea St
Sapphire
Loring St
Missouri S
1 stat. mi.
1 Km
Depth contours in meters

MBC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32°48'0"N
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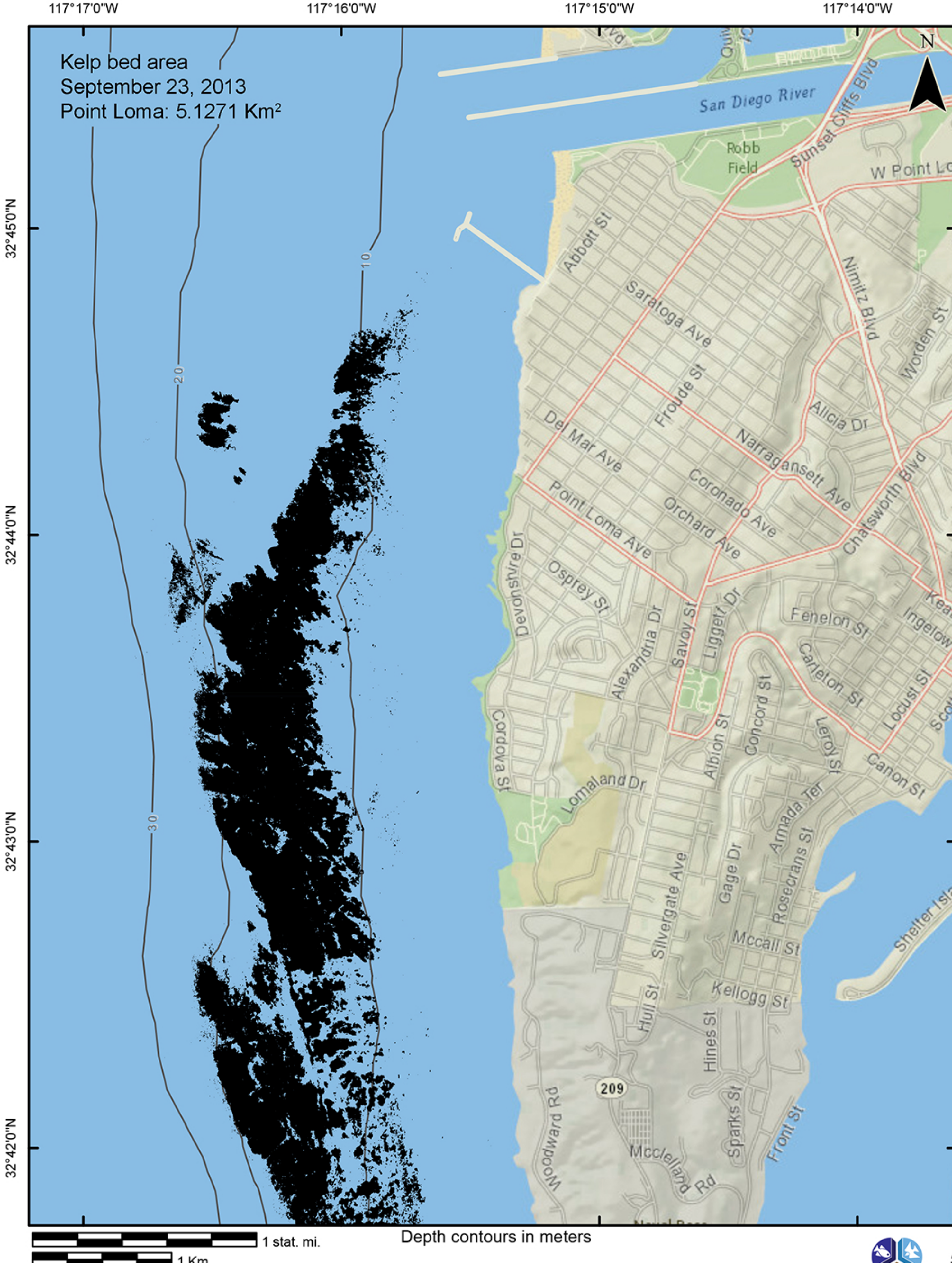
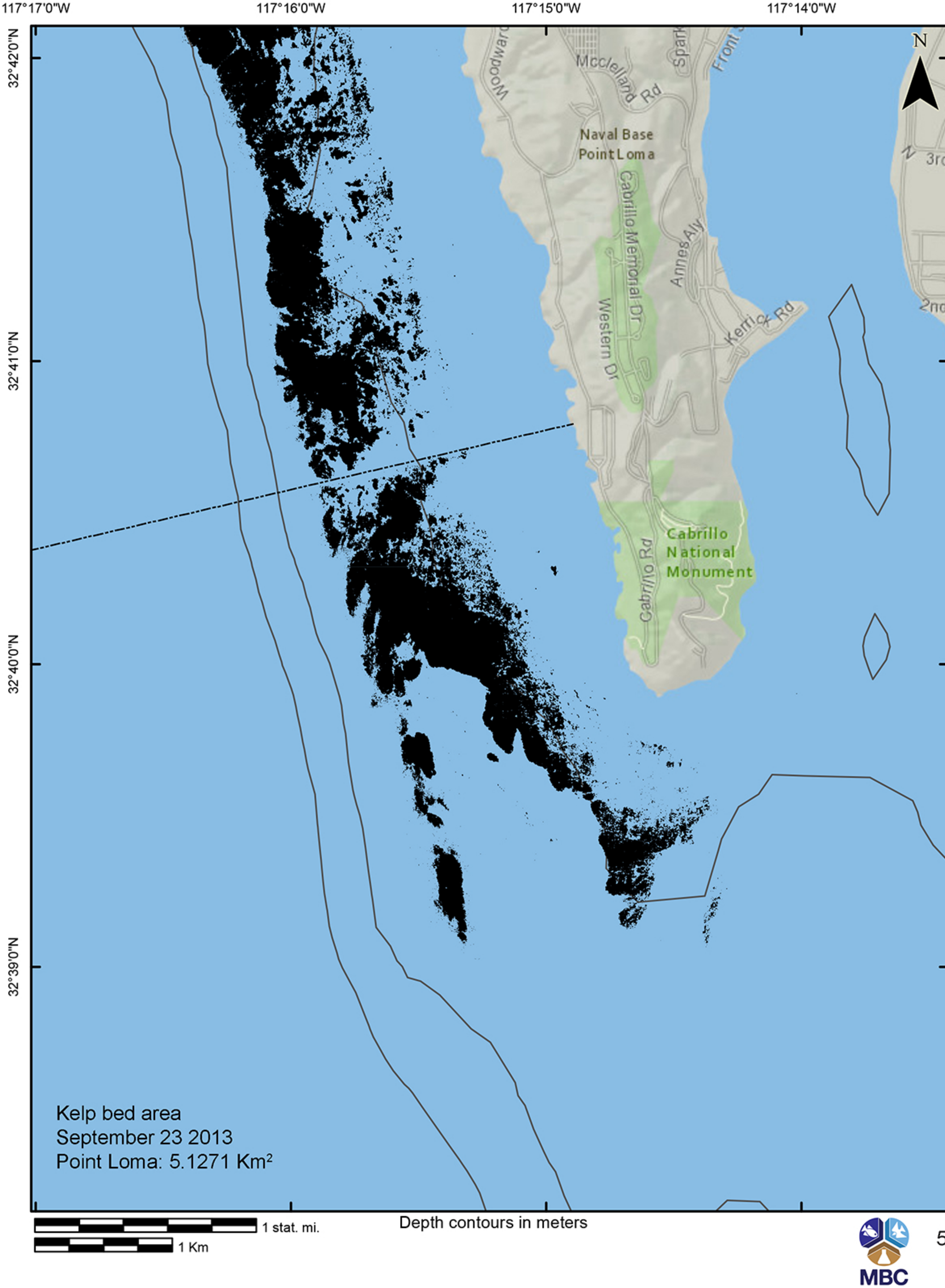
32°45'0"N
N
Loring St
Missouri St
Everts St
Diamond St
Garnet St
Hornblend St
Haines St
Jewell St
Morrell St
Oliver Ave
Pacific Beach Dr
Shasta St
Pacific Beach Artificial Reefs
Bayside Walk
Moorland Dr
Bayside Ln
Mission Bay
VACATION ISLAND
Island Ct
W Mission Bay Dr
Perez Cove Way
Mission Bay Park Artificial Reef
Quivira Rd
Mission Blvd
Quivira Ct
San Diego River
Sunset Cliffs Blvd
Robb Field
W Po
Abbott St
Saratoga Ave
Nimitz Blvd
10
20
Kelp bed area
December 16, 2013
Mission Bay: None
1 stat. mi.
1 Km
Depth contours in meters
MBC



Depth contours in meters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117°14'0"W
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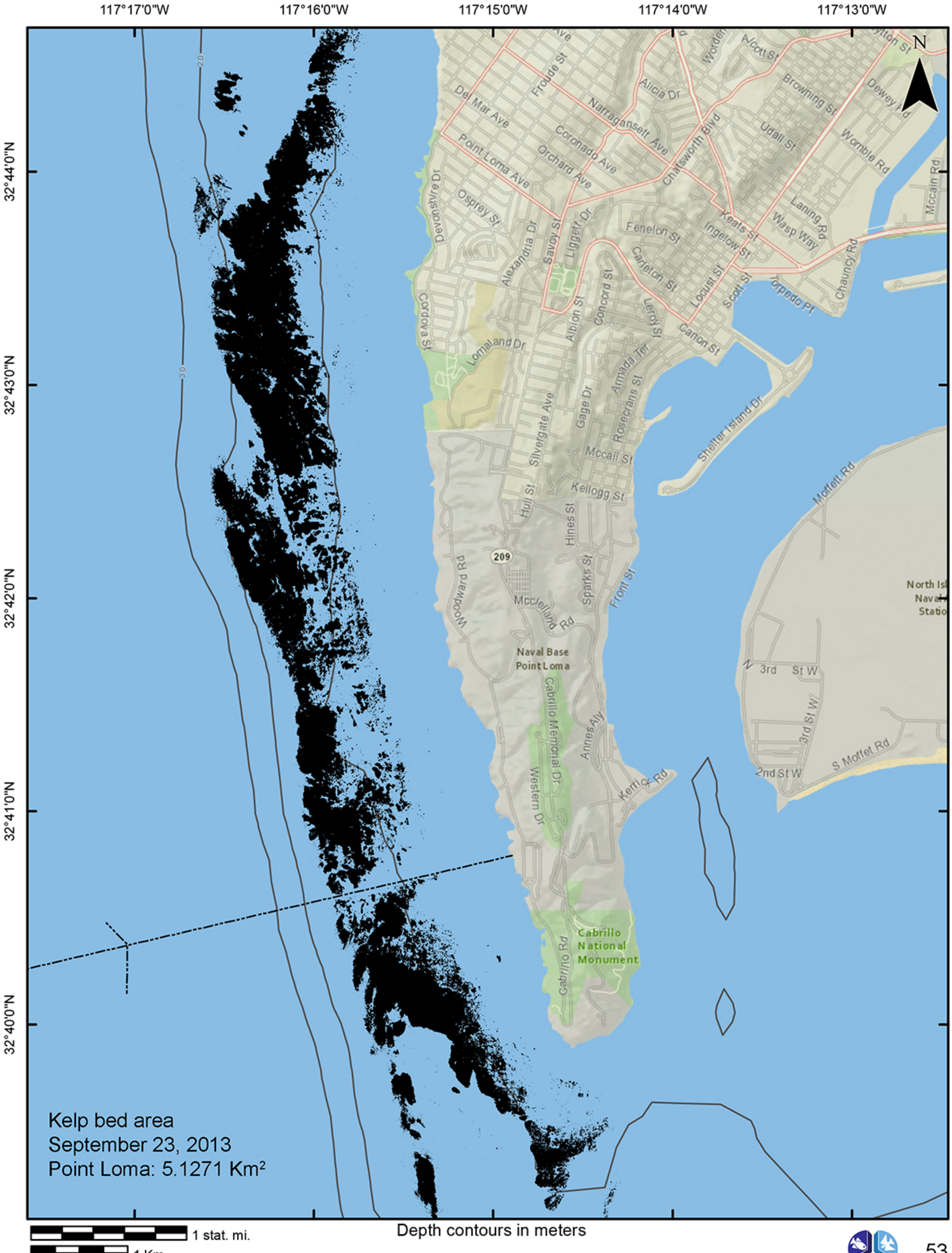
32°41'0"N
32°40'0"N
32°39'0"N
N
Woodward
Mcclelland Rd
Spark
Front
N 3rd
2nd
Naval Base Point Loma
Cabrillo Memorial Dr
Annes Aly
Western Dr
Kerrick Rd
Cabrillo Rd
Cabrillo National Monument
Kelp bed area
September 23 2013
Point Loma: 5.1271 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC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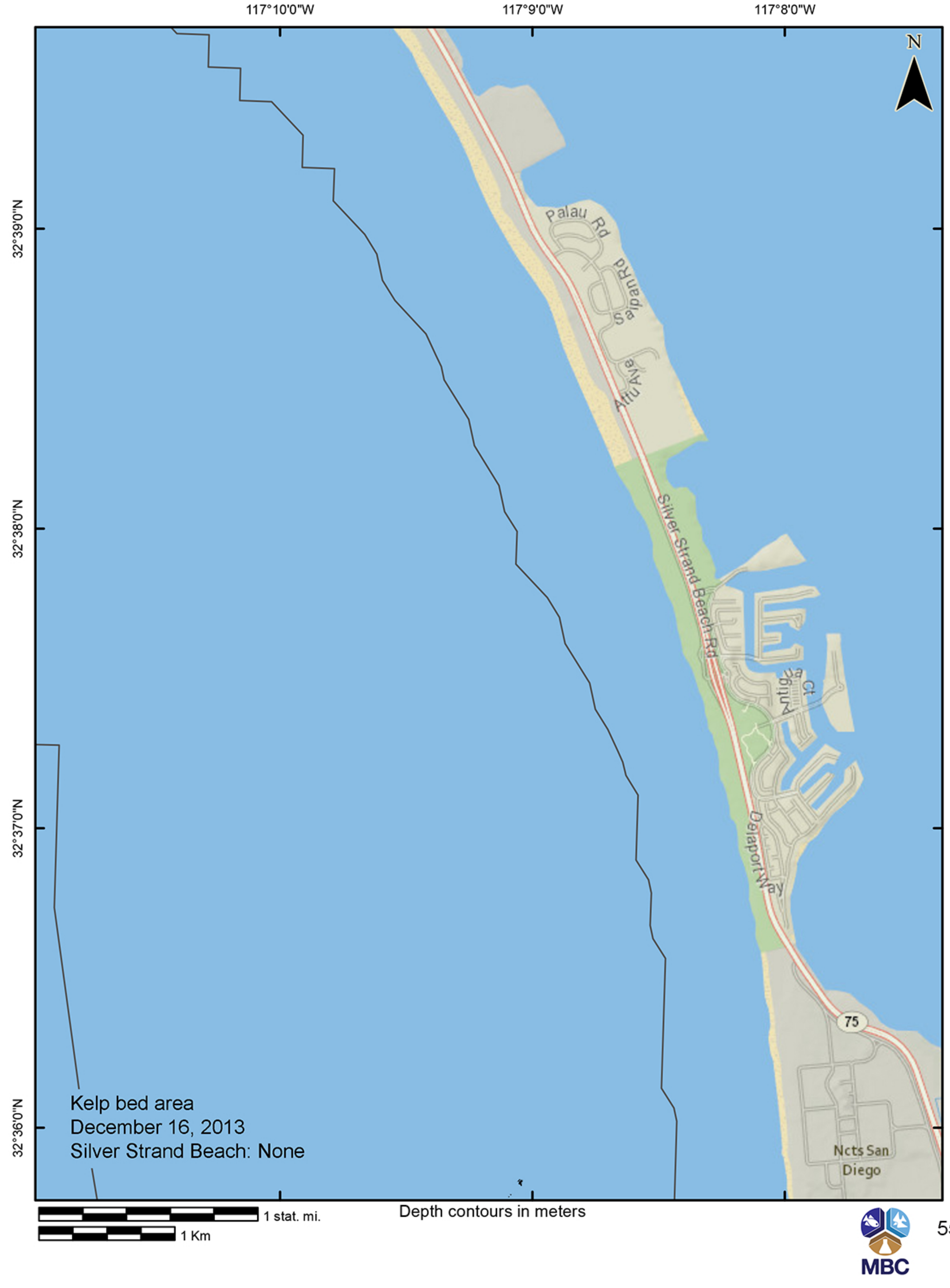
32°43'0"N
32°42'0"N
32°41'0"N
32°40'0"N
N
20
30
Froude St
Del Mar Ave
Narragansett Ave
Alicia Dr
Browning St
Dewey Rd
Point Loma Ave
Coronado Ave
Orchard Ave
Chatsworth Blvd
Udall St
Womble Rd
Devonshire Dr
Osprey St
Fenelon St
Keats St
Ingelow St
Laning Rd
Wasp Way
Mccain Rd
Alexandria Dr
Savoy St
Liggett Dr
Carleton St
Locust St
Scott St
Torpedo Pt
Chauncy Rd
Cordova St
Lomaland Dr
Albion St
Concord St
Leroy St
Canon St
Armada Ter
Silvergate Ave
Gage Dr
Rosecrans St
Shelter Island Dr
Mccall St
Kellogg St
Moffett Rd
Hull St
Hines St
209
Sparks St
Front St
Woodward Rd
Mcclelland Rd
North Isl
Naval
Statio
Naval Base
Point Loma
Cabrillo Memorial Dr
Annes Aly
3rd St W
3rd St W
Western Dr
Kerrick Rd
S Moffet Rd
2nd St W
Cabrillo Rd
Cabrillo
National
Monument
Kelp bed area
September 23, 2013
Point Loma: 5.1271 Km²
Depth contours in meters
1 stat. mi.
1 Km


117°14'0"W
117°13'0"W
117°12'0"W
117°11'0"W
117°10'0"W
32°42'0"N
32°41'0"N
32°40'0"N
N
North Island Naval Air Station
Sea N Air Golf Course
Coronado
282
Read Rd
Utgoff Ave
Bay Rd
Quentin Roosevelt Blvd
F Rd W
N 3rd St W
3rd St W
2nd St W
S Moffet Rd
J Rd E
L Rd
2nd St
D Ave
7th St
9th St
H Ave
Pine St
Adella Ln
Pomona Ave
Adella Ave
Ocean Blvd
Tarawa Rd
Roi Rd
Attu Rd
Tulagi Rd
S Seal Rd
Rendova Cir
10
Kelp bed area
December 16, 2013
Coronado: None
1 stat. mi.
1 Km
Depth contours in meters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32°39'0"N
32°38'0"N
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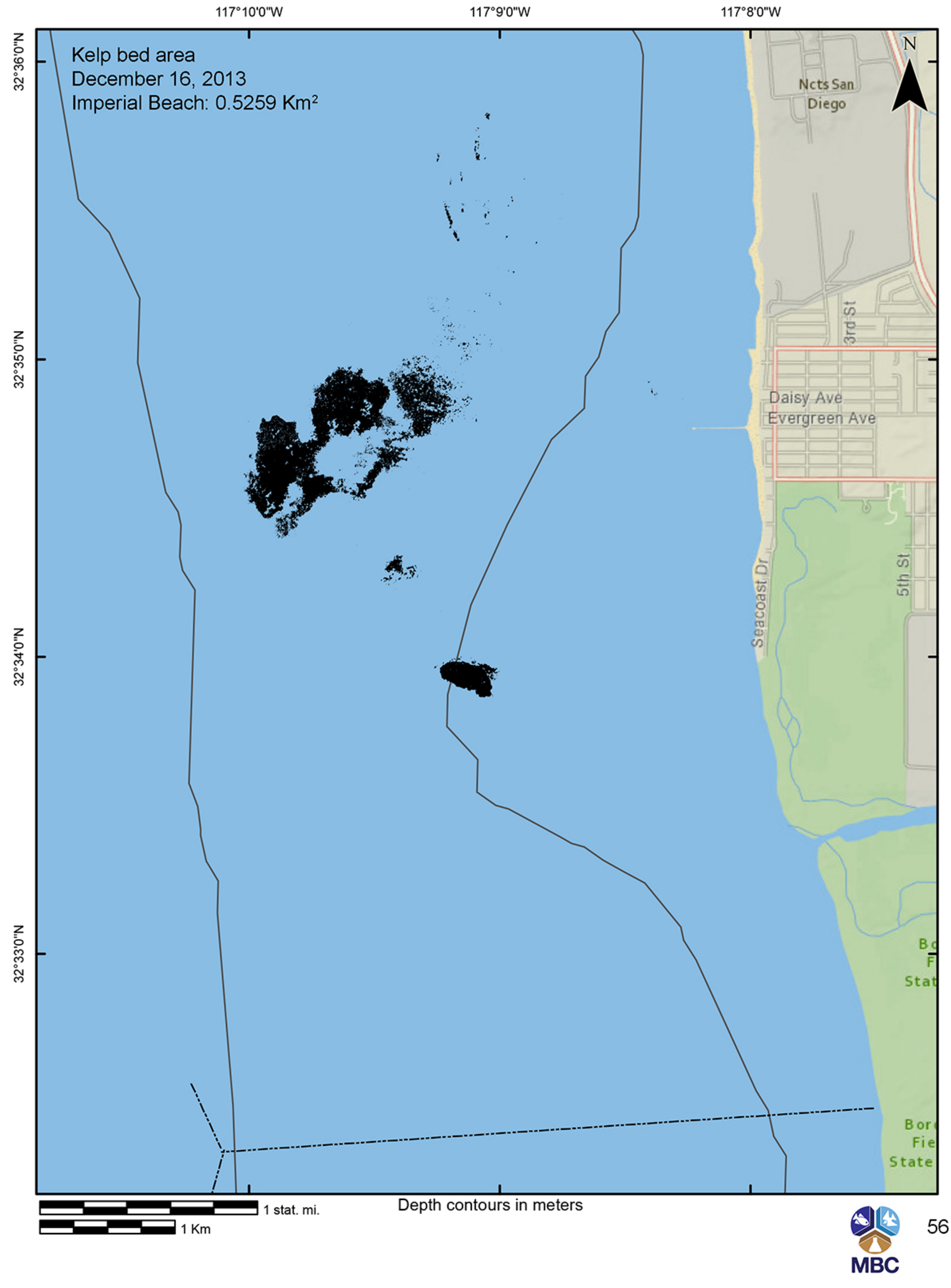
32°36'0"N
N
Palau Rd
Saipan Rd
Attu Ave
Silver Strand Beach Rd
Antigua Ct
Delaport Way
75
Ncts San Diego
Kelp bed area
December 16, 2013
Silver Strand Beach: None
1 stat. mi.
1 Km
Depth contours in meters
MBC


Kelp bed area
December 16, 2013
Imperial Beach: 0.5259 Km²
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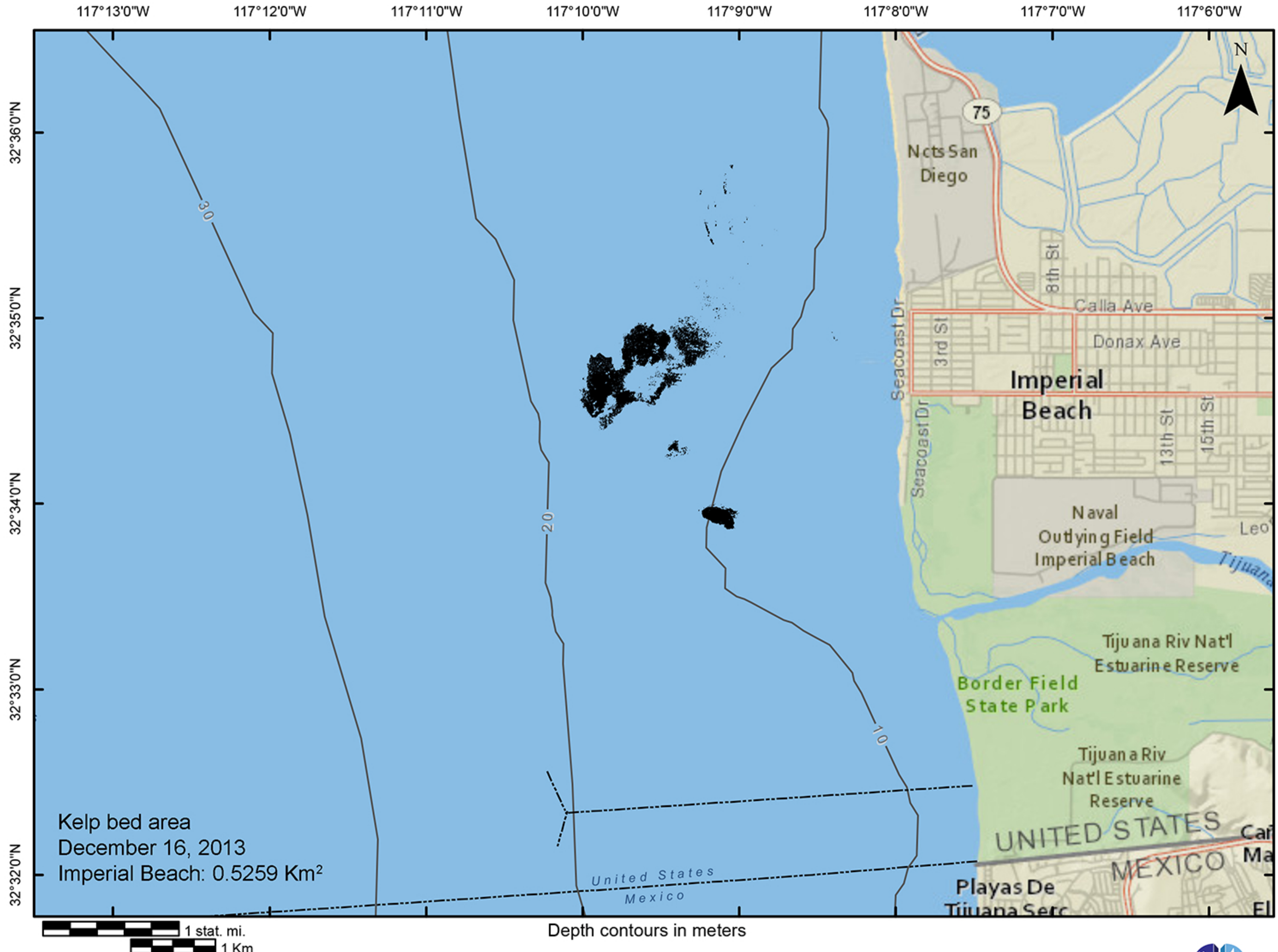
117°8'0"W
32°36'0"N
32°35'0"N
32°34'0"N
32°33'0"N
N
Ncts San Diego
3rd St
Daisy Ave
Evergreen Ave
Seacoast Dr
5th St
1 stat. mi.
1 Km
Depth contours in meters
MBC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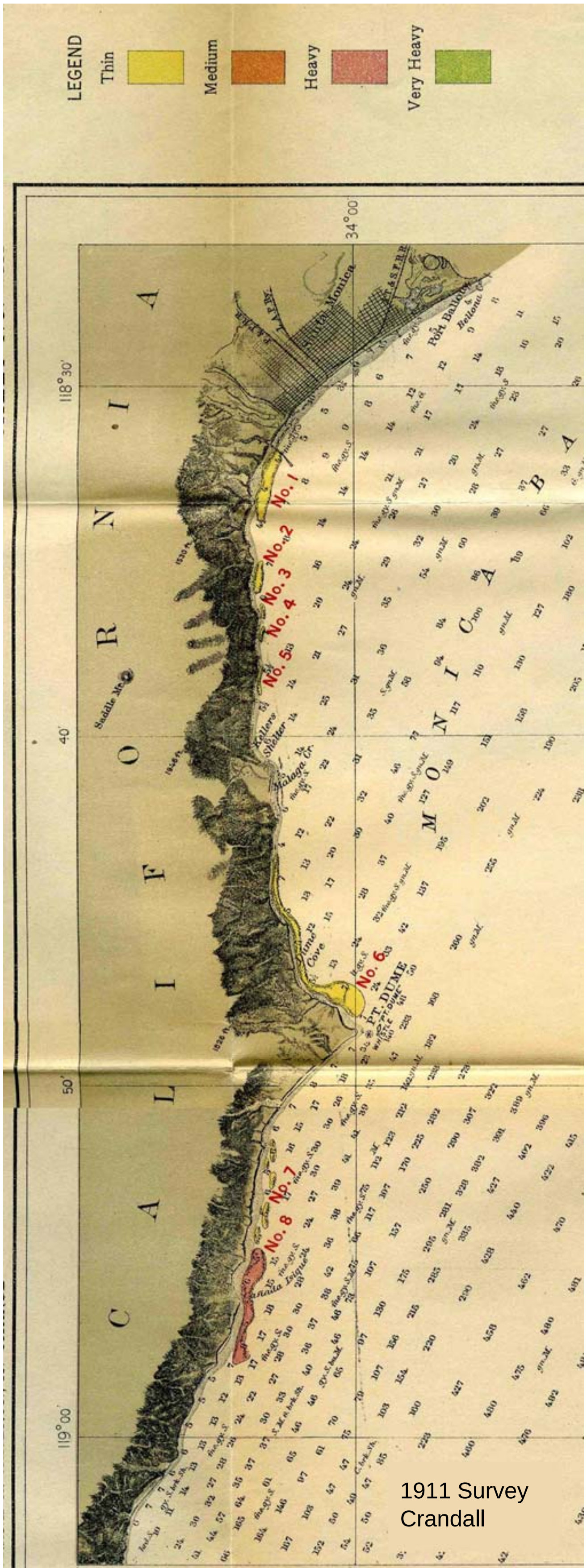
117°7'0"W
117°6'0"W
32°36'0"N
32°35'0"N
32°34'0"N
32°33'0"N
32°32'0"N
N
30
20
10
75
Ncts San Diego
8th St
Calla Ave
Seacoast Dr
3rd St
Donax Ave
Imperial Beach
13th St
15th St
Naval Outlying Field Imperial Beach
Tijuana
Tijuana Riv Nat'l Estuarine Reserve
Border Field State Park
UNITED STATES
MEXICO
Playas De Tijuana Secc
United States
Mexico
Kelp bed area
December 16, 2013
Imperial Beach: 0.5259 Km²
1 stat. mi.
1 Km
Depth contours in meters

MBC

APPENDIX B

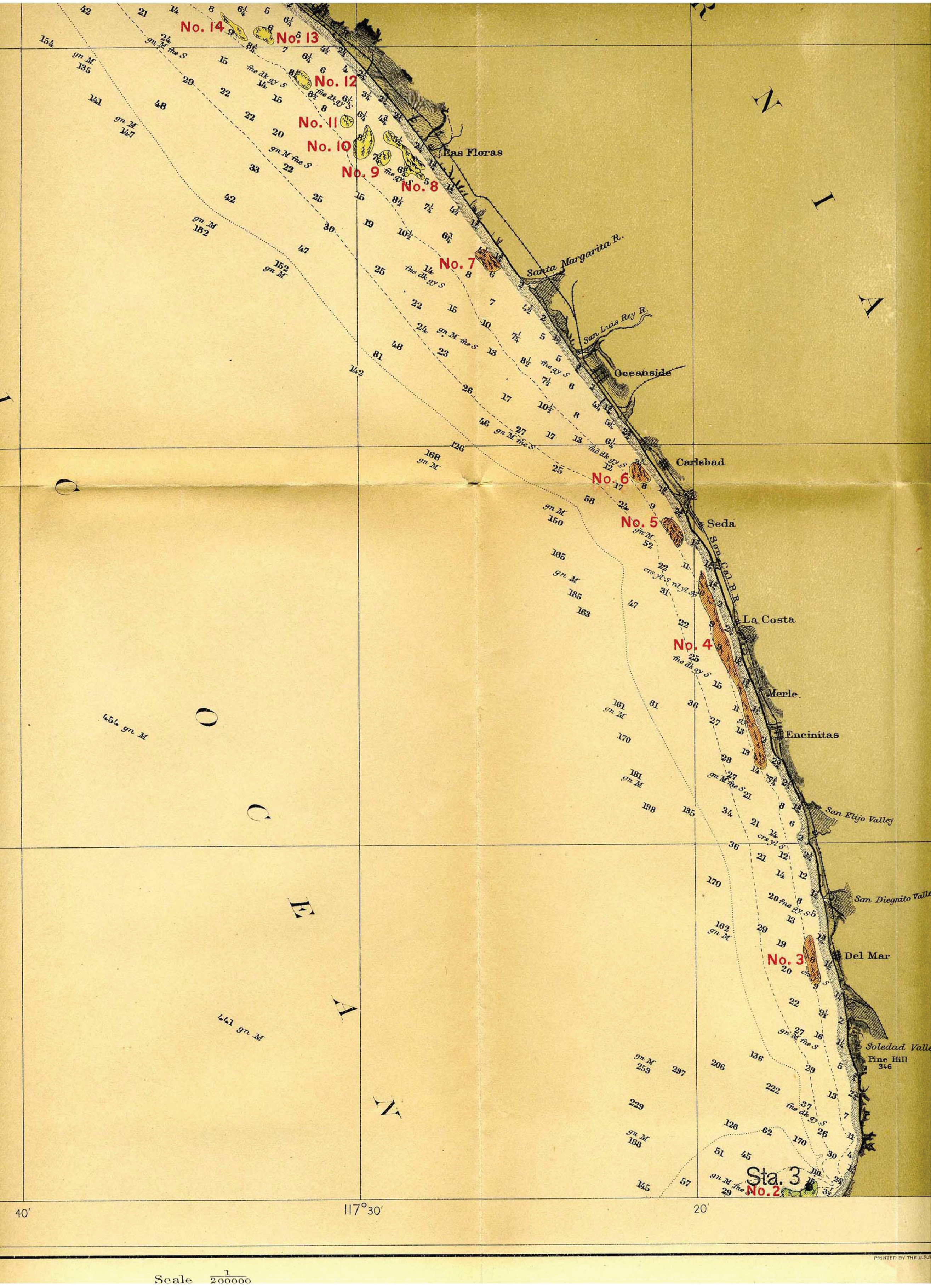
Historic Coverage Area of Kelp Canopies



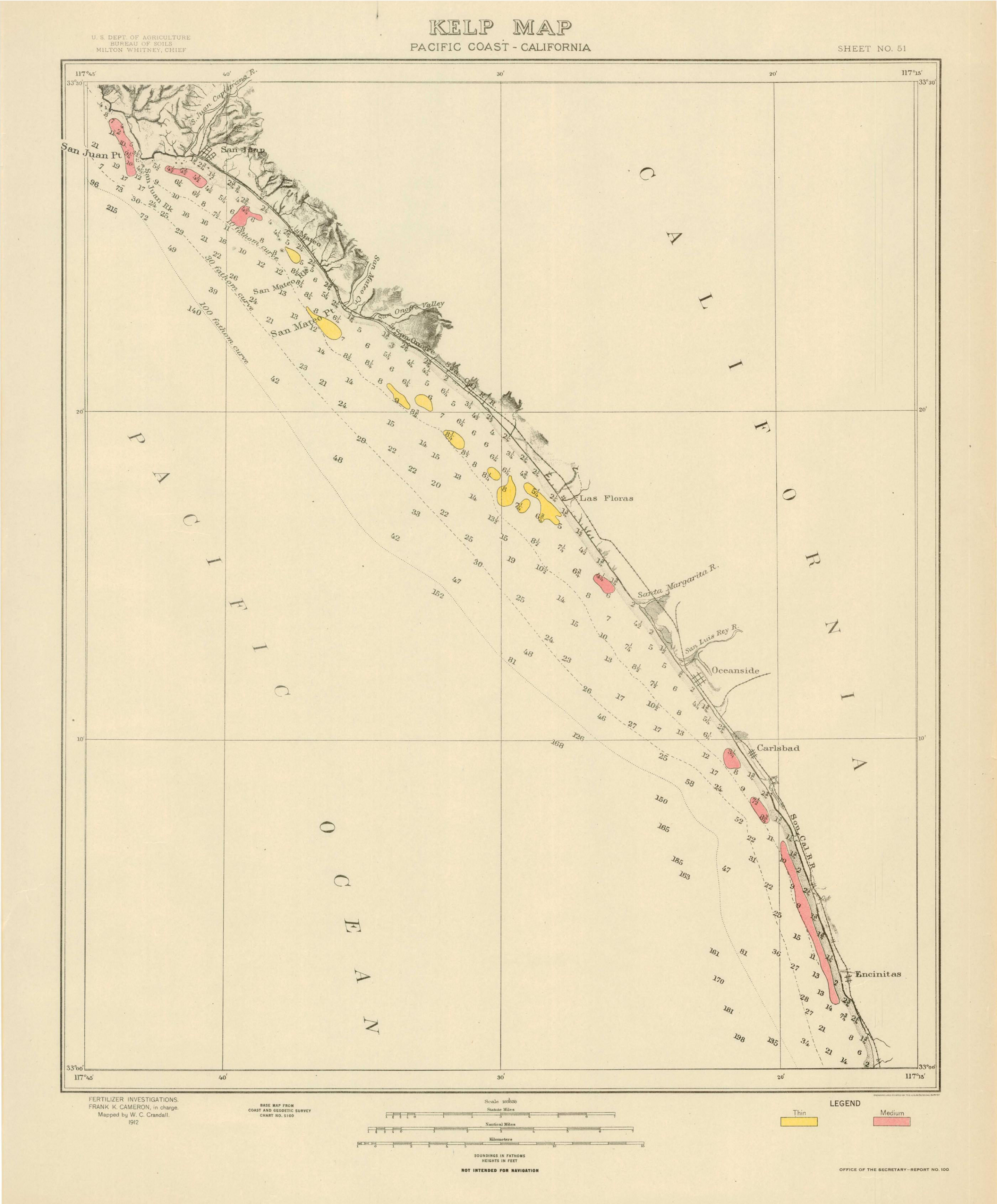
1911 Survey
Crandall


U. S. DEPT. OF AGRICULTURE
BUREAU OF SOILS
MILTON WHITNEY, CHIEF
FRANK K. CAMERON, IN CHARGE
MAP OF KELP GROVES.
SHEET NO. XVI
UNITED STATES - WEST COAST
CALIFORNIA
LOS ANGELES HARBOR
AND VICINITY
WILMINGTON
SAN PEDRO
San Pedro Hill
Smiths I.
East San Pedro
Pt Fermin
Pt Vincente
Rocky Pt
No. 21
No. 22
No. 23
No. 24
118°24'
118°20'
118°16'
33°46'
33°42'
1911 Survey
Crandall
Mapped by
W. C. Crandall
Senate Doc. 190; 62d Cong., 2d Sess.

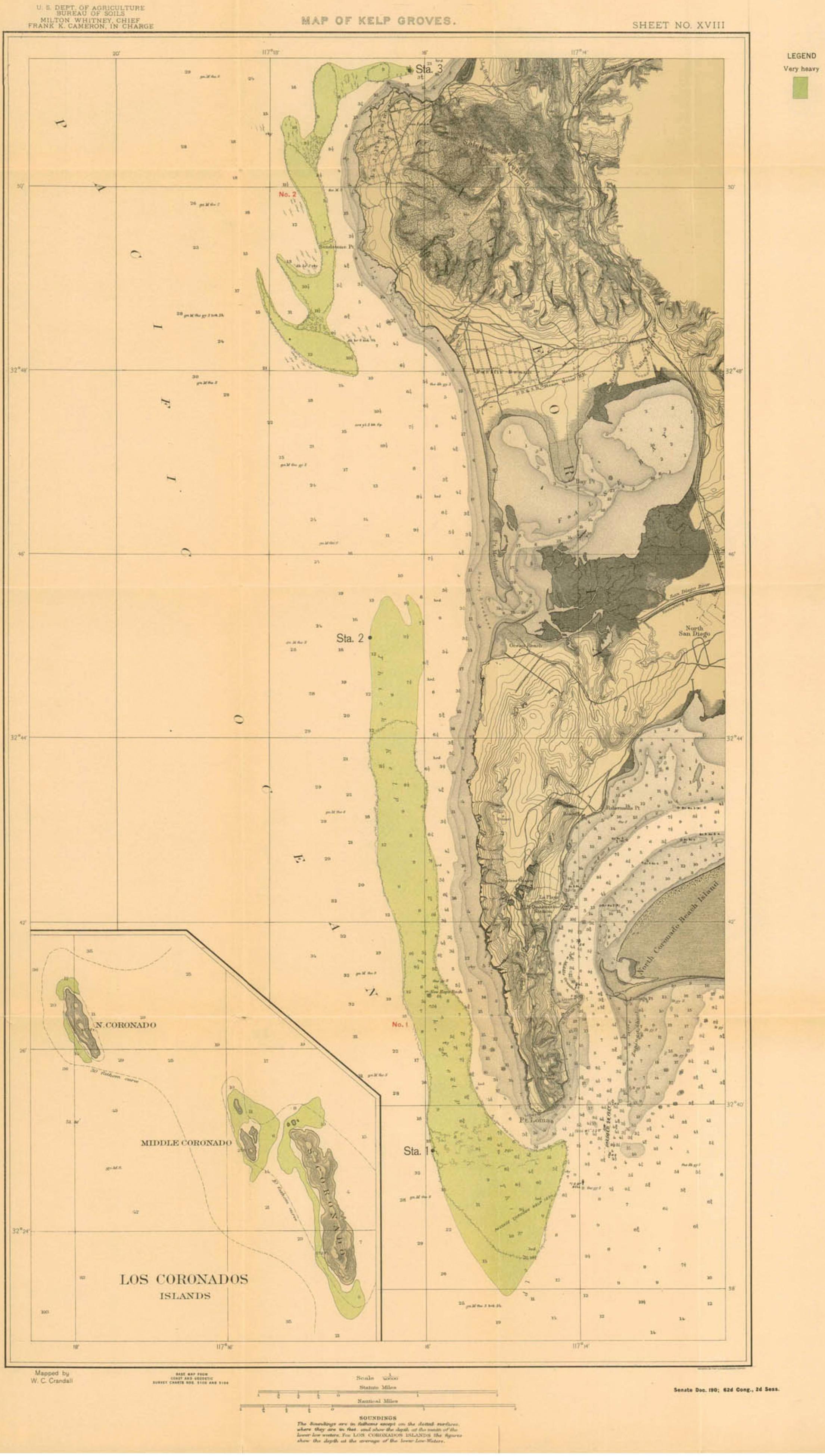
1911 Crandall kelp bed survey, Newport to San Onofre



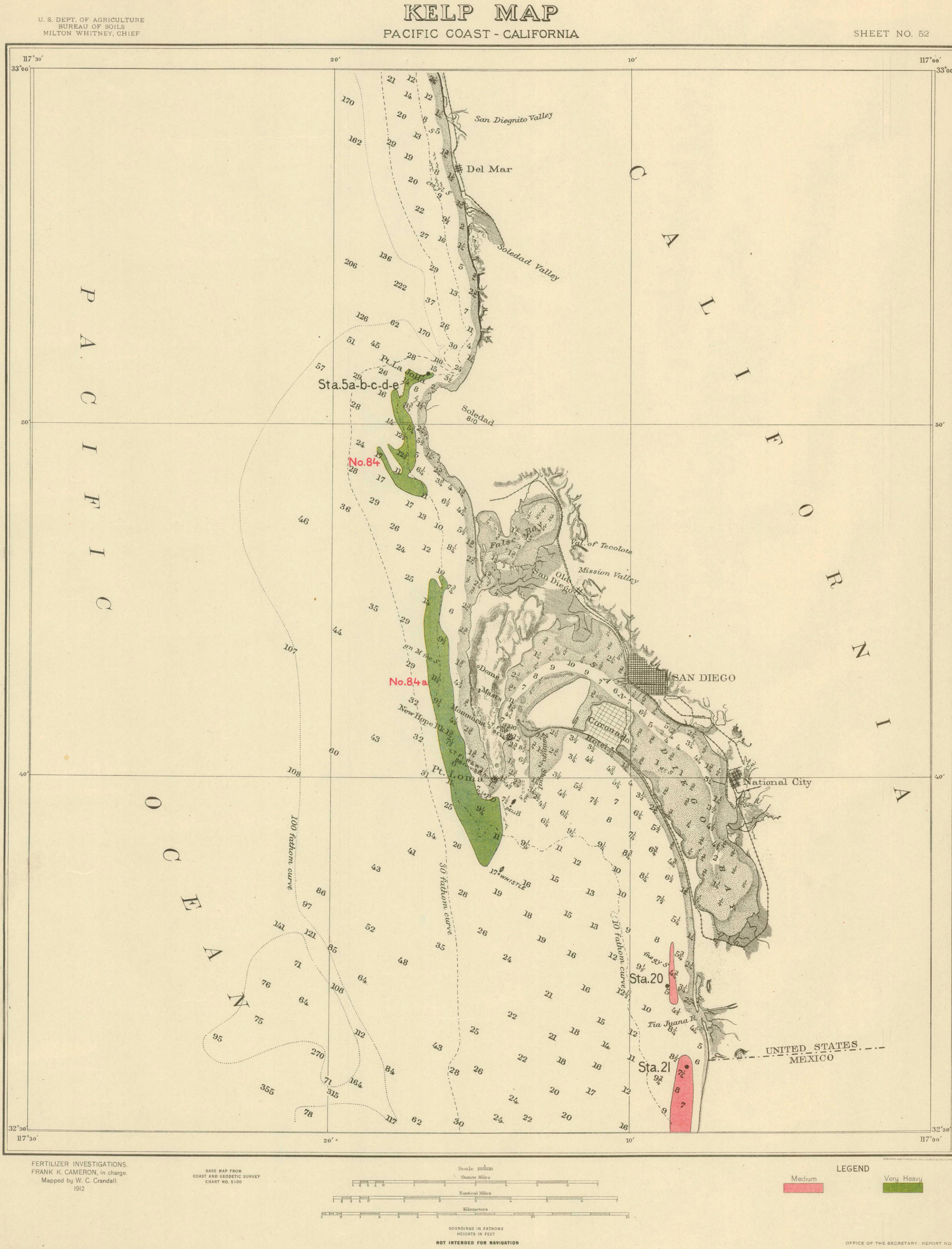
1911 Crandall kelp bed survey, San Onofre to Del Mar



1911 Crandall kelp bed survey, San Juan to Encinitas



1911 Crandall kelp bed survey, La Jolla to Point Loma



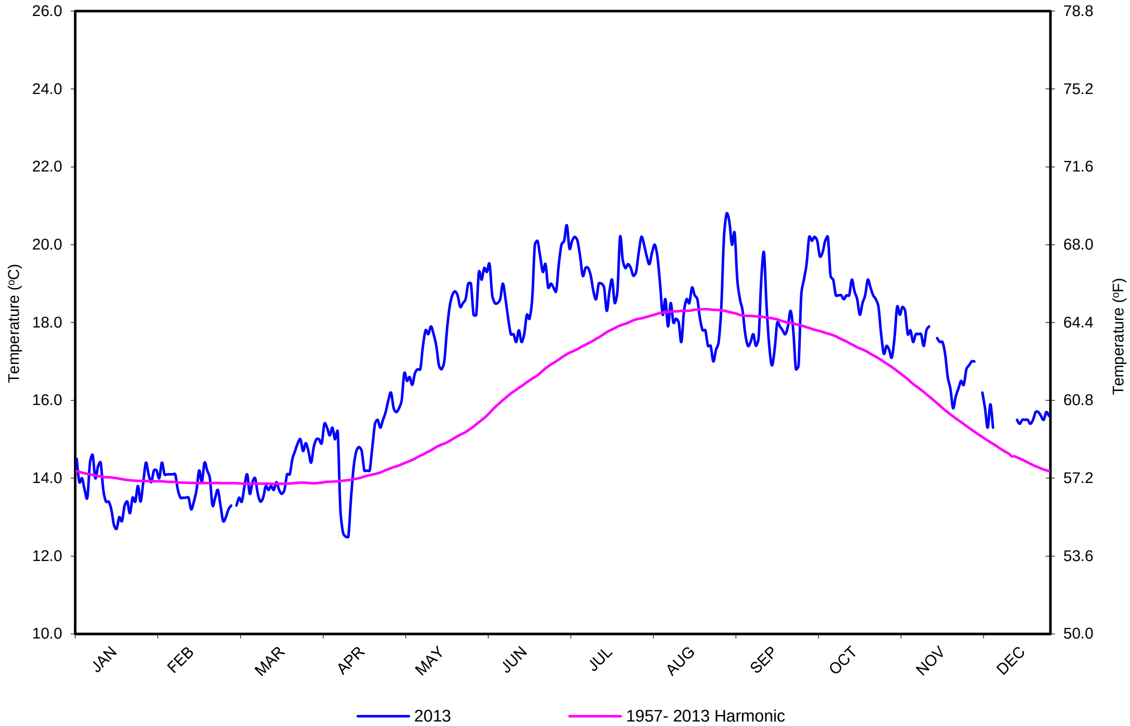
1911 Crandall kelp bed survey, La Jolla to Imperial Beach

APPENDIX C

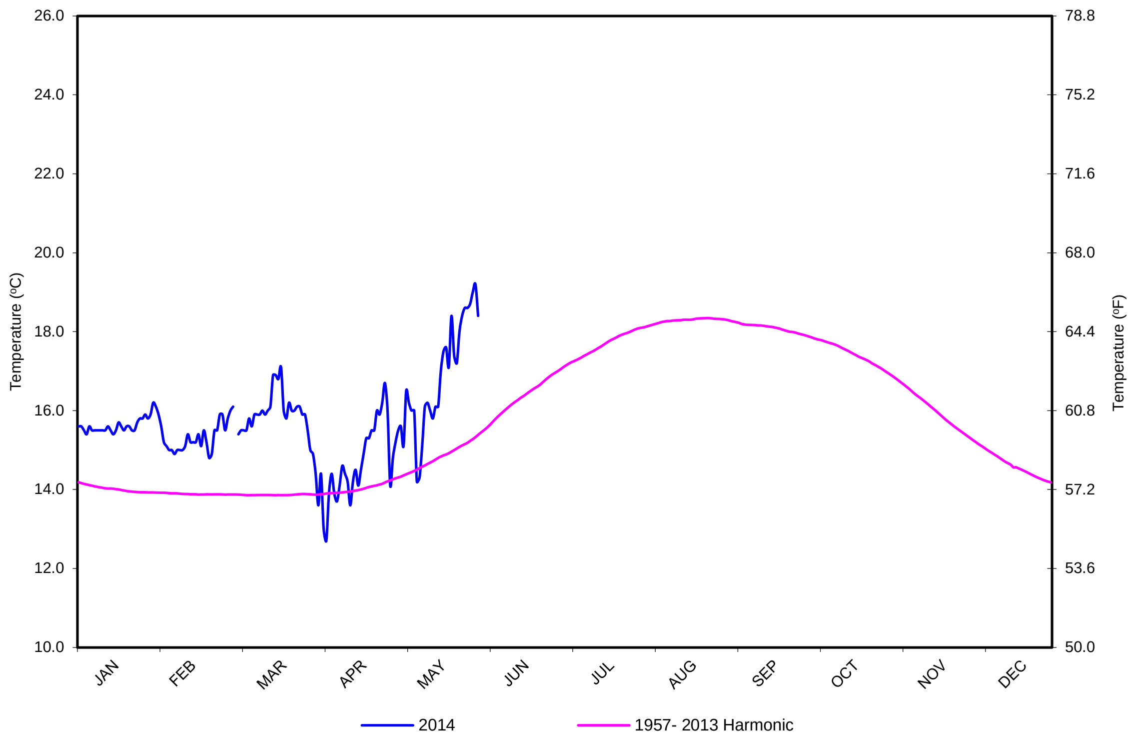
Sea Surface Temperatures

Point Dume
Sea Surface Temperature

2013

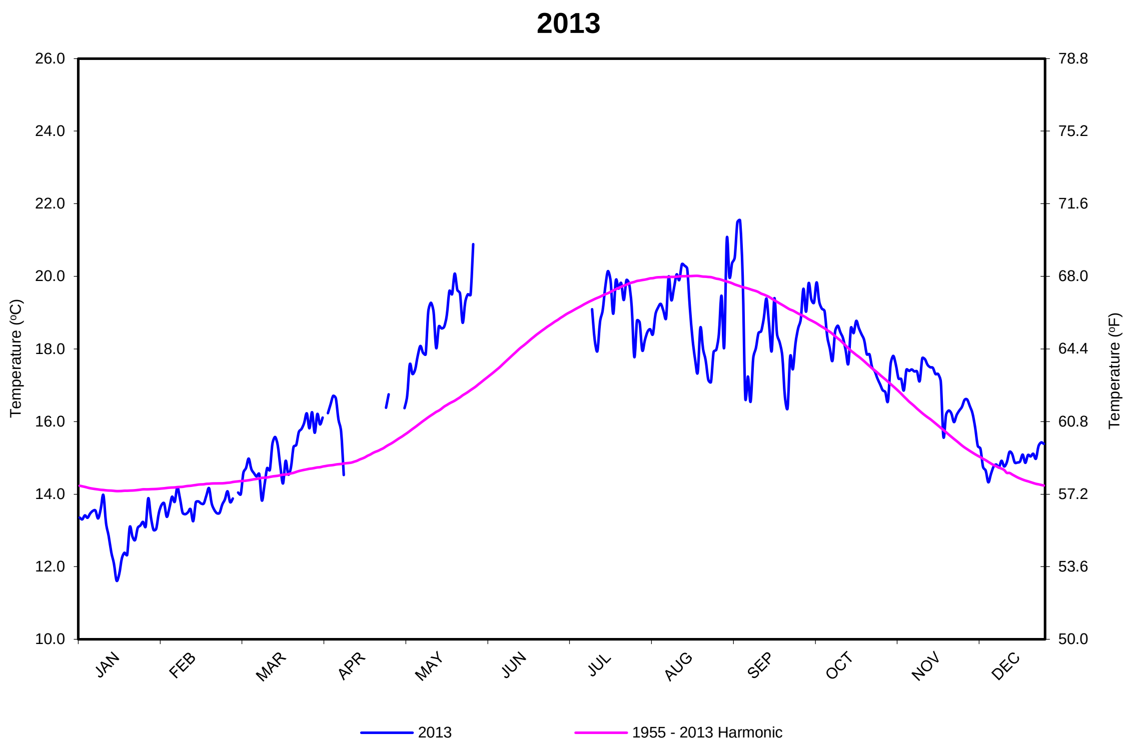


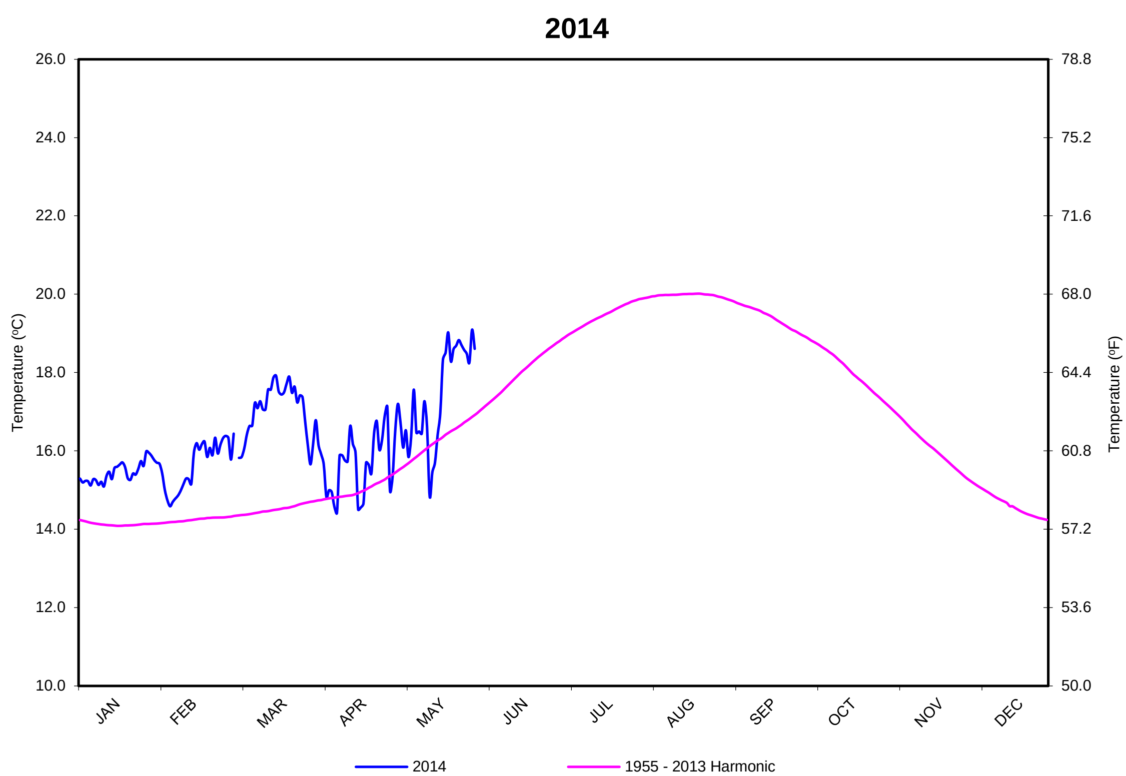
2014



Daily sea surface temperatures (SST) at Point Dume for 2013 and through May 2014.

Santa Monica Pier
Sea Surface Temperature

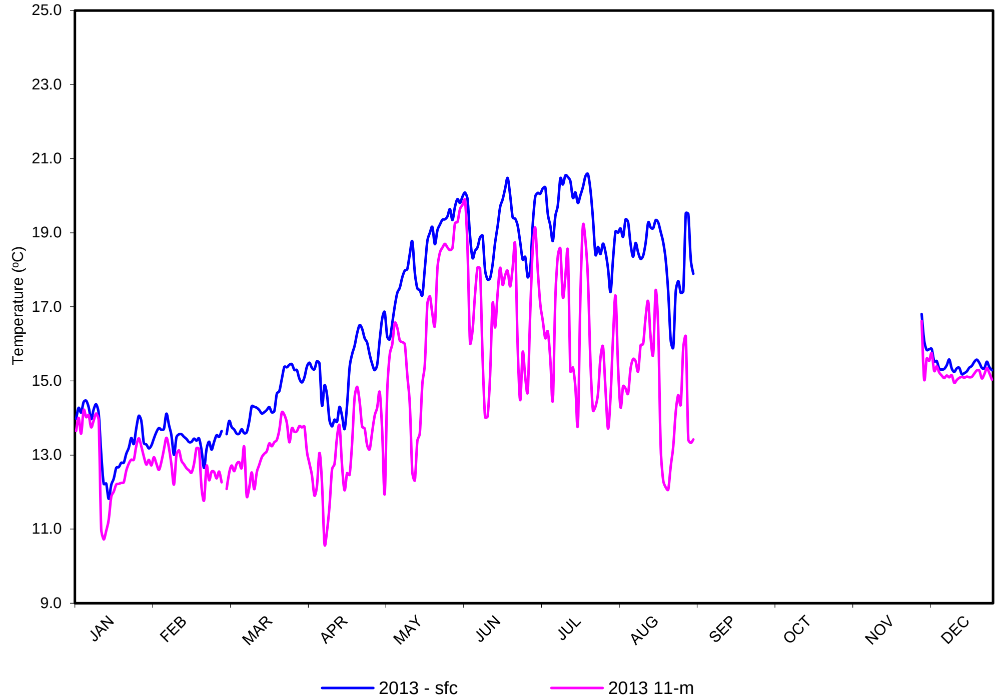




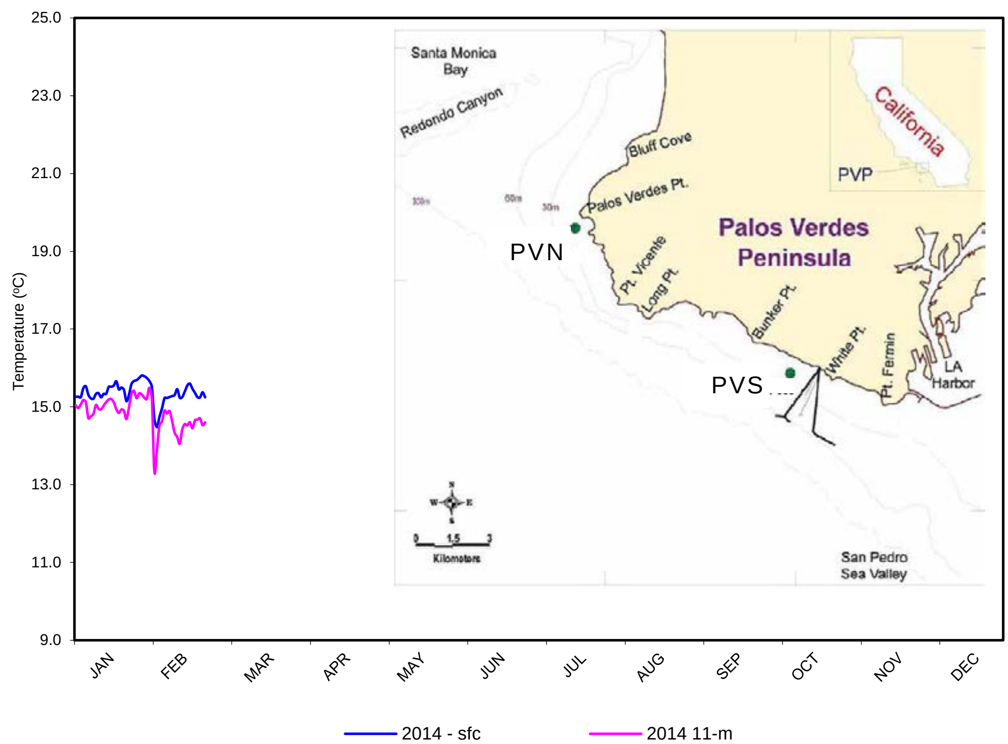
Daily sea surface temperatuares (SST) at Santa Monica Pier for 2013 and to May 2014.

Palos Verdes PVN
Sea Surface Temperature

2013

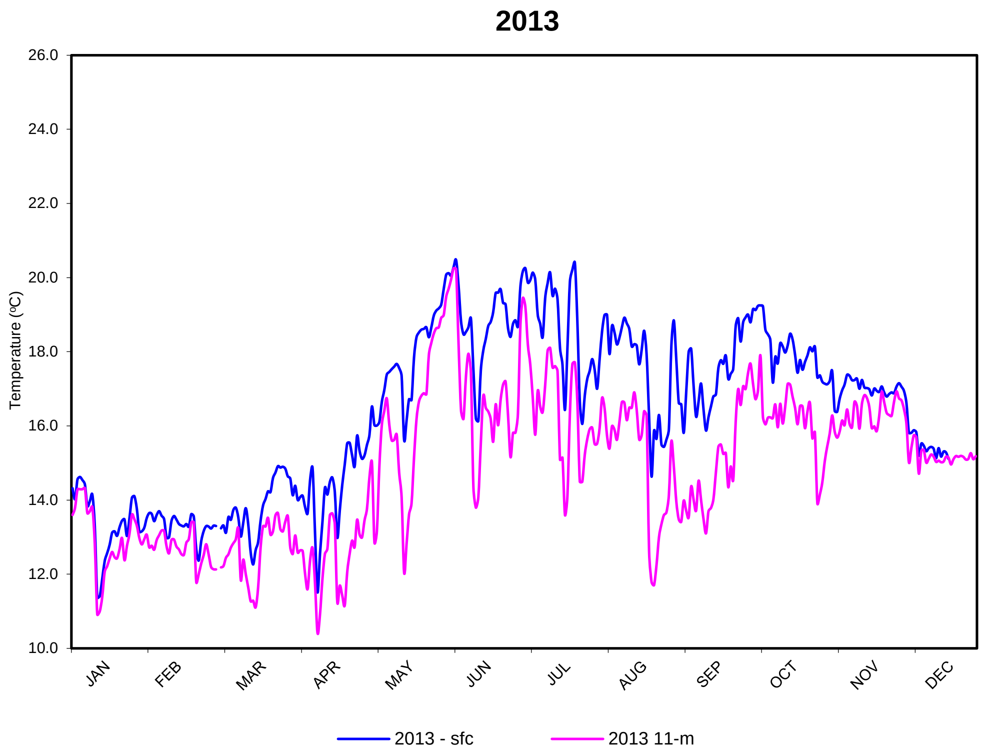


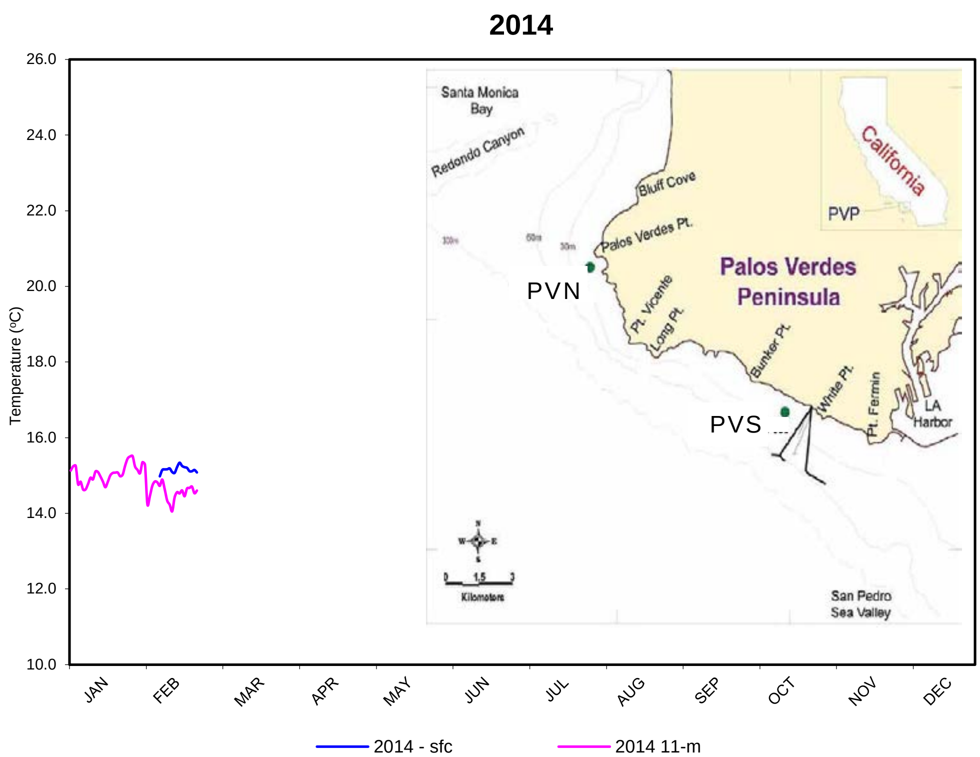
2014



Daily sea surface temperatures (SST) at Station Palos Verdes North for 2013 and through February 2014.

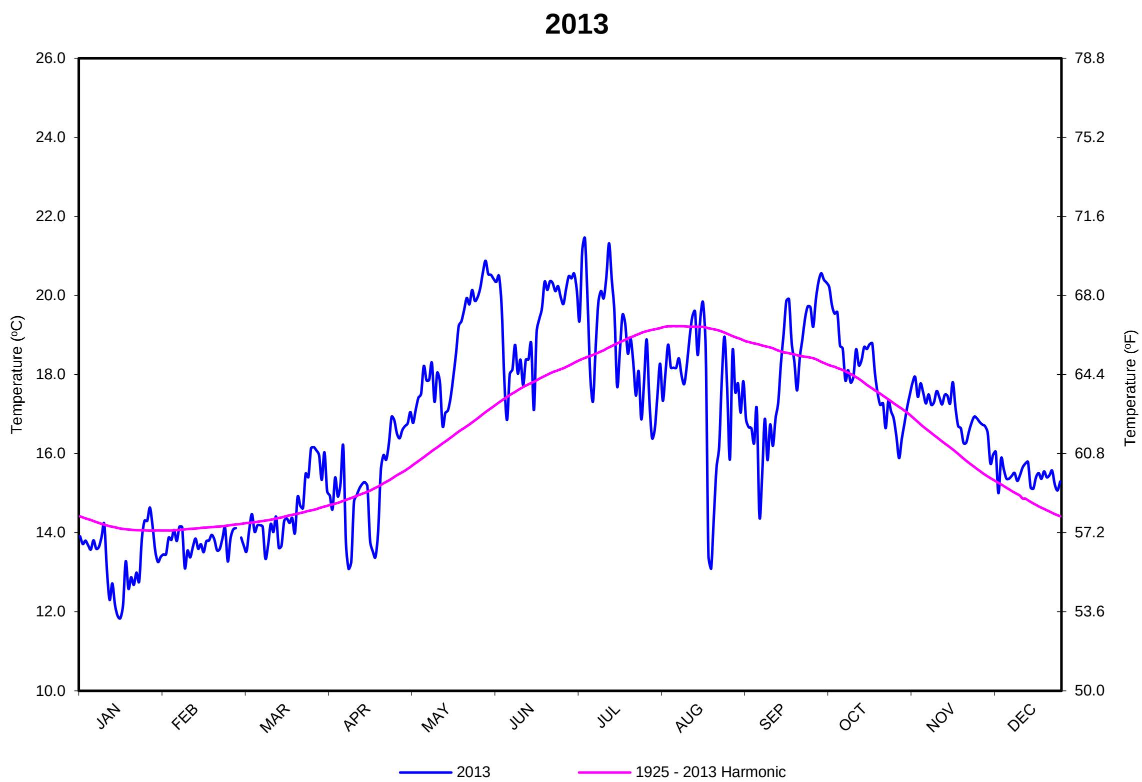
Palos Verdes PVS
Sea Surface Temperature

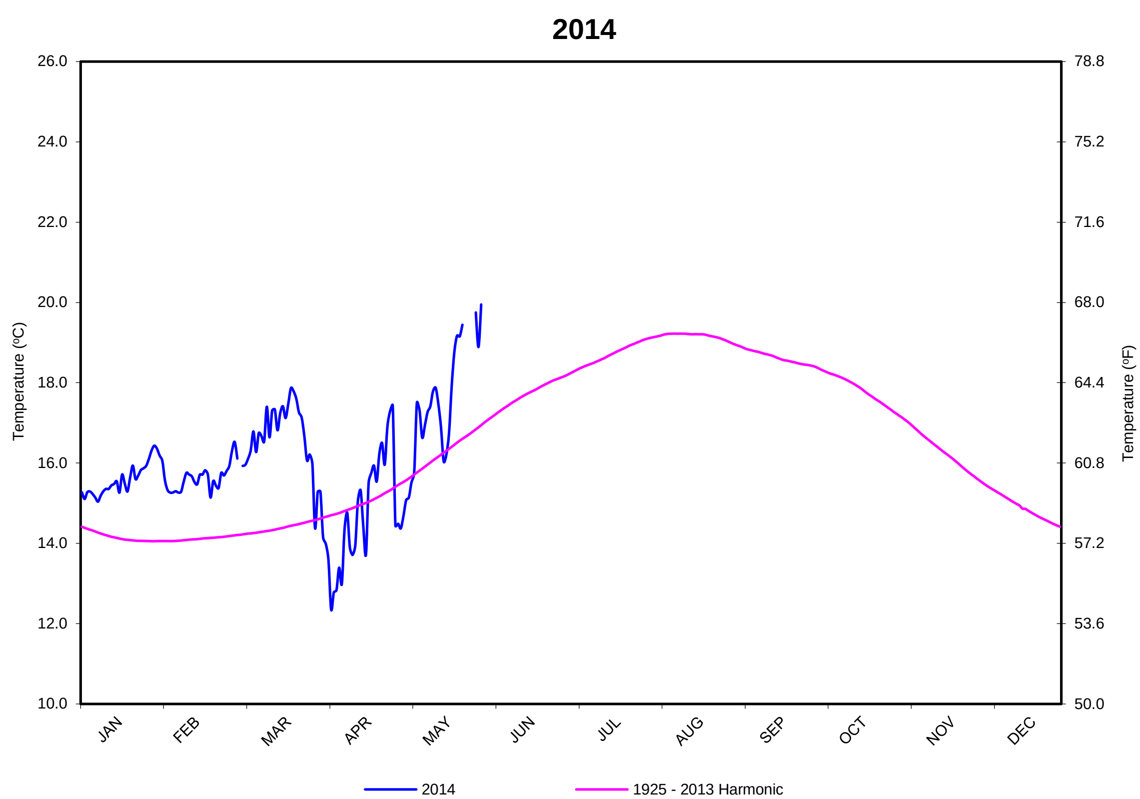




Daily sea surface temperatures (SST) at Station Palos Verdes South for 2013 and through February 2014..

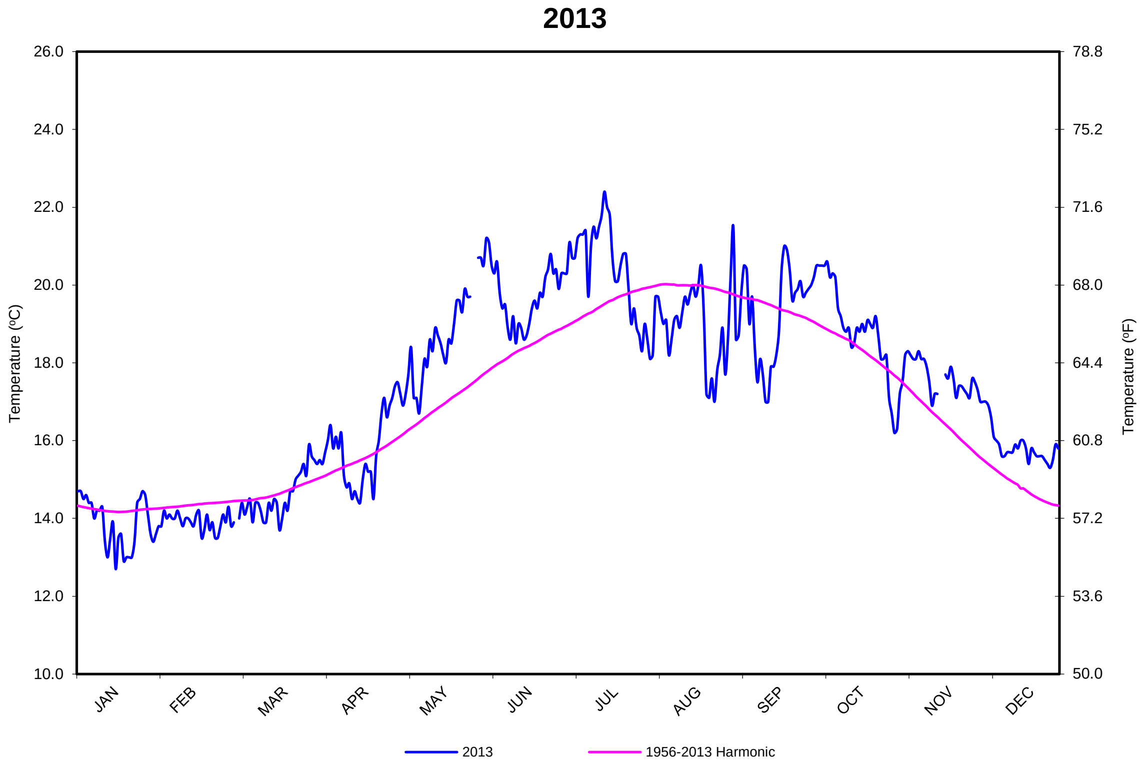
Newport Pier
Sea Surface Temperature

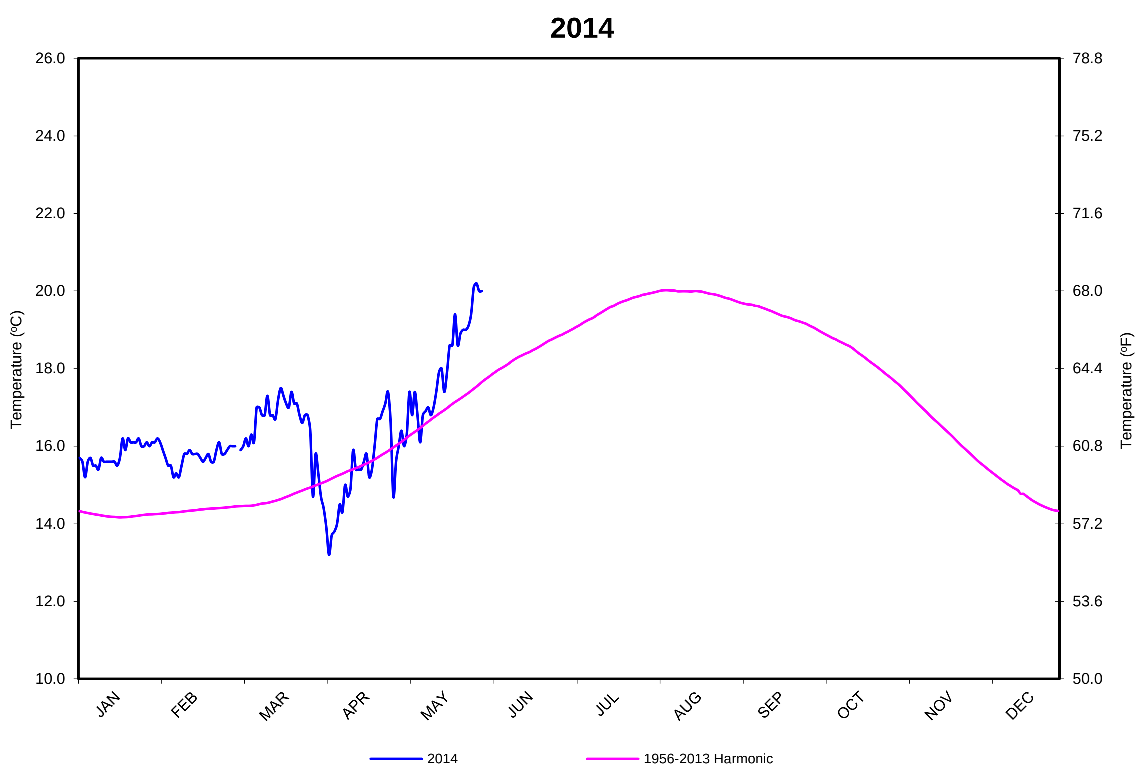




Daily sea surface temperatures (SST) at Newport Pier for 2013 and through May 2014.

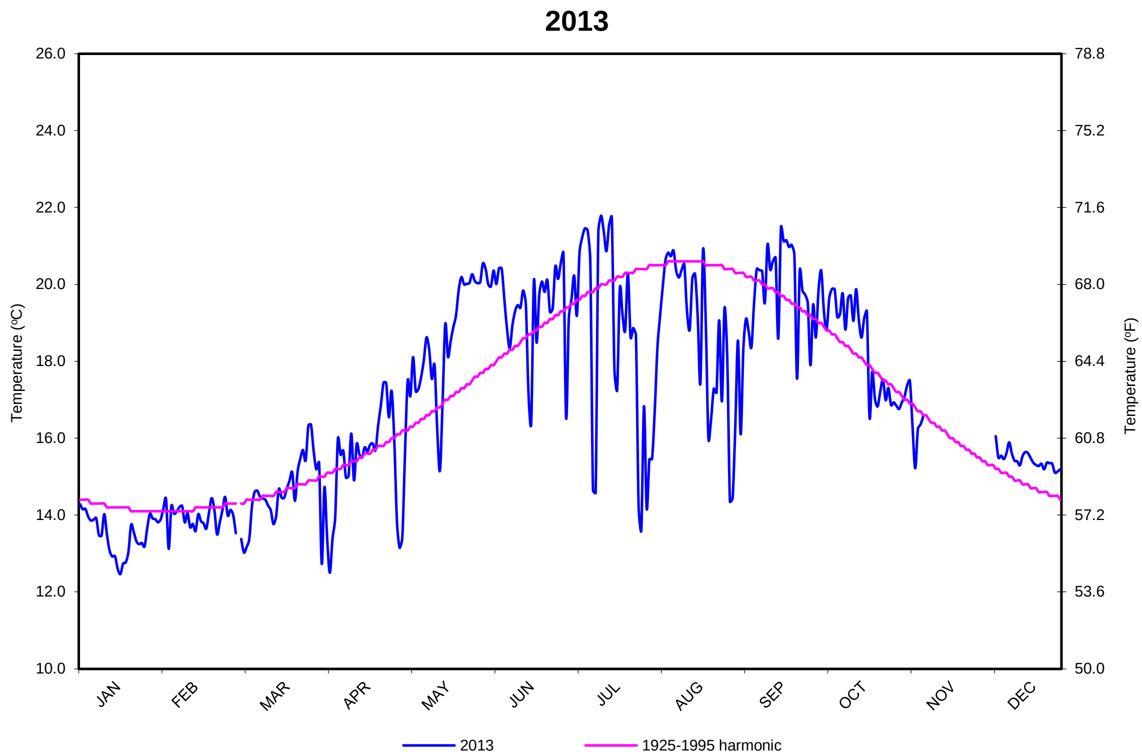
San Clemente Pier
Sea Surface Temperature

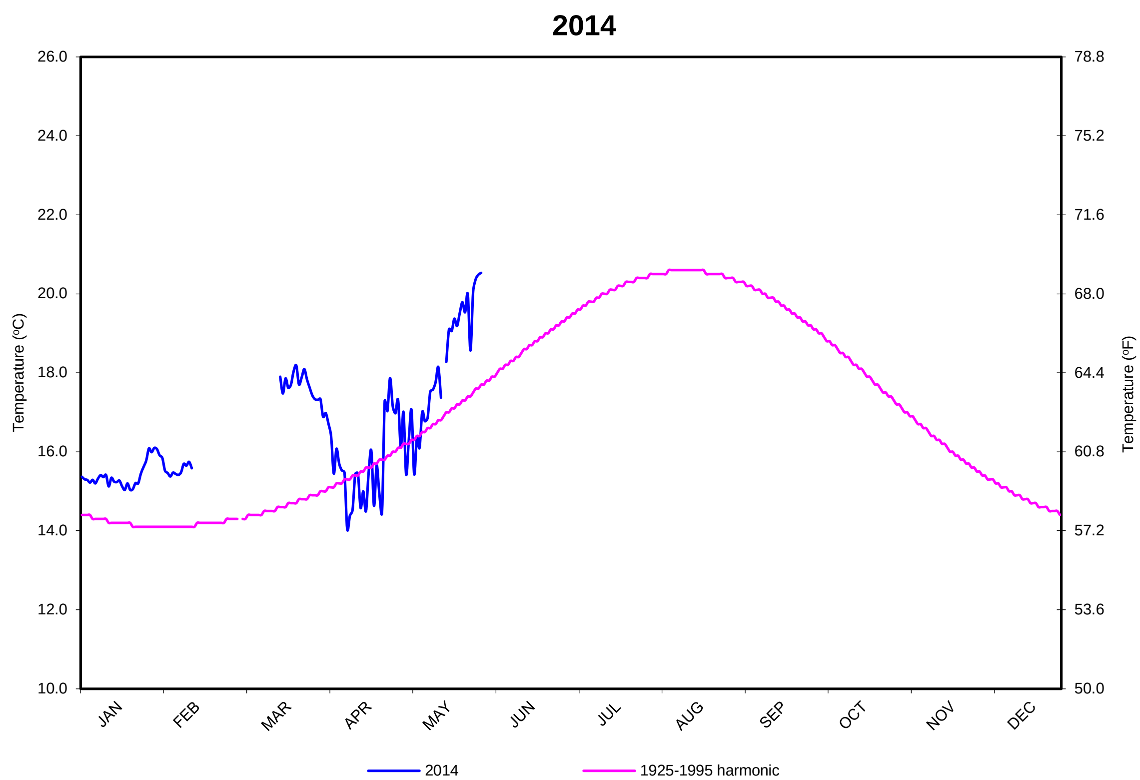




Daily sea surface temperatures (SST) at San Clemente for 2013 and through May 2014.

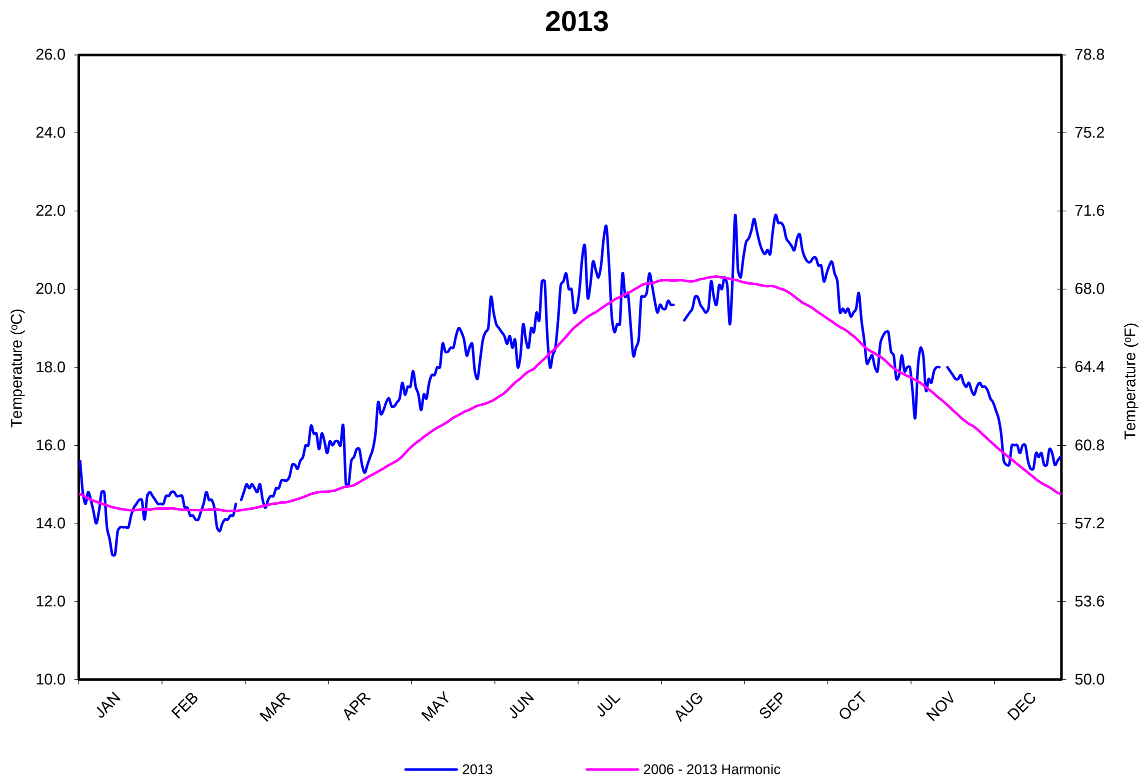
Scripps Pier
Sea Surface Temperature

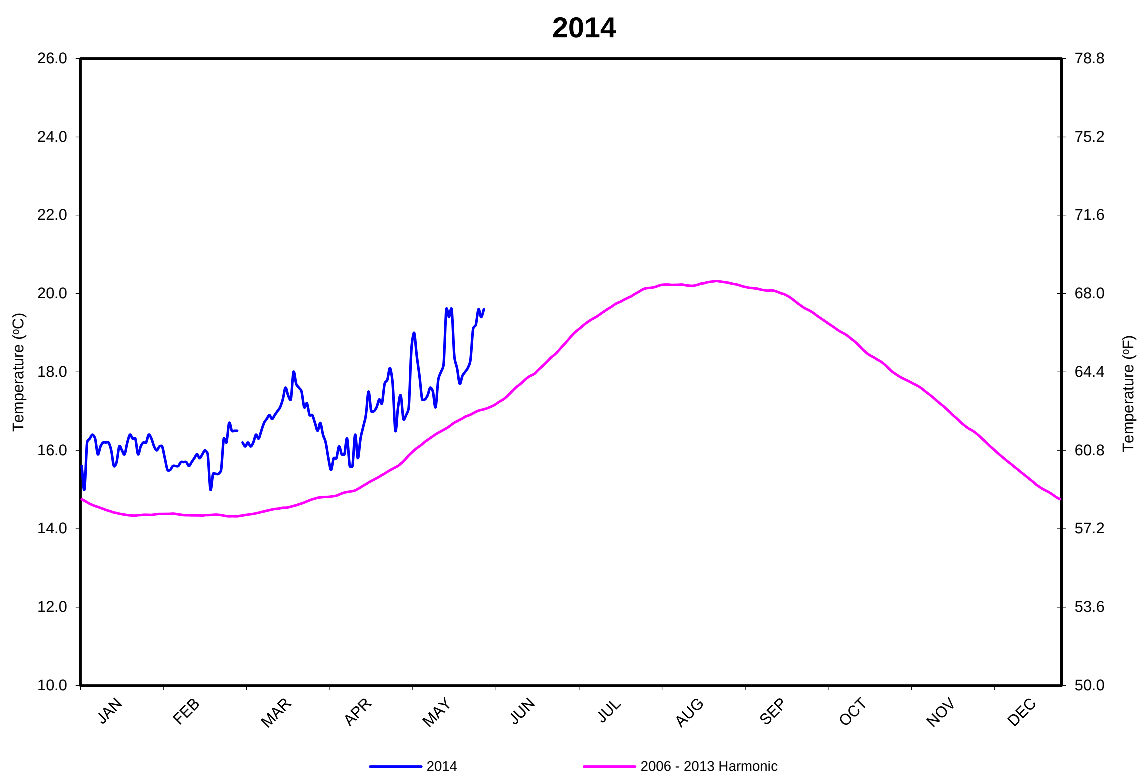




Daily sea surface temperatures (SST) at Scripps Pier for 2013 and to May 2014.

Point Loma South
Sea Surface Temperature





Daily sea surface temperatures (SST) at Point Loma South for 2013 and through May 2014.

APPENDIX D

Flight Data Reports

Ecoscan Resource Data
Data Acquisition
Flight Data Report

Contracting Agency/Contact		Contract/Order #/Agency File #	
Contracting Agency:	MBC Applied Environmental Sciences	**Contract/Order #:**	
Division:		**Agency File #:**	
Contact/Title:	Michael Curtis	**Calendar**	
Address:	3000 Redhill Ave.	**Services Ordered:**	3/13
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	5/13/13
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	5/13

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow

Project Title		**California Coastal Kelp Resources - Ventura to Oceanside- May 13, 2013**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Imperial Beach (U.S./Mexican border)
Survey Data Flow	**Acquisition** Processing Analysis Presentation	Vertical color IR digital imagery of all coastal kelp canopies within the survey range Survey imagery indexed and delivered to MBC for further processing and analysis All survey imagery presented with 8"x10" contact sheets (12 images/per page)

Aerial Resource Survey Flight Data for:		**May 13, 2013**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1515-1703
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	2.7' (+) to 2.4' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	Low glare present
	Other 3:	Photographer:	Van Wagenen	Comments:	Excellent Conditions

Range (s) Surveyed	Ventura to Imperial Beach	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed.
Imagery Quality/ Comments	Excellent	All surface kelp canopies, were photographed within the above range and the image processing was conducted normally. All of the imagery was judged of excellent quality and was useable for the subsequent maping of the kelp resource.
	Lens Note	30mm (digital SLR camera) is similiar focal length to 50mm (35mm film SLR camera)

Ecoscan Resource Data
143 Browns Valley Rd.
Watsonville, CA 95076
(831) 728-5900 (ph./fax)

Signed: ______________________ Bob Van Wagenen, Director

Copy To:

Ecoscan Resource Data
Data Acquisition
Flight Data Report

Contracting Agency/Contact		Contract/Order #/Agency File #	
Contracting Agency:	MBC Applied Environmental Sciences	**Contract/Order #:**	
Division:		**Agency File #:**	
Contact/Title:	Michael Curtis	**Calendar**	
Address:	3000 Redhill Ave.	**Services Ordered:**	7/13
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	7/15-16/13
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	8/13

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- July 15-16, 2013**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Imperial Beach (U.S./Mexican border)
Survey Data Flow	**Acquisition**	Vertical color IR digital imagery of all coastal kelp canopies within the survey range
	Processing	Survey imagery indexed and delivered to MBC for further processing and analysis
	Analysis	
	Presentation	All survey imagery presented with 8"x10" contact sheets (12 images/per page)

Aerial Resource Survey Flight Data for:		**July 15-16, 2013**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1500-1700 (both dates)
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	4.4' (+) to 4.8' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	Some glare present
	Other 3:	Photographer:	Van Wagenen	Comments:	Excellent Conditions

Range (s) Surveyed	Ventura to Imperial Beach	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed.
Imagery Quality/ Comments	Excellent	All surface kelp canopies, were photographed within the above range and the image processing was conducted normally. All of the imagery was judged of excellent quality and was useable for the subsequent maping of the kelp resource. Some glare present from Ventura to Long Beach.
	Lens Note	30mm (digital SLR camera) is similiar focal length to 50mm (35mm film SLR camera)

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Flight Data Report

Contracting Agency/Contact		Contract/Order #/Agency File #	
Contracting Agency:	MBC Applied Environmental Sciences	**Contract/Order #:**	
Division:		**Agency File #:**	
Contact/Title:	Michael Curtis	**Calendar**	
Address:	3000 Redhill Ave.	**Services Ordered:**	9/13
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	9/23/13
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	10/13

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow		
Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- September 23, 2013**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Imperial Beach (U.S./Mexican border)
Survey Data Flow	**Acquisition** Processing Analysis Presentation	Vertical color IR digital imagery of all coastal kelp canopies within the survey range Survey imagery indexed and delivered to MBC for further processing and analysis All survey imagery presented with 8"x10" contact sheets (12 images/per page)

Aerial Resource Survey Flight Data for:		September 23, 2013			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1513-1647
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	3.3' (+) to 1.7' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Optimum Conditions

Range (s) Surveyed	Ventura to Imperial Beach	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed.
Imagery Quality/ Comments	Excellent Lens Note	All surface kelp canopies, were photographed within the above range and the image processing was conducted normally. All of the imagery was judged of excellent quality and was useable for the subsequent maping of the kelp resource. 30mm (digital SLR camera) is similiar focal length to 50mm (35mm film SLR camera)

Ecoscan Resource Data
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Signed: ____________________ Bob Van Wagenen, Director

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Data Acquisition
Flight Data Report

Contracting Agency/Contact		Contract/Order #/Agency File #	
Contracting Agency:	MBC Applied Environmental Sciences	**Contract/Order #:**	
Division:		**Agency File #:**	
Contact/Title:	Michael Curtis	**Calendar**	
Address:	3000 Redhill Ave.	**Services Ordered:**	12/13
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	12/16/13
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	12/13

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- December 16, 2013**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Imperial Beach (U.S./Mexican border)
Survey Data Flow	**Acquisition**	Vertical color IR digital imagery of all coastal kelp canopies within the survey range
	Processing	Survey imagery indexed and delivered to MBC for further processing and analysis
	Analysis	
	Presentation	All survey imagery presented with 8"x10" contact sheets (12 images/per page)

Aerial Resource Survey Flight Data for: **December 16, 2013**

	Survey Type	Aircraft/Imagery Data		Associated Conditions	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	2-4 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1308-1453
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	0.7' (+) to 0.7' (-) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Optimum Conditions

Range (s) Surveyed	Ventura to Imperial Beach	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed.
Imagery Quality/ Comments	Excellent	All surface kelp canopies, were photographed within the above range and the image processing was conducted normally. All of the imagery was judged of excellent quality and was useable for the subsequent maping of the kelp resource.
	Lens Note	30mm (digital SLR camera) is similiar focal length to 50mm (35mm film SLR camera)

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Watsonville, CA 95076
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Signed: ______________________ Bob Van Wagenen, Director

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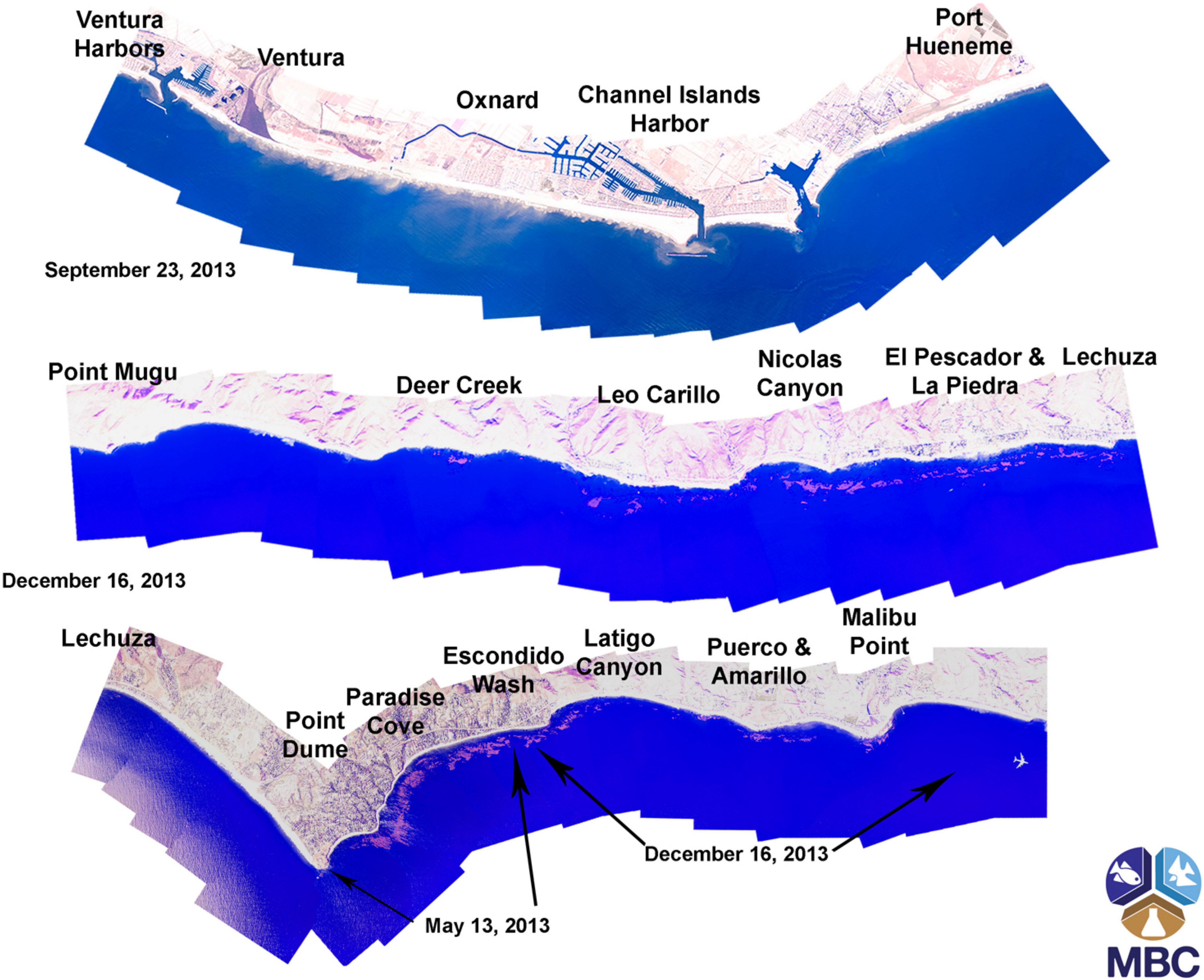
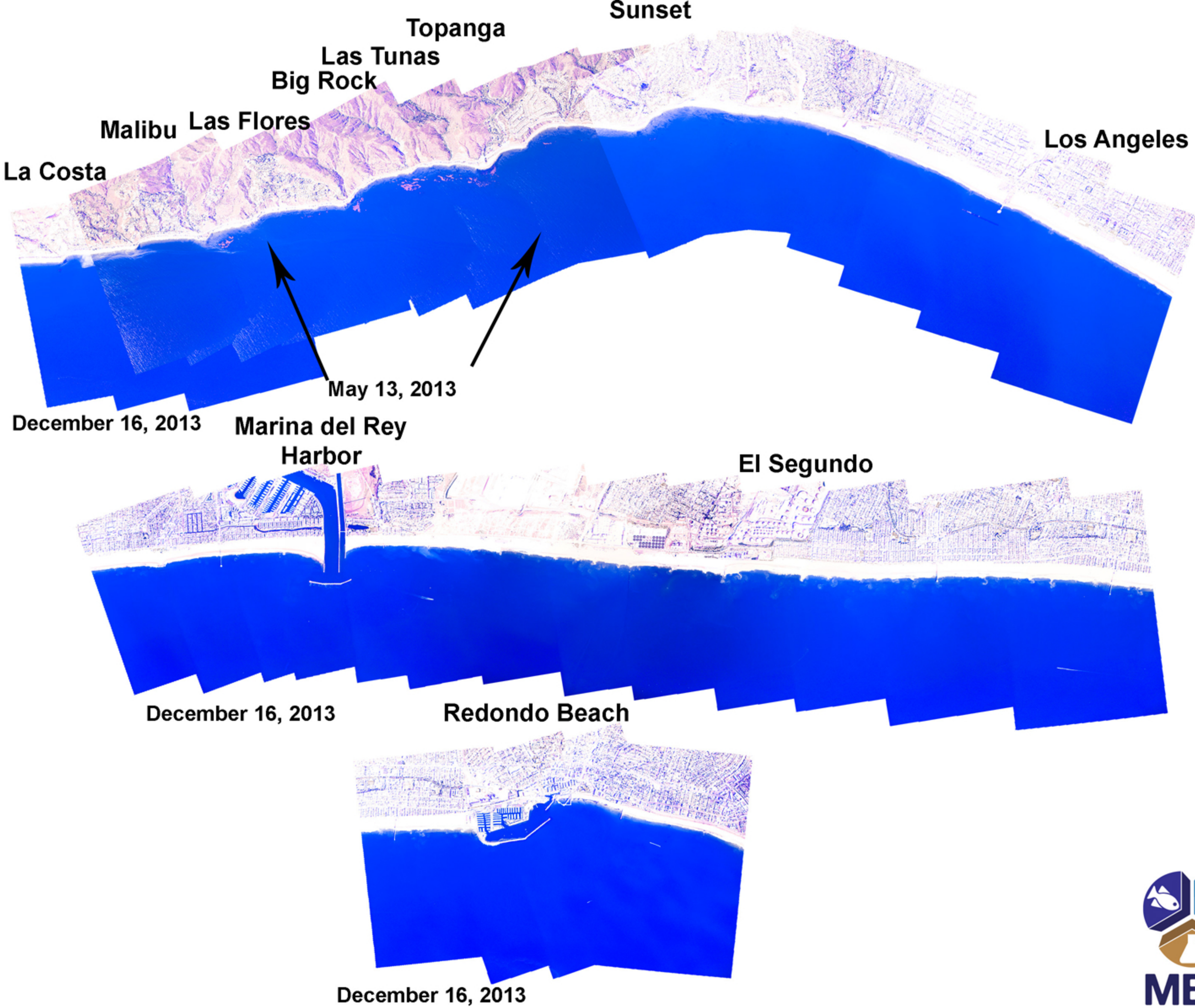
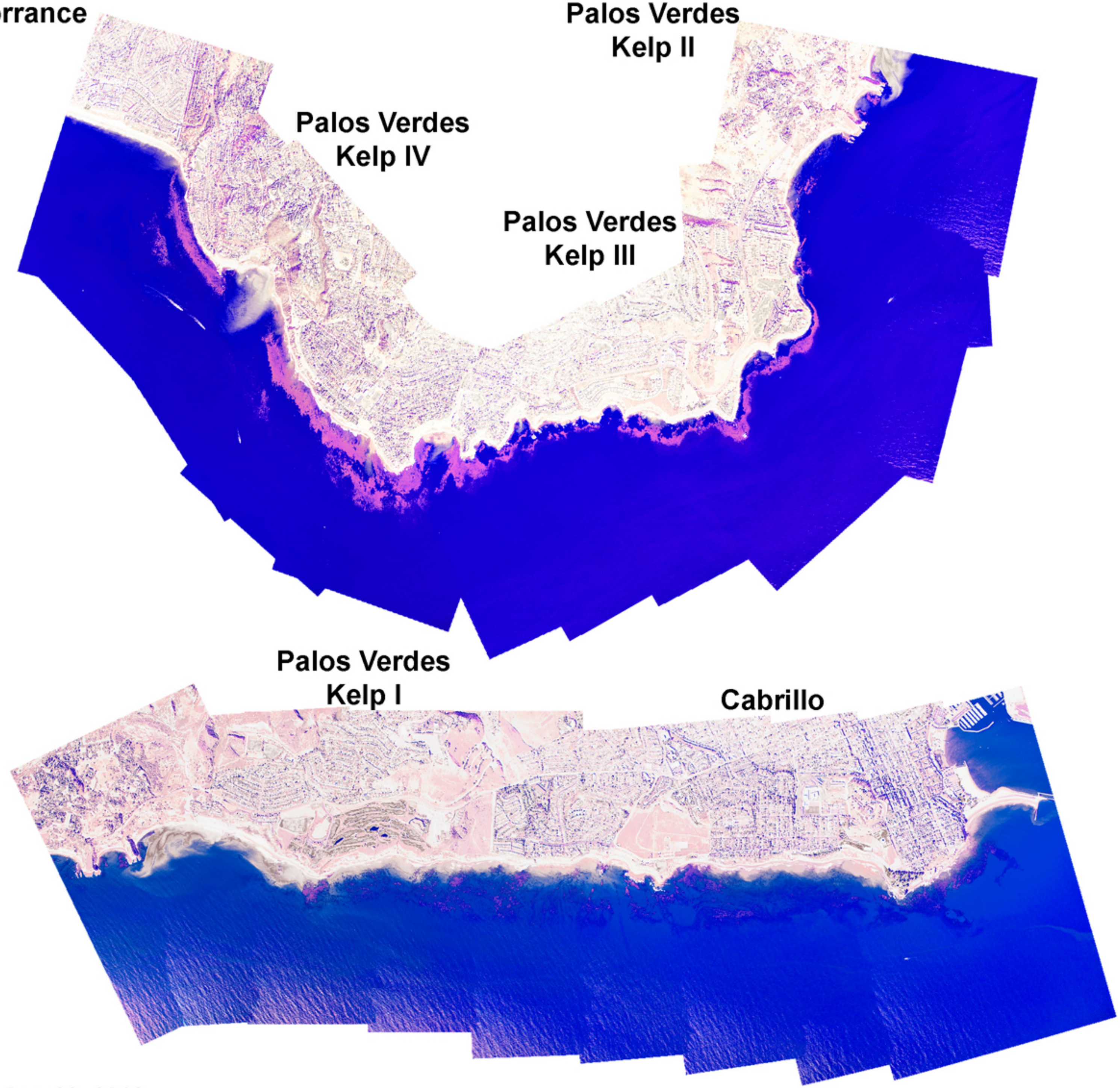
APPENDIX E

Kelp Canopy Aerial Photographs

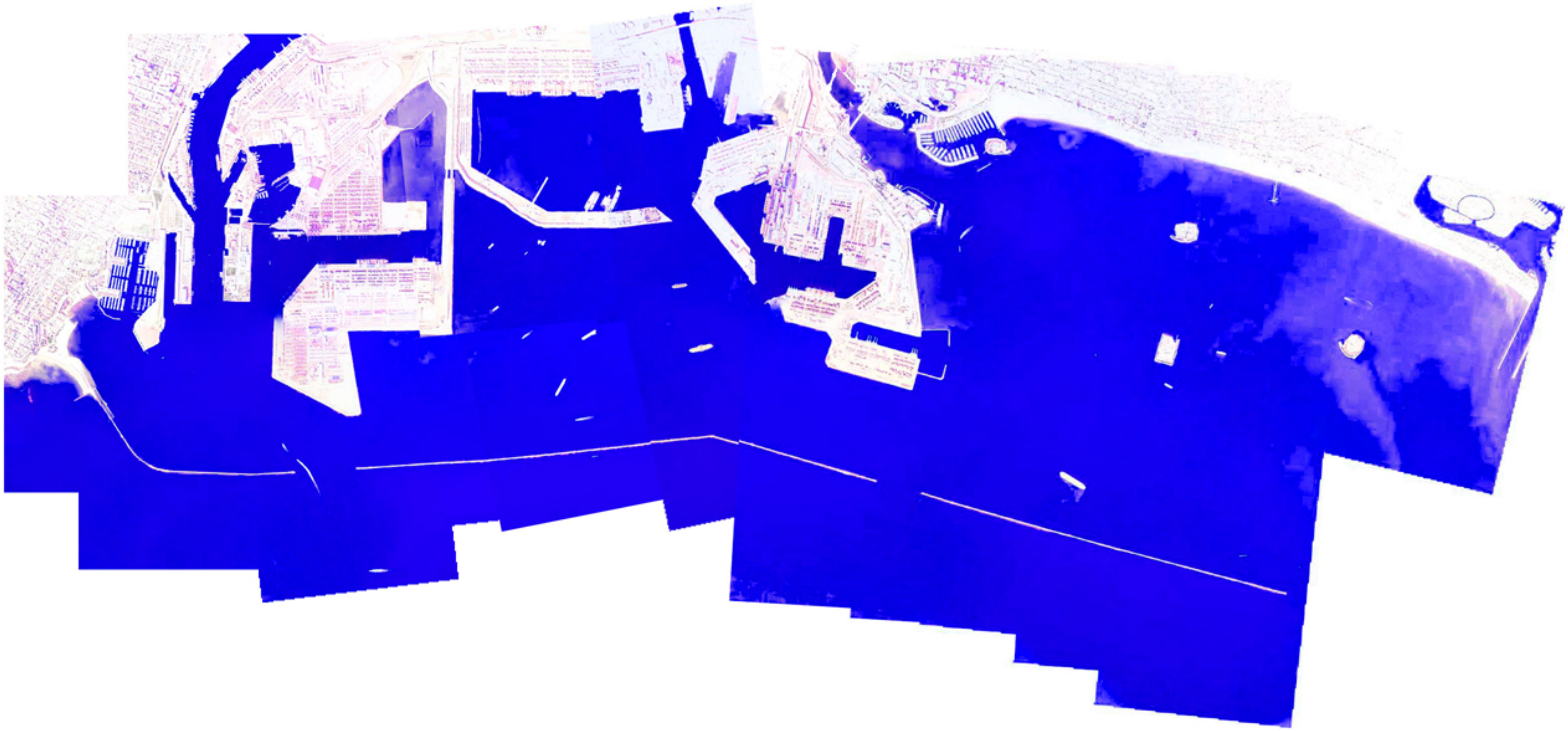


Ventura Harbors
Ventura
Oxnard
Channel Islands Harbor
Port Hueneme
September 23, 2013
Point Mugu
Deer Creek
Leo Carillo
Nicolas Canyon
El Pescador & La Piedra
Lechuza
December 16, 2013
Lechuza
Point Dume
Paradise Cove
Escondido Wash
Latigo Canyon
Puerco & Amarillo
Malibu Point
December 16, 2013
May 13, 2013

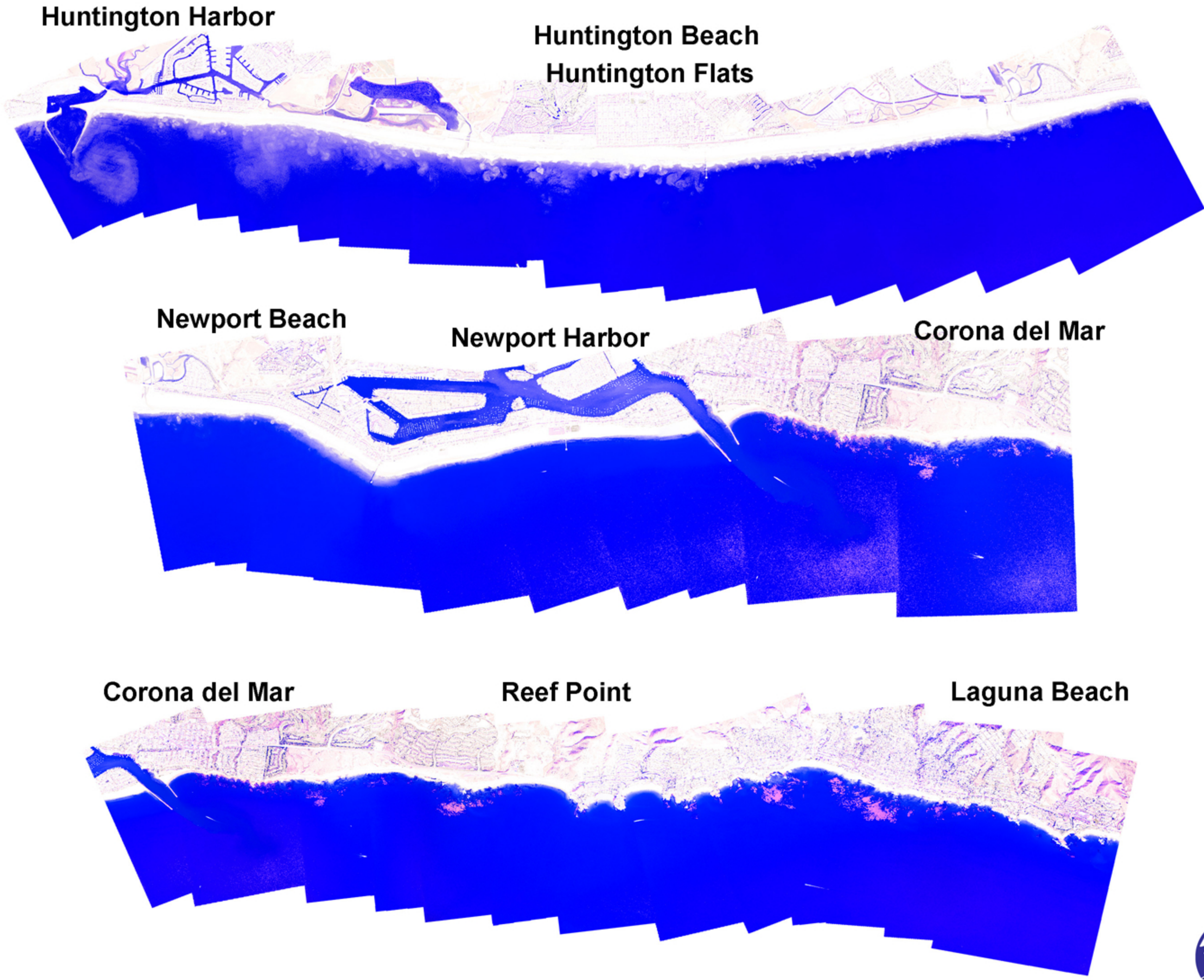

Sunset
Topanga
Las Tunas
Big Rock
Las Flores
Malibu
La Costa
Los Angeles
May 13, 2013
December 16, 2013
Marina del Rey
Harbor
El Segundo
December 16, 2013
Redondo Beach
December 16, 2013


Torrance
Palos Verdes Kelp IV
Palos Verdes Kelp II
Palos Verdes Kelp III
Palos Verdes Kelp I
Cabrillo
December 16, 2013
MBC

POLA/POLB Harbors

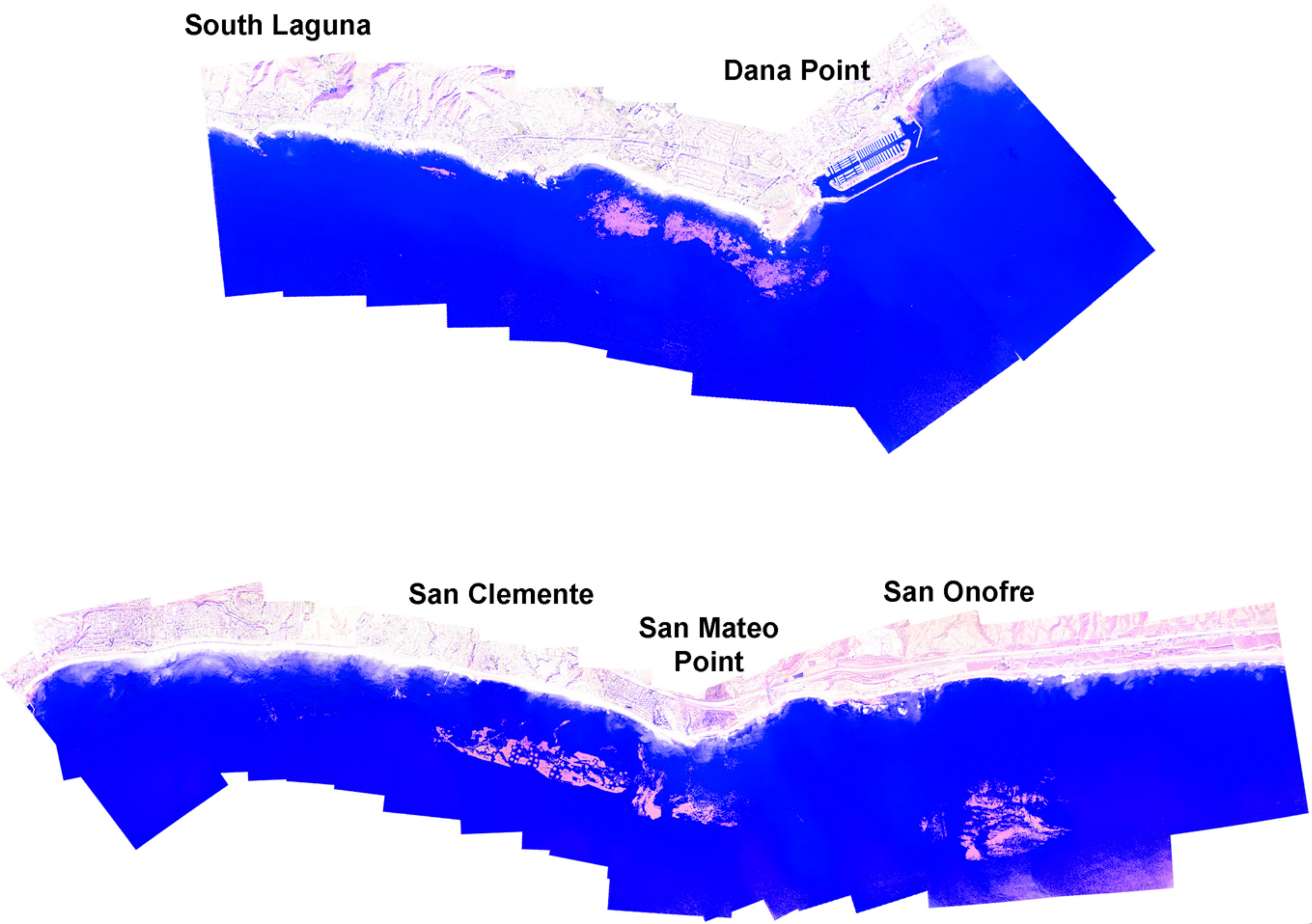


December 16, 2013

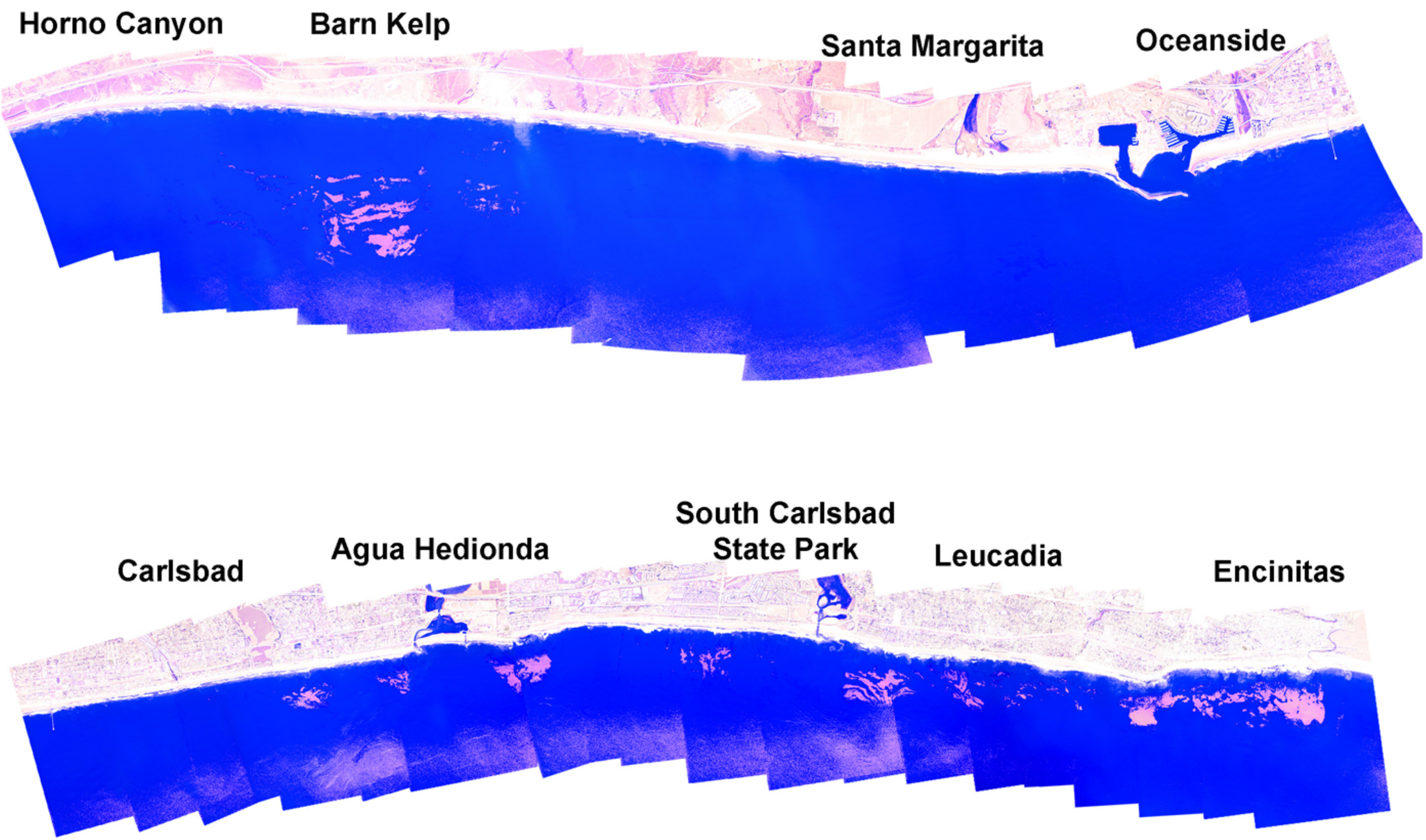


December 16, 2013

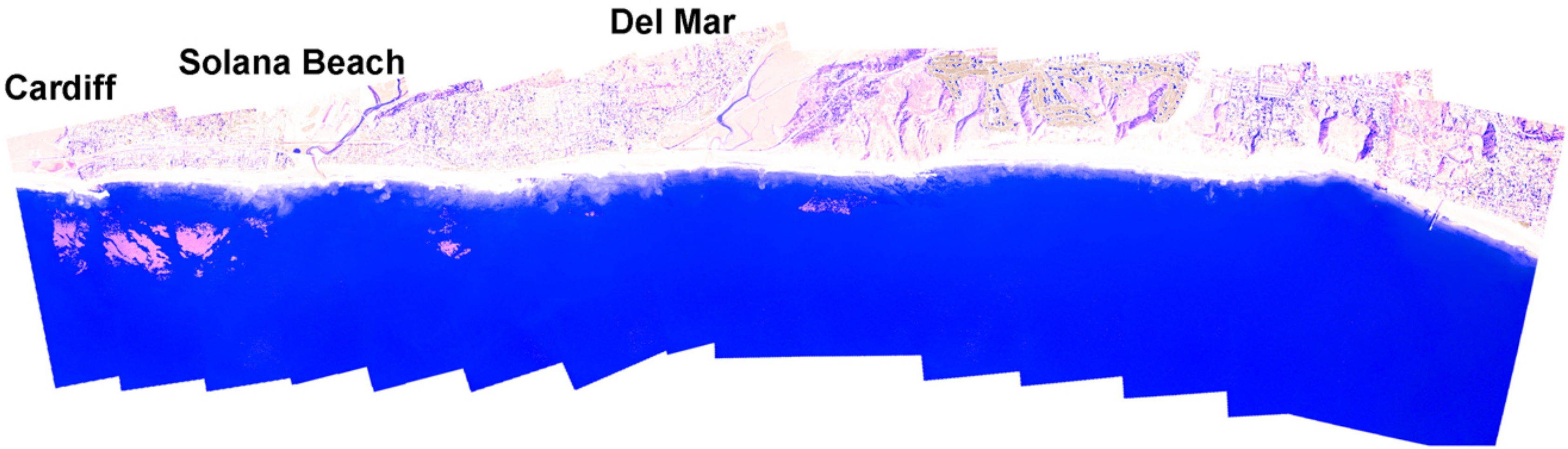
MBC

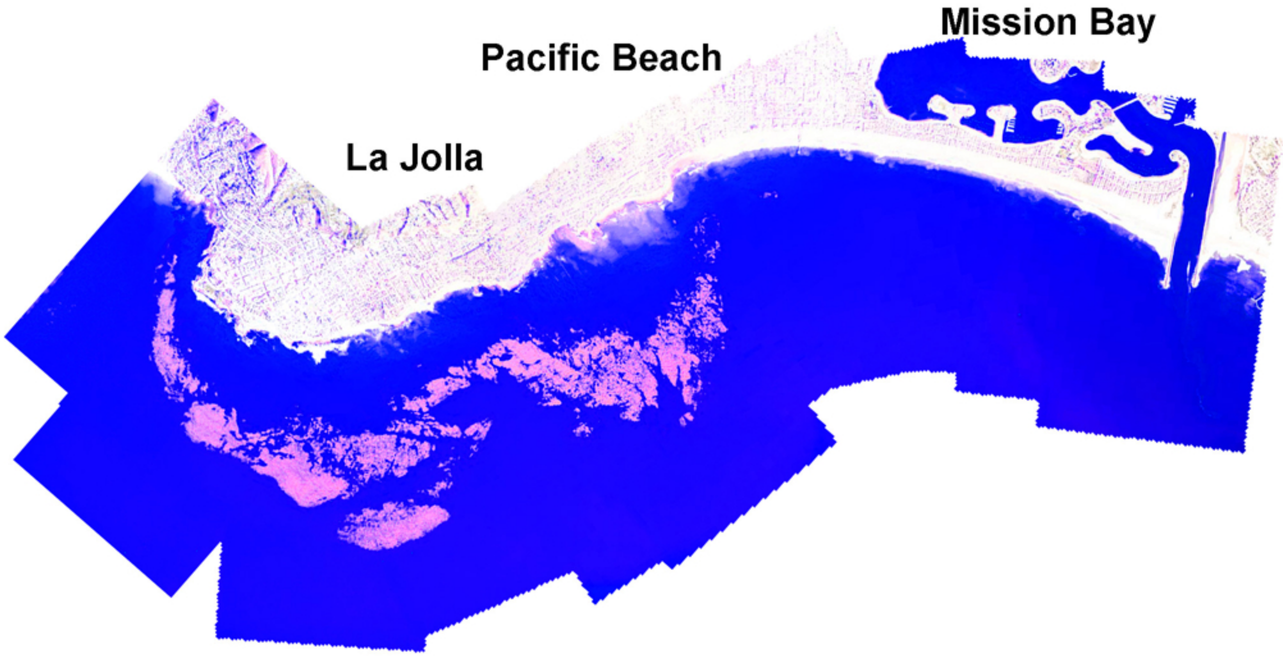


December 16, 2013



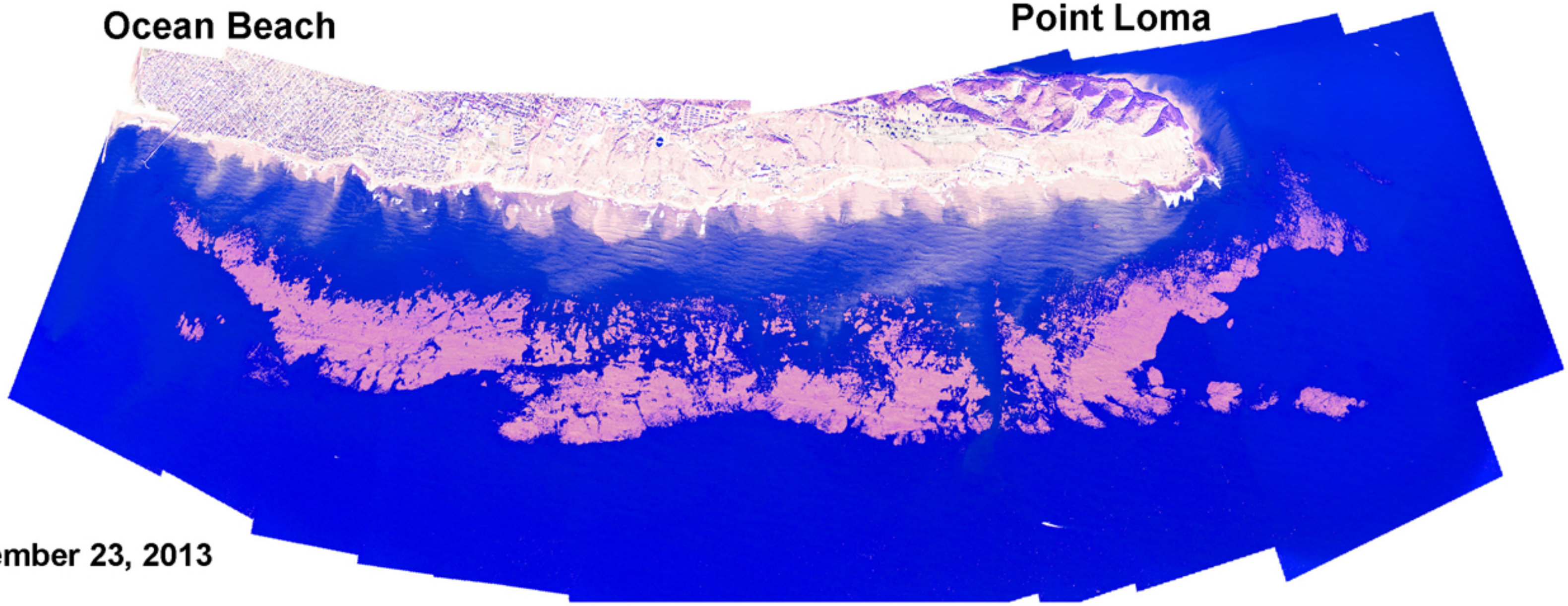
December 16, 2013





MBC

December 16, 2013



September 23, 2013

December 16, 2013