STATUS OF THE KELP BEDS 2012

July 16, 2013

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

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STATUS OF THE KELP BEDS 2012

VENTURA, LOS ANGELES, ORANGE, AND SAN DIEGO COUNTIES

CENTRAL REGION AND REGION NINE KELP SURVEY CONSORTIUMS

JULY 2013

EXECUTIVE SUMMARY

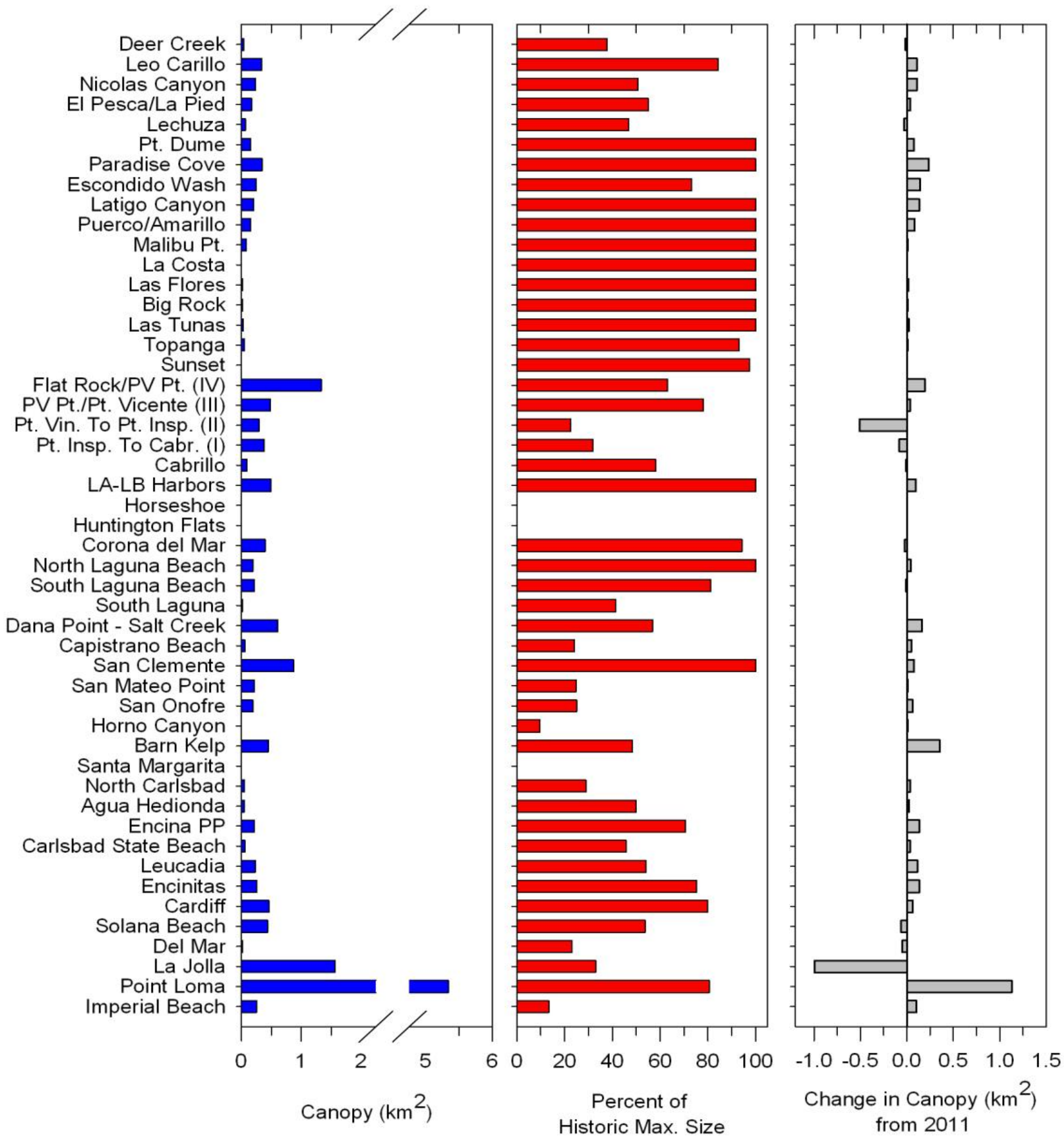
Foreword. Continuing favorable environmental factors in 2012 contributed to the maintenance and enhancement of the giant kelp beds offshore of the Central Region and Region Nine coastlines. Regional kelp canopy coverage totaled 17.5 km^2. A total of 6.1 km^2 of giant kelp coverage was found in the Central Region and 12.2 km^2 in Region Nine. These represented increases from the 4.8 km^2 and 10.8 km^2 recorded in 2011 in the Central Region and Region Nine, respectively. The 2012 giant kelp study demonstrated that oceanographic environmental factors during a prolonged La Niña, such as the availability of nutrients (or lack thereof) coupled with local topographic variations in current patterns, continued to control the fate of the kelp beds and contributed to the overall increases in most of the kelp beds along the southern California coastline. There was no evidence to suggest that any of the two region's various dischargers had any perceptible influence on the persistence of the giant kelp beds.

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. The Central Region Kelp Survey Consortium (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 of the 435 kilometers of the Southern California Bight coastline from Ventura Harbor to the Mexican Border.

Aerial surveys of the giant kelp beds from Ventura Harbor to the Mexican Border were conducted by MBC *Applied Environmental Sciences* (MBC) on 12 April, 26 June, 1 October, and 28 December during 2012. One aerial survey has also been completed for the 2013 survey year on 13 May and another is scheduled for July. 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 appropriate base maps to facilitate intra-annual comparisons and for ease of analysis.

Central Region Giant Kelp Survey Results 2012. In the Central Region, the maximum measured kelp canopy increased from 4.427 km^2 square kilometers (km^2) in 2011 to 5.665 km^2 in 2012. The number of kelp beds displaying canopy has remained markedly similar with the total number of beds monitored for the Central Region at 26 historic or existing kelp beds. The total amount of kelp present increased since the inception of the CRKSC program, peaking in 2009 with canopy coverage of 6.406 km^2, an amount greater than during any past CRKSC survey and of any past synoptic surveys (when all areas were surveyed) since 1989.

A close look at the graph indicates that many of the Central Region kelp beds (from Deer Creek to Corona del Mar) were a considerable percentage of their maximum size since CRKSC monitoring commenced. Overall, kelp bed canopy coverage in the region was much larger than the 10-year average (4.122 km^2) since initiation of monitoring by the Central Region Kelp Consortium in 2003.



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 2011.

As far as the greatest extent of canopy coverage during the quarterly surveys, 2012 was slightly atypical with most of the beds north Point Dume reaching their greatest extent in June, while most of those from Point Dume and south to Laguna Beach followed the historical pattern with their greatest extent reached in the December survey. The exceptions in this range were the Palos Verdes I and Cabrillo kelp beds that were largest in April 2012 (Appendix A). Throughout the entire study area, kelp canopy coverage increased but not uniformly, with distribution of kelp among the region's 26 kelp beds varying widely. The five

CRKSC beds comprising Fish and Wildlife (F&W) Bed No.17 increased in area by about 25% and the six beds comprising F&W Bed No.16 increased by more than 50%. The six CRKSC beds of F&W Bed 15 also increased by almost 50%, but as the beds that comprised it are very small, little change was noted. F&W Bed 14 increased with the Palos Verdes Beds IV and Bed III increasing by about 10%; in contrast, F&W Bed 13 (encompassing the shoreline from Point Vicente to the Los Angeles Harbor Breakwater) decreased by about 4%. In total, the Palos Verdes kelp beds increased in size by about 8% in 2012. F&W Bed 12 from Newport to past Laguna Beach grew greatly as the beds in that region continued to reclaim territory lost during El Niños of the 1980s and 1990s.

Region Nine Giant Kelp Survey Results 2012. In Region Nine, the maximum measured kelp canopy increased from a total of 10.379 km^2 in 2011 to 11.882 km^2 in 2012. As noted in the graph, only about one fourth of the beds in the north and south were greater than 70% of their historical maximum size observed during the Region Nine monitoring history. The much longer history in the Region Nine of consecutive monitoring (46 years) versus that of the Central Region (10 years) encompasses several very favorable kelp growth periods in Region Nine. 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. Overall, kelp bed coverage in the region was much larger than the 46-year average (6.726 km^2) since initiation of monitoring in Region Nine in 1967.

Coverage increases and decreases among the 24 historic or existing kelp beds were mixed across the Region Nine; however, most kelp beds increased in size during 2012. The kelp bed at North Laguna Beach decreased slightly while the South Laguna Beach bed recorded a slight increase; these two beds (although large during the December 2012 aerial survey) reached their greatest extent during the April 2012 survey. Kelp coverage in these two beds is the result of extensive and successful restoration programs conducted in the area since 2002, with canopies as large or larger than observed in the early 1980s and 1990s. The beds from South Laguna south to Cardiff Beach were all notably larger during the December aerial survey with the exceptions of the San Clemente and San Mateo kelp beds, that were equally large during the April 2012 survey. Most of these beds were larger than measured in 2011 (however, South Laguna, Solana Beach, Del Mar, and La Jolla were smaller). Solana Beach was only marginally smaller, while the small Del Mar kelp bed lost about two-thirds of its canopy during 2012. La Jolla kelp was very robust in the southern half, but displayed a much thinner canopy in the northern portion. Point Loma kelp increased along its entire length and taken together La Jolla and Point Loma were slightly larger in 2012 than in 2011. Imperial Beach kelp bed regained some of the canopy lost during the past several years, but was still far smaller than during 2007-2009.

The large-scale changes to the kelp beds noted are typical responses to El Niño and La Niña events (El Niño Southern Oscillation or ENSO), while the finer-scale variation observed in prior years indicates there still remains variation due to multi-decadal effects/regime changes within a region that we cannot yet accurately predict. In spite of this uncertainty, the kelp beds of the Central Region and Region Nine maintained kelp beds in 2012 with overall increases from the previous year, indicating the resiliency observed during the past surveys in both regions.

Conclusion 2012. The giant kelp surveys of 2012 continued to demonstrate that most kelp bed dynamics in the Central Region and Region Nine are controlled by the large-scale oceanographic environment while micro-variations in local topography and currents can cause anomalies in kelp bed performances. None of the kelp beds in the region reacted contrary to what was observed region wide. There was no evidence of any adverse effects on the giant kelp resources from any of the region's dischargers. The remarkable recovery of the kelp beds over the past seven years could be augmented in 2013. Although the National Oceanic and Atmospheric Administration (NOAA) indicates El Niño neutral conditions have been present since May 2012, nutrients still appear to be replete in the region based on observations of increases or maintenance of canopies in the two regions from the May 2013 overflight. A warming trend observed in NOAA's ENSO index for early 2013 could portend changes in the patterns of kelp growth along the Central Region and Region Nine coastlines in 2013.

INTRODUCTION

Giant kelp (*Macrocystis pyrifera*) beds have been mapped quarterly off Ventura, Los Angeles, and portions of Orange counties for the Central Region Kelp Survey Consortium (CRKSC) since 2003, and since 1983 by the Region Nine Kelp Survey Consortium (RNKSC), that monitors the kelp beds off Orange and San Diego counties. In 1983, the San Diego Regional Water Quality Control Board (SDRWQCB) initiated a kelp bed monitoring program for ocean dischargers within Orange and San Diego counties that was followed by implementation of a similar kelp monitoring program by the Los Angeles Regional Water Quality Control Board in 2003. It was agreed among the funding participants (SDRWQCB in 1983 and LARWQCB in 2003) 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 CRKSC combined with the RNKSC monitoring programs, continuous and synoptic coverage is provided of the kelp beds along approximately 220 of the 270 miles of the southern California mainland coast from Ventura Harbor to the Mexican Border. A map showing the geographical range and the ocean dischargers located within the CRKSC and RNKSC is shown in Figures 1 and 2.

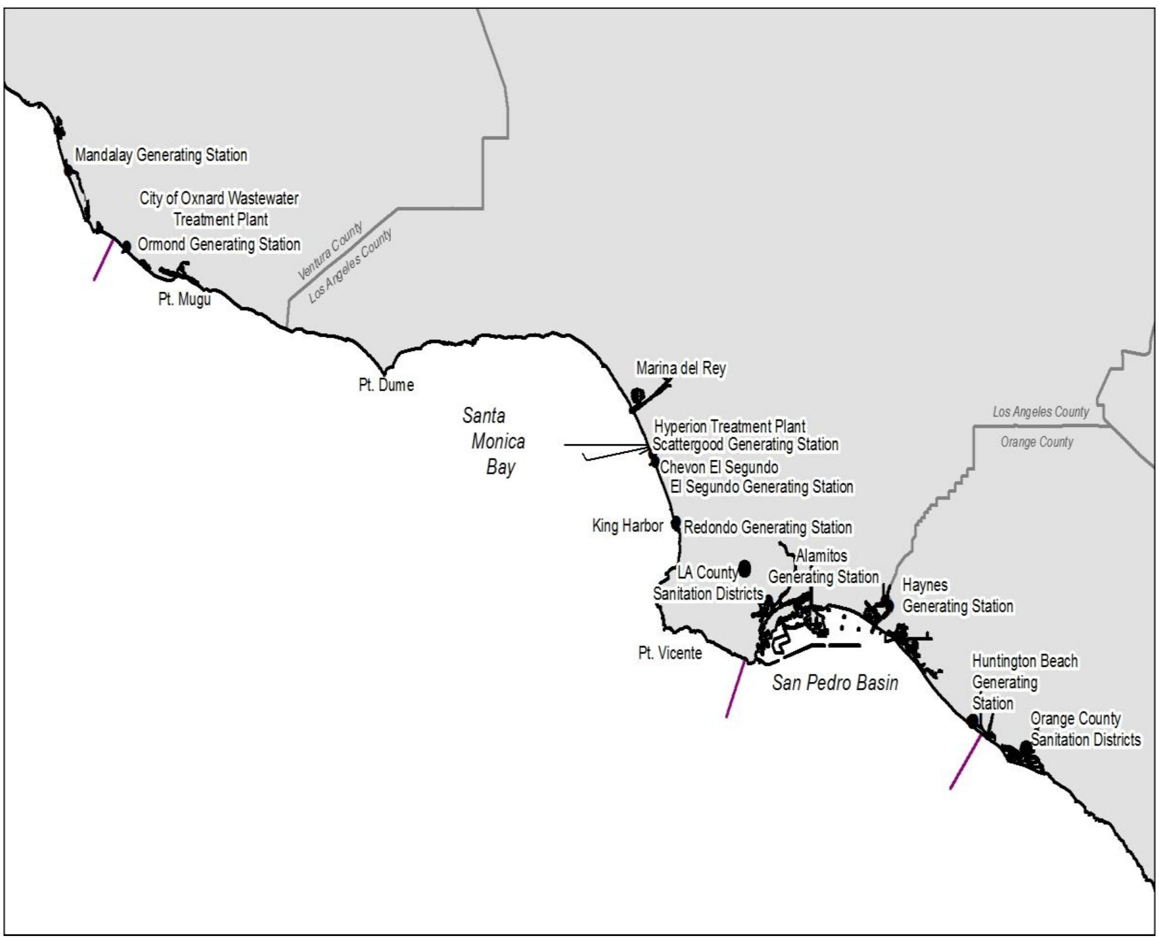


Figure 1. Ocean dischargers located within the Central Region kelp survey area.

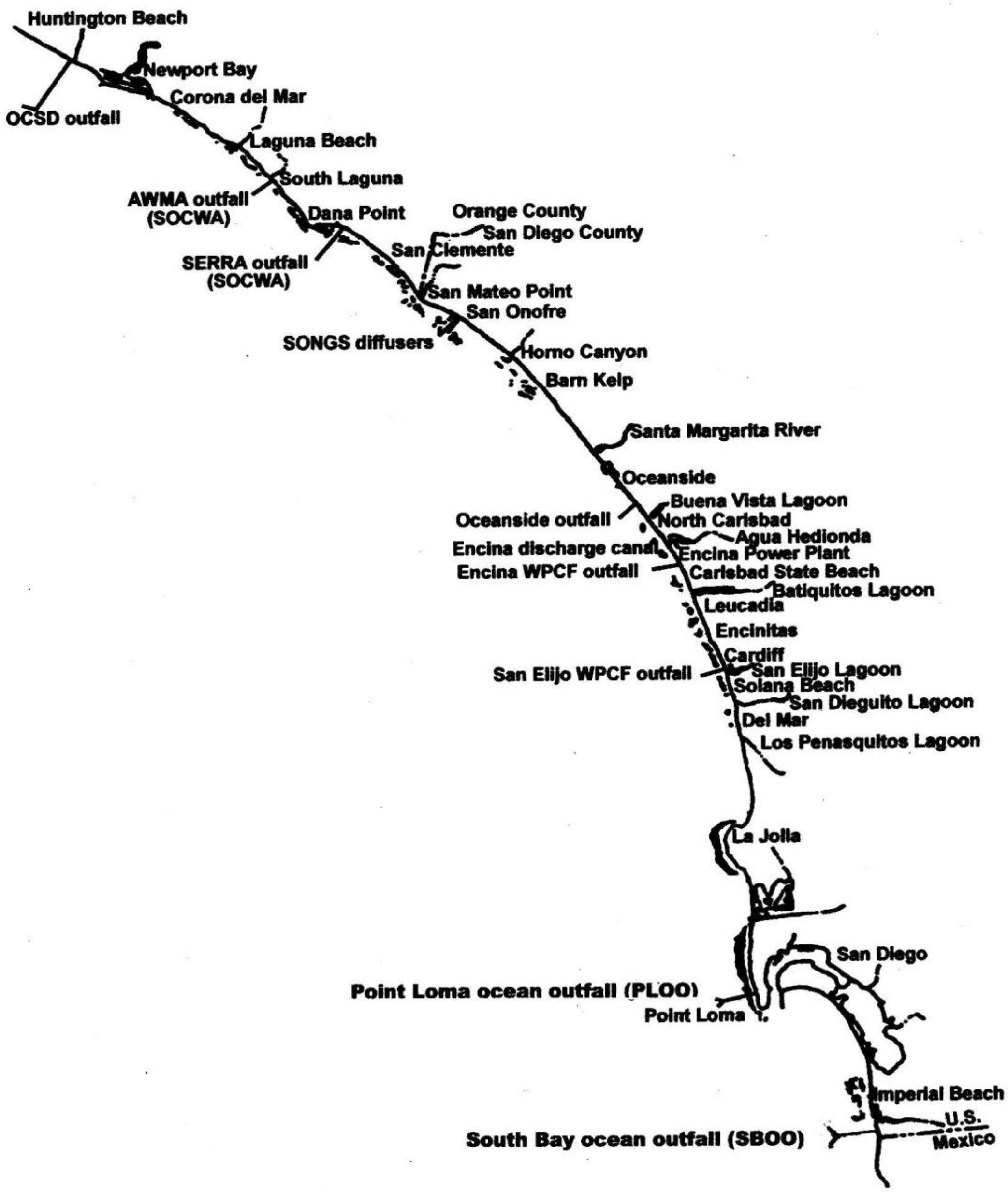


Figure 2. Ocean dischargers located within the Region Nine kelp survey area.

LIFE HISTORY OF GIANT KELP

Kelp consists of a number of species of brown algae of which 10 are typically found from the Mexican Border to Point Conception (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 southern and central 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, Foster and Schiel 1985, Dayton 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, as is observed along portions of the Santa Barbara coastline. Like 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 in depths exceeding 30 m. Along the mainland coast, high productivity, terrestrial inputs and continental shelf mixing result in greater turbidity and hence lower light levels. Consequently, kelp generally does not 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.

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.

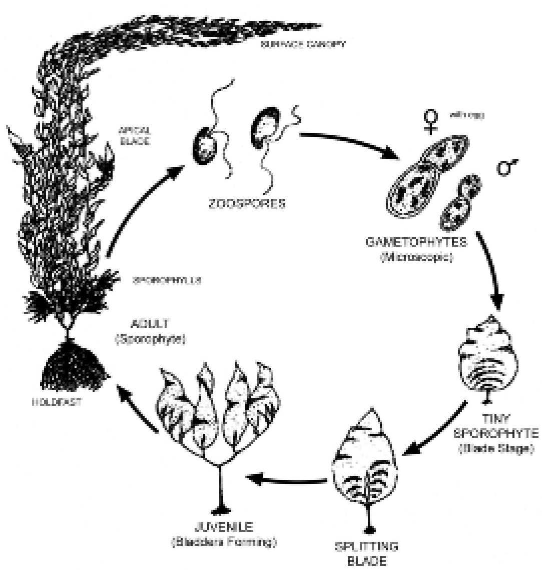


Figure 3. Kelp life cycle.

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, thus enhancing recruitment (Duggins et al. 1990), that further acts to increase animal biomass in the vicinity. For these reasons, giant kelp is also of great importance to sport and commercial fisheries.

HISTORICAL KELP SURVEYS 1911–2011

Giant kelp bed size and health is known to be highly variable but there has been a downward trend in canopy coverage in the ensuing century from 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 to this day. Using this methodology, all of the existing kelp beds in the Central Region and Region Nine area 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 have been questioned (Hodder and Mel 1978 [SAI 1978], Neushul 1981). These authors contended that measurement errors may 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 the area was estimated between points. Modern aerial surveys reveal numerous holes and a fair degree of patchiness in such beds, Crandall's estimates do 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 our baseline as anecdotal reports from area stakeholders reported by Cameron (1915) indicate kelp beds in 1911 were in fairly poor condition at the time of Crandall's survey from that seen in previous years.

Although the historical El Niño Southern Oscillation (ENSO) index suggests that the previous five years before 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 in 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 $kilometers^2$]) 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).

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

Due to the large sizes reported by Crandall, Neushul (1981) assumed there was a scaling error, re-measured the maps, and produced 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, the original maps of Palos Verdes by Crandall (1912) were re-measured by MBC using computer-aided spatial estimation software (including Malaga Cove), and the resulting area (2.57 Nm^2) was slightly greater but very similar to that reported by Crandall (2.53 Nm^2). Therefore, the actual sizes of the beds that Crandall reported were probably relatively accurate since the areal survey extent and configuration he reported has been confirmed from contemporary charts (Hodder and Mel 1978, Neushul 1981). MBC measurements using state-of-the-art digital renderings of the original kelp bed images actually increased the size of Crandall's beds by about 3%.

Any attempt to place a percentage decrease on Crandall's measurements would be subject to potentially huge errors, thus we retain Crandall's kelp bed areas as the baseline estimate. In defense of Crandall's estimates, the total regional area was probably larger from 1928–1934 than Crandall measured in 1911 (Tables 2 and 3). Based on the size 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 kelp beds. 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 suggesting even larger losses have occurred over time (Cameron 1915).

The next complete kelp survey of the southern California region was not undertaken until 1955. This survey indicated the beds in the Central Region had decreased greatly (to 6.750 km^2) only 36% of that recorded in 1911 (18.815 km^2), and beds in Region Nine were similarly reduced to 40% (16.990 km^2) of the 1911 total of 41.563 km^2. The most significant losses during this period were that of Sunset Kelp (offshore of Santa Monica) that 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 began decreasing sometime after 1945. By 1947, the Palos Verdes beds had decreased to 3.6 km^2 and 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 for that recorded in 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 during the 1967 survey and the total for the region at only 4.400 km^2. La Jolla Kelp bed was only about 0.330 km^2 in 1967 and stayed small until after 1975, and then became a consistently large kelp bed (over 1 km^2) through most of the next three decades.

Restoration activities began in 1974 by the Kelp Habitat Improvement Project; at that time the Palos Verdes beds had decreased to 0.015 km^2. In 1975, after restoration, those beds began increasing and covered 4.5 km^2 during the exceptionally good 1989 year (North and Jones 1991). The impetus provided by the 1989 La Niña also resulted in almost 6 km^2 of kelp canopy in the Central Region and more than 16 km^2 in Region Nine, but kelp totals 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 4 and 5).

Table 2. Historical canopy coverage in km² of 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 mi^2 converted to km^2
b = Estimate in mid-1920s
c = Ecoscan (1990) indicates 2.003 km^2 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 km^2 of San Diego and Orange County kelp beds from 1911 to 1994 surveys. Values represent approximately the maximum coverages for each year. Areal estimates from 1967 on were derived from charts based on infrared aerial photographs.

	Canopy Area (km^2)																					
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).

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

Table 4. Historical canopy coverage in km^2 of Ventura, Los Angeles, and Orange County kelp beds to Laguna Beach, from 2003 to 2012. Areal estimates for 2003-2012 were derived from infrared aerial photographs.

	Canopy Area (km^2)									
Kelp Bed	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1 Deer Creek	0.089	0.107	0.053	0.026	0.046	0.074	0.105	0.062	0.055	0.041
2 Leo Carillo	0.318	0.399	0.171	0.150	0.145	0.207	0.255	0.232	0.226	0.337
3 Nicolas Canyon	0.308	0.362	0.195	0.038	0.473	0.268	0.433	0.291	0.130	0.240
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
5 Lechuza	0.105	0.104	0.041	0.022	0.106	0.075	0.105	0.096	0.096	0.066
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
6 Pt. Dume	0.012	0.029	0.028	0.053	0.065	0.070	0.104	0.094	0.078	0.154
7 Paradise Cove	0.162	0.258	0.035	0.036	0.100	0.223	0.244	0.259	0.109	0.346
8 Escondido Wash	0.214	0.250	0.078	-	0.339	0.278	0.321	0.267	0.104	0.248
9 Latigo Canyon	0.125	0.161	0.032	0.007	0.186	0.124	0.195	0.142	0.070	0.202
10 Puerco/Amarillo	0.074	0.051	0.039	0.055	0.095	0.064	0.115	0.126	0.069	0.153
11 Malibu Pt.	0.011	0.013	0.008	0.008	0.016	0.011	0.012	0.066	0.074	0.084
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
12 La Costa	0.001	0.002	-	-	-	-	0.001	0.001	-	0.003
13 Las Flores	0.009	0.023	0.004	-	0.005	0.001	0.005	0.005	0.008	0.025
14 Big Rock	0.005	0.014	0.002	0.001	0.004	0.002	0.005	0.006	0.007	0.018
15 Las Tunas	0.003	0.018	0.004	-	0.008	0.005	0.019	0.015	0.007	0.030
16 Topanga	0.0002	0.002	0.0001	-	-	0.001	0.002	0.052	0.041	0.048
17 Sunset	-	-	-	-	-	-	0.004	0.008	0.007	0.008
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
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
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
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
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
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
22 Cabrillo	0.062	0.070	0.102	0.161	0.100	0.060	0.163	0.124	0.103	0.095
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
Total 18-22 PV	1.425	0.589	1.098	2.187	2.062	2.916	3.998	2.494	2.396	2.599
23 POLA-POLB Harbor	ND	ND	0.147	0.494	0.118	0.213	0.151	0.277	0.397	0.495
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
Total 22-26 (F&W 10)	0.002	0.002	0.147	0.517	0.172	0.302	0.246	0.438	0.816	0.890
TOTAL	3.105	2.698	2.075	3.161	4.076	4.793	6.406	4.817	4.427	5.665

ND = No Data; "-" = 0
Sources: MBC (2004-2012).

Seemingly confirming suspicions that Crandall's measurements were not accurate, the Imperial Beach kelp bed south of San Diego measured 0.984 km^2 in 1911, and never again in that century was measured to be larger than about 0.727 km^2 (occurring in 1987). However, at 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 San Diego and Orange County kelp beds from 1989 to 2012 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
N Laguna Beach	-	0.001	-	-	-	-	-	-	0.0004	-	-	-	-	0.002	0.005	0.093	0.147	0.192
S Laguna Beach	-	-	-	-	-	-	-	0.005	0.0002	0.008	-	-	0.001	0.025	0.058	0.098	0.221	0.214
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
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
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
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
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
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
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
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
Horno Canyon	-	-	-	-	-	0.002	0.034	-	0.001	-	-	-	0.015	0.083	0.018	0.081	-	0.008
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
Santa Margarita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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
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
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
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
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
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
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
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
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
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
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
Torrey Pines	-	-	-	-	-	-	-	-	-	-	-	0.010	-	0.001	0.0004	0.003	0.031	0.034
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
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
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
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
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

NOTE: "-" = 0; Tr = Trace <100 m^2

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. It is also known that there are 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) (that refers 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 resulting in warming or cooling of the waters along the South and North American western coast).

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 the supply of nutrients into the inshore waters from upwelling, but blooms of phytoplankton can also sufficiently occlude light that they negatively impact kelp health. Phytoplankton blooms were probably responsible for a large, region-wide decrease in canopy coverage in 2005 that continued into 2006. Shading effects on kelp recruitment are well documented by Dean et al. (1989). Several, 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 amounts of rainfall/runoff were below average in 2012, and phytoplankton blooms were not persistent, shading issues did not present serious, deleterious effects on the kelp beds of the region.

Sedimentation. Several kelp forests have been impacted by sedimentation. 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 made in the 1970s and later, as well as shifting landscapes. Historically, sewage discharge included fine particulate matter that reduced light penetration while 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 late-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 impacts at Barn kelp.

Nutrients. In addition to light, kelp also requires nitrates and other materials 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 nutrients. 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, that 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 will 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 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 areas with persistent winds close to shore, smaller upwelling events occur in shallower waters. 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 have a strong correlation 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 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 temperature drop (1.9°F), 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).

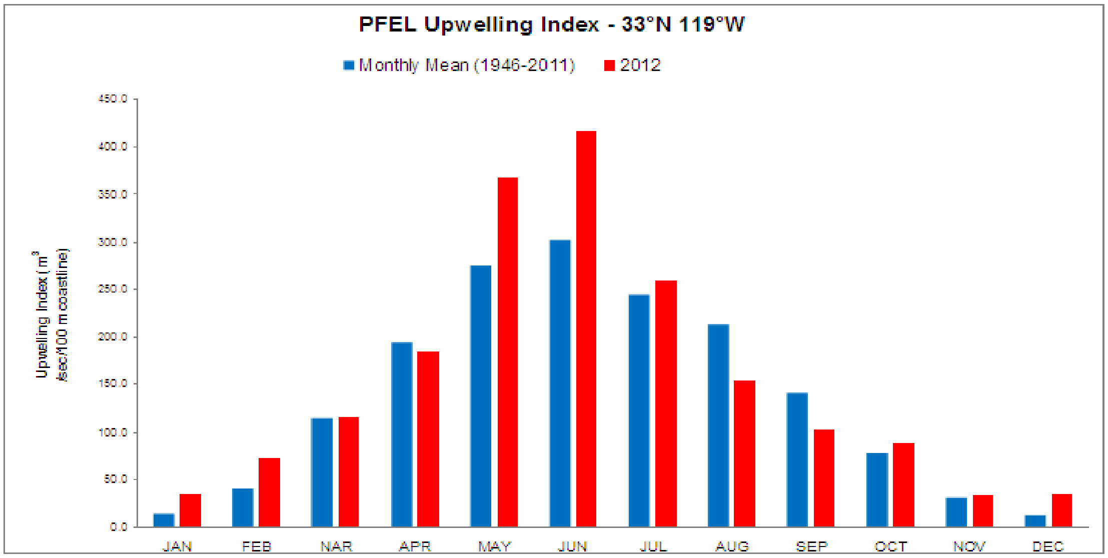


Figure 4. Upwelling Index comparing monthly mean (1946–2011) to January–December 2012.

Grazing. Kelp herbivores (such as 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 have been implicated in the wholesale loss of kelp beds at San Mateo Point, Palos Verdes, Imperial Beach, and have had large detrimental effects on many other kelp beds (North and Jones 1991). In southern California, sea urchin (*Strongylocentrotus* spp and *Lytechinus pictus*) overgrazing results in urchin barrens. The sustainability of urchin barrens requires immigration from other, non-barren sites as urchins sampled 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 had become denuded. Urchin barrens persist 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 typically as a result of adverse nutrient-deficient periods and elevated 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*) are heavily overgrazed while those with healthy otter populations are 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 resulting from large swells can break fronds or 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 overpower a more firmly attached neighbor and rip its holdfast free. The resultant mass of entangled, loose giant kelp can drift through a kelp bed ripping out hundreds or thousands of giant kelp in the snowball effect, and these kelp 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 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 that occurring during El Niño events, occurred more frequently than before 1976 (Adams et al. 2008, Seymour 2011). Prior to 1976, the wave climate was dominated by energy generated in the GOA. The Southern California Bight coastline was largely protected from GOA-sourced waves via the island shadow effect (Pawka et al. 1984; Seymour et al. 1989).

A shift south in the dominant trajectory minimized the island protection for the coastal area as more waves delivered their full energy to Orange and San Diego County coastlines (Figure 5). This energy likely at times swamped all other physical and biological regulators of existing, persistent kelp forests (Reed et al. 2011) such as occurred during the 1982–1983 El Niño and the January 1988 storm (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 two-fold factors of the 200-Year Great Storm of 1988 combined with the La Niña of 1989 produced kelp beds in areas that had been 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 exposure of bed rock for spore colonization (MBC 1990, Seymour et al. 1989, Appendix B).

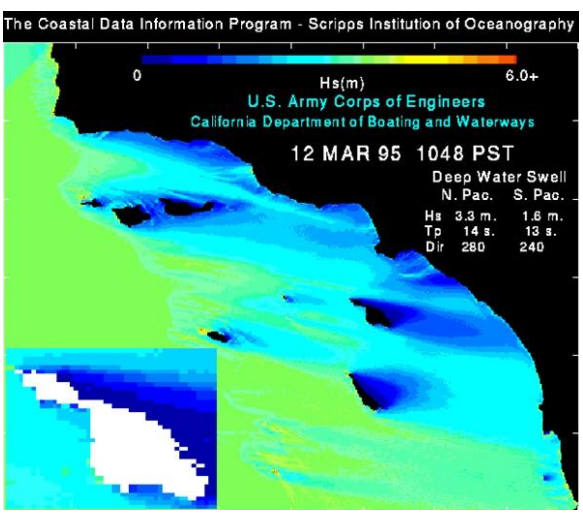


Figure 5. Depiction of the blue shadow effect from offshore islands providing protection to mainland kelp beds.

ENSOs. 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 Southern California Bight coastline resulting in substantial damage to local giant kelp forests (Seymour et al. 1989; Edwards and Estes 2006). While ENSO events can elicit global effects, a given event may not necessarily produce local effects (Tsonis et al. 2005). Recently reported El Niño conditions in 2009–2010 resulted in no measurable response along the Southern California Bight (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 certain years that are designated El Niño or La Niña years, there may not necessarily be locally poor or good kelp growth for the year.

Using several oceanographic models and looking at a variety of variables, a multivariate ENSO Index (NOAA-MEI 2013) has been compiled that uses these variables to identify cold water and warm water periods since the early 1870s (Figures 6 and 7). As depicted, it is clear that most of 2009 was a warm water period; however, as Tsonis et al. (2005) and Bjorkstedt et al. (2010) suggested, this may not necessarily cause local effects. The last two years are a prime example of this: while the ENSO index indicated that 2009 was a warm year, southern California kelp beds were larger than they had been in years, whereas most of the period from early 2010 to present has been a cold-water period, but many kelp beds were smaller in 2011 than in either 2010 or 2009, suggesting that due to the complicated giant kelp life cycle there may be a lag time before effects are fully matured.

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 that tracks periods of SSTs at the equator above the mean (warm water events) and below the mean (cold water events) indicates that the 30 years between 1977 and 2007 were characterized by unrelenting warm spells. 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 to about 1872 to approximately 1918 (covering the period of Crandall's survey), 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 La Niñas interspersed by one shorter El Niño.

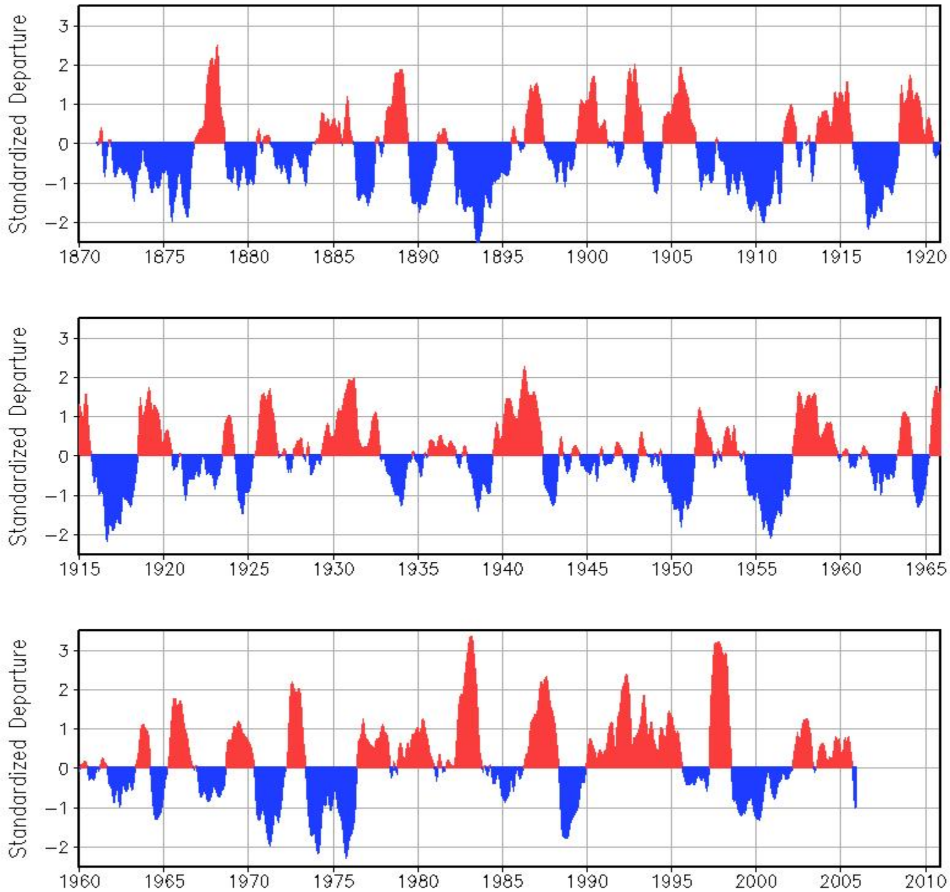


Figure 6. Multivariate ENSO Index from 1870 through 2006, NOAA-MEI.

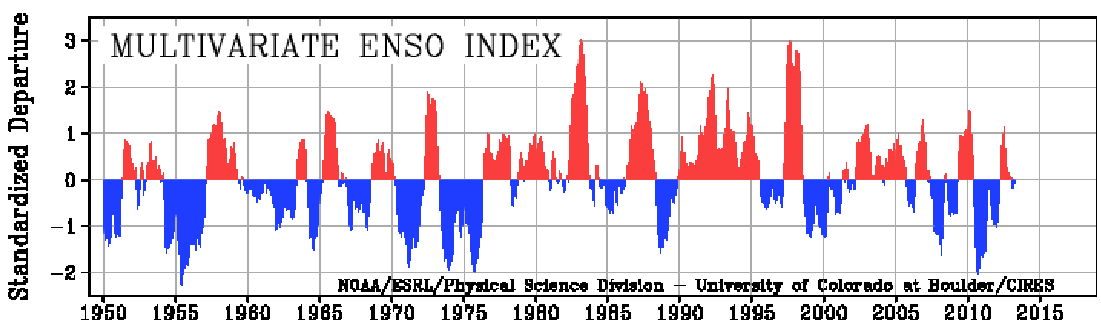


Figure 7. Multivariate ENSO Index from 1950 through 2013, NOAA, MEI.

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). It appears the cause of the loss of kelp at the Point Loma outfall was not related to the sewage, but probably the accompanying turbidity from particulates in the wastewater discharge (North 2001, City of San Diego 1992a,b). Other factors have included unchecked runoff from coastal construction projects, 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 kelp bed (Salt Creek/Dana Point Kelp)(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. The loss of the Horseshoe Kelp bed was probably from turbidity due to an increasing population and dumping of sediment from dredging of the Los Angeles and Long Beach Harbors, while 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 appreciate. 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 physical oceanographic environmental changes have had a greater effect than previously believed. Low-frequency oceanographic regime shifts occurring on 20– to 40–year cycles 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 looking at sea water density, that in itself may be a better indicator of the presence of nitrates/nutrients than temperature over time, appears to indicate that a major shift occurred about 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, 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 replete conditions 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 climate-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 the local marine communities including large changes in abundance and biodiversity (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; McGowan et al. 2003; Bograd and Lynn 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 that 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 dissipate, it was assumed that conditions 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 from the long-term MEI data compiled against the kelp canopy coverage.

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 existed offshore of Point Dume, Sunset Beach, Crystal Cove, just south of San Onofre, Horno Canyon, Santa Margarita, and near the Mexican Border. As there are no known human-induced perturbations of these areas, it appears these beds have disappeared due to shifting sediments causing inundation of low-lying reefs (or kelp was growing on the sand in some of these locations). Subtidal observations on the seafloor at these historically established kelp beds at Sunset Beach (offshore of Santa Monica), Crystal Cove, San Onofre, Santa Margarita, and the Mexican Border, indicate that no suitable hard substrate is found on the bottom for 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

In the CRKSC program area, extending from the Santa Barbara-Ventura County line to Laguna Beach in Orange County, 26 existing or historic kelp beds were identified, 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–2011a). One kelp bed, Sunset kelp (near Santa Monica), has not been observed since the initiation of monitoring by the CRKSC in 2003, but was observed as a very small bed during the Ecoscan’s 1989 survey and has only been observed since at the submerged breakwater off Santa Monica. The kelp surrounding the breakwaters of the Ports of Los Angeles and Long Beach only recently have been included as a bed in the CRKSC region upon realization in 2005 that there existed considerable giant kelp in the Ports. The disappearance of these three kelp beds was likely the result of greater turbidity and sedimentation in these areas related to increased industrialization and population throughout southern California during World War II and into the late-1960s. One other historic kelp bed (Corona del Mar/Irvine Coast) has reappeared after absences of one to several decades resulting from a series of El Niño events in the 1980s and 1990s that extirpated the kelp from the area.

The continued loss 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 (as has been observed 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 as is observed in the Santa Barbara area. 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. CRKSC monitoring began following a strong cold-water La Niña event in 1999. This followed the largest El Niño warm-water event on record in 1997–1998. Due to the stimulus provided by La Niña conditions, 23 of the 26 kelp beds that were known to support kelp in the last half of the 20th century all supported a surface canopy during 2003. (Review of the slides indicated the POLA area had unquantified kelp that year). All three missing beds had substantial canopies prior to 1950.

Administrative Kelp Bed Lease Areas. Each kelp bed description following is a portion of California Department of Fish and Wildlife's (CDF&W) administrative kelp bed lease areas that can contain 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 exist outside of the Fish and Wildlife Kelp Beds, in that case 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 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 and effect relations.

Administrative kelp bed areas in California waters are numbered and 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.

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 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 determine if specific sub-areas of the much larger Fish and Wildlife Kelp Bed lease areas were responding atypically compared to the other beds in the area. For example, Fish and Wildlife Kelp Bed (lease area) No. 17 encompasses over 10 kilometers of coastline. Therefore, we have determined natural breaks in the beds (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 names in use locally.

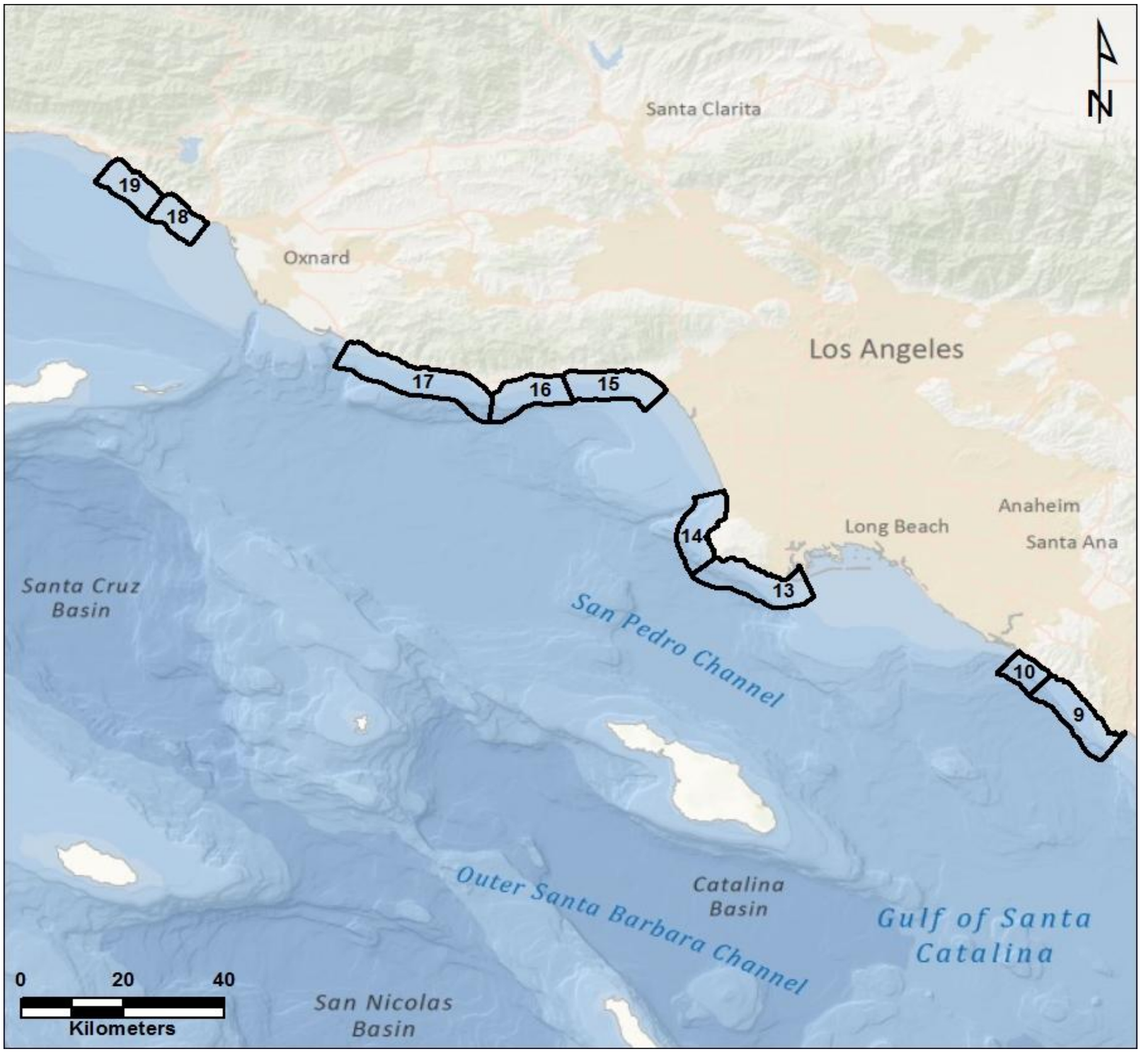


Figure 8. Administrative kelp bed leases in the Central Region study area.

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 nearshore bottom sediment north 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 north of Deer Creek in the areas downcoast and offshore of Ventura Harbor, the City of Oxnard, the Mandalay Generating Station, Channel Islands Harbor, Ormond Beach Generating Station, and from Port Hueneme south to Point Mugu. There are, however, small kelp stands that form along the breakwaters of Ventura Harbor, Channel Islands Harbor breakwater, and the Port Hueneme breakwater. Just south from Point Mugu, five kelp beds are found: these include 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 10 times during the past century, and therefore large gaps exist in the historical record. Historically, these beds covered as much as 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 was markedly similar to the survey in 1967 (4.144 km^2). These five beds have persisted though time and have survived environmental perturbations during the past decade that included El Niños, La Niñas, and unusually persistent plankton blooms; however, they have not combined to obtain an aerial coverage of much greater than 1 km^2 during the past decade of monitoring (Table 4). Kelp coverage in this area began to decline after 1967, continuing through 1999. At some point after the July survey of 1999, coinciding with the La Niña of 1999–2000, kelp began to increase again. 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 was generally larger-than-average, but despite a continuing La Niña, the beds were lower in coverage than they had been during 2009 with canopies in the region totaling 0.857 km^2 at their peak during 2012.

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. These beds include Point Dume, Paradise Cove, Escondido Wash, Latigo Canyon, Puerco/Amarillo, and Malibu Point. Kelp canopy coverage in Fish and Wildlife Kelp Bed No.16 has varied considerably over time. (Appendix A). From the historic data, the 1911 measurements of 3.4 km^2 decreased by about one third by 1955 (2.14 km^2), and then increased by 1967 to about 2.54 km^2, about 74% of the 1911 measurements (Crandall 1912). These beds were in a severe decline by the Ecoscan Survey of 1989 (0.220 km^2) and by 1999, a decade later, the effects of the severe 1997–1998 El Niño culminated in a coverage of only 0.03 km^2 for the six beds, by 1999. The beds had recovered by the first CRKSC survey of 2003, although kelp canopy coverage was still much lower than recorded in the 1960s and 1970s, but the canopy area totaled 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 again recovered strongly in 2007 to 0.801 km^2, and remained large in 2008, though with a slightly smaller coverage 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 beds; however, they began to recover throughout 2010 reaching a sizeable fraction (96%) of their 2009 status and covered 0.954 km^2 by December. Although conditions appeared favorable, never-the-less, most of the beds decreased by about one half in 2011 to 0.504 km^2. In 2012, the kelp beds began to respond to the favorable conditions and in total canopy covered 1.189 km^2, that was their highest coverage since CRKSC monitoring began in 2003.

Fish and Wildlife Kelp Bed Number 15. This bed begins just past 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 the purview of Kelp Bed 15: they include 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, that covered 0.960 km^2 and appeared to cover a similar area 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 Fish and Game Kelp Bed 15 was only a remnant of that noted in the 1911 survey, with only 0.02 km^2 of kelp coverage 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 run-off, adversely impacting the local kelp beds. 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 readily recolonize the area. 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. However, in 2006 the total areal coverage in this region was further reduced to 0.001 km^2, that is much less than 1% of the 1911 value. The kelp beds in this region were very small in 2007, and three (La Costa, Topanga, and Sunset) were missing; however, Bed 15's total size was larger (0.017 km^2) than recorded in 2006. Although the Topanga kelp bed reappeared as a very small bed in 2008, the total kelp coverage of the region decreased to 0.0009 km^2. Reversing this trend, all of the beds appeared in 2009 (the first time all beds were present since CRKSC monitoring began) and increased to a regional coverage peak of 0.131 km^2, by the end of December 2012.

South of Sunset Beach, another large gap in kelp cover exists 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 Redondo breakwater and extends along the Palos Verdes Peninsula to Point Vicente. From Redondo Beach sandy bottom predominates for about four kilometers in a southerly direction, and then rocky substrate becomes prevalent at Malaga Cove of the Palos Verdes Peninsula and southward. This area has intermittently supported large kelp beds from Malaga Cove to Point Vicente. 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 began a good recovery 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.

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 had very large kelp beds, totaling just under 3 km^2; they too were very large from aerial photos taken in 1928 and 1945, 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 the kelp beds in this region and by the 1980s, great improvements in kelp canopy coverage were recorded. 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.

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 rip rap. As more and more rip rap 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; about 0.15 km^2 of kelp was observed. Subsequently, the CRKSC added the harbor to their regular quarterly survey and recorded kelp peaking in the harbor at almost 0.5 km^2 in 2006 and it was slightly larger than that in 2012.

Well offshore of San Pedro on the relatively shallow alluvial deposition from the Los Angeles River that extends 10 to 15 km offshore, kelp beds were historically present in the first half of the 20^{th} century. The largest bed (1.94 Km^2) was found at Horseshoe kelp growing near the 20-m (11-fathom) isobath. Further south, past Alamitos Bay and Huntington Harbour, sand predominates in the nearshore area, with the exception of groins at the entrance to Bolsa Chica Wetlands and the cliffs at Huntington Beach.

Just offshore of the north end of the cliffs off Huntington Beach, a low-lying reef (Huntington Flats) is found in the shallow inshore area. This area supported a kelp bed in the early part of the 20^{th} century; however, no record has been found that indicates the areal coverage of that kelp bed. Further south, sandy bottom with no hard substrate continues downcoast to Newport Harbor, and there is no suitable habitat for kelp along the coast from Huntington Flats past the Huntington Beach Generating Station and the Orange County Sanitation District outfalls until reaching Newport Harbor.

Fish and Wildlife Kelp Bed 10. From Newport Harbor south to Abalone Point in north Laguna Beach, the CRKSC program monitors the Corona Del Mar/Irvine Coast kelp beds that lie within the confines of Bed 10 (Figure 9). Small stands of kelp occur along the Newport Harbor breakwater, particularly along the inside edge of the upcoast jetty. Continuing southward downcoast, rocky substrate is present out to the 12- to 18-m contour lines. Although these are a collection of small kelp beds, collectively they are referred to as the Corona Del Mar/Irvine Coast kelp beds, and aggregately covered about 0.75 km^2 in 1911; since then they have declined and were only about 30% of that size by the 1970s. They were virtually extirpated from this region by the El Niño of 1982–1984, very small beds briefly reemerged in the late 1980s due to kelp restoration efforts and 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 conducted by MBC Applied Environmental Sciences (MBC) beginning in 2000, and the Coast Keepers in 2003, continuing until there were ultimately measurable kelp bed canopies by 2007 and successful completion of the restoration by 2009 (MBC 2010c). These beds have continued to increase through 2012 to more than 50% of historic levels. These kelp beds are nearly contiguous from Newport Harbor to just north of Abalone Point in Laguna Beach where CRKSC coverage ends and RNKSC coverage continues down to the Mexican Border.

DESCRIPTION OF THE REGION NINE KELP BEDS

In the Region Nine kelp survey area extending from Abalone Point in Laguna Beach (Orange County) and south to the Mexican Border, California Department of Fish and Wildlife 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 have shown up ephemerally (Santa Margarita and Torrey Pines), and four other areas of interest (marinas and small boat harbors) (MBC 1994–2003, 2004b–2011b). The Consortium's monitoring began following a strong warm-water event: an El Niño in 1982–1984. 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 the year immediately following this event.

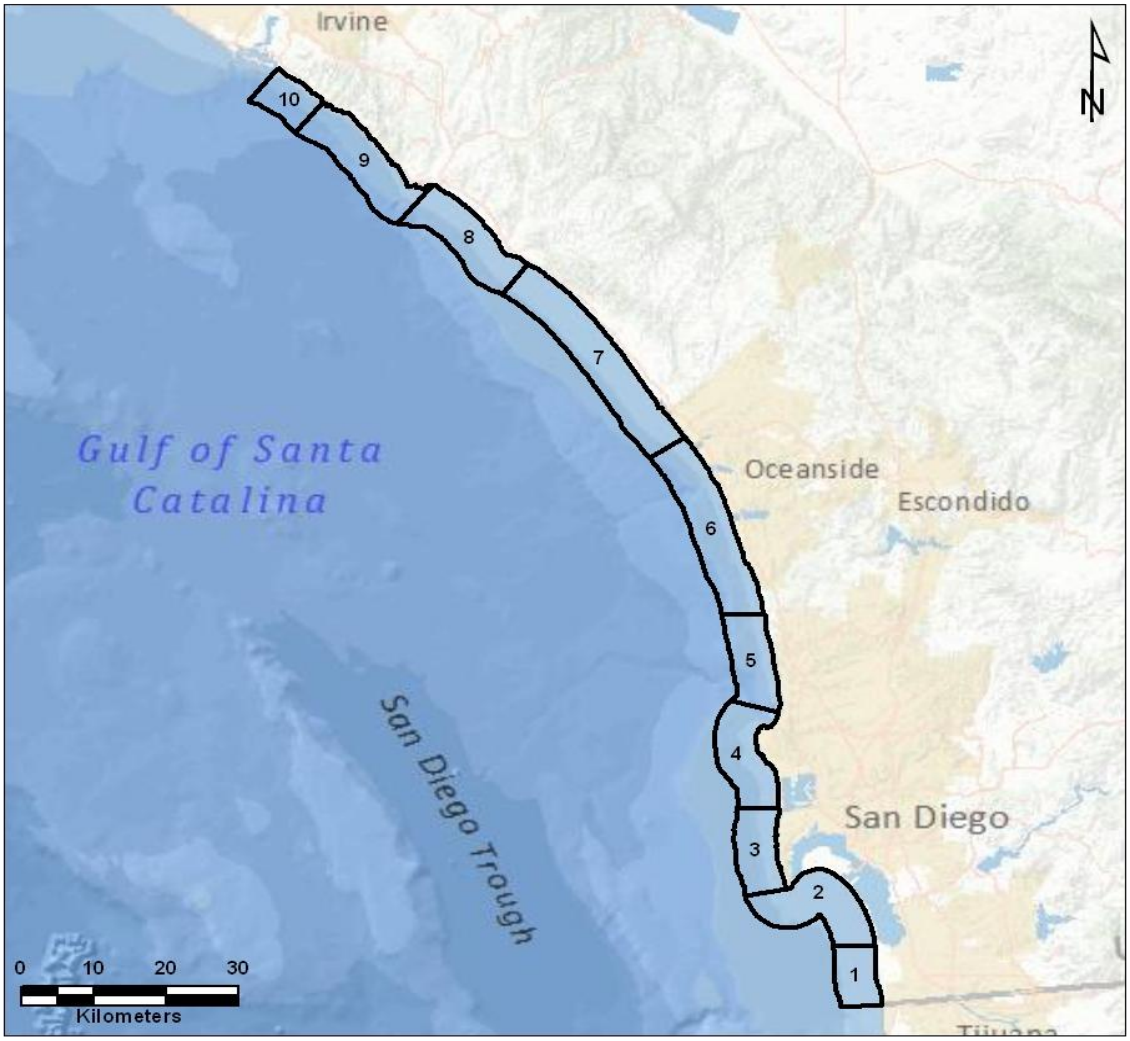


Figure 9. Administrative kelp bed lease areas in the Region Nine study area.

Fish and Wildlife Kelp Bed Number 9. Kelp Bed 9 encompasses five beds in the Region Nine program including those of North Laguna Beach, South Laguna Beach, South Laguna, Salt Creek/Dana Point, and Capistrano Beach, and stretches from Abalone Point at the north end of Laguna Beach, through Laguna Beach, around Dana Point headlands, and ends just north of San Clemente. Available hard-bottom substrate is intermittent with sandy substrate predominating in much of the area. Hard-bottom subtidal habitat is more pronounced just north of Main Beach extending for about two kilometers south and then becoming mostly sandy once again. The hard substrate, where found, does not extend much beyond depths of 12 m until reaching Dana Point/Salt Creek. Crandall did not record giant kelp in the North and South Laguna Beach region, but he noted that kelp strands were unusually small so their lack could just indicate a bad year for kelp in the area. By 1955, North and South Laguna Beach were fairly large covering 0.68 km^2. South Laguna, Dana Point/Salt Creek, and Capistrano kelp beds covered almost 2.7 km^2 in 1911; they were still large in 1955 covering at least 2 km^2, but declined rapidly thereafter staying small through the late 1980s. They began to recover and were over 1 km^2 in 1989, declined in the 1990s and through most of the 2000s, then again obtained a coverage of near 1 km^2 in 2008 through 2010. This area too was devoid of kelp from about 1993 until restoration efforts began in 2002.

MBC began kelp restoration in several locations in both North and South Laguna Beach for a mitigation project, and Orange County Coast Keepers began kelp restoration in the North Laguna Beach area. Both programs met with varying degrees of success through 2007, before environmental conditions ultimately favored the efforts resulting in fair-sized canopies that appeared in 2008, reached mitigation goals by 2009, and have become progressively larger through 2012. Beginning at South Laguna and at the Salt Creek-Dana Point kelp beds, rocky bottom extends to depths of 18 m offshore of Salt Creek-Dana Point and supports large stands of kelp during favorable years. Another relatively large bed (Doheny kelp at 0.75 km^2 in 1911) was found just south of Dana Point; this bed disappeared sometime after 1955 but well before the construction of Dana Point Harbor. A much smaller kelp bed appears in that location during good kelp years. South of Dana Point, rocky bottom is restricted to depths of 15 m or less and again intermittent rock, cobble, and sand substrate is found in the nearshore environment to San Clemente.

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 50 ft. Crandall (1912) reported several large beds in this region. A small bed (0.206 km^2) was located about the area that would have been just offshore of the San Clemente Pier (Crandall 1912); this bed was much larger in 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, two distinct beds totaling 0.652 km^2 were present at the current location of the San Onofre kelp bed (Crandall 1912). In 1911, there existed another 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 in spring 1956 but was reduced to about half its former size (North and Jones 1991). The bed was not observed in a survey in 1963 or 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 south 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 Crandall's survey of 1911 have been inundated by sand.

Fish and Wildlife Kelp Bed Number 7. Kelp Bed 7 includes Horno Canyon and Barn kelp to just north of Oceanside. 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 survey (1912). 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 including 2012. Barn kelp is a layered, shelf-reef community extending out to depths of 15 m. Maps of Barn kelp from 1911 show it to have been a very large kelp bed covering 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. Beyond Barn kelp to the south 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 it has only been observed in 1991 and 1992 since at least 1955. Only small areas of hard substrate are found offshore 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 a predominantly sand bottom in a dynamic environment.

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. Crandall recorded two large beds in this region. One was in the present day location of the North Carlsbad/Agua Hedionda kelp beds and 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, while the other was in the location of the Encina Power Plant bed; it was very large, totaling about 0.858 km^2. Rocky substrate is found out to depths of 18 m offshore of most of this area, supporting good canopy coverage with intermittent sand patches between the beds.

Fish and Wildlife Kelp Bed Number 5. Bed 5 is located south of North Carlsbad, and encompasses kelp beds from Leucadia, Encinitas, Cardiff, Solana Beach, and more or less continuously to Del Mar. Crandall 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 is found just south of the Del Mar kelp beds to offshore Torrey Pines, where reefs are found that periodically support some kelp. Sandy substrate predominates past Scripps Pier to the beginning of the La Jolla Kelp Bed.

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 out to depths of 27 m or more. At Pacific Beach to just past the entrance to Mission Bay, sand predominates in the inshore environment and very little hard substrate is found. 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).

Fish and Wildlife Kelp Bed Number 3. This bed is the northern portion of a very extensive bed (Point Loma Kelp Bed) that runs the length of the peninsula for several miles.

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 to the Mexican Border. The kelp is situated in depths ranging from about 6 to 8 m and extending out to depths of about 55 ft. This area supported a bed that was almost 1.0 km^2 in 1911, 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 grew to almost 1.5 km^2. Although very little kelp is noted beyond Imperial Beach to the Mexican Border due to a predominantly sandy substrate, 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.

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 Point Dume, Santa Monica Pier, Newport Pier, San Clemente Pier, and Scripps Pier. At these locations, automated samplers measure conductivity, temperature, and fluorometry every 1 to 4 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 was also provided by Los Angeles County Sanitation District from monitoring stations offshore Palos Verdes Peninsula (Stations PVS and PVN).
- Water temperature data from the Coastal Data Information Program (CDIP) Point Loma South data buoy, that records water temperature, wave height, period, and direction every 30 minutes.

Sea and swell height data from CDIP data buoys located at Santa Monica Bay, San Pedro, Dana Point, and Torrey Pines. 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 surveying for Region Nine 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 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 successful flights. 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 (as designated by the two consortiums) 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 to place into the specific Fish and Wildlife geo-spatial shape file. Each mosaic was geo-referenced to match at least three prominent features on the map and converted to 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. The vessel surveys for the 2012 survey year were conducted on 20 December 2012 and 17 January 2013. Once per survey year, typically between October and December, a vessel survey is conducted of all of the Region Nine kelp beds. The survey entails locating the main canopies visually (or during poor years by latitude and longitudes 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 canopy in regards to 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 will be selected for focused biologist-diver surveys. Typically these surveys will investigate apparent causes of a bed's atypical behavior (where it disappears or is greatly reduced) during a period when closely aligned regional beds are increasing. For example, we have investigated a persistent hole in the San Mateo kelp bed and found urchins to be the cause, and we have also implicated urchins 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 on smaller scales than the Southern California Bight are not readily available. In contrast, temperature measurements in the marine environment have been ongoing for decades in many areas along the coast resulting in a readily available resource that can reliably predict nutrient availability. A temperature/nutrient index covering several decades is 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 replete or when depleted to establish possible temporal trends. Sea surface temperatures from the Point Dume, Santa Monica Pier, two Palos Verdes stations, Newport Pier, San Clemente Pier, Scripps Pier, and the Point Loma South CDIP buoy were used to determine the theoretical availability of nutrients in the region. Comparing these long-term means at representative stations, the variability of SST in 2012 tracked closely between Point Dume in the north, Newport in between, and Scripps Institution of Oeanography (SIO) in the south where the combined data sets indicated cool SSTs with numerous upwelling events (Figure 10). This relationship between temperature and nutrients appeared very favorable beginning about mid-February 2012 and extending through early-April at Point Dume; it stayed relatively unfavorable through most of the remainder of the year with temperatures becoming cool in late-December 2012 through March 2013 but spiking upward in April (Figure 11). The northernmost station in the Central Region was tracked by SSTs at Point Dume (Figure 11). Average temperatures at Point Dume are typically much cooler than the rest of the Central Region resulting in a high average NQ of 42.5 (4 years); the temperature pattern stayed similar to that of the remainder of the region in 2012–2013 (Table 6). Temperature further south in the range was tracked at Santa Monica Pier. Temperatures at Santa Monica Pier followed the same pattern with mostly cooler-than-average temperatures with an average NQ = 27.8 for the 11 years and an NQ of 31 in 2012–2013 (Table 6, Figure 12). Two stations further south were at either end of the Palos Verdes peninsula: Station PVN in the northern section near Lunada Bay (Figure 13) and the Palos Verdes PVS station on the southern end at Royal Palms (Figure 14). Temperatures appeared to track closely with each other at the PVN and PVS stations with NQs of 25 and 30, respectively, at the two stations. Temperatures at the 11-m depth station indicated a close congruity with each other and based on the temperature likely there were ample nutrients below the thermocline throughout most of the year.

Table 6. Seasonal kelp nutritional index Central Region based on weighting values given to monthly temperature data derived from Point Dume (PD), Santa Monica Pier (SMP), Palos Verdes PVN & PVS, and Newport Pier (NP). 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). 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 2013.

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
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	2
		SMP	-	-	-	-	-	2	1	-	3	2	1
		PVN	-	-	-	-	-	-	-	-	2	-	2
		PVS	-	-	-	-	-	-	-	-	4	-	3
		NP	1	-	-	-	-	2	-	-	2	-	2
4	14.01-15.00°C	PD	-	-	-	-	-	-	-	3	4	2	2
		SMP	3	1	2	3	3	3	3	5	3	4	1
		PVN	-	-	-	-	-	-	-	-	2	2	1
		PVS	-	-	-	-	-	-	-	-	3	3	1
		NP	2	2	1	3	4	3	4	3	3	4	2
2	15.01-16.00°C	PD	-	-	-	-	-	-	-	4	3	1	-
		SMP	4	1	2	-	2	1	2	1	1	-	2
		PVN	-	-	-	-	-	-	-	-	2	1	2
		PVS	-	-	-	-	-	-	-	-	2	1	1
		NP	3	2	3	1	1	-	2	3	3	1	1
1	16.01-17.00°C	PD	-	-	-	-	-	-	-	-	-	2	2
		SMP	1	2	2	3	-	1	1	1	2	2	1
		PVN	-	-	-	-	-	-	-	-	3	1	1
		PVS	-	-	-	-	-	-	-	-	1	-	1
		NP	2	2	1	-	-	1	3	1	1	2	1
Season	NQ	PD	-	-	-	-	-	-	-	58	52	34	26
		SMP	21	24	22	37	16	33	25	23	40	34	31
		PVN	-	-	-	-	-	-	-	-	31	11	25
		PVS	-	-	-	-	-	-	-	-	63	14	30
		NP	24	14	11	22	18	29	23	19	35	34	27

PD = Point Dume, SMP = Santa Monica Pier, PVN = Palos Verdes North,
PVS = Palos Verdes South, NP = Newport Pier

Table 7. The kelp nutritional index for Region Nine of each month based on weighting values given to Sea Surface Temperature (SST) data compiled monthly and derived from Scripps Institution of Oceanography (SIO) pier data, Newport Pier, San Clemente Pier (SCP), Point Loma South, and historic Kerckhoff Marine Laboratory (KML) SSTS. These data are shown in part to better define the temperature regime of the region. 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
Veighting Factor	*14*	*8*	*4*	*2*	*1*	Season	Season	Season	Season	Season
Season	2.01-13.0°	3.01-14.0°	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)					
2012-2013	-(-)	2(2)	2(1)	1(2)	1(1)	25	27	12	NA	19
2011-2012	1(-)	-(1)	4(4)	1(2)	2(-)	28	34	21	NA	23
2010-2011	-(-)	2(-)	3(4)	3(-)	1(1)	17	35	20	NA	19
2009-2010	-(-)	-(-)	3(-)	3(4)	1(1)	9	19	11	NA	11
2008-2009	-(-)	-(-)	4(2)	2(2)	3(1)	11	23	15	NA	NA
2007-2008	-(-)	2(1)	3(2)	-(1)	1(3)	21	29	NA	NA	NA
2006-2007	-(-)	-(-)	5(2)	1(2)	1(-)	12	18	NA	23	NA
2005-2006	-(-)	1(-)	3(1)	1(4)	2(-)	12	22	NA	24	NA
2004-2005	-(-)	-(-)	2(-)	2(3)	1(2)	8	11	NA	13	NA
2003-2004	-(-)	-(-)	2(2)	2(2)	2(-)	12	14	NA	14	NA
2002-2003	-(-)	1(-)	2(-)	3(4)	1(3)	11	24	NA	23	NA
2001-2002	-(-)	-(1)	4(3)	1(1)	1(2)	24	27	NA	19	NA
2000-2001	-(-)	1(1)	1(4)	3(-)	1(1)	25	70	NA	19	NA
1999-2000	-(-)	-(-)	2(3)	3(2)	2(4)	20	51	NA	16	NA
1998-1999	-(-)	1(3)	4(2)	-(1)	3(2)	36	64	NA	27	NA
1997-1998	-(-)	-(-)	-(-)	-(-)	3(2)	4	11	NA	3	NA
1996-1997	-(-)	1(-)	-(2)	-(2)	1(1)	13	34	NA	9	NA
1995-1996	-(-)	-(-)	2(3)	1(1)	1(-)	15	32	NA	11	NA
1994-1995	-(-)	-(-)	2(2)	1(4)	3(-)	16	38	NA	13	NA
1993-1994	-(-)	-(-)	1(1)	2(3)	2(2)	12	10	NA	10	NA
1992-1993	-(-)	-(-)	-(-)	3(3)	1(2)	8	9	NA	7	NA
1991-1992	-(-)	-(-)	2(2)	1(1)	3(2)	12	16	NA	13	NA
1990-1991	-(-)	-(-)	2(2)	3(2)	1(-)	16	23	NA	13	NA
1989-1990	-(-)	1(1)	2(1)	1(3)	1(-)	15	21	NA	19	NA
1988-1989	1(-)	2(2)	1(2)	1(1)	-(1)	27	39	NA	36	NA
1987-1988	-(-)	1(-)	2(2)	1(1)	1(1)	11	21	NA	19	NA
1986-1987	-(-)	(-)	2(-)	1(3)	1(2)	8	11	NA	11	NA
1985-1986	-(-)	-(-)	2(-)	2(2)	2(3)	7	20	NA	14	NA
1984-1985	-(-)	3(-)	1(2)	1(3)	1(-)	14	35	NA	31	NA
1983-1984	-	-	1	3	2	ND	10	NA	12	NA
1982-1983	-	-	-	4	2	ND	12	NA	10	NA
1981-1982	-	1	3	1	1	ND	40	NA	23	NA
1980-1981	-	-	3	2	2	ND	23	NA	18	NA
1979-1980	-	-	2	3	1	ND	24	NA	15	NA
1978-1979	-	2	2	1	1	ND	40	NA	27	NA
1977-1978	-	-	-	2	3	ND	7	NA	7	NA
1976-1977	-	1	-	2	1	ND	17	NA	14	NA
1975-1976	-	2	4	-	-	ND	50	NA	32	NA
1974-1975	-	5	1	1	1	ND	41	NA	45	NA
1973-1974	-	3	1	1	1	ND	52	NA	31	NA
1972-1973	-	-	2	4	2	ND	19	NA	18	NA
1971-1972	2	1	3	-	-	ND	49	NA	48	NA
1970-1971	2	1	2	1	1	ND	52	NA	47	NA
1969-1970	-	2	-	3	2	ND	23	NA	24	NA
1967-1968	-	-	3	2	2	ND	24	NA	18	NA
ND = no data					Average Since 1967	16.6	28.3	15.8	20.1	18.0
- = 0					Since 1977	15.5	26.2	15.8	16.6	18.0
					1967-1976	NA	35.6	NA	30.3	NA

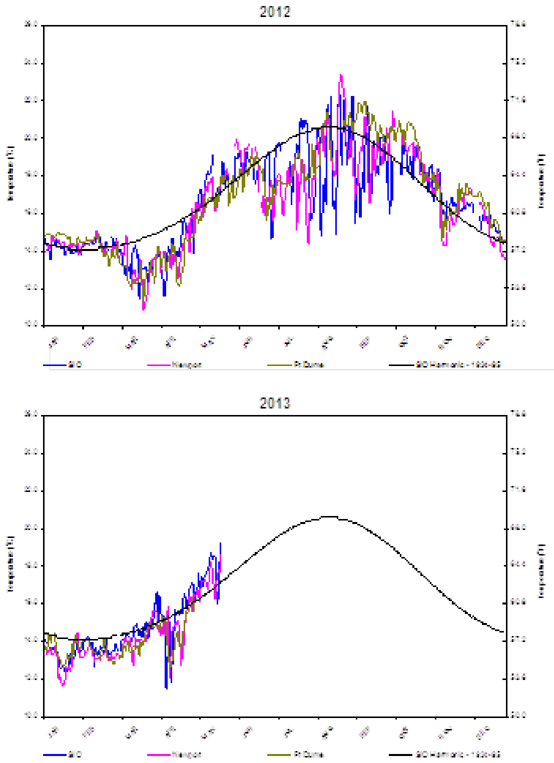
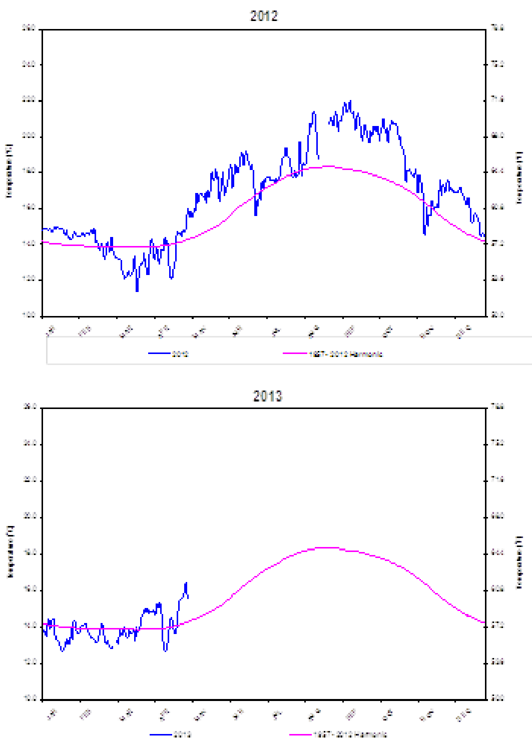


Figure 10. Sea surface temperatures (SST) for three stations in the study region for 2012 and through April 2013.

At the southern portion of the Central Region range and near the beginning of Region Nine, SSTs at Newport Pier (Figure 15) indicated temperatures were very similar to the northern portion (with an NQ of 27) for the nutrient year (Table 7). Although there was ample congruity with the more northern stations, the Newport Pier data indicated a rapid pulsing of nutrients than observed at the other stations. The variability of nutrients may be due to its location near the mouth of a submarine canyon and strong upwelling. SSTs were average during the beginning of the year, but became cooler in late-February through mid-April. Temperatures then became warmer-than-average until early-June, The Newport Coast (based on the SSTs) was characterized by conditions supportive of upwelling during June and July, and co-occurred with above average temperatures through the remainder of the year. The beginning of 2013 started with cooler-than-average temperatures at most monitoring stations. The midsection of the southern portion of the range was characterized by SSTs from San Clemente Pier. San Clemente Pier data was similar to that seen at Santa Monica Pier with major upwelling events occurring more-or-less synoptically with that observed at Santa Monica Pier (Figure 16). Scripps Pier SSTs were similar to those at Newport, other than more upwelling pulses were observed in the data from Scripps from June to early-September (Figure 17).

At Scripps Pier the NQ value has averaged 16.6, at Point Loma south the average has been 15.8, and at San Clemente Pier it has averaged 18.0. These values would indicate that the beds in these three regions have had below-average nutrient availability in the last few years. These low NQs and the higher 28.3 NQ average at Newport Pier over the past 46 years would appear to indicate that nutrients are not evenly distributed in southern California and that the kelp beds are generally stressed and must rely on above-average years to propagate effectively. The NQ index during the 1997–1998 year is a good example, since it indicated a particularly bad year for giant kelp beds in the Southern California Bight. In this example, the nutrient quotient yielded a seasonal NQ value of 4 at Scripps Pier, 3 at Kerckhoff, and 11 off Newport Beach. In contrast, the 1988–1989 year (a year in that kelp beds had reached their maximum extents in several decades) had nutrient quotient values of 27, 36, and 39, respectively (Table 7). The NQ index was 25 at Scripps Pier and 27 at Newport Pier for the 2012–2013 season through mid-May (ends on June 30) indicating an above average-year for nutrients. However, the lack of nutrients (based on warmer SSTs) at San Clemente (NQ=19) and at the Point Loma South buoy (NQ=12) may have contributed to some of the variability in the growth and diminished canopies observed in some of the region's kelp beds.



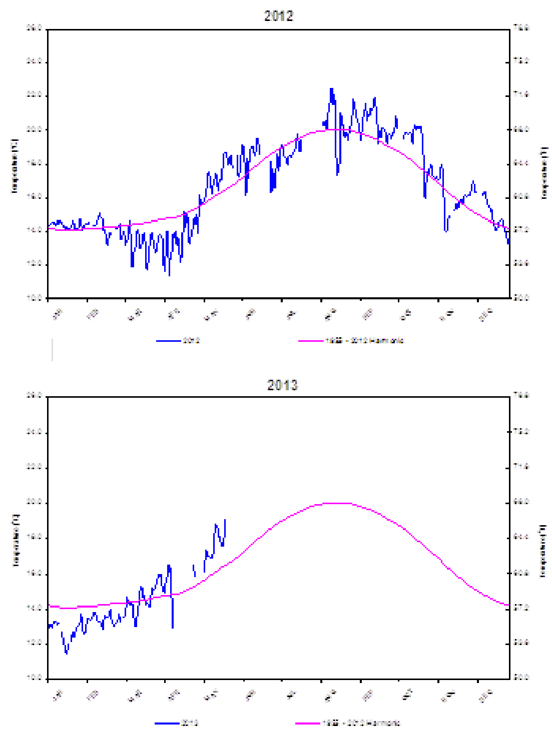


Figure 11. Sea surface temperatures (SST) at Point Dume for 2012 and to April 2013.

Figure 12. Sea surface temperatures (SST) at Santa Monica Pier for 2012 and to May 2013.

The extreme southern portion of Region Nine was tracked by the Point Loma south buoy. Point Loma SSTs were muted in comparison to those of Scripps with minimal nutrients available to the kelp other than three to four months in both 2012 and 2013 (Figure 18).

To summarize, the 2012–2013 season nutrient quotient at Point Dume was 26, Santa Monica Pier was 31, it was 25 at Palos Verdes North and 30 at Palos Verdes South, 27 at Newport Pier, and 25 at Scripps Pier (all near or above average) indicating that nutrients were above average at disparate locations across the Central Region and Region Nine. At times there was a rather large disparity between nutrient quotients across the region, such as observed at San Clemente (19) and Point Loma (12), that is in part due to variability in local oceanographic regimes between the beds near Point Dume at the northern end of the range, Santa Monica Bay, Palos Verdes, Newport Beach in the middle and those to the south (San Clemente, Scripps Pier, and Point Loma). This variability is driven by prevailing flow characteristics and bathymetric features that probably 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.

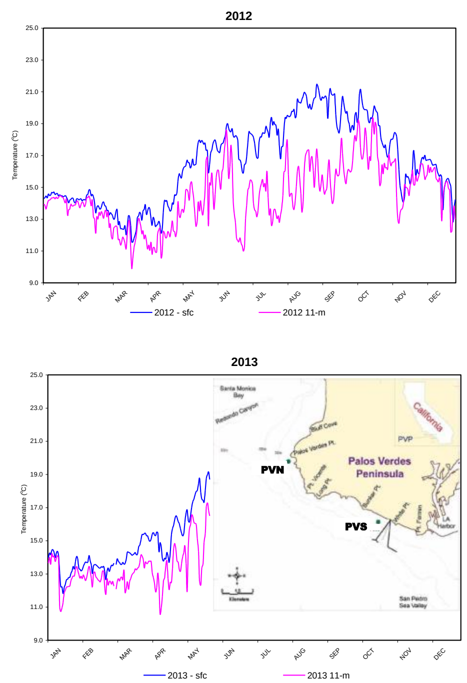


Figure 13. Sea surface temperatures (SST) at Station PVN offshore Palos Verdes for 2012 and to January 2013.

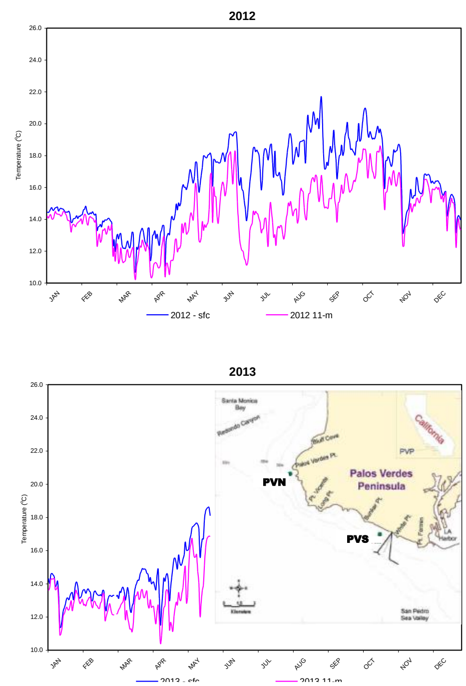


Figure 14. Sea surface temperatures (SST) at Station PVS offshore Palos Verdes for 2012 and to January 2013.

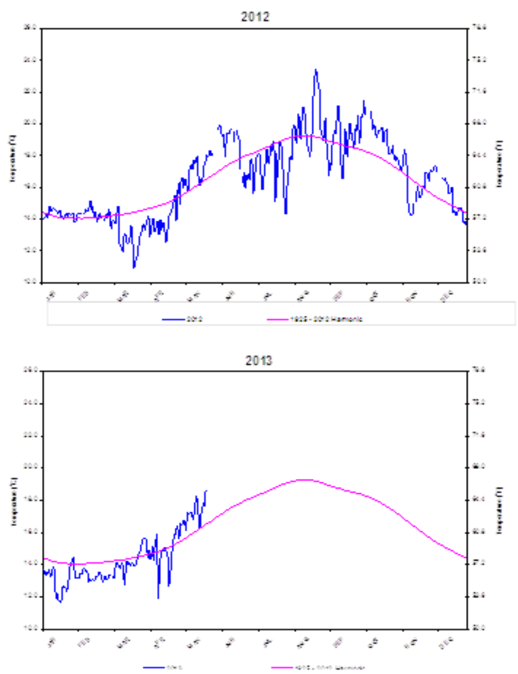


Figure 15. Sea surface temperatures (SST) at Newport Pier for 2012 and to March 2013.

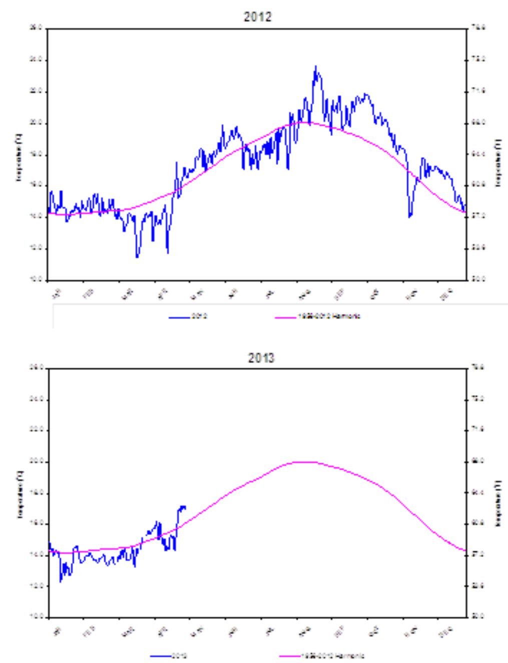


Figure 16. Sea surface temperatures (SST) at San Clemente for 2012 and to April 2013.

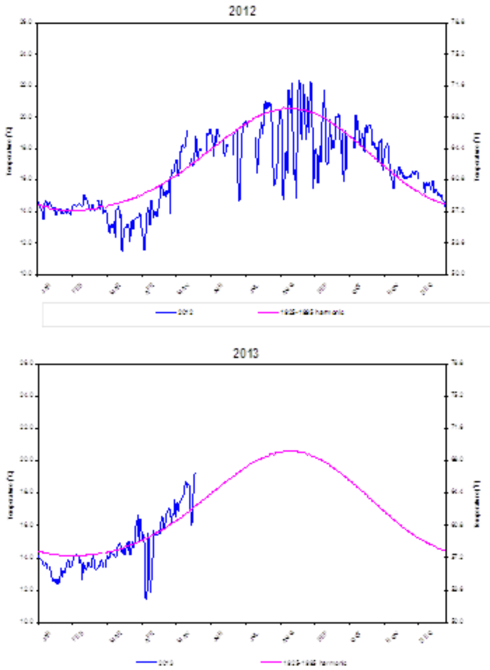


Figure 17. Sea surface temperatures (SST) at Scripps Pier for 2012 and to May 2013.

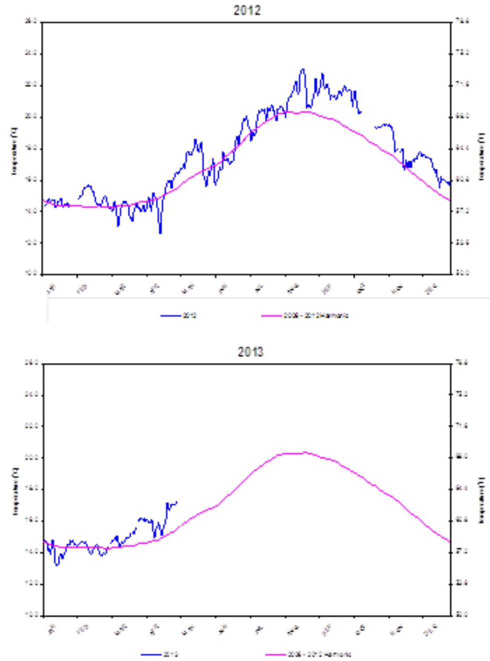


Figure 18. Sea surface temperatures (SST) at Point Loma South for 2012 and to April 2013.

WAVE HEIGHTS

Typical swell sizes and directions were observed through most of 2012, with swells approaching the region from the west near 80% of the time at the northern portion of the range near Port Hueneme (Figure 19). In the middle of the range at San Pedro, waves were recorded also out of the west almost 70% of the time (Figure 20). Offshore of Point Loma at the far southern end of the range, waves were from the west about 40% of the time, with a strong component out of the south and the southwest combined another 40% of the time (Figure 21). High-energy waves that negatively impact the southern California coastline usually are low-frequency, high-amplitude waves approaching from the west. Such conditions briefly existed during March and April, and June when a wave sensing buoy (Scripps Coastal Data Information Program [CDIP] Station 111, Figure 22) at Anacapa Passage (offshore of Port Hueneme) recorded high-amplitude waves near or over 3.5 m (with some over 3.65 m) in April 2012. Wave heights reached over 3 m in March, and were approaching 3 m in May (Figure 23). At San Pedro CDIP Station 092 wave heights exceeded 3.5 m during February, March, April, May, and again in December 2012 (Figure 24). The highest waves (up to 3.8 m) occurred in February 2012. About 30 km south downcoast at Dana Point CDIP Station 096, waves were more subdued, with wave heights approaching 3.5 m only in March, while a few exceeded 3 m in April (Figure 25). At Oceanside CDIP Station 045, wave amplitude was higher, approaching 4 m in April, and 3.5 m in March and December (Figure 26). The Point Loma South CDIP Buoy 191 recorded high-amplitude

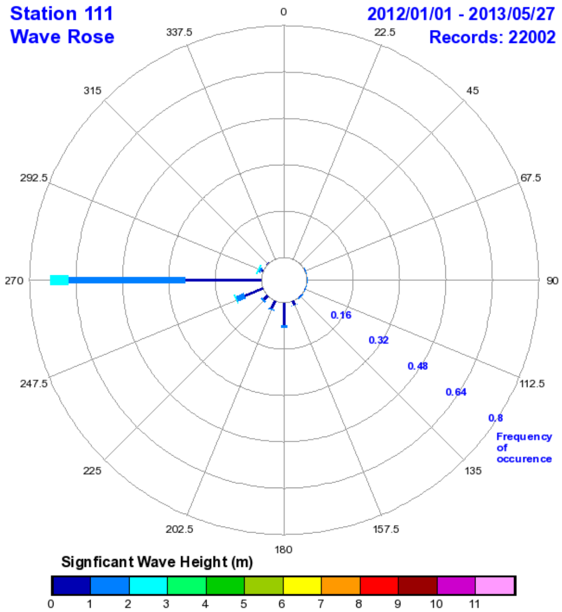


Figure 19. Wave Rose significant wave direction Anacapa Passage, CA from 2012 through May 2013.

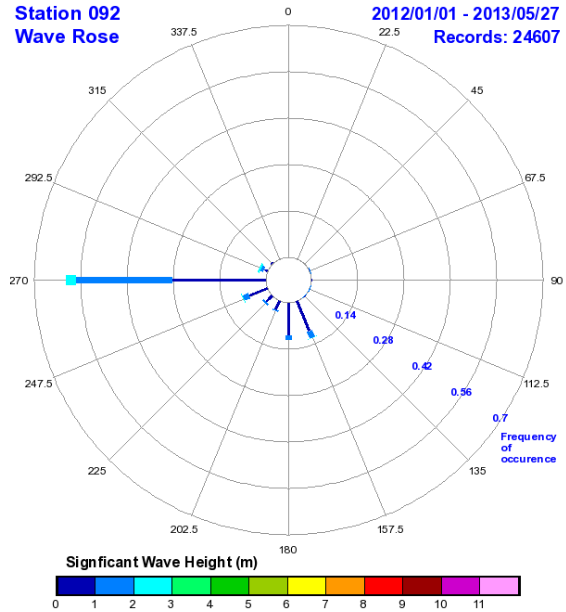


Figure 20. Wave Rose significant wave direction San Pedro, CA from 2012 through May 2013.

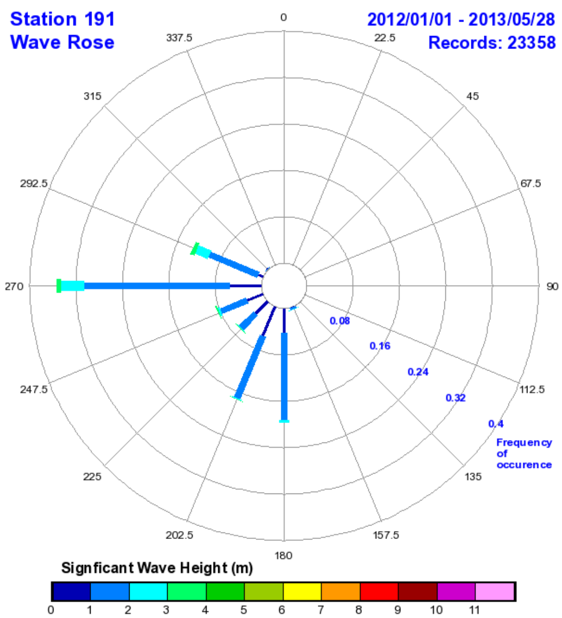


Figure 21. Wave Rose significant wave direction Point Loma, CA from 2012 through May 2013.

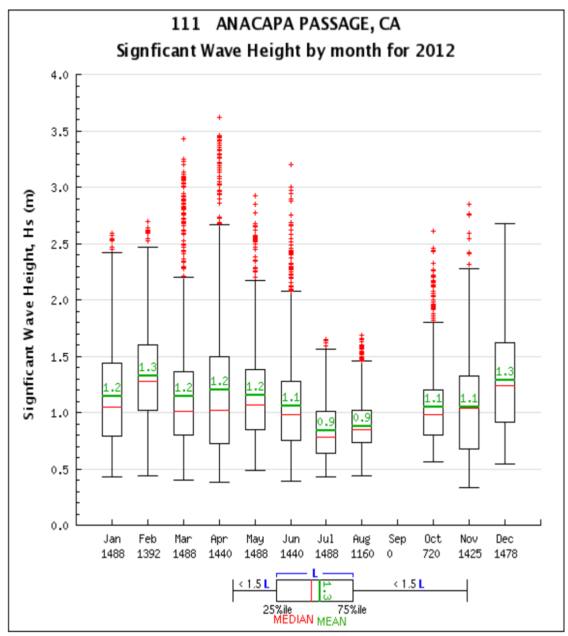


Figure 22. Significant wave heights offshore Anacapa Passage, CA for 2012.

waves exceeding 4 m in March and April and approaching 4.5 m in December 2012), while high-amplitude waves over 3 m were also recorded in January and February (Figure 27. 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. Fortunately, there were only brief periods of fairly large waves recorded during 2012; they were not persistent and there was no evidence of any substantial impacts on the kelp beds in the Central Region or Region Nine.

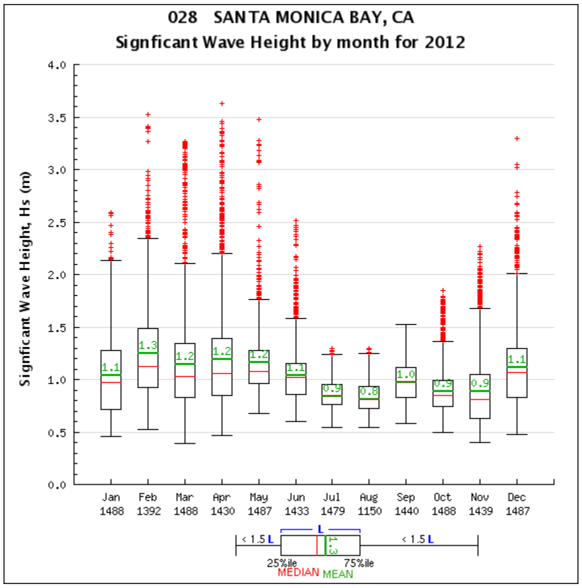


Figure 23. Significant wave heights offshore Santa Monica, CA. 2012.

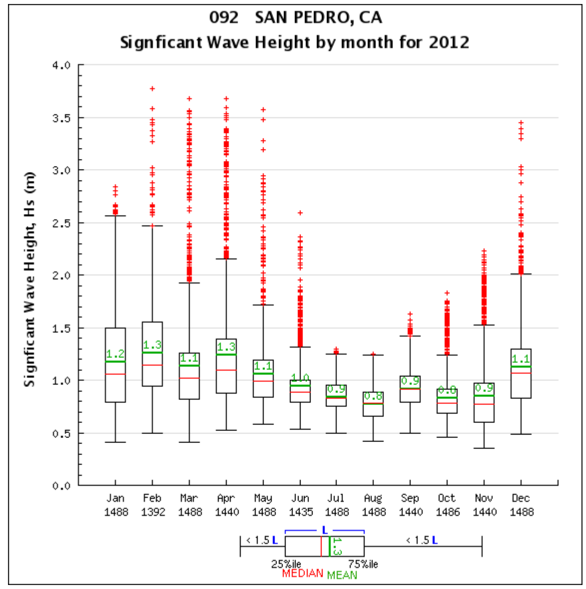


Figure 24. Significant wave heights offshore San Pedro, CA. 2012.

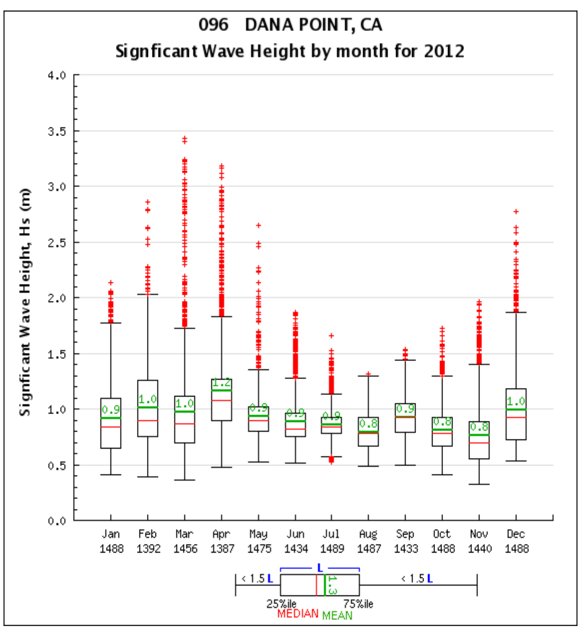


Figure 25. Significant wave heights offshore Dana Point, CA. 2012.

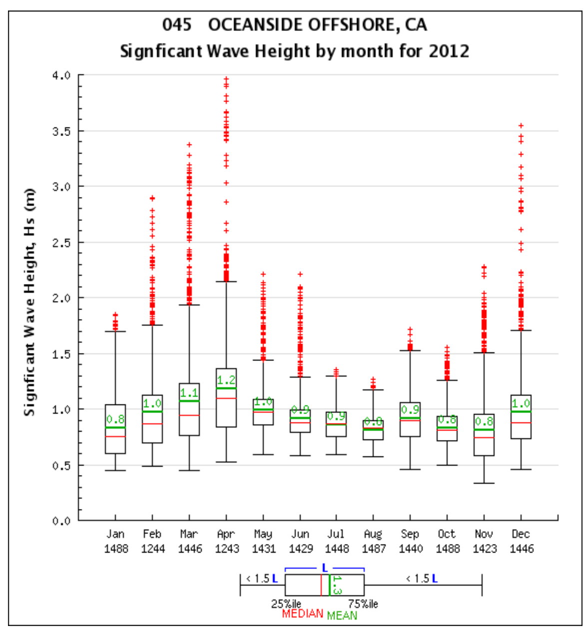


Figure 26. Significant wave heights offshore Oceanside, CA. 2012.

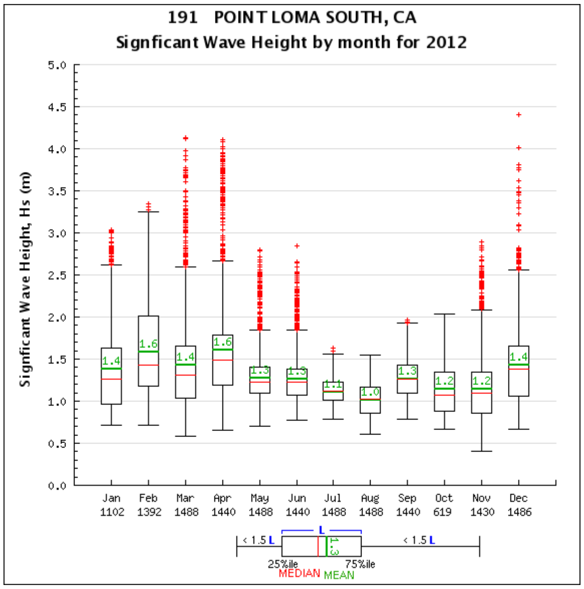


Figure 27. Significant wave heights offshore Point Loma, CA. 2012.

RAINFALL AND WATER CLARITY

Periods of sustained high turbidity in near-shore waters often result from high rainfall; however, during the 2012 rain year, rainfall was well below the long-term average of 14.46 inches In Los Angeles County (recorded at LAX). There was less than 9 inches of rainfall at LAX and less than 7 inches in Orange County (Orange County Airport) and San Diego County (recorded at Lindberg Field) which led to relatively high water clarity throughout the year (Figure 28, NOAA 2013). There were periods when the rivers and streams ran strongly and nearshore waters were turbid; however, turbidity did not persist for sustained periods in the region during 2012 (SCCOOS 2013). Fortunately, runoff in 2012 was not correlated with any damage to the kelp beds. Rainfall occurred in the early part of 2012, although about 1.7 inches occurred in March in Los Angeles County, about 1.25 inches in Orange County, and slightly over one inch in February in San Diego County. The only period of very heavy rainfall occurred during December when 2.75 inches fell in Los Angeles County, 2.5 inches in Orange County, and 2.25 inches in San Diego County.

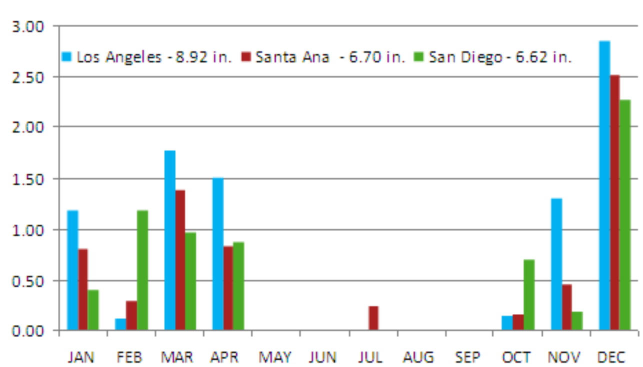


Figure 28. Rainfall recorded for Los Angeles, Orange, and San Diego Counties, 2012.

There were periods of algal blooms in the region, but they did not persist for sustained periods during 2012. Monitoring efforts show that these dense blooms were caused primarily by phytoplankton, such as the dinoflagellate *Lingulodinium polyedrum* or the diatom *Pseudo-nitzschia* spp (SCCOOS 2013). Cell counts of *L. polyedrum* indicated the populations were relatively low through most of the year, with an average of 3,000 cells/liter but concentrations were much higher (100,000 cells/liter) in September through much of December in algal patch samples taken offshore of Santa Monica (Figure 29). Samples taken at Scripps Institution of Oceanography had much lower concentrations during most of the year, only spiking upward to about 3,000 cells/liter during early-January and the last three months of the year (Figure 30). 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).

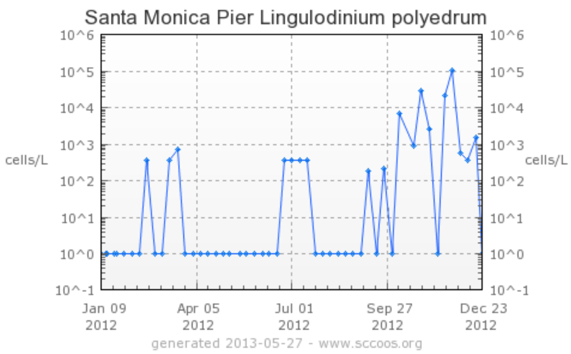


Figure 29. Phytoplankton concentrations at Santa Monica Pier 2012.

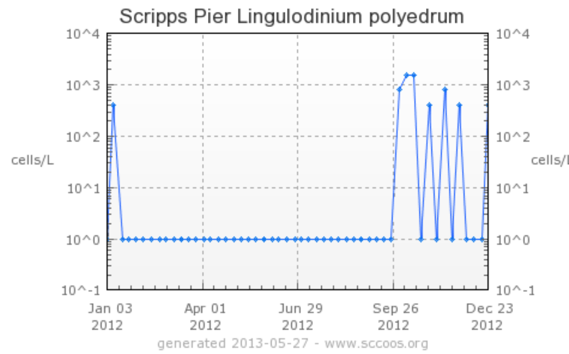


Figure 30. Phytoplankton concentrations at Scripps Pier 2012.

Although the concentrations of these phytoplankton could have greatly reduced light availability on the bottom in 2012 and thereby decreased photosynthetic opportunities, their duration offshore in 2012 was not sufficient to have adversely affected the health of the kelp beds of the Central Region or Region Nine.

2012 QUARTERLY OVERFLIGHT SUMMARY

Aerial surveys were flown on 6 April, 26 June, 1 October, and 28 December 2012. One survey has been completed for the 2013 survey year on 13 May 2013 (Appendix C).

Reasonable attempts were made to conduct one aerial overflight within each of the four quarters in the year (Table 8). Flight conditions were generally good during most of the surveys. Aerial surveys indicated that most kelp beds decreased between the December 2011 survey and the April 2012 survey (Tables 9 and 10). The March survey was conducted about one week late due to overcast conditions along the southern California coast over much of the spring and summer. The June survey was conducted on schedule about two and one half months later, and the September survey was conducted one day late on 1 October. Flight conditions for that survey were generally good with a forecast indicating clear conditions along the entire range and the flight proceeded normally until a cloud bank settled in over the southernmost four kelp beds in Region Nine. A lengthy wait in the region did not resolve the issue and attempts to collect this data over the next month were unsuccessful. The December survey was scheduled on 28 December 2012. Due to the effects of the La Niña, and based on the results of the surveys, maximum canopy coverage varied throughout the year with the December overflight data generally depicting the kelp beds at their greatest extent, but for some beds the April survey results were not appreciably different along much of the coast. The June survey still depicted some beds with large canopies, especially in the northern sections of the Central Region and Region Nine, whereas the October survey tended to show canopies at their lowest extent for the year along the coast of both regions (Tables 9 and 10).

Table 8. Synopsis* of Status of Planned Aerial Flights 2012.

Target Date	**Mid-March**	**Status**	**Results**
Planned Flight	19-Mar-12	Cancel	Wind, Seas,CloudsCover
	26-Mar-12	Cancel	Overcast Entire Range
	6-Apr-12	**Flown**	**Tide, Wind, Clear Skies**
Target Date	**Mid-June**	**Status**	**Results**
	18-Jun-12	Cancel	Overcast Entire range
	26-Jun-12	**Flown**	**Tide, Wind, Clear Skies**
Target Date	**Mid-September**	**Status**	**Results**
	15-Sep-12	Cancel	Partly Cloudy Entire Range
	19-Sep-12	Cancel	Tide, Cloud Cover
	25-Sep-12	Cancel	Tide, Cloud Cover
	1-Oct-12	**Flown**	**Good Visibility/Fog moved in La Jolla So**
La Jolla South	11-Oct-12	Cancel	Rain, Partly Cloudy Entire Range
La Jolla South	15-Oct-12	Cancel	Fog Partly Cloudy San Diego Area
La Jolla South	30-Oct-12	Cancel	Fog, Partly Cloudy Entire Range
Target Date	**Mid-December**	**Status**	**Results**
	18-Dec-12	Cancel	Sea Swell, Partly Cloudy Entire Range
	28-Dec-12	**Flown**	**Generally Good Visibility Entire Range**

* See Appendix C for entire Flight Status Report

2012 VESSEL SURVEY SUMMARY

Boat surveys were conducted during most of the year from Newport Beach to Barn kelp and in late-December and early-January in the southern portion of Region Nine to document the kelp canopies and verify anomalies suggested by the earlier data. Following the 20 December 2012 and 17 January boat surveys, most kelp canopies appeared to have maintained their sizes or increased slightly from canopies observed in late-2011. The Newport Coast beds were slightly smaller, while the north Laguna Beach beds were larger but slightly smaller in the south. Many of the beds increased by 10 to 20% or more, with Barn kelp increasing almost four-fold. Kelp near Salt Creek/Dana Point appeared healthy with dark yellow fronds indicating nutrients were recently available and beds from North Carlsbad to Cardiff also had large canopies with dark yellow fronds. In contrast, La Jolla was very patchy in the north and was noticeably smaller than the previous year, while at Point Loma the canopy coverage was excellent and there appeared to be no particular areas of concern. Imperial Beach kelp bed was found in several widely separated areas and growing out beyond the 18 m contour in some locations.

Data from the late-December boat survey and diver surveys at Wheeler J. North Kelp Reef, Barn, Del Mar, and Imperial Beach kelp beds confirmed that the kelp beds along the coast were receiving adequate nutrition in December and January based on the dark yellow color of the tissues. Sedimentation was low on the blades, and encrustations on the blades were generally less than 10% of the fronds (although higher at some sites). Apical meristem tips (scimitars) were generally viable (not broken off) on at least 50% of the surface fronds and most (80%) of the fronds were young. There were no obvious diseases such as black rot, holes, or sinking fronds.

Table 9. Rankings assigned to the 2012 aerial photograph surveys of the Ventura and Los Angeles County kelp beds, and rankings assigned to a May 2013 aerial survey. 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 would represent the average status. Central Region Kelp Consortium.

	2012 Surveys				2013
Kelp Beds	April 06	June 26	October 01	December 28	May 13
Ventura Harbor *	2.5	2.5	2.5	2.0	2.5
Channel Islands *	2.0	2.0	2.5	2.0	2.0
Port Hueneme *	2.5	2.5	3.0	2.5	3.0
Deer Creek	3.0	3.5	3.0	3.0	3.0
Leo Carillo	3.0	3.0	2.5	3.5	3.5
Nicolas Canyon	3.0	3.5	2.0	3.0	3.5
El Pescador/La Piedra	3.0	3.5	2.0	3.0	3.5
Lechuza Kelp	2.5	3.0	2.0	2.5	3.5
Point Dume	2.5	3.0	2.0	3.5	3.5
Paradise Cove	3.0	2.5	2.0	4.0	3.5
Escondido Wash	3.0	2.5	2.5	4.0	4.0
Latigo canyon	3.5	3.0	3.0	4.0	4.0
Puerco/Amarillo	3.5	3.0	3.0	4.0	4.0
Malibu Pt.	3.5	3.0	2.5	4.0	3.5
La Costa	1.0	-	-	2.0	2.0
Las Flores	1.0	NI	2.5	4.0	3.5
Big Rock	3.0	2.5	2.0	4.0	4.0
Las Tunas	3.0	2.0	1.5	3.5	3.5
Topanga	0.5	3.0	1.5	4.0	3.5
Sunset	1.0	1.0	1.0	1.0	0.5
Marina Del Rey *	3.0	1.0	2.5	4.0	0.5
Hyperion Pipeline *	2.5	2.0	2.5	3.0	-
Redondo Breakwater *	3.0	2.0	1.5	3.0	2.5
Malaga Cove - PV Point (IV)	3.5	3.0	3.0	4.0	3.5
PV Point - Point Vicente (III)	3.0	3.0	3.5	4.0	4.0
Point Vicente - Inspiration Point (II)	3.5	3.5	3.5	4.0	3.0
Inspiration Point - Point Fermin (I)	4.0	2.5	3.0	2.5	2.5
Cabrillo	3.0	2.0	2.0	3.0	3.0
LB/LA Harbor and Breakwaters	3.0	2.0	2.0	3.0	2.5
Horseshoe Kelp	-	-	-	-	-
Huntington Flats	-	-	-	-	-
Newport Harbor *	3.0	4.0	2.0	2.5	2.0
Corona Del Mar	3.5	3.0	2.0	3.0	2.5
North Laguna Beach	4.0	3.0	2.0	3.5	3.0

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.

Observations on the dive survey at Wheeler J. North Reef recorded visibility at 3 to 5 m, hydroids present on about 40% of the blades in mid-water, and good coverage of kelp on bottom with a few missing holdfasts. Fishes were abundant during a 15-minute swim including Kelp Perch (*Brachyistius frenatus*) and Topsmelt (*Atherinops affinis*) in the upper canopy, and Sheephead (*Semicossyphus pulchrum*), Señorita (*Oxyjulis californiensis*), Barred Sandbass (*Paralabrax nebulier*), Kelp Bass (*Paralabrax clathratus*), Black Perch (*Embiotoca jacksoni*), and Halfmoon (*Medialuna californiensis*) on the bottom. Large macro-invertebrates were also present, such as a few red urchins (*Strongylocentrotus franciscanus),* no purple urchins (*S. purpuratus*), giant keyhole limpet (*Megathura crenulata*), wavy top turban snail (*Lithopoma undosum)*, the ornate tube worm (*Diopatra ornate*), bat stars (*Asterina miniata*), and both California golden (*Muricea californica*) and brown gorgonians (*M. frutico*sa) in relatively low density.

Table 10. Rankings assigned to the 2012 aerial photograph surveys of the San Diego and Orange County kelp beds, and rankings assigned to a May 2013 aerial surveys. 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 would represent the average status. Region Nine Kelp Consortium.

	2012 Surveys				2013
Kelp Bed	April 06	June 26	October 01	December 28	May 13
Newport Harbor *	3.0	4.0	2.0	2.5	2.0
Corona del Mar	3.5	3.0	2.0	3.0	2.5
No. Laguna Beach	4.0	3.0	2.0	3.5	3.0
So. Laguna Beach	4.0	3.0	2.5	3.5	3.0
South Laguna	2.0	1.0	2.0	2.5	3.0
Salt Creek-Dana Point	2.5	2.5	2.5	4.0	3.5
Dana Marina *	2.5	2.0	2.0	2.5	2.0
Capistrano Beach	2.5	2.5	2.0	4.0	1.0
San Clemente	4.0	2.5	3.0	4.0	4.0
San Mateo Point	3.5	3.0	1.5	3.5	2.5
San Onofre	2.0	-	-	2.5	3.0
Pendleton Reefs *	-	-	-	-	-
Horno Canyon	-	-	-	0.5	1.5
Barn Kelp	1.0	0.5	-	2.5	3.0
Santa Margarita	-	-	-	-	-
Oceanside Harbor *	1.0	1.0	1.0	2.0	1.0
North Carlsbad	2.5	2.5	2.5	3.0	3.0
Agua Hedionda	1.0	1.5	1.0	2.5	2.5
Encina Power Plant	2.5	2.0	2.0	3.0	3.5
Carlsbad State Beach	1.0	-	1.0	3.5	4.0
North Leucadia	-	-	1.0	3.0	3.5
Central Leucadia	2.5	3.0	2.0	3.5	4.0
South Leucadia	3.0	2.5	2.0	3.5	3.5
Encinitas	2.5	2.5	2.0	4.0	3.5
Cardiff	2.5	2.0	1.0	3.5	3.5
Solana Beach	2.0	2.5	1.5	3.5	3.5
Del Mar	1.0	-	-	2.0	0.5
Torrey Pines Park	1.0	0.5	NI	4.0	3.0
La Jolla Upper	1.5	1.0	NI	2.5	2.5
La Jolla Lower	2.5	2.0	NI	3.0	2.5
Point Loma Upper	2.5	2.5	NI	3.0	3.5
Point Loma Lower	1.5	2.5	NI	3.0	3.0
Imperial Beach	-	0.5	NI	2.0	1.5

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.

At Barn kelp, a dive was conducted to determine the status of the newly emerging kelp forest. Topside observations indicated the canopy was of about medium density, but covering a larger area than previously seen and apical meristem tips (scimitars) were generally intact (not broken off). Tissues were medium yellow indicating nutrients were recently present, but not at the frequency to deepen the blade color, and sporophyll blades (reproductive blades at the base of the giant kelp) were well developed. Visibility was only about 1 to 2 m, but adequate to see the bottom flora and fauna. The bottom was characterized by intermittent sand, cobble, and rock, with a few old kelp holdfasts and low densities of purple and red urchins in the area we surveyed. Other species observed included Southern palm kelp (*Ptergophora californica*) at low densities, bat star, giant sea star (*Pisaster giganteus*), and blood star (*Henricia leviuscula*). The only fish species observed was juvenile Blacksmith (*Chromis punctipinnis*).

Another dive was conducted at Del Mar kelp bed. The density of this kelp bed was thin, frond lengths were 3 to 5 m, but only about 40% of the fronds were young. Apical meristem tips were mostly intact, and sedimentation on the fronds was light, while encrusting hydroids were heavy (50 to 75%) at mid-depth. Visibility was 5 to 8 m on bottom, temperature was 12°C, and the bottom was characterized by low-lying bed rock with some sand patches and several large sand stone reefs. The most conspicuous algae on bottom was *Desmarestia* (acid kelp) in patches between the kelp holdfasts. Sporophyll blades on the kelp were well developed. Fishes were abundant near the larger reefs including Sheephead, Señorita, Barred Sandbass, Kelp Bass, Black Perch, and Garibaldi (*Hypsopops rubicundus*), and large macro-invertebrates such as sheep crab (*Loxorhynchis grandis*), and spiny lobster (*Panulirus interruptus)* were especially abundant on the reefs.

Imperial Beach kelp bed was also intensely scrutinized due to its habit of disappearing and reappearing after very long absences. It appeared to be once again recovering so a dive was conducted on the outskirts of the deepest kelp patch. The 200- by 50-m patch of kelp had very dark yellow tissue coloration indicating recently adequate nutrients. About 80% of the fronds were mature, 50% of the apical meristem tips were broken, and about 20% of the blades were covered with encrusting bryozoans. The bottom was cobble with some old holdfasts present on bottom and the giant kelp bed included about 10% elkhorn kelp (*Pelagophycus porra*) and some small foliose red algae (Rhodophyta) on bottom. Macro-invertebrates included chestnut cowry (*Cypraea spadicea*), yellow rock crab (*Metacarcinus anthonyi*), sheep crab, spiny lobster, bat star, coon stripe shrimp (*Pandalus danae*), and two-spot *Octopus bimaculoides*). The only fish observed were Black Eyed Goby (*Rhinogobiops nicholsii*) and Stripefin Ronquil (*Rathbunella alleni*). The bed appeared to be very healthy and occurred on substrate reminiscent of more northern kelp beds.

Most of the kelp beds appeared to capitalize on the relatively good conditions of 2011 and increased in coverage in 2012. While one of the very large beds in the region lost considerable canopy coverage, its next door neighbor gained a similar amount. The boat ground-truth survey and diver notes on the individual beds indicate that, overall, kelp had favorable responses to nutrient pulses available in 2012.

2012 KELP CANOPY SUMMARY

Central Region. Utilizing the 2012 aerial surveys, the following changes were documented in the 26 CRKSC kelp beds in 2012:

- 19 kelp beds increased
- 5 kelp beds decreased
- 2 kelp beds were not present, both of them absent for decades.

Results of the 2012 Central Region kelp survey indicated that the maximum measured kelp canopy increased from 4.427 km^2 in 2011 to 5.665 km^2 in 2012 (Table 4).

Region Nine. The following changes were documented in the 24 RNKSC kelp beds in 2012:

- 18 kelp beds increased
- 5 kelp beds decreased
- 1 kelp bed was unchanged (not present)

Of the two small beds at Torrey Pines and Santa Margarita that appear sporadically in the region in exceptional (in terms of nutrient availability) years, only Torrey Pines was present in 2012, whereas Santa Margarita has not been observed since 1992.

Results of the 2012 Region Nine survey indicated that the maximum measured kelp canopy increased from 10.379 km^2 in 2011 to 11.882 km^2 in 2012 (Table 5).

NOAA ENSO data indicated that cooler-than-average temperatures were observed in 2012, that followed a cooler-than-average 2011 and 2010 (La Niña conditions). However, temperatures did begin to increase above average in November and December as recorded by the NOAA Climate Diagnostic Center (www.cdc.noaa.gov). The large increase in kelp growth during 2012 year suggests that the kelp growth was nurtured by nutrients below and above the thermocline.

STATUS OF THE 50 KELP BEDS IN CENTRAL REGION AND REGION NINE IN 2012

The following is a synopsis of the status of each individual bed during the 2012 survey year based upon the quarterly surveys. The kelp beds of Central Region have been above the long-term average (4.001 km^2) since 1967 for the past six years (Figure 31).

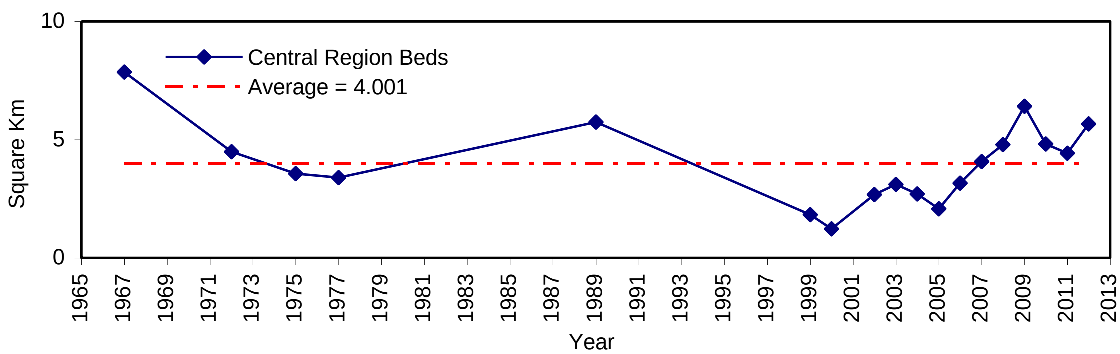


Figure 31. Combined canopy coverages at all kelp beds in Central Region from Ventura to Laguna Beach.

CENTRAL REGION KELP SURVEYS

FISH AND WILDLIFE KELP BED 16 (Ventura River Mouth to Point Mugu)

Ventura Harbor, Channel Islands Harbor to Point Mugu 2012. A small amount of giant kelp was noted growing along the breakwaters of Ventura Harbor (0.0133 km^2), Channel Islands Harbor (0.0103 km^2), and at Port Hueneme (0.0183 km^2) in 2012. No kelp was noted offshore of either Mandalay or Ormond Beach Generating Stations. No kelp was noted south of Port Hueneme until Deer Creek. The same pattern of no kelp growth, except along the breakwaters of Ventura Harbor, Channel Islands Harbor, and Port Hueneme, was also observed during the first survey of 2013.

FISH AND WILDLIFE KELP BED 17 (Point Mugu to Point Dume)

Deer Creek 2012. 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). The subsequent years again recorded it at about one-half that size. Despite an ongoing La Niña in 2012 that increased the size of most beds in the region, the bed declined from the 0.055 km^2 observed in 2011 and only reached 0.041 km^2 in 2012. The Deer Creek kelp bed was compared to the average bed area per year (ABAPY) size of the northern and central portions of the Central Region kelp beds to determine whether it was responding synoptically with the beds from the same area. Kelp beds in the Palos Verdes portion of the Central Region were treated separately as they are typically larger beds and appear to react atypically from the other beds of the Central Region. The Deer Creek kelp varied closely with the other beds in its region during the past 10 years, but varied in 2012 with the ABAPY suggesting its response was slightly out of synchronization with the other beds in the region (Figure 32).

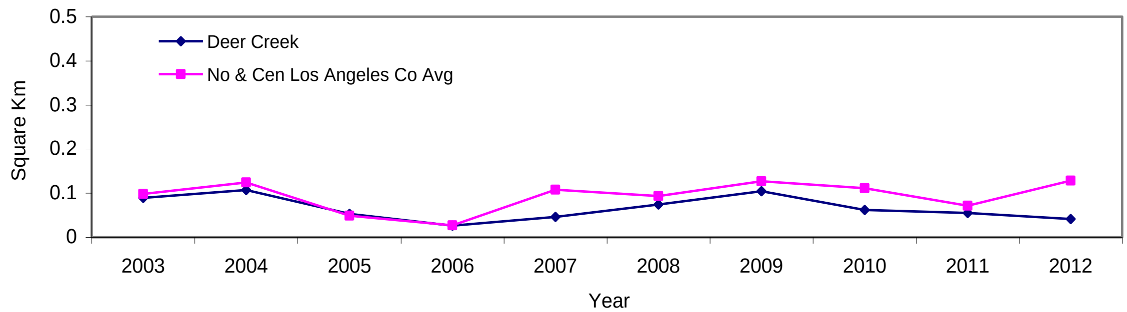


Figure 32. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Deer Creek for the years shown.

Leo Carillo 2012. Leo Carillo kelp is incorporated in Fish and Wildlife Kelp Bed 17, and was included in the measurements of Crandall (1912). It was a very large bed in 1911 covering 2.5 km^2. By a 1967 survey, that pooled all five beds in Fish and Wildlife Kelp Bed 17, it probably was still very large as the total area for the five beds was markedly similar to what Crandall measured in 1911. By 1972 a trend of decreasing bed sizes occurred as the total canopy coverage for the Fish and Wildlife region decreased from over 4 km^2 in 1967 to 2.5 km^2 in 1972, but was down to 1.5 km^2 by 1977. By 1989, the beds were much smaller as noted in overflight photographs taken by Ecoscan (1990). As the Ecoscan survey occurred during a period of exceptional nutrient availability (a very strong La Niña event), 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. As they have not significantly recovered during the past 20 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 them were growing on sandy bottoms. It appears likely these beds to the north 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 and finally reaching a substantial percentage of its 2004 peak in 2012 at 0.337 km^2. With the exception of the 2007 and 2008 years, Leo Carillo kelp has reacted synoptically with the kelp beds in the region; however, in 2012, the ABAPY peak was less sharp than that of Leo Carrillo kelp bed (Figure 33).

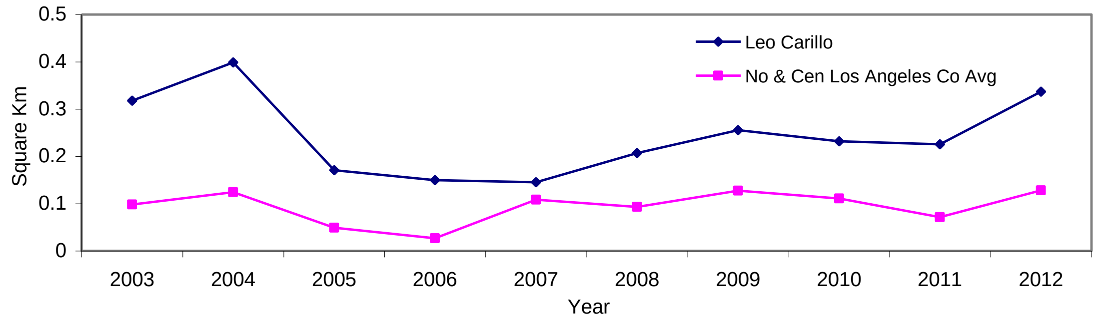


Figure 33. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Leo Carillo for the years shown.

Nicolas Canyon 2012. Crandall's (1912) measurements of the Nicolas Canyon kelp bed indicated it was a very large bed in 1911 at 1.26 km^2. By a 1967 survey that pooled the area of the five beds in the region designated as Fish and Wildlife Kelp Bed 17, it probably was still very large as the total area for the five beds was markedly similar to what Crandall measured in 1911. Through surveys in the 1970s, the bed probably shrunk in size greatly as noted by the decreasing total kelp canopy coverage of Fish and Wildlife Kelp Bed 17 (Table 2). Aerial photographs of the bed by Ecoscan (1990) indicate that by 1989 this bed was much smaller than recorded previously (probably as a result of the agents discussed previously), and was of a similar size to that noted in 2003 (0.308 km^2) or 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. It peaked again in 2009, and then declined in 2010. In spite of what should have been good nutrient conditions by December 2011, the Nicolas Canyon kelp bed decreased to less than half that recorded the previous year, but responded to a good nutrient regime in late-2012 and again increased to about one-half its maximum size (0.240 km^2). 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 large stimuli, such as when nutrients became more abundant in 2007 and 2009 (Figure 34).

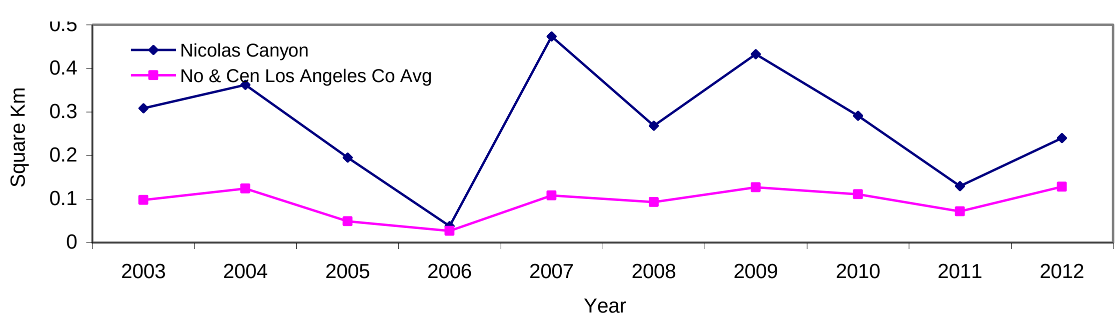


Figure 34. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Nicolas Canyon for the years shown.

El Pescador/La Piedra 2012. Maps by Crandall (1912) indicated that the El Pescador/La Piedra kelp bed was 0.252 km^2 in 1911. Aerial photographs of the bed by Ecoscan (1990) indicate that in 1989 this bed was slightly larger in size than that observed by Crandall, and based on the total for the five beds probably similar to that noted in 2003 (0.243 km^2) (MBC 2004a). By 2004, the bed increased in canopy coverage 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 then made a good recovery in 2012 to 0.173 km^2 (still only one-half of its peak size) by December 2012. When comparing the El Pescador/La Piedra bed to the ABAPY, it was evident that it was larger than the average bed size but its response has typically mirrored that of the regional beds (Figure 35).

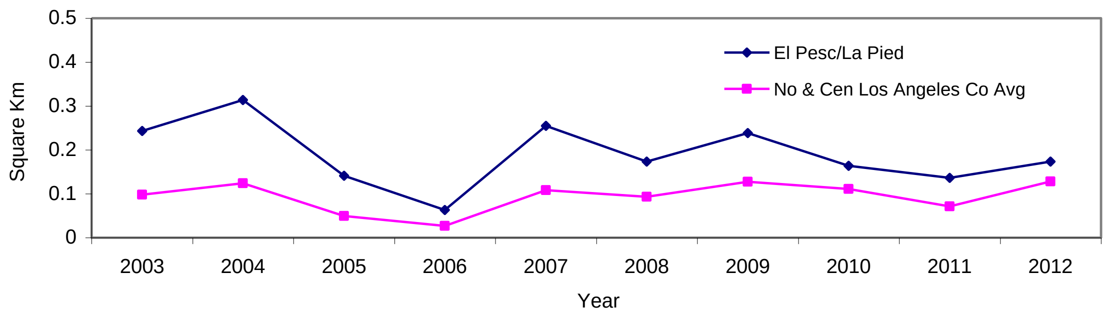


Figure 35. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off El Pescador/La Piedra for the years shown.

Lechuza 2012. Lechuza kelp bed is the southernmost bed included in Fish and Wildlife Kelp Bed 17. 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 growth was found (in the midst of a very strong El Niño). Visual inspection of Ecoscan (1990) images of the kelp bed suggest that in 1989 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). In 2005, the largest canopy coverage observed was 0.041 km^2. It reached a similar size as 2003 in 2007 and 2009, but has remained only about one-half that size since. In 2010, the Lechuza kelp bed lost canopy early in the year but made a good recovery by December 2010, increasing to 0.096 km^2, a significant fraction of that observed in June of 2009. The 2011 year recorded the bed as moderately large and increasing by December 2011 to the same size as noted in 2010; however, like Deer Creek, it also decreased in 2012 to a coverage of about 0.066 km^2. The Lechuza kelp bed was almost exactly the size of, 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 36).

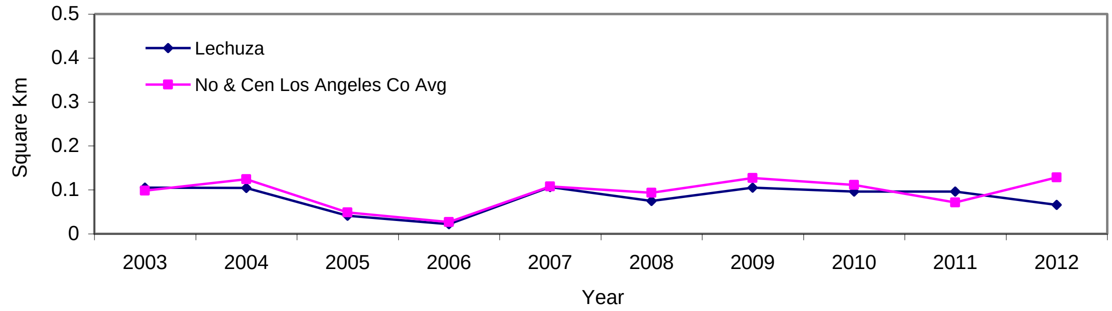


Figure 36. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Lechuza for the years shown.

FISH AND WILDLIFE KELP BED 16 (Point Dume to Malibu Point)

Point Dume 2012. Point Dume demarks the western boundary of Fish and Wildlife Kelp Bed 16. Point Dume kelp bed historically was a sizable kelp bed, totaling 0.686 km^2 in 1911 (Crandall 1912). Since then, Point Dume kelp bed 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, as there is very little visible reef structure 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. From aerial surveys by Ecoscan (1990), this kelp bed in 1989 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). Reversing a trend seen at other more northern kelp beds of the Central Region, the Point Dume kelp bed appeared larger in the December 2006 survey and was measured to be 0.053 km^2, subsequently the bed stayed similar, or had a slight upward trend through 2008. This trend continued and by June 2009, it totaled 0.104 km^2, the largest bed at this location since CRKSC monitoring began. Kelp canopy coverage in 2010 was lower by the December 2010 survey to just under 0.094 km^2. The 2011 surveys indicated severe reductions by April, but the bed began to increase in size during the remainder of the year and totaled (0.078 km^2) only slightly less than the previous year by the December 2011 survey. In 2012, the bed increased to the largest (0.154 km^2) it has been in the 10 years of CRKSC monitoring. The Point Dume kelp bed was typically in synch with the ABAPY, and has been since 2006 (Figure 37).

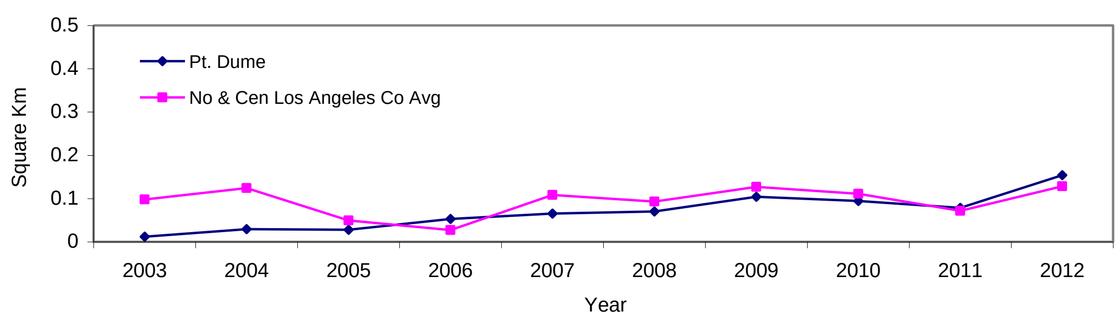


Figure 37. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Pt. Dume for the years shown.

Paradise Cove 2012. 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 growth. None-the-less, this bed declined considerably in size by a survey conducted in 1967, a slide that continued until the late 1970s (Table 2). While no areal measurements were made by MBC from the overflight surveys of Ecoscan (1990), the images from the survey suggest that in 1989 the coverage 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 observed in 2005 occurred in the 22 June survey; it was calculated at 0.035 km^2 and it was only slightly larger at 0.036 km^2 in 2006, an 80% reduction from that recorded in 2004. Cooler waters with nutrients allowed the kelp bed area to increase to 0.100 km^2 in 2007, with further increases in coverage by June 2009 to 0.244 km^2. The cooling trend abated in later 2009 and affected the kelp bed adversely by the end of the year. Paradise Cove kelp began a good recovery through November 2010 resulting in a fairly robust kelp bed covering 0.259 km^2 by the late December survey. The following year (2011), Paradise Cove reacted in concert with most of the other beds in the region and decreased to less than one-half the coverage in 2010. 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 The Paradise Cove kelp bed has been larger than average during most of the last decade, and has usually responded in concert with the ABAPY (Figure 38).

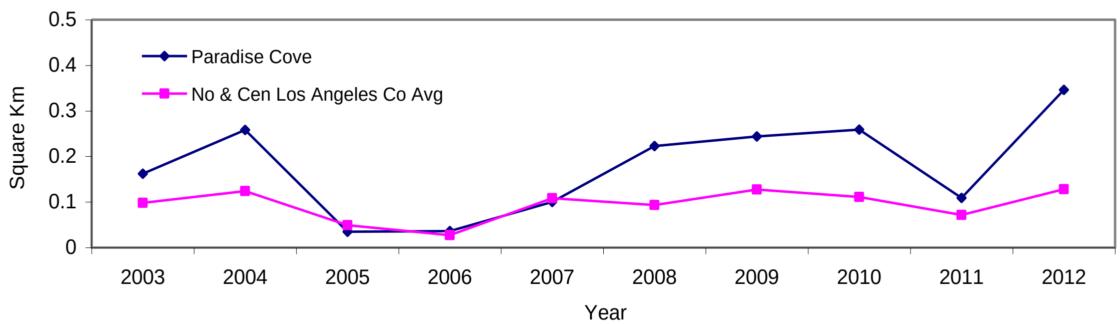


Figure 38. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Paradise Cove for the years shown.

Escondido Wash 2012. Escondido Wash kelp bed is one of the denser beds of Fish and Wildlife Kelp Bed 16, totaling 0.583 km^2 in 1911 (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 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 very small, noticeably less 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 in late 2007, but decreased to 0.278 km^2 by the December 2008 survey, before increasing to 0.321 km^2 by March 2009. Thereafter, the kelp bed began declining through the remainder of the year, but made a good recovery by the December 2010 survey when the bed rebounded to cover 0.267 km^2. The Escondido Wash kelp bed did not respond favorably to local nutrient conditions in 2011 and was much reduced by December 2011 (0.104 km^2), but like its neighbor to the north it reacted very favorably to what appeared to be a better nutrient regime in 2012 and increased to a size (0.248 km^2) near that observed in 2010. This bed is typically larger than the ABAPY, and generally mirrors the trends in the ABAPY (Figure 39).

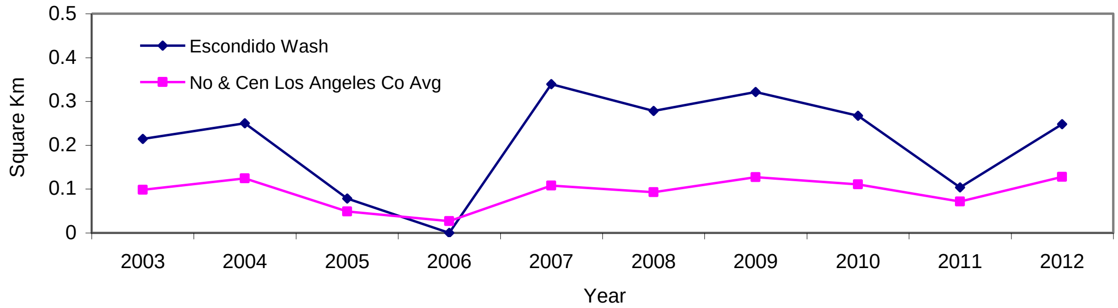


Figure 39. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Escondido Wash for the years shown.

Latigo Canyon 2012. Crandall's (1912) maps of 1911 were used to calculate that the Latigo Canyon kelp bed covered an area of 0.446 km^2 (Table 2). Aerial photographs of the bed by Ecoscan (1990) indicate that by 1989 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 only attained a size of 0.032 km^2, an 80% reduction from the previous year. The Latigo Canyon kelp bed continued to remain much smaller than it was in 2004, measuring only 0.007 km^2 on the December 2006 survey; however, by the end of 2007, the bed increased to 0.186 km^2. By December 2008, the bed had decreased to 0.124 km^2 but made a good recovery by March 2009, increasing to a coverage of 0.195 km^2. The bed became smaller during the remainder of 2009, before recovering by the March 2010 survey. The 2010 surveys recorded a bed that was somewhat reduced but still a substantial kelp bed becoming robust and covering 0.142 km^2 by the December 2010 survey. The continuing La Niña did not provide a local stimulus to the Latigo Canyon kelp bed and it too decreased to 0.070 km^2 in 2011, about one half of the total in 2010. In 2012, the Latigo Canyon kelp bed attained its largest size (0.202 km^2) since the CRKSC monitoring began in 2003. The Latigo Canyon kelp bed is very near the ABAPY for the region, and has tracked relatively close during the 10 years of monitoring (Figure 40).

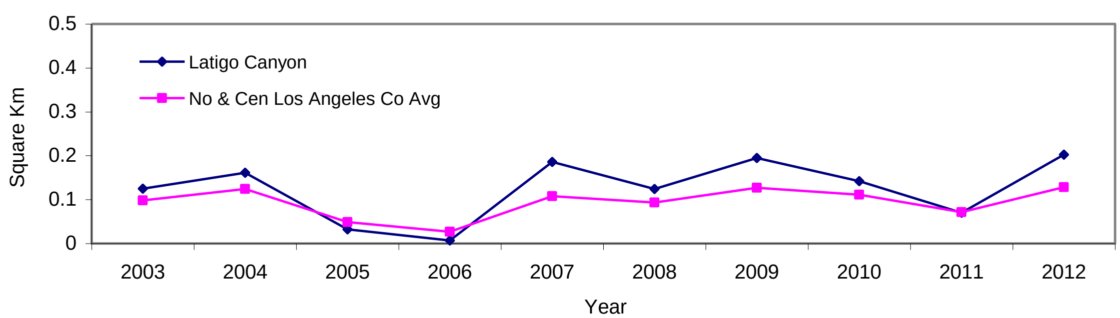


Figure 40. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Latigo Canyon for the years shown.

Puerco/Amarillo 2012. 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. From aerial surveys by Ecoscan (1990) in 1989 this kelp bed was considerably larger than in 2003

(0.074 km^2) and 2004 (0.051 km^2). The 2005 maximum areal coverage was 0.039 km^2; unlike its northern neighbors, it increased in 2006 to 0.055 km^2 and responded well to the advent of the La Niña in 2007 increasing to 0.095 km^2. The areal coverage of the Puerco/Amarillo kelp bed in the December 2008 survey was 0.064 km^2; the bed mirrored its neighbors by decreasing, suggesting nutrients were limiting in this region as compared to further north at Paradise Cove. By June 2009, the bed reached its largest size (0.115 km^2) for 2009 as it was noted as very poor in September with only slight changes by December 2009 (MBC 2010a, Table 9). In 2010, the kelp bed began to recover and was again robust in December 2010, covering an area of 0.126 km^2. Nutrients, in spite of the long lasting La Niña, were apparently lacking in this region in 2011, as the bed decreased similarly to the Latigo Canyon bed directly north to 0.069 km^2, but again like its neighbors, it was larger (0.153 km^2) than any previous CRKSC survey in December 2012. This bed typically trended synoptically with the ABAPY from 2007 through 2012, although slightly lower than the ABAPY in 2004 (Figure 41).

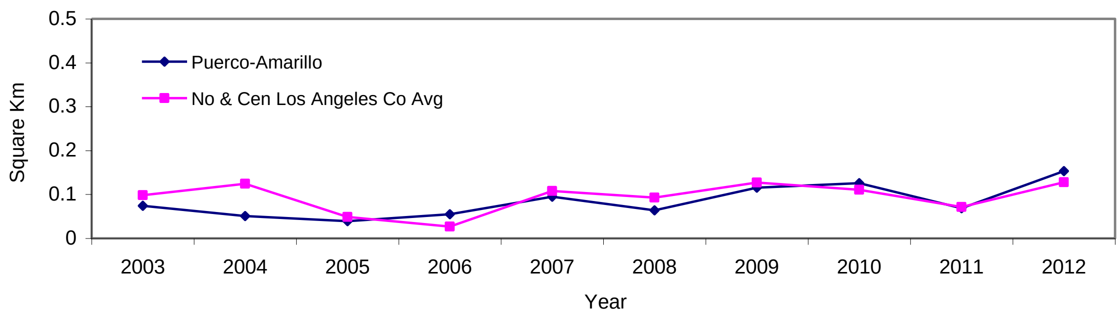


Figure 41. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Puerco/Amarillo for the years shown.

Malibu Point 2012. Malibu Point marks the eastern-most boundary of Fish and Wildlife Kelp Bed 16. Crandall (1912) did not record kelp off Malibu Point either because it was very small or it was non-existent during his survey. A small amount of surface kelp was observed by Ecoscan (1990) similar to the size recorded from the 2003 CRKSC survey, when 0.011 km^2 was measured. The bed slightly increase in 2004 to 0.013 km^2, although coverage decreased in 2005 when only 0.008 km^2 was observed. The Malibu Point kelp bed maintained a similar small size through 2009. Ongoing kelp restoration projects apparently combined with favorable conditions by December 2010 resulting in the largest bed (0.066 km^2) at this location since 2003. Bucking the trend for all of the other beds of Fish and Wildlife Bed 16, the Malibu Point kelp bed increased in 2011 to a slightly larger canopy of 0.074 km^2 and in 2012 it continued to increase to 0.084 km^2, the largest extent of kelp observed since CRKSC monitoring began in 2003.The Malibu Point kelp bed was smaller than the ABAPY and did not appear to be greatly stimulated by any upwelling events that spiked the ABAPY upward in 2007 or 2009, but it began to approach the ABAPY in 2010. The bed coincided with the ABAPY in 2011, but the trend was flatter than the ABAPY's upward trend in 2012 (Figure 42).

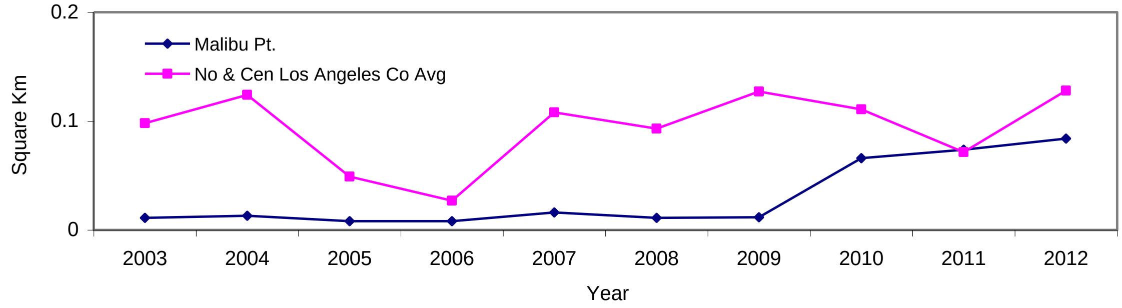


Figure 42. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Malibu Pt. for the years shown.

FISH AND WILDLIFE KELP BED 15 (Malibu Point to Santa Monica Pier)

La Costa 2012. La Costa kelp bed is the western-most bed in Fish and Wildlife Kelp Bed 15. Crandall (1912) included this kelp bed in his measurements; however, it appeared to have been located further south than its present position. Historically, La Costa kelp bed was small with canopy coverage of only 0.021 km^2 (Crandall 1912). However, from all available reports, this kelp bed never came close to the same amount of coverage, at least not after 1955. From aerial surveys by Ecoscan (1990), no surface canopy was present for this kelp bed in 1989. In 2003, 0.001 km^2 of surface canopy was recorded and 0.002 km^2 was seen in 2004 (Table 2). No surface canopy was seen in any of the quarterly surveys from 2005 through 2008, but it reappeared in December 2009 as a small bed totaling 0.001 km^2. The kelp bed was small but back to a coverage of 0.001 km^2 in December 2010. 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. Compared to the ABAPY, the kelp bed at La Costa has not reacted in any measurable way since 2003 (Figure 43).

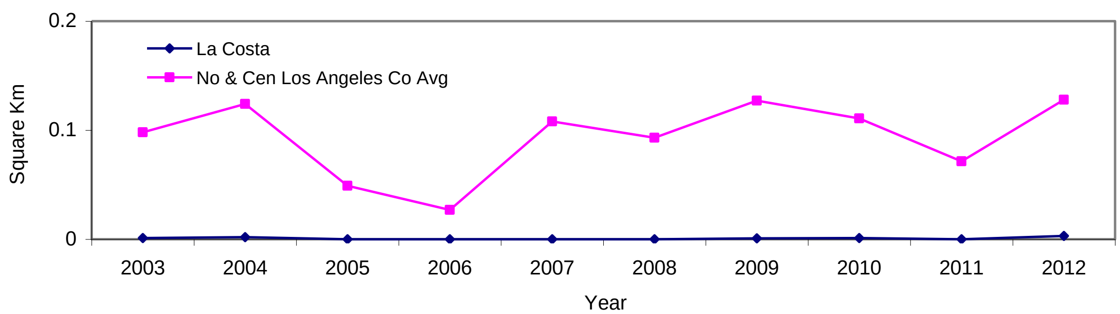


Figure 43. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off La Costa for the years shown.

Las Flores 2012. The surface canopy of Las Flores kelp bed was small in 1911 at 0.014 km^2 (Crandall 1912), and inspection of the aerial overflight survey by Ecoscan (1990) revealed that the kelp bed was much the same in 1989. Canopy measurement in 2003 was 0.0089 km^2, however in 2004 the density of the canopy increased, with 0.023 km^2 recorded, a size that was 61% larger than in 1911 (MBC 2004a, 2005a). This bed disappeared during the second and third quarterly surveys in 2004 and then reappeared during the fourth quarterly survey of 2004 (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, when a small bed was present with a surface canopy area of 0.005 km^2; it subsequently became smaller by the end of 2008 measuring only 0.001 km^2, but increased again to 0.005 km^2 by June 2009. It became smaller during the remainder of 2009 and through August of 2010 before once again increasing to 0.005 km^2 by November and December 2010. The bed stayed small but began to increase by the December 2011 survey to 0.008 km^2. The December 2012 survey indicated that the bed had grown larger than during any other survey of the CRKSC and at 0.025 km^2 was slightly larger than in 2004. Compared to the ABAPY, since 2003 the kelp bed at Las Flores has not reacted with the ABAPY except for upward spikes in 2004 and 2012 (Figure 44).

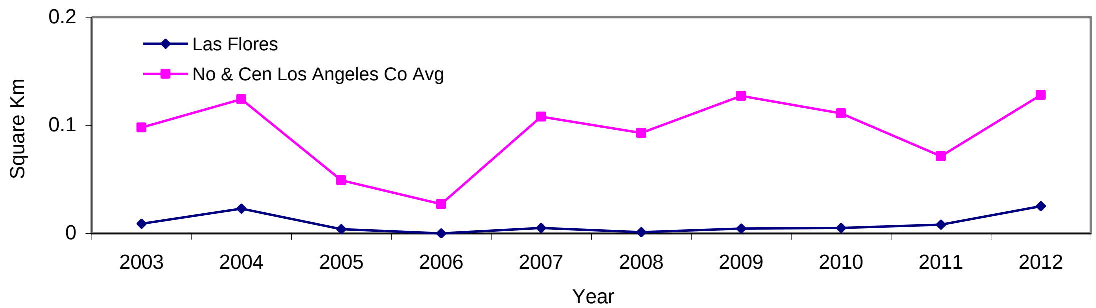


Figure 44. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Las Flores for the years shown.

Big Rock 2012. Big Rock kelp was measured by Crandall (1912) to be 0.017 km^2, that appeared to be similar to what was present in 1989 (Ecoscan 1990). Surface canopy values in 2003 were 0.005 km^2, and in 2004 the bed increased to 0.014 km^2 (Table 2). In 2005, the greatest surface area measured was 0.002 km^2; this bed continued to decrease in size throughout the year and was very small, but was the only bed with any canopy (0.001 km^2) in the region as recorded during the December 2006 survey when a small remnant of kelp canopy was present just east of the Big Rock Beach headland. This remnant increased to 0.004 km^2 by the December 2007 survey, decreased to 0.002 km^2 by the end of 2008, and again increased to 0.005 km^2 by the June 2009 survey. It waxed and waned through August 2010 but became slightly larger covering an area of 0.006 km^2 by November and December 2010. Although not visible during the first two surveys of 2011, it reappeared in October and was slightly larger (0.007 km^2) in December. By December 2012, it had the largest surface canopy (0.018 km^2) since the inception of the CRKSC program. Big Rock kelp has also been consistently very small and well below the ABAPY for the region, but with two spikes upward in 2004 and 2012, suggesting the same nutrient regime is bathing these relatively close sites (Figure 45).

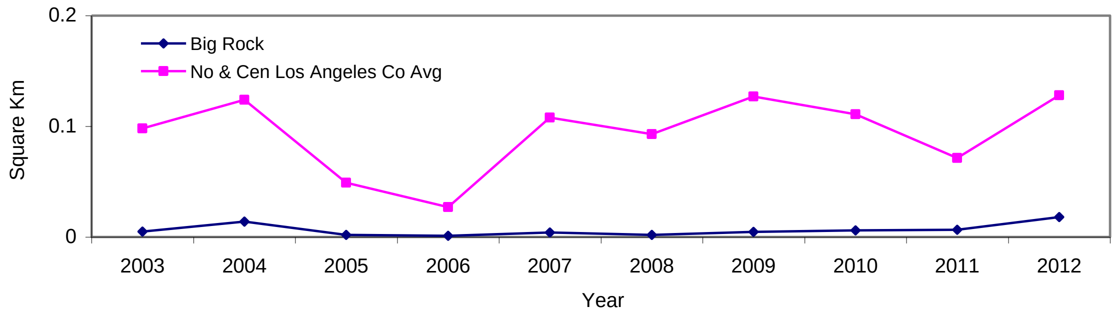


Figure 45. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Big Rock for the years shown.

Las Tunas 2012. Las Tunas kelp bed was small in 1911 at 0.017 km^2 (Crandall 1912), and Ecoscan (1990) aerial surveys showed that by 1989 the kelp bed was approximately one-quarter of the historical size. By 2003, surface canopy of this kelp bed measured only 0.003 km^2 (Table 2). However, in 2004 Las Tunas kelp bed had increased considerably to 0.018 km^2, almost identical 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 quarterly surveys; however it reappeared by the December 2007 survey and measured 0.008 km^2. In 2008, the bed again decreased leaving a small bed with a surface canopy area of only 0.005 km^2; by the June 2009 survey, the bed had increased to a coverage of 0.019 km^2; it became smaller during the remainder of 2009 but began increasing in size by the August and November 2010 surveys culminating in a bed of about 0.015 km^2 by December 2010. In 2011 the bed remained very small through October and then began to increase again and measured 0.007 km^2 by the December survey, and in concert with the other beds in the region increased by the 2012 December survey to 0.030 km^2, about double that recorded by Crandall in 1911. Las Tunas is a very small bed well below the ABAPY for the region, but appeared to respond in the same direction of the ABAPY through most years (Figure 46).

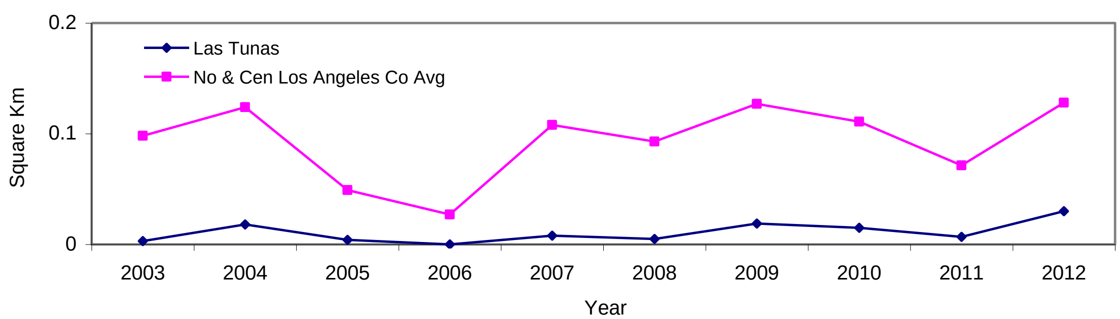


Figure 46. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Las Tunas for the years shown.

Topanga 2012. Topanga kelp bed was observed by Crandall (1912); it was small, and calculated from the maps to be about 0.017 km^2. In 1989 this bed was very small, approximately one-tenth its historical size (Ecoscan 1990). The bed was considerably smaller in 2003, measuring about 0.0002 km^2 (Table 2). This bed was absent for much of the year in 2004, but then reappeared by the fourth quarterly survey with a canopy size of 0.0024 km^2. In 2005, surface canopy was only observed as a trace amount of surface kelp

(0.0001 km^2). None of the 2006 or 2007 surveys recorded any canopy at this location, but it reappeared as a very small bed 0.0009 km^2 in 2008, and increased to the maximum canopy size seen of 0.002 km^2 by June 2009. Thus, it was surprising to see the bed begin to increase in November and December 2010 to 0.052 km^2, 26 times larger than it had been since CRKSC monitoring began and three times larger than recorded by Crandall (1912). In 2011, it was smaller (0.041 km^2) by the December survey but still much larger than Crandall recorded at the beginning of the previous century. In 2012, it increased to almost as large (0.048 km^2) as it was in 2010 indicating a favorable nutrient regime. Topanga is a very small bed well below the ABAPY for the region, but its upward trend in 2010 and its more moderate decrease in 2011 and increase in 2012 was atypical of that of the ABAPY's trend (Figure 47).

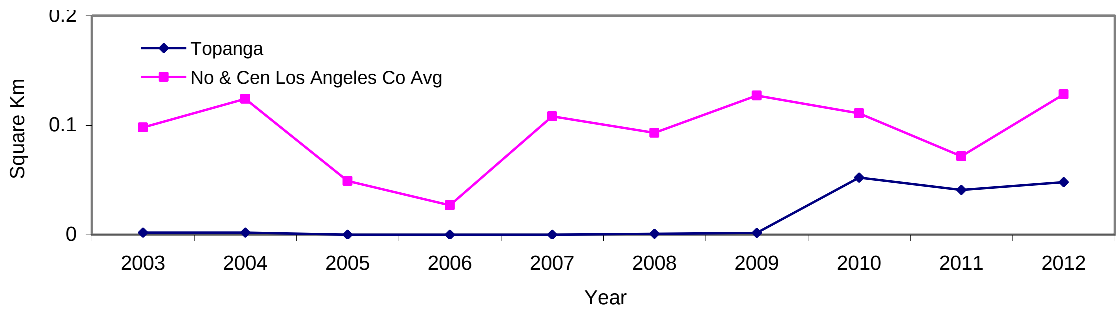


Figure 47. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off Topanga for the years shown.

Sunset 2012. In 1890 and in 1911, Sunset kelp bed was large at 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 Beach during the preceding 40 years. This loss was either due to sand inundation of the reef structure or because kelp may have grown on the sand that could have been extirpated by a violent storm during the preceding 40 years. In any case, no hard substrate is found in 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). This bed marks the eastern boundary of Fish and Wildlife Kelp Bed 15. 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 2012 (Table 9).

CRKSC CENTRAL (Santa Monica Pier to Redondo Beach Breakwater Southern Tip)

Santa Monica Pier to Redondo Beach Breakwater Southern Tip 2012. Although no kelp was noted in 2003 or 2004 in the region from the Santa Monica Pier to Marina del Rey Harbor, a small amount of kelp was noted along the breakwaters of the Marina del Rey Harbor and King Harbor in Redondo Beach in April 2005 and at slightly higher concentrations in December 2006, particularly near the northern end and inside 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 through the 2012 surveys, kelp has been noted at both the Marina del Rey and Redondo Beach-King Harbor breakwaters during some portion of the year.

Redondo Beach Breakwater Southern Tip to Malaga Cove, Torrance 2012. 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-bottom substrate. No kelp was seen south of King Harbor until Malaga Cove at the Palos Verdes Peninsula in 2012.

FISH AND WILDLIFE KELP BEDS 14 (Malaga Cove to Point Vicente) and 13 (Point Vicente 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). Appendix B also lists historical canopy areas from SWQCB (1964), Ecoscan (1990), and North (2000). 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 20th 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 from the Joint Water Pollution Control Plant (JWPCP), that commenced operations off White Point in 1937 (IMR 1954). The first measurement of local kelp bed extent following initiation of the discharge was in 1945 when the extent 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 in 1989–1990 (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 California Department of Fish and Wildlife reporting from 1.343 km^2 (Bedford, CDF&W 2004, pers. comm.) to 2.84 km^2 of kelp coverage (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 provides 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 that year. 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
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 has buried many low-lying reefs in the area, 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 1 m between the 3 and 15 m isobaths within the depth range suitable for kelp bed formation.

Palos Verdes IV 2012. The Palos Verdes kelp beds have the most complete record of all the beds in the Central Region because of surveys conducted by the California Department of Fish and Wildlife and monitoring efforts by Los Angeles County Sanitation Districts. Palos Verdes IV kelp bed is one of the two beds included in Fish and Wildlife Kelp Bed 14. 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 in present day Fish and Wildlife Kelp Bed 14 from Flat Rock at Malaga Cove to Point Vicente. In 1928 aerial photographs, the beds were measured to have increased to 9.912 km^2; however by 1945, all beds along the Palos Verdes Peninsula began a dramatic decline in kelp bed size, especially in Fish and Wildlife Kelp Bed 14 (SWQCB 1964, Appendix B). By 1958, only a small remnant of the Palos Verdes kelp beds was present in the CRKSC-designated Palos Verdes IV (PV IV) kelp bed area. 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 CRKSC PV IV kelp bed (Ecoscan 1990). Since 1989, areal extent of these beds has declined. In 2002, approximately 1.4 km^2 of canopy coverage was observed over the entire Fish and Wildlife Kelp Bed 14. Specifically in the PV IV kelp bed, 0.196 km^2 of kelp coverage was seen in 2003 at the initiation of the CRKSC program (MBC 2004a). By 2004, this area had 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 2). In the first quarterly survey on 20 April 2006, kelp coverage at PV IV kelp bed increased in size from that seen in the previous year, increasing to the largest aerial 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 6), as the total for the four kelp beds of the Palos Verdes Peninsula exceeded that of 2008. Responding to a favorable nutrient regime, the beds in this region increased still further in March 2009 to 2.122 km^2 of kelp canopy (Table 6). The beds were reduced by the September and December 2009 surveys and the 2010 March survey, but by the August survey the beds were increasing 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, but increased slightly during the October and December 2011 survey to 1.139 km^2, virtually the same as 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. The PV IV kelp bed was typically much larger than the average kelp bed in the region (Figure 48). It is apparent from the ABAPY graph that 2003 through 2005 were very reduced growth years for all of the beds in the region, particularly to this portion of the region; however, it is equally clear from the ABAPY that PV IV kelp bed responded with the ABAPY, though generally with a sharper upward or downward trend through 2012.

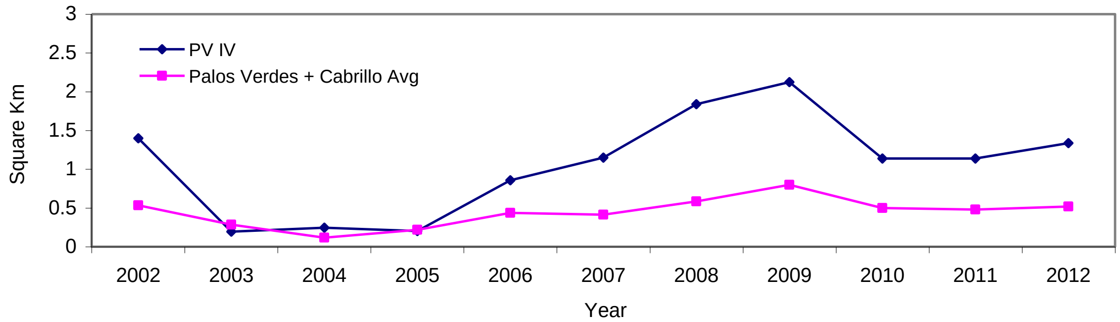


Figure 48. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV IV for the years shown.

Palos Verdes III 2012. 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 being that during periods of area-wide kelp canopy decline, 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 had increased considerably to 0.045 km^2, while in 2004 it remained similar in size at 0.040 km^2 (Table 2). The greatest areal extent in 2005 was 0.056 km^2, a 29% increase over the previous year. Canopy coverage increased even more by the December 2006 survey, especially within Lunada Bay, reaching 0.135 km^2 in surface coverage. However, the June 2007 survey total of 0.074 km^2 was the largest extent of the bed for the year indicating that localized conditions were not as favorable in 2007 for this section of the coastline. In 2008, conditions were highly favorable; the kelp bed in this section 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 III, the canopy coverage at PV II increased to 0.624 km^2 indicating varying oceanographic regimes over a relatively short distance. This was a total kelp coverage area greater than any since 1989; however, as mentioned previously, it was probably larger than this from 1990 through 1991, as the total kelp bed area of PV III kelp had 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 by the equally large October and December 2011 surveys. 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. This bed has typically been well below the ABAPY, but atypically in 2010, the kelp bed outperformed the ABAPY. It has, however, generally responded to the same stimuli as observed in the ABAPY in 2011 and 2012 (Figure 49).

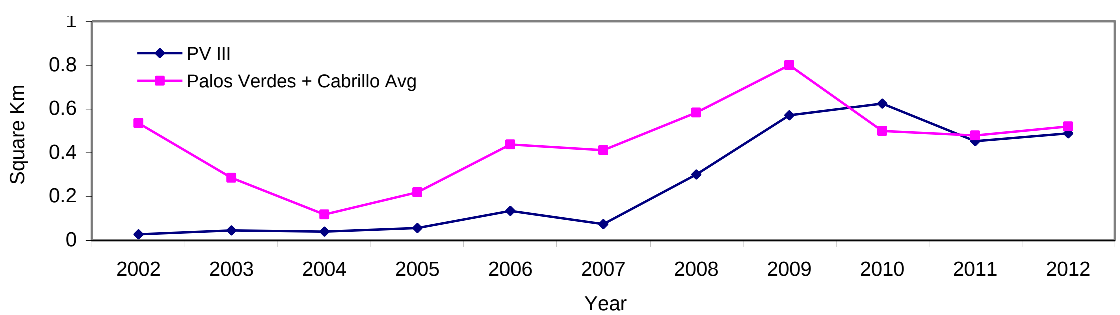


Figure 49. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV III for the years shown.

Palos Verdes II 2012. Palos Verdes II (PV II) kelp bed includes the offshore kelp from Point Vicente to Inspiration Point and is one of the two beds included in Fish and Wildlife Kelp Bed 13. Historically Fish and Wildlife Kelp Bed 13 contained considerably less kelp than in Fish and Wildlife Kelp Bed 14. Areal coverage of these beds 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 in the 2006 December survey, totaling 0.082 km^2. Unlike the other two beds in the Palos Verdes Peninsula, these beds decreased to 0.034 km^2 by the June 2007 survey and remained smaller during the subsequent two aerial surveys in 2007. Like PV III and PV IV kelp beds, Palos Verdes II increased in 2008 to 0.108 km^2 and 0.163 km^2 by June 2009. Responding like PV III, PV II was also larger in August 2010, reaching a total of 0.222 km^2 and bucking the trend it was larger still through the December 2011 surveys totaling 0.238 km^2. The bed increased even larger through every survey of 2012 culminating in a total coverage of 0.295 km^2 by December 2012, the largest total of any CRKSC survey. This was greater than seen since 1989, although with the caveat that the beds were probably larger from 1989 to 1991, based on the total for the four bed areas (Table 11). PV II kelp bed was also much smaller than the ABAPY, and any response to stimuli appeared to be muted in this region, although the bed has responded usually in step with the ABAPY (Figure 50).

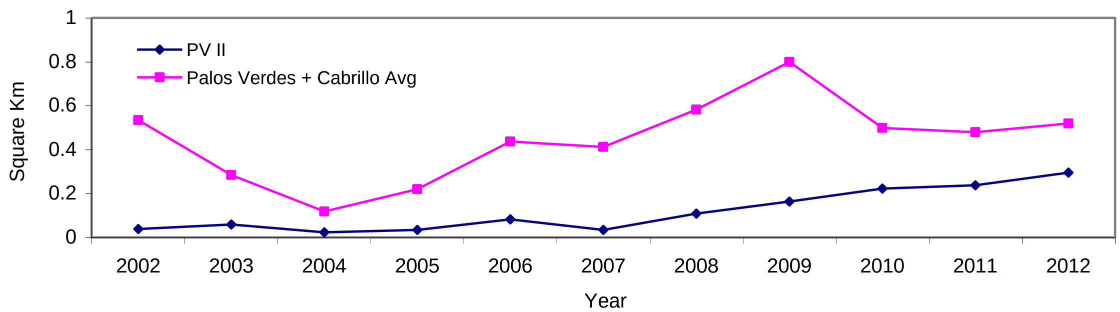


Figure 50. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV II for the years shown.

Palos Verdes I 2012. 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, thus slightly exaggerating the size of PV I kelp bed in those years and decreasing the 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, the recalculated total of these two beds included all canopy west of Point Fermin as PV I kelp bed and all canopy east of the point was included as Cabrillo kelp bed. New 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. However, by the December 2006 survey, canopy coverage increased dramatically to 0.951 km^2 along the entire length of the PV I kelp bed. Despite this increase and the advent of the La Niña, kelp in this region 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, covering 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 for this region since 2004. Although much smaller by the April 2011 survey, it increased by the August 2011 survey and stayed larger (0.465 km^2) than observed in 2010 through the December 2011 survey. It also responded unfavorably to the nutrient regime and atypically decreased (0.384 km^2) after the April 2012 survey through the remainder of the year. PV I kelp bed was considerably larger than the ABAPY for most years, but was nearly identical to it in 2008; it has reacted synoptically with the ABAPY since 2008 (Figure 51).

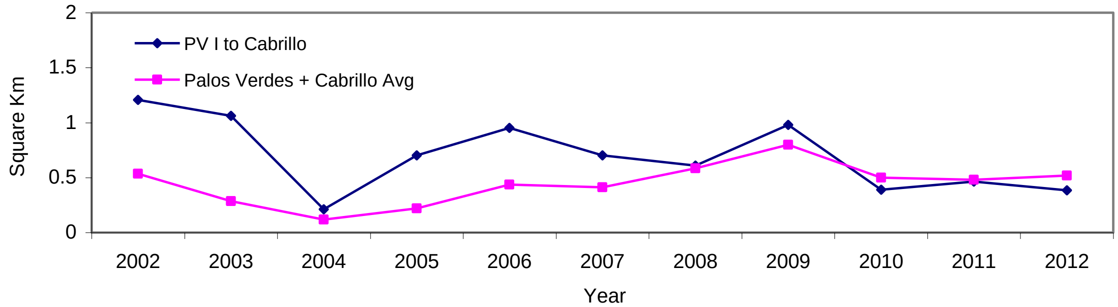


Figure 51. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off PV I for the years shown.

Cabrillo 2012. The Cabrillo kelp bed includes the area east of Point Fermin up to and including the groin extending from the beginning of the Port of Los Angeles breakwater. While Fish and Wildlife Kelp Bed 13 includes the area up to San Pedro breakwater lighthouse, it is unclear whether or not Cabrillo kelp bed has been historically included since it is east of Point Fermin, which has been 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). Cabrillo has consistently maintained a dense kelp bed since 1989, although Cabrillo kelp canopy declined markedly during the 1998 El Niño. As mentioned in the discussion of Palos Verdes 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 are 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 more than 40% 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. With the advent of the La Niña in 2007, kelp in this region responded atypically by decreasing in area to 0.100 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 (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 began to increase in areal extent by November resulting in a coverage of 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 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, we elected to use the April data for the Cabrillo kelp bed total coverage (0.095 km^2). The bed was small, but with the exception of a downward decline in opposition to the ABAPY in 2008 and 2012, it mirrored the ABAPY (Figure 52).

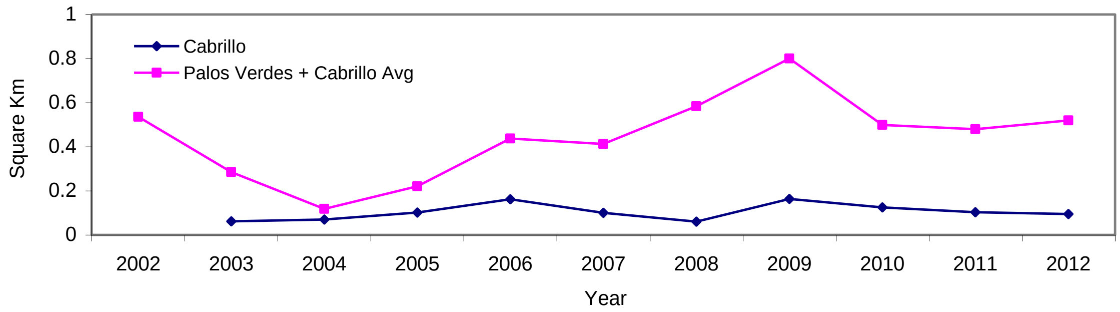


Figure 52. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off Cabrillo for the years shown.

POLA-POLB Breakwaters 2012. 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 harbor. This kelp was not adequately considered in previous CRKSC reports before 2005, but is now being measured on a yearly basis. 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 seen in the photographs, that 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 ground-truthed to determine whether the algae in the infrared photographs may have been feather boa kelp (*Egregia menziesii*) or *Sargassum* sp in addition to *Macrocystis pyrifera*. However, a shipboard visual inspection of the growth along the breakwater and within the confines of the harbors confirmed that the major portion was giant kelp (*M. pyrifera*). The more inclusive survey of the port complex in 2006 indicated that 0.494 km^2 of giant kelp was found on the inner and outer breakwaters of Los Angeles and Long Beach Harbors (Table 2). The beds decreased in 2007 to 0.118 km^2, but increased again in 2008 to 0.213 km^2. In 2009 during the minor El Niño, the beds decreased to 0.151 km^2, but the beds increased to 2012 with 0.495 km^2 (the highest since monitoring commenced). The giant kelp in the Ports of Long Beach and Los Angeles ABAPY appeared to be mirroring the Palos Verdes kelp beds through 2008, but were in opposition to the ABAPY with an upward trend through 2011 and trending upward steeper than the ABAPY through 2012 (Figure 53).

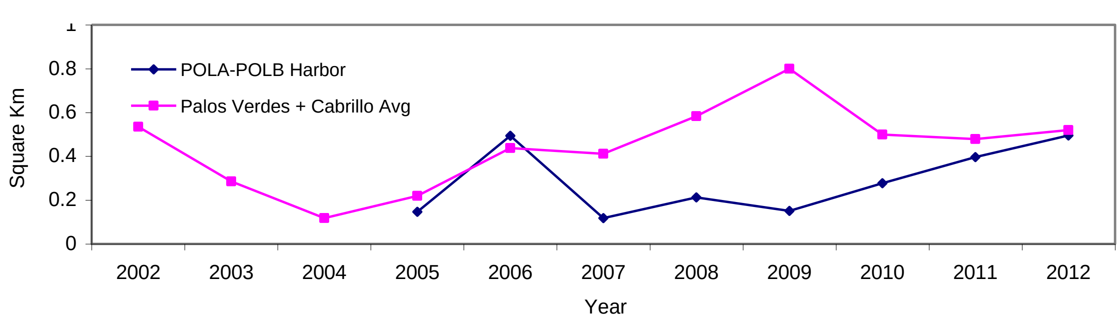


Figure 53. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp bed off POLA-POLB Harbor for the years shown.

CRKSC SOUTH (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, that existed prior to 1950.

Horseshoe Kelp 2012. Horseshoe kelp was located offshore of San Pedro Harbor at the 11-fathom curve at depths ranging from 18 to 25 m. It was not noted 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 size 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 dredge material, including an island in Los Angeles Harbor, was placed on the banks in this area covering 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 probably are responsible for the loss. It is possible that during periods of especially good water clarity and nutrient availability, kelp will again recruit to the area. However, continued ship traffic and inadequate water quality/clarity conditions persist. 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. No aerial surveys in 2012 or in surveys covering the preceding five decades have recorded the presence of giant kelp at the Horseshoe kelp fishing location (North 1968; Bedford, CDF&G 2004 pers. comm.; MBC 1994–2003, 2004a,b–2011a,b). Whatever the mechanism responsible for the loss of the kelp beds in this location, it remains that no giant kelp has formed a canopy there since the 1950s, indicating an inability for giant kelp beds to reestablish at that location.

Huntington Flats 2012. 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 200 yards 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 region. A Fish and Wildlife Commissioner, an avid sport fisher, told North about the location of a kelp bed that used to exist 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 with approximately 0.3 m of relief above the surrounding sand. Visibility on the reef was less than 1 m, resulting from the resuspension 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 in starting a kelp bed restoration project in the Huntington Flats area. They collected tires, filled them with concrete, and 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 ended 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 2012. A small bed formed offshore of Huntington Harbor in 1989 on the rocky riprap of the remains of Oil Island Esther, that was destroyed during storms in the 1980s. The kelp was present for approximately one year, but has not been seen since. No kelp is found from Huntington Flats to Newport Harbor, which includes the area offshore of the Huntington Beach Generating Station and Orange County Sanitation District outfalls. 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 found in high densities. Kelp is usually found growing along the inside of the northwest breakwater in Newport Harbor, and narrow bands of kelp were observed in the 2012 quarterly surveys. Kelp at Huntington Flats has not been noted in any of the CRKSC surveys through 2012.

Newport/Irvine Coast - Corona del Mar to Crystal Cove 2012 Giant kelp in this region consisted of a number of small beds (collectively called the Newport/Irvine Coast kelp bed) covering 0.755 km^2 of the nearshore coastline 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 1982–1984, 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 operations began in 2000 at sites located at Corona del Mar near Arch Rock 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 it indicated that purple urchins were still prevalent in the area, 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 had canopy during any of the aerial surveys of 2005, but the Newport/Irvine Coast kelp bed was the largest bed in Orange County in 2006 (0.023 km^2) including all the kelp beds south to La Jolla. By 2007, it had grown substantially (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 either end of Crystal Cove offshore of the cottages with the beds near reef point at Scotchman's Cove also expanding; by the end of 2008, the total of all of the Newport/Irvine Coast kelp beds was (0.089 km^2), that 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, that was the largest amount recorded since 1979 when 0.200 km^2 was recorded in that location (North and MBC 2001). The 2011 aerial surveys indicated that the beds continued to expand as a result of a sustained La Niña. 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 3 of the 4 surveys in 2012, the beds were slightly larger during the April survey at 0.395 km^2 that was a slight decrease from 2011. This indicates that as a result of kelp restoration efforts from 1986 through 2009, the beds of this region have recovered from their total extirpation in the early 1980s (MBC 2010c). The ABAPY indicates this bed followed the 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 (result of restoration efforts) until about 1989, was lost again, and returned (again as the result of further restoration efforts) in 2003 and has roughly followed the ABAPY since (figure 54).

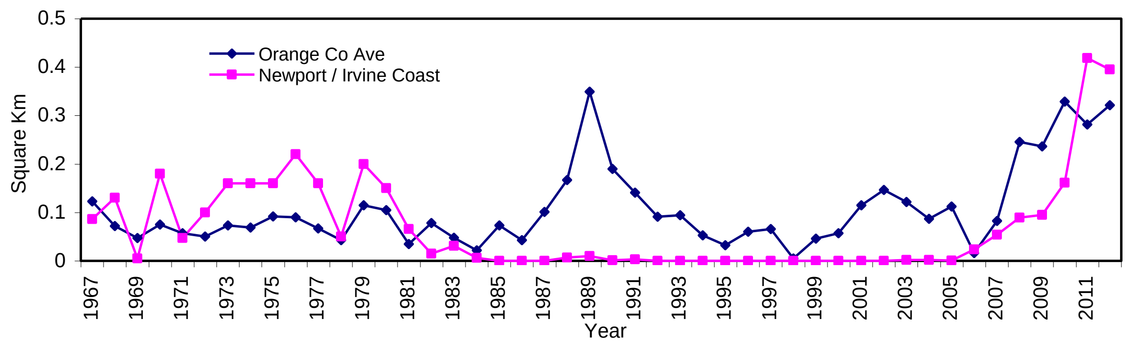


Figure 54. Comparisons between the average Orange County ABAPY and the canopy coverages of the kelp bed off the Newport/Irvine Coast for the years shown.

REGION NINE KELP SURVEYS

FISH AND WILDLIFE KELP BED 10 (Newport Beach to Abalone Point, Laguna Beach)
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 as there can be distinct differences between the beds of Orange and San Diego counties based on localized upwelling and oceanographic exposure. Therefore, the area of each individual bed since 1967 has been compared over time which shows RNKSC kelp canopy coverage over the past six years has been well above average (6.722 km^2) for the region (Figure 55). 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)

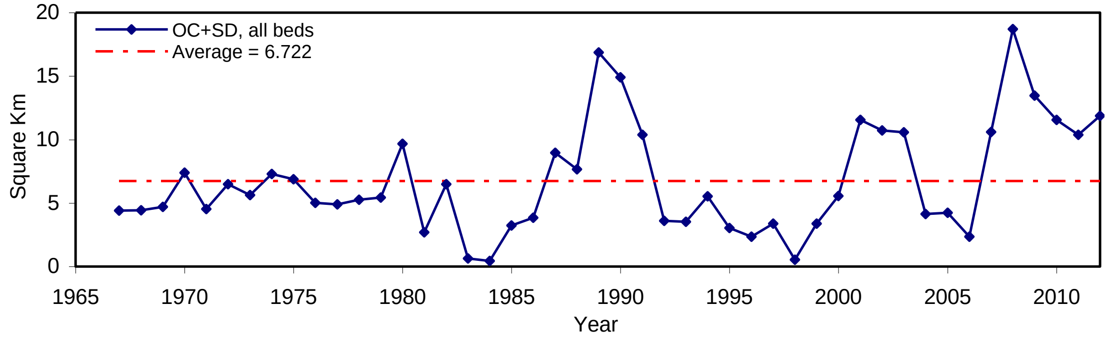


Figure 55. Combined canopy coverages of all kelp beds in Orange and San Diego Counties.

and Point Loma (PL) as they tend to skew the data (Figure 56). As can be seen in Figure 55, strong upwelling events, such as those associated with La Niña, and warming events such as El Niño, cause sharp upward and downward trends across the region's kelp beds. Comparison of the individual beds to each sub-region further refines the ability to identify underperforming beds and determine possible reasons for the anomalous results. It is important to conduct these comparisons as 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 and effect relations underperforming beds and determine possible reasons for the anomalous results. It is important to conduct these comparisons as 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 and effect relations.

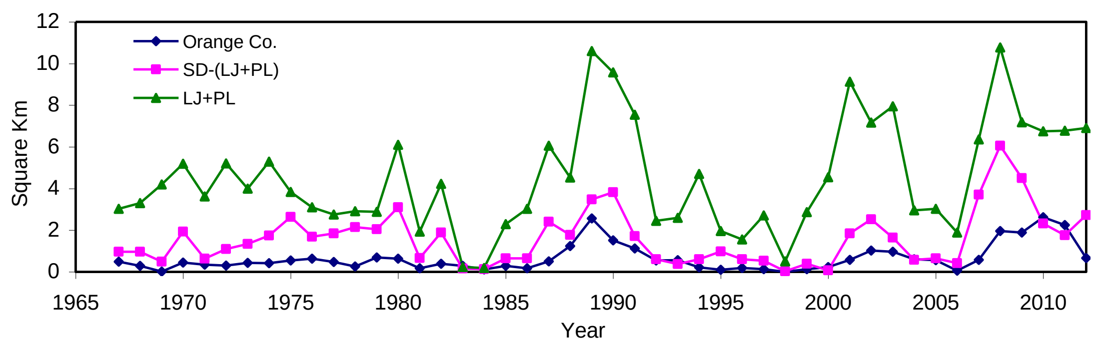


Figure 56. Diagram showings components of the Total Area graph partitioned into the kelp beds of: Orange County; San Diego County less La Jolla and Point Loma ((SD-(LJ+PL)); La Jolla plus Point Loma (LJ+PL).

FISH AND WILDLIFE KELP BED 9 (North Laguna Beach to Capistrano Beach)

North Laguna Beach/South Laguna Beach 2012. 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, apparently there was only a trace of kelp in the area of North and South Laguna Beach, as Crandall 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 were recorded at 0.680 km^2. Thereafter they stayed relatively small and by 1967, they were listed as very small beds totaling only 0.005 km^2 for both. By 1976 the beds again began to increase in size and stayed substantial until peaking in 1989 at 0.319 km^2 (Table 3). The beds persisted for a few years, becoming smaller with North Laguna Beach disappearing in 1991, while the larger bed at South Laguna Beach lasted until 1993. Giant kelp disappeared from North Laguna Beach in 1991 due to several small El Niños, coupled with 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 as a prelude 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 observed 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 (increasing to about one-third of the density seen in early 2005) of various sizes were found throughout the restoration area. These giant 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 survey of 2008. The kelp beds continued to increase in 2009 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. As these beds had disappeared after the 1989 maximum of 0.187 km^2 was reached, the calculation of a coverage of 0.191 km^2 in December 2010 indicated that these beds had fully recovered as the result of thousands of hours of restoration efforts over an eight-year period (MBC 2010c). The Laguna Beach kelp beds continued to increase in 2011 to 0.368 km^2, a long-term record that would be broken by the early-April 2012 aerial survey that indicated that the Laguna Beach kelp beds were larger (0.406 km^2) than at any time in the continuous 46-year record, but not as large as the canopy coverage in 1955 of 0.680 km^2 (Table 3). The ABAPY for the two Laguna Beach bed areas also followed the fortunes of the other beds in the region, surviving the El Niño of 1982–1984, until about 1994 when they too were extirpated from the region. 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 upward spike of the ABAPY (Figure 57).

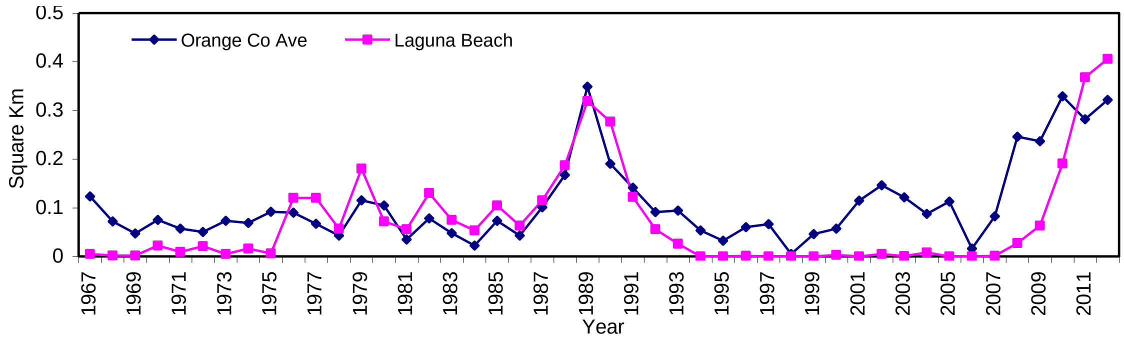


Figure 57. Comparisons between the average Orange County ABAPY with the history of Laguna Beach kelp (i.e., the sums of canopy coverages for North Laguna Beach plus South Laguna Beach kelp) for the years shown.

South Laguna 2012. Giant kelp was not recorded at this location in Crandall's 1911 survey. A record from 1955 suggests that as much as 2.02 km^2 of kelp coverage was present at Salt Creek-Dana Point and spilling into the South Laguna region. Based on that assessment, it was likely the bed was near 0.100 km^2 (twice what has been recorded for this bed). 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 then was gone until 2000. It persisted for the next several years and the various kelp beds were visible in the region in early 2005, but 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 was not seen during subsequent aerial surveys and no kelp was seen anywhere in the region in spite of numerous fathometer searches throughout 2006. Small kelp beds were seen at the south end of South Laguna in early 2007 that became much larger by the end of 2007. Several boat surveys in early 2008 documented a continuous strip of adult giant kelp in 12- to 15-m depths extending from Salt Creek north about 0.5 km, stopping well before Aliso Creek. By the end of 2008, the bed canopy measured 0.023 km^2 (Table 2). However, by March 2009, the bed canopy decreased to 0.017 km^2 and decreased thereafter until December when it again began to increase. 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 again to a similar coverage observed in 2008 of 0.023 km^2. A dive survey of the site on 28 December 2011 observed a very large canopy for the area. Visibility was approaching 5 m and kelp holdfasts on the bottom appeared healthy. Drift algae appeared sufficient on bottom for the minor amount 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 had been 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. The ABAPY indicated that the bed responded to relatively large stimuli such as the 1989–1990 La Niña and responded to the increase in the Orange County average noted from 2007 to 2010, and to the decrease in 2011 (Figure 58). While the ABAPY was slightly positive in 2012, the kelp bed marginally retreated (Figure 58).

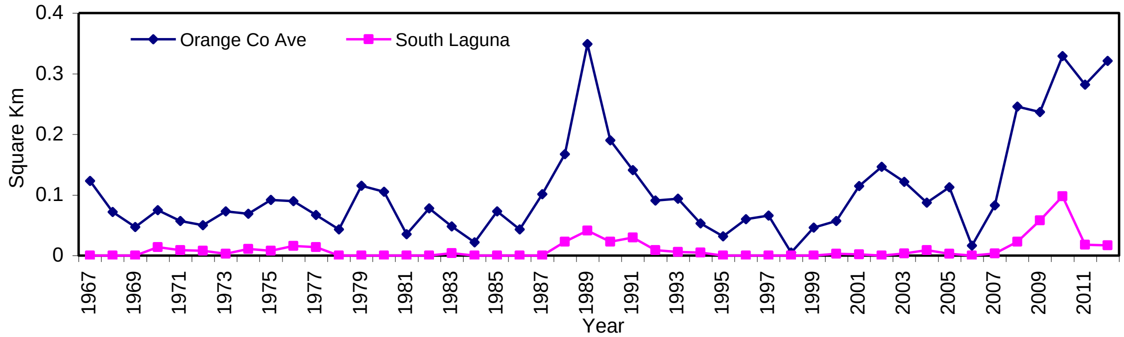


Figure 58. Comparisons between the average Orange County ABAPY and the canopy coverages of the kelp bed off South Laguna for the years shown.

Salt Creek-Dana Point 2012. Kelp beds in the Salt Creek-Dana Point area were large in Crandall's 1911 survey, totaling 1.170 km^2 (Table 3). It appears that they were even larger in 1955, when a survey covering the Salt Creek-Dana Point 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 0.900 km^2 in 1989. Coverage was about 0.2 to 0.5 km^2 through 1993, but was much smaller through 1999. These beds had been in a continuing decline since the La Niña of 1989, but made a good recovery in 1999 due to the La Niña, that continued through 2002. Kelp canopy was extensive and on the surface from depths of 11 m extending out to 20 m by the end of 2002, and covering an area of 0.432 km^2, then again became smaller and disappeared in 2006. By January 2006, boat surveys 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, diving and boat surveys indicated a few kelp were on the surface in late-June and divers reported seeing a few adults and more small juvenile and sub-adults present on bottom in a mid-July survey. Kelp beds in the Salt Creek-Dana Point area were not visible in the March 2007 aerial survey, but were found during dive surveys in March and May on bottom where good recruitment of juveniles and sub-adults was recorded. During the June 2007 overflight, canopy had formed and was becoming extensive. By late December 2007 a canopy totaling 0.302 km^2 had formed. The bed responded favorably in 2008, and by mid-year canopy was extensive, but became smaller over the summer and re-emerged in the late fall as a thick canopy totaling 1.068 km^2 in area (almost matching the bed size Crandall reported from 1911) during the December overflight of 2008. 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, with further reductions as the year progressed, and a slight recovery by the 17 December survey. Dive surveys in March and June 2009 continued to record 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 a large area but reduced to 0.442 km^2) having lost kelp on the outside deeper and inshore shallower portions of the bed. A dive in the area indicated there were many floating holdfasts, possibly the results 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. As can be seen in the ABAPY for the Salt Creek-Dana Point kelp beds, this bed followed the ABAPY rather closely, although typically well above the average (Figure 59).

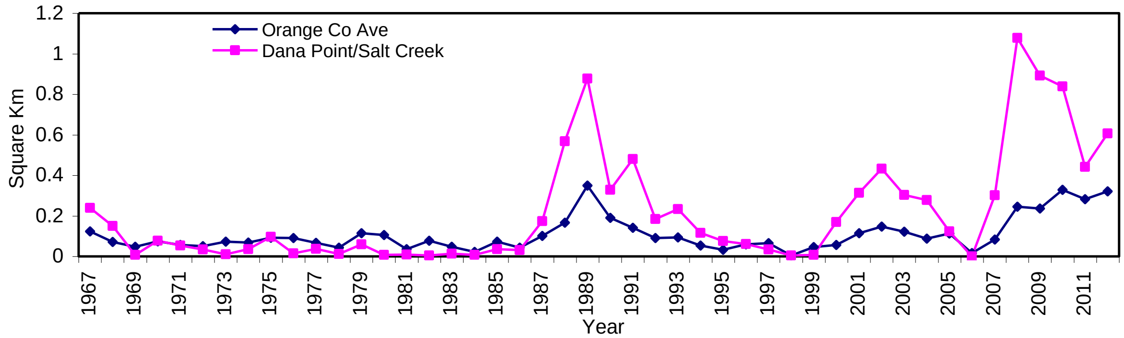


Figure 59. Comparisons between the average Orange County ABAPY and the canopy coverages at the Dana Point/Salt Creek kelp bed for the years shown.

Capistrano Beach 2012. The baseline for this stretch of the coastline is Crandall's map of 1911 showing canopy coverage of 1.578 km^2. This total included a very large bed offshore of Doheny Beach covering 0.755 km^2, 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. The beds at Capistrano Beach were small in 1967, the bed at Doheny had disappeared with the construction of Dana Point Harbor, and kelp in the area only covered 0.08 km^2. The bed stayed small or was missing until 1989, when the beds increased in canopy size to 0.233 km^2. The beds were large until 1993, became either very small or non-existent through 2001, and then in 2002 they reached 0.118 km^2. The beds shrunk once again and stayed small through 2008. In 2009, however, kelp was classified as very good and increased greatly by June 2009 to 0.071 km^2, but still much lower than observed in the 1989 to 1992 period 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 may have been below the surface as the boat survey conducted one week later appeared to indicate there were more dense canopies in the region than appeared on the aerial photos. Better conditions by December 2012 resulted in increases to the canopy coverage and the bed totaled 0.056 km^2. The ABAPY for Capistrano Beach shows that this bed and the San Clemente beds respond typically to stimuli such as the El Niño and La Niña (Figure 60).

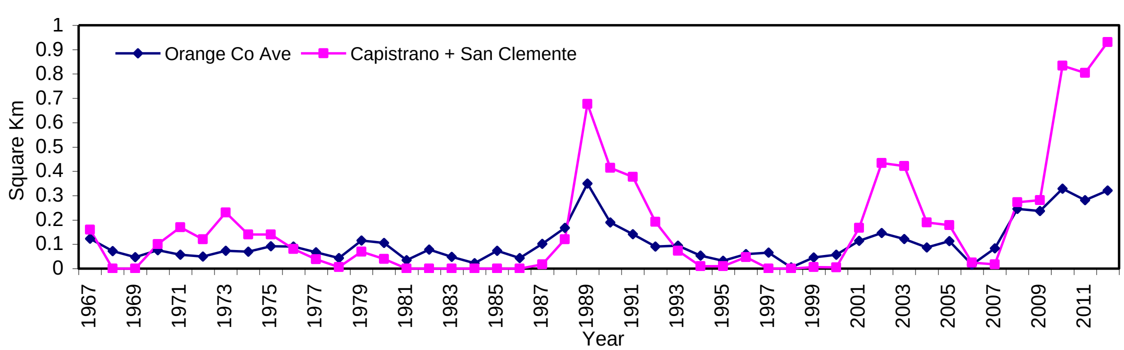


Figure 60. Comparisons between the average Orange County ABAPY and the canopy

coverages at the Capistrano Beach plus San Clemente kelp beds for the years shown.

San Clemente 2012. In 1911, Crandall recorded the beds as covering an area of 0.206 km^2. The beds at San Clemente were very large in 1955 considering that the total for San Clemente, San Mateo Point, and San Onofre covered 6.3 km^2 that was more than twice as large as Crandall reported (1912), were still larger than Crandall reported in 1959, but were small by 1967, covering only 0.08 km^2, and stayed small or were missing until 1988. From 1989 through 1991, they were larger than Crandall reported, then began a major decline through 2001. Kelp disappeared with the advent of the 1997–98 El Niño, but responded to stimuli to reach a canopy coverage of 0.124 km^2 in 2001 and then to 0.352 km^2 in 2003. Scattered giant kelp was noted throughout the region, but the largest change was the placement of approximately 50 small artificial reefs measuring 40 by 40 m each offshore of San Clemente in 2002 on barren sand at depths of about 12 to 15 m. Kelp immediately recruited to these reefs and soon had canopies in the shape of small squares visible during most of the aerial surveys of 2002 and 2003. They 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 or about 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, as noted during boat surveys, the artificial reefs in the area still had kelp subsurface, 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 aerial photos from the December 2006 survey, but the kelp beds stayed small in 2007. In 2008, stimuli early and late in the year produced a canopy totaling 0.203 km^2. In early 2008, Southern California Edison (SCE) added additional reef material (covering 152 acres=0.615 km^2 in total) and kelp was reported as recruiting 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 when 0.210 km^2 of kelp canopy was recorded. Kelp was beginning to be visible at the new SCE reefs, but much of the kelp was still subsurface by the end of 2009 (Table 2). 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 recorded 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 boat 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, then rebounded in December to 0.874 km^2. This bed probably benefits from its proximity to San Mateo Point and its localized upwelling. The ABAPY for the San Clemente bed shows that this bed and the Capistrano Beach bed respond typically to stimuli such as the El Niño and La Niña (Figure 60).

San Mateo Point 2012. San Mateo kelp bed was large in 1911 when Crandall reported it as covering 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 again became 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. After that period it began a slow decline, becoming precipitous by 1994. 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. San Mateo kelp bed decreased greatly in 2004 to one-half of its 2003 size (0.242 km^2), but kelp appeared robust through the March 2005 survey. Kelp subsequently decreased and disappeared during the remainder of 2006. As observed during boat surveys, small beds were 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 barrens), but the beds began to increase and dive surveys in the area in April and May reported abundant kelp on bottom (Moore 2007, pers. comm.). The canopy coverage totaled 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 totaling 0.487 km^2 by the December 2008 survey, larger than it had been since 1989. Although 2009 appeared to be limited in nutrients, kelp none-the-less increased by the March 2009 survey to 0.545 km^2, but decreased somewhat during the next two surveys and made a recovery by December. 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 noted (North and Jones 1991), the bathymetry below the hole is a rocky cobble and boulder reef area that is elevated above the surrounding reef. North thought that the area preferentially recruits sea urchin larvae 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 along the kelp bed 1 to 2 m wide 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 boat survey of 2011, the aerial survey recorded a canopy (0.203 km^2) far less than one half that observed the previous year. The kelp bed remained large in April, all but disappeared by October, but rebounded in December 2011 to cover an area of 0.216 km^2. The ABAPY for the San Mateo kelp bed showed that the bed responds typically to stimuli such as the El Niño and La Niña by following the Orange County average relatively close (Figure 61).

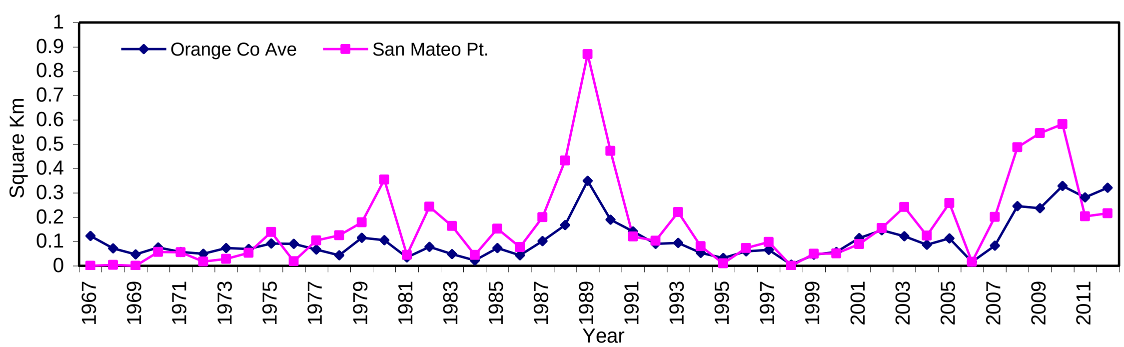


Figure 61. Comparisons between the average Orange County ABAPY and the canopy coverages of the San Mateo Point kelp bed for the years shown.

San Onofre 2012. The kelp beds at San Onofre were large in 1911 when Crandall reported them as covering 1.029 km^2. Based on a total for two beds near San Onofre and another (missing since at least 1959) to the south downcoast about 3 km near Pendleton Artificial Reef (PAR), it was likely the beds remained fairly large during surveys of 1955 and 1959, but were missing from 1967 to 1971, only to reappear 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, became much smaller and then increased in 1980 to 0.160 km^2 and again increased greatly from 1988 to 1990 culminating in a total canopy size of 0.763 km^2 in 1990.

The beds waxed and waned during the next decade and a half, seldom getting larger than 0.100 km^2. In 2002, the beds were about 0.162 km^2, but by 2003 it was apparent that the beds had decreased by about 33%, and still further by 2004, mostly due to the disappearance of the inshore bed and scattered beds north of the diffusers. Kelp canopies appeared very good 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. They were, however, the only beds in the nearby region that persisted into January 2006. No surface canopy was present during the remainder of 2006 through March 2007. A boat survey indicated that small canopies were present and kelp was reported on bottom indicating recent recruitment; the beds became fairly robust by the end of December 2007 and totaled 0.320 km^2 in canopy coverage.

The aerial surveys of 2008 indicated that kelp beds stayed relatively similar in size in the spring, waned in the summer, and recovered well in the fall and winter, resulting in the canopy increasing in size to 0.476 km^2, the best in almost two decades (1990). As 2009 began, the kelp beds appeared very good during the March aerial survey, but canopy coverage decreased to a still robust 0.419 km^2; however, kelp coverage decreased during the two subsequent aerial surveys, and then made a small recovery by December. The recovery continued through 2010 resulting in a robust canopy covering 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, it decreased to 0.127 km^2. In 2012, San Onofre kelp was absent in the June and October survey, but again rebounded and a small canopy was present in a few areas covering 0.191 km^2. Because of their location in a similar geographically area, San Mateo kelp has been used in several scientific papers as a control station for San Onofre kelp. It is of interest to demonstrate that the San Onofre and San Mateo beds react very similar to stimuli as depicted in Figure 62. The ABAPY for the San Onofre kelp bed shows that this bed responds typically to stimuli such as the El Niño and La Niña following the San Diego County average relatively close (Figure 63).

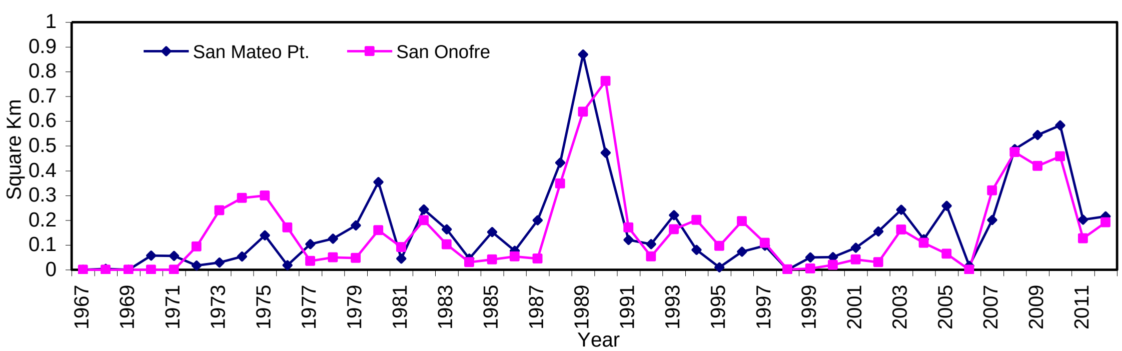


Figure 62. Comparison of histories of canopy coverages for the kelp beds off San Mateo Point and San Onofre. Operations at Unit 2 of the San Onofre Generating Station (SONGS) commenced in 1983. SONGS Unit 3 became operational in 1984.

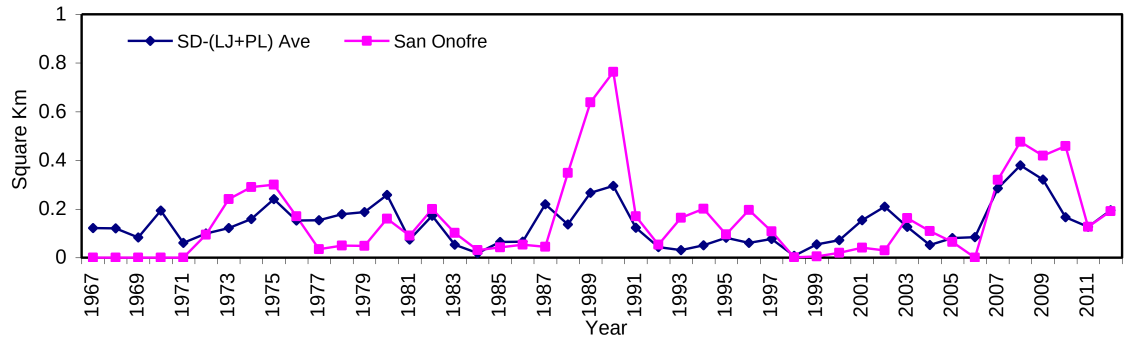


Figure 63. Comparisons between the average SD-(LJ+PL) ABAPY and the canopy coverages of the San Onofre kelp bed for the years shown.

Horno Canyon 2012. Kelp in this region appeared as a small bed to the north of Barn kelp in Crandall's 1911 survey, recording a canopy coverage of 0.172 km^2. Kelp was not recorded here again until 1988 as a very small bed of 0.006 km^2, and it became as large as 0.040 km^2 before disappearing again in 1992. After an absence of another seven years, a small kelp canopy formed here in 2000. As conditions at Barn kelp were excellent from late 2000 through 2002, its proximity probably enhanced opportunities for kelp at this location and the few giant kelp found scattered in the area in 2002 had increased in density by 2003, 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 the early aerial surveys of 2007. During the December 2007 survey, small canopies formed and were covering an area of 0.015 km^2. A few giant kelp were also seen at PAR during a boat survey in December 2007. Kelp canopies in this region appeared larger in 2008 than ever recorded and canopy 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 and decreased further throughout the remainder of 2009. As it had been a long time since any diving surveys had been conducted at PAR, a diving survey was conducted in January 2010. Large numbers of sea fans and urchins, but only two ragged and grazed kelp recruits, were found growing on isolated rocks in the area. Small kelp beds comprising the Horno Canyon kelp bed appeared numerous 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 surveys or boat surveys through the area in 2010 nor was kelp observed in the aerial or boat surveys of 2011 in either location. Horno Canyon in 2012 was again comprised of scattered kelp covering a large area, but only amounting to 0.008 km^2 of kelp coverage. The 2012 ABAPY for the Horno Canyon kelp beds indicated that these small beds are only viable during very large stimuli such as the La Niñas of 1989–1990, 2001, 2007–2008, and again in 2010–2012 (Figure 64).

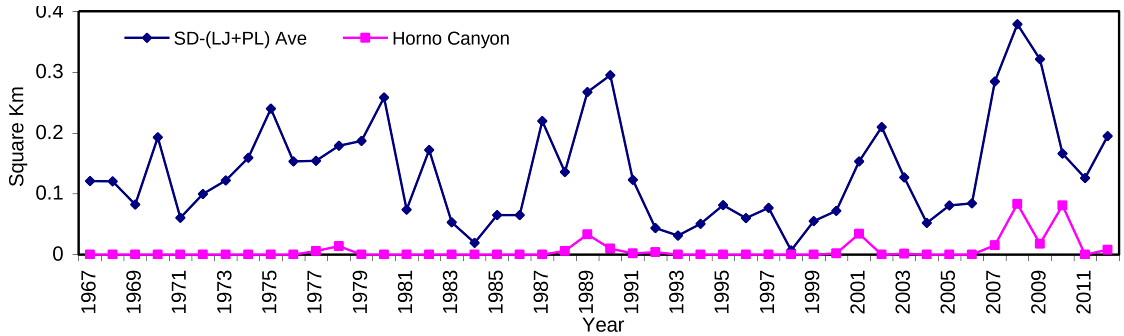


Figure 64. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Horno Canyon kelp bed for the years shown.

Barn Kelp 2012. Barn kelp bed was very large 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 it was composed of small scattered beds totaling about 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 then again became much smaller and disappeared in 1981, not reappearing until a small bed was observed 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, to 1998, the bed vacillated in size between zero and 0.260 km^2. In 1999, the bed reappeared and covered 0.310 km^2 and increased in size in 2000 (the La Niña of 1999–2000 apparently provided a similar stimulus to kelp growth), and was considerably larger during the overflights of 2001 and in 2002 and covered an area of 0.667 km^2, thereby becoming the largest it had been 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 (covering an area of 0.466 km^2) of its size last seen in 2003. This coverage was maintained in 2008, decreasing some in summer, but by the December 2008 aerial survey, Barn kelp had increased greatly in size covering an area of 0.858 km^2 (larger than it had been since the 1955 survey), 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 again increased as evidenced by the larger beds seen with each succeeding aerial survey in 2010; however, the loss of kelp in the last half of 2009 resulted in a bed that was smaller in 2010, but none-the-less it was still a substantial kelp bed of 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. The ABAPY indicated that this bed, other than for a severe downturn from 1980 to 1987, typically reacted similarly to the other beds in the San Diego region, including in 2012 (Figure 65).

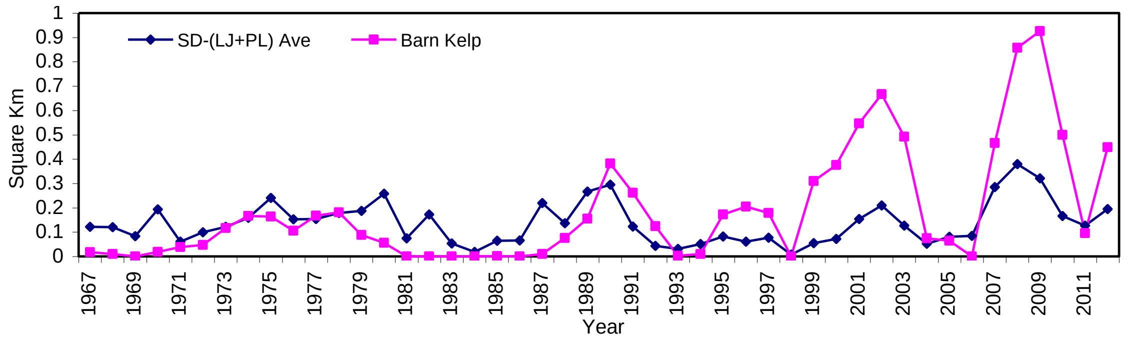


Figure 65. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of Barn Kelp for the years shown.

Santa Margarita 2012. In 1911, Santa Margarita was the site of a substantial kelp bed covering 0.858 km^2; only a remnant of this formerly large bed has been seen since. Kelp disappeared here sometime before regular surveys began in 1967 by Dr. North. No kelp was seen during any of the boat or aerial surveys until 1991, when a small bed appeared covering an area of 0.049 km^2; it was much smaller in 1992, and has not been seen since despite searching the area of the last known kelp beds. No kelp was observed at this location in 2012 despite careful viewing of the photos and efforts to find kelp during a 17 January 2013 boat survey.

North Carlsbad 2012. The small kelp beds that comprised North Carlsbad kelp bed were observed to be substantial covering 0.480 km^2 during Crandall's 1911 survey. Based on the total for the area covering North Carlsbad and the five beds north of it, it was probably about one-half that size in 1955 and 1959, but was much reduced by 1963. The beds increased to 0.120 km^2 by 1980, and became larger with a canopy size of 0.165 km^2 by 1990. The interim between these two periods saw a wide variation of kelp bed sizes from 0 to about 0.100 km^2. After 1990, the kelp bed again became smaller and disappeared during the last few years of the century. All canopy had disappeared from this site due to the El Niño of 1997–1998, but a sparse canopy was again found during the boat survey of November 2001. The bed continued to expand and became denser in 2002 indicating that environmental conditions continued to be favorable through late 2002. A small but dense bed was seen in 2003 (totaling 0.053 km^2), but it soon began to thin and was much less dense by the March 2004 survey and was not visible again until the December survey of 2004. A small bed was seen in early 2005, but it stayed small and was not seen 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 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 the December 2007 survey depicted a newly expansive kelp bed larger than any seen 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 kelp canopy had increased to 0.135 km^2, but declined throughout the remainder of the year, with a robust resurgence by December 2009. This resurgence stalled by the November 2010 survey due to lack of nutrients, but an increase was observed with a canopy totaling 0.078 km^2 during the late December 2010 survey. 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 to 0.052 km^2. In 2012, the ABAPY for the North Carlsbad and Agua Hedionda kelp beds indicated that these beds tended to disappear or become very small during periods of intermediate-to-low nutrient availability, and react strongly to stimuli such as large La Niña events. It has followed the ABAPY fairly close, but has been out of sync during the last two years (Figure 66).

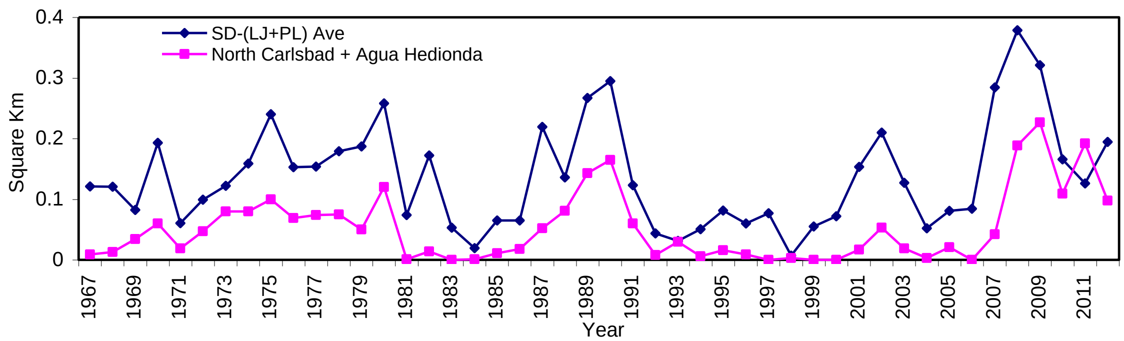


Figure 66. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the North Carlsbad plus Agua Hedionda kelp beds for the years shown.

Agua Hedionda 2012. 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 covering only 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 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 March aerial flight of 2005. The kelp bed actually increased in 2005 to a greater total surface canopy than seen since 1996, before surface canopy disappeared in 2006. The kelp bed off Agua Hedionda was not observed during 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 the area was poised to recover pending adequate nutrients and favorable environmental conditions. No kelp was observed in the region during any of the first three aerial surveys of 2007, but a relatively large bed (0.016 km^2) appeared in December 2007 larger than had been seen since 1991. The sudden appearance of the bed was indicative that the kelp was surviving below the thermocline (reinforced by the youthful appearance of the fronds during a boat survey in late 2007), taking advantage of good nutrient conditions. Kelp canopy at Agua Hedionda was smaller during the first three aerial surveys of 2008, but was apparently doing well below the thermocline. When cool waters returned in late fall, the kelp bed increased greatly in size with a 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 by December 2009. The large loss of canopy observed during the mid-to-latter part of 2009 reversed in 2010, but the canopy only measured 0.031 km^2 by the December 2010 aerial survey. No increase in kelp coverage and density occurred until the December 2011 survey when it covered 0.022 km^2. Kelp at this site was scattered and small during the first three aerial surveys in 2012, but there were two distinct patches of canopy measuring 0.046 km^2 observed during the aerial survey on 28 December and 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. The ABAPY in 2012 for the Agua Hedionda Kelp and North Carlsbad kelp beds indicated that these beds, other than a severe downturn from 1980 to 1986 and again from 1994 to 2000, reacted negatively to El Niño events, as did all the beds in the San Diego region. However, they did not recover (as most of the other beds did) from the downturns during relatively nutrient-neutral periods; not returning until the large stimuli of the La Niña events (Figure 66).

Encina Power Plant 2012. 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 lumped together in surveys in 1955 and 1959, the total area of which suggests this bed was probably substantial during the two survey years. A subsequent (lumping) 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 totaling 0.006 km^2 of canopy coverage. By 1975, it was much larger with surface canopy coverage totaling 0.144 km^2. It decreased in size until 1988, when favorable conditions produced canopies covering 0.161 km^2, increasing still further in 1989 to 0.251 km^2. After a few years the bed again decreased greatly in size and finally disappeared from 1997 to 2002. The Encina Power Plant bed in 2003 had increased in size while surrounding beds decreased. 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 Encina Power Plant for other required studies documented that the kelp bed increased from that noted in March 2005 (Weston 2005), indicative of the strong response the kelp bed can have to nutrient pulses. The loss of canopy by June 2005, caused apparently by a lack of nutrients as evidenced by Scripps SSTs, demonstrated how quickly the bed can deteriorate in their absence. Dive surveys conducted in the area offshore of Encina Power Plant in spring 2005 recorded much lower densities (about one-third less) of kelp on bottom as compared to that recorded in 2004 (Weston 2005).

The kelp canopies were not visible during any surveys of 2006. A boat cruise in late-July 2006 did not observe any surface canopy, but substantial numbers of sub-adult, juvenile, and recruiting kelp were noted on bottom indicating a recovery could take place in the late fall and winter with a return of favorable environmental conditions. A long, hot summer, with SSTs well above average, resulted in no kelp on the surface during either the September or December 2006 surveys. The bed was absent for the first three aerial surveys of 2007, but following favorable environmental conditions, the bed returned in December 2007 as a relatively large bed covering an area of 0.081 km^2. The Encina Power Plant kelp bed had scattered canopies during June 2008 and it was larger than observed in December 2007, becoming very large by the December 2008 survey when the bed covered an area of 0.306 km^2. By the March 2009 survey, the kelp canopies had dropped to 0.215 km^2 and became smaller throughout the remainder of 2009, disappearing entirely in September, but reappearing in December 2009 almost as large as noted in March suggesting nutrients were again available. The bed was large in August 2010 and only slightly larger in the December

2010 survey (0.176 km^2) and attained a large percentage (81%) of its 2009 size. The Encina Power Plant kelp bed was observed in three distinct patches in 2011 over a large area, but it too decreased to a coverage of 0.084 km^2. The bed had decreased considerably by the August survey, but began increasing during both the October and December surveys. It was relatively small throughout the first three surveys of 2012, but reacted to presence of nutrients in the last several months of the year to increase to a total of 0.216 km^2 of canopy coverage by December. In 2012, the ABAPY for the Encina Power Plant kelp bed indicated that this bed mirrored the other beds in the San Diego region generally reacting favorably or negatively with large stimuli such as the La Niña and El Niño and mirroring the ABAPY during the past several years (Figure 67).

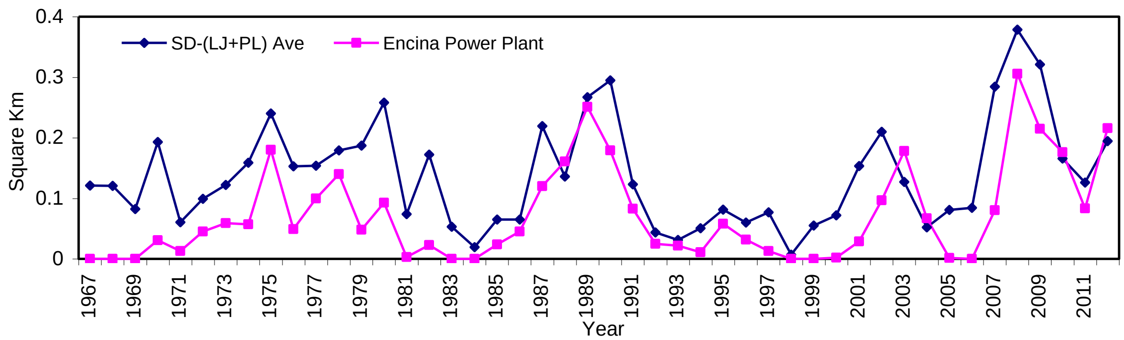


Figure 67. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Encina Power Plant kelp bed for the years shown.

Carlsbad State Beach 2012. This bed was comprised of many mid-size canopies during Crandall's survey of 1911, covering a total area of 0.499 km^2. It was part of a much larger bed that spanned the coastline from Carlsbad State Beach, southward past Leucadia, and ending at 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 began to decline by 1963 and most of the next decade. The bed was not recorded again until 1967 during an aerial survey by North (North and MBC 2001) when small canopies covering an area of only 0.032 km^2 were observed. The kelp bed increased by 1975 to 0.200 km^2, but was small thereafter until 1989 when it increased again to 0.251 km^2. After being absent since 1996, a trace of kelp was observed during the fall survey of 2000, and small canopies were noted during the last survey in December 2000. A sparse giant kelp bed was present in 2001, that 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 survey year. Only a trace of kelp was seen by the end of 2003, and again in 2004. The kelp bed was not observed in any of the aerial surveys of 2005–2006, but, it reappeared as small canopies (0.064 km^2) with young kelp fronds in late-2007. By the December 2008 survey, the kelp bed offshore of Carlsbad State Beach 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, waning throughout the remainder of the year with a large canopy showing by the December 2009 survey. That canopy was reduced by the March 2010 survey and became further reduced by the early-November survey, but rebounded by the late-December 2010 survey to an area of 0.069 km^2 of canopy coverage. In 2011, the kelp bed at Carlsbad State Beach lost canopy during the first three surveys, but increased again by the 21 December survey, but only to a canopy coverage of 0.024 km^2. During the vessel survey one week later, it was noted as scattered kelp with only one large patch of about 100 by 150 m in area. By late-2012, conditions improved and the kelp coverage increased to 0.058 km^2 by the December survey. In 2012, the ABAPY for the Carlsbad State Beach kelp bed indicated that this bed was similar 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, continued to react closely with the ABAPY throughout the last three decades (Figure 68).

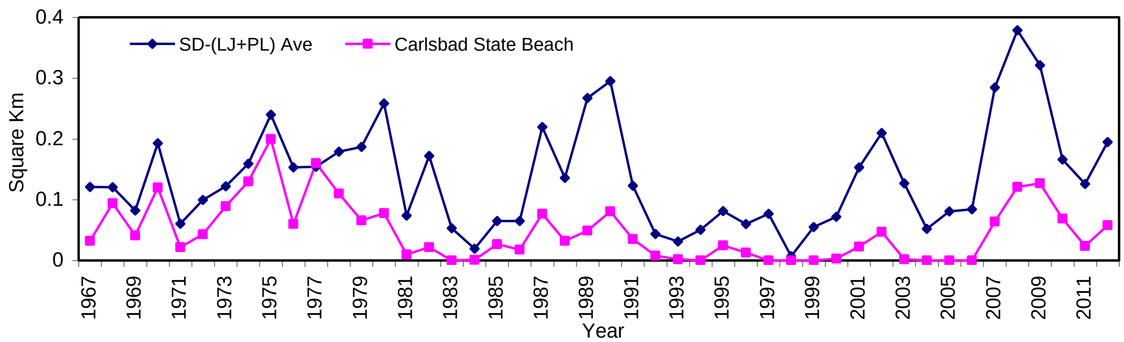


Figure 68. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Carlsbad State Beach kelp bed for the years shown.

Leucadia 2012. The Leucadia kelp beds referred to as the North, Central, and South Leucadia kelp beds because of distinct breaks in the sections covered an estimated area of 1.996 km^2 during Crandall's survey of 1911. It was a portion of a much larger bed that spanned the coastline from Carlsbad State Beach, southward past Leucadia, and ending at Encinitas (Table 1). Based on the total for several beds in the region, this bed was probably quite substantial in 1955 and 1959, but began to decline by 1963 and most of the next decade. Kelp was next recorded in 1967 as substantial beds covering 0.240 km^2, becoming twice that size by 1975 (0.500 km^2), and larger still by 1980 (0.670 km^2). They were still substantial (over 0.150 km^2 in area) from 1987 to 1991, and again in 1995. Kelp disappeared from aerial surveys during 1998 but apparently survived below the thermocline, as the beds reappeared relatively soon in 1999. In the October 2000 survey, beds were observed in all three locations off of Leucadia and increased slightly in the December survey. The three beds continued to increase from 2001 through 2003, with a total surface canopy coverage of 0.185 km^2 in 2003. In 2003, the three main beds offshore of Leucadia appeared much smaller, as 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 (0.045 km^2).

The beds of Leucadia appeared to be increasing during the first two aerial surveys of 2005 with all three main beds improving by June. However, none of the beds were 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 boat cruise 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 had 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, became smaller during the next two surveys, but were very close to their March size by the December 2009 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 in April than the northern bed, but they still only increased 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 neighboring beds had clearer water; no cause for the turbidity was observed. The three beds of Leucadia all decreased by the end of 2011, measuring only 0.119 km^2. The beds were small or absent (October survey) until the December 2012 survey where they again increased well over that of the previous year to a canopy coverage of 0.232 km^2. In 2012, the ABAPY for the Leucadia kelp beds indicated that these beds mirrored the other beds in the San Diego region, but the degree of separation has become more muted since 1983 (Figure 69).

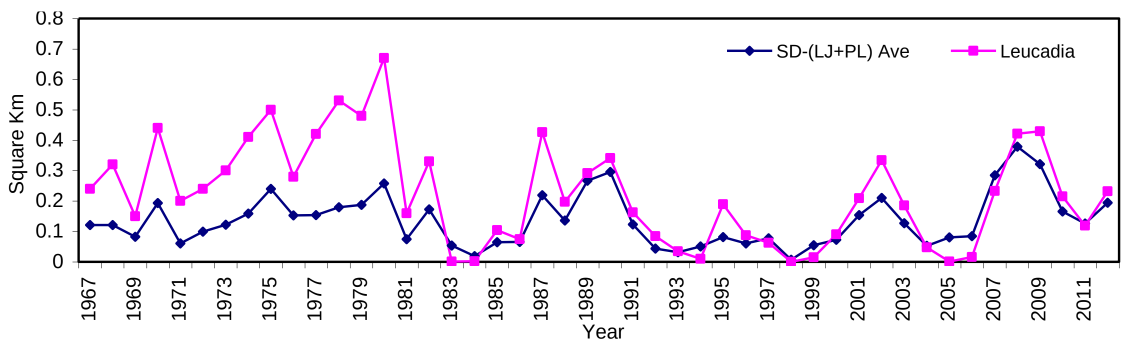


Figure 69. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Leucadia kelp bed for the years shown.

Encinitas 2012. Encinitas kelp bed was estimated to cover about 0.832 km^2 during Crandall's 1911 surveys (it was part of a much larger bed that spanned the coastline from Carlsbad State Beach, southward past Leucadia, and ending at Encinitas). Two surveys conducted in 1955 and 1959 lumped all the kelp in the region with large totals that suggest the bed at Encinitas was probably present and substantial during those two surveys. A survey conducted in 1963 again lumped this bed, but as the total area was much smaller it indicates that Encinitas kelp bed was also 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 was observed to be small canopies covering an estimated 0.065 km^2. By 1970, the canopies had improved and covered 0.173 km^2 and by 1980 the bed covered 0.228 km^2. The bed was not that large again until 1987 through 1990 (reaching a canopy coverage of 0.241 km^2 in 1990), decreasing thereafter until about 2001 when it again covered 0.131 km^2. The kelp bed offshore of Encinitas formed a small canopy in 1999 following a total loss of canopy in 1998.

By December 2002, the canopy was considerably larger and there was an uninterrupted expanse of kelp throughout all of the offshore area of Encinitas. Canopies decreased by 2003 to 0.05 km^2 and continued a downward trend. Kelp in this region increased during the first two surveys of 2005, but diminished during the last half of the year with only a trace of kelp by January 2006. This whole region was subjected to intense phytoplankton blooms during much of the 2006 year and this (combined with a weak nutrient regime), severely impacted the area. 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 rebounded to become a substantial bed by the December 2007 aerial survey covering 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 maybe the 1955–1959 period). The kelp bed again decreased to 2007 levels 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 much reduced by the end of 2010 to 0.128 km^2.The Encinitas bed covered a very large area in 2011, and unlike the other nearby beds to the north, it did not decrease greatly with the canopy measuring only 0.124 km^2. In 2012, it remained a healthy kelp bed during most of the year (decreasing 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 4 to 6 m long on the surface. In 2012, the ABAPY for the Encinitas kelp bed indicated that this bed almost exactly mirrored the other beds in the San Diego region (Figure 70).

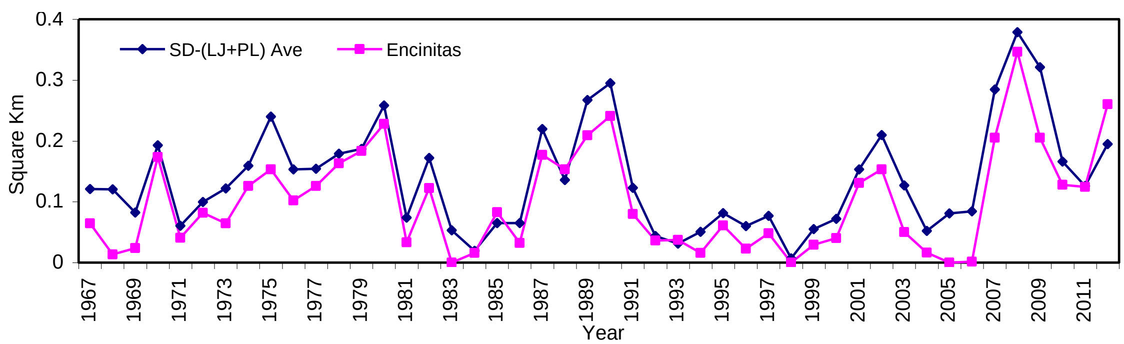


Figure 70. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Encinitas kelp bed for the years shown.

Cardiff and Solana Beach 2012. Crandall did not record a kelp bed in this region in 1911. As the two beds are typically quite large during current surveys, it suggests that unknown environmental factors probably were responsible for their absence. Cameron (1915) reported that seafarers indicated the kelp beds were in poorer condition than typical 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 Del Mar kelp beds as well, 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 beds. By 1975, the individual total coverage was 0.125 km^2 for Cardiff and 0.290 km^2 for the Solana Beach beds, and by 1980 they had increased in area to 0.442 km^2 for Cardiff and 0.690 km^2 for the Solana Beach beds. Following a few poor years during the El Niño of 1982–1984, kelp increased to cover an area of 0.575 km^2 offshore of Cardiff and 0.488 km^2 offshore of Solana Beach in 1989. Kelp beds in both locations 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 at the beginning of the La Niña. The Cardiff and Solana Beach kelp beds continued to expand in 2002 (0.405 km^2 offshore of Cardiff and 0.488 km^2 offshore of Solana Beach), but 2003 documented a 50% reduction, a trend that continued in 2004 as both of these giant kelp beds decreased to 0.045 and 0.022 km^2, respectively. 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, the Cardiff bed had no canopy, 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 boat survey 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*) a kelp herbivore, ranging in size from 14 to 18 cm in length, were observed in about a 15-minute survey indicating that kelp canopy has been 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 had caused a decline in the adult kelp populations in the early portion of the year and through the summer. Small canopies formed by December 2006 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). They were larger than had been seen 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 was 0.484 km^2 offshore of Cardiff (largest bed size since 1989) and 0.823 km^2 offshore of Solana Beach (its largest size in the record). As can be seen in our record, substantial beds can disappear as they did in 2006 and reappear two years later in 2008 as very large beds, that possibly explains 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. Both the Cardiff and Solana Beach kelp beds did not appear to be affected by the downturns in coverage in the north and far surpassed the performance of those beds, both of them increasing greatly (Cardiff to 0.395 km^2 and Solana Beach to 0.504 km^2) in 2011. Canopies were noted as very large during the vessel survey in December 2011, kelp tissues were dark yellow indicating probably adequate nutrients in the recent past. Surface frond lengths were long (5–7 m) and about 70 to 90% of the them were mature. In 2012, the ABAPY for the Cardiff and Solana Beach kelp beds indicated that these beds 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 compared to the remainder of the beds in the region (Figure 71).

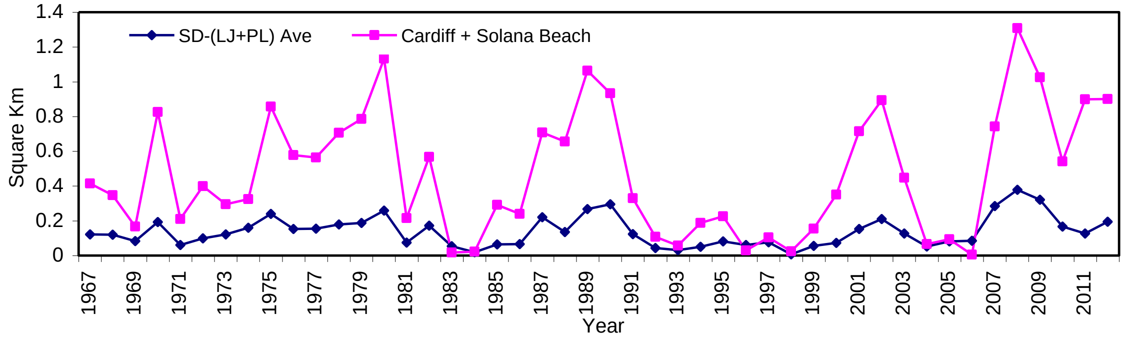


Figure 71. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Cardiff and Solana Beach kelp beds for the years shown.

Del Mar 2012. Del Mar kelp bed was 0.823 km^2 during Crandall's survey of 1911. The bed of giant kelp at Del Mar is isolated by surrounding sand. 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. The depth of this low relief 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 reported in 1955, 1959, and 1963, its area was lumped with 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 canopy sizes of 0.310 km^2 in 1979. The bed shrank until 1989, when it began responding favorably to a La Niña, but then again was small through 1995. In 1995, canopy again increased at Del Mar and then 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 were again present in December. Small kelp canopies at Del Mar were present in the April overflight of 2001, but 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 last 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 very small in 2005 and as such was not large enough to sustain the stresses of inadequate nutrients and disappeared from the surface during aerial surveys. Del Mar kelp bed was not observed during any of the surveys of 2006 and was not observed during a boat survey through the area in late July 2006. The bed reappeared in 2007 and was larger than had been seen since 1995, after an absence of three years. 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, but became somewhat larger by December 2008 covering an area of only 0.057 km^2. Del Mar kelp bed was reduced by March 2009, but stayed substantial in June. Kelp was below the thermocline in September and reappeared in December as a bed with a canopy coverage of 0.044 km^2. Although a small bed, it stayed substantially the same size (0.038 km^2) in 2010 as it was in

2009. It actually 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 indicating with favorable conditions the area was available to potentially grow to 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. The ABAPY for the Del Mar kelp bed indicated that this bed which typically had mirrored the other beds in the San Diego region has reacted opposite the ABAPY during the last two years, and since 1983 has stayed relatively small in spite of large stimuli that occurred and positively affected the other beds in the region (Figure 72).

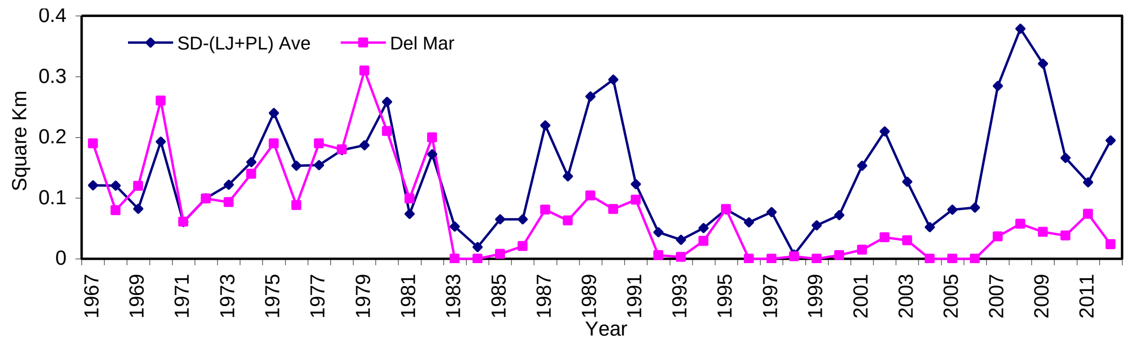


Figure 72. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Del Mar kelp bed for the years shown.

Torrey Pines 2012. Torrey Pines kelp bed appeared in our records as a small trace of kelp in 1988 and 1989 during the La Niña. It reappeared in 2006 as a measurable canopy at 0.01 km^2 with scattered giant kelp about 1.5 km south of Scripps Pier and another concentration about 3.5 km south (MBC 2007b). Another concentration of scattered giant kelp was found about 1.5 km south of that position (5 km south of the pier). By 2007, no kelp was observed in the area, but a small amount was observed in 2008 and 2009 about 3.5 km south 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 south of Scripps Pier and it was substantial at 0.031 km^2, it was almost the same size in 2012 and in the same location at a coverage of 0.034 km^2. The boat survey observations 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 indicating adequate nutrients, and the fronds were noted as being about 50% mature and 25% young. Horizontal frond length was 4 to 5 m, but only about 20% of the visible apical meristem tips were viable. One giant kelp was observed at the artificial reef about 2.5 km south of the pier.

La Jolla 2012. La Jolla kelp bed was composed of two main canopies and were large when Crandall measured them in 1911, covering 7.889 km^2. The canopy coverage was larger still in a 1934 (8.161 km^2) aerial survey and continued to be very large in 1941 (7.847 km^2), but apparently suffered a reversal during some portion of the next 14 years, as by 1955 it only covered an area of 1.660 km^2. In a survey conducted in 1959, the beds were again large, 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, the beds 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 1982–1984 (covering 0.032 and 0.034 km^2 during the latter two years). The beds rebounded in 1987 covering over 2.0 km^2 and then increased to 4.755 km^2 in 1989, a significant fraction

(60%) of the size seen in 1911. By 1990, they were 75% of their 1911 size with canopy coverage of 5.943 km^2. Kelp beds at La Jolla began to increase in late 1998 after a very poor year during the El Niño of 1997–1998. The beds rapidly increased in size during the La Niña of 1999–2000.

The kelp beds were very large in the April 2000 aerial survey and the beds appeared to be reclaiming canopy in the shallow portions of the bed that disappeared in 1998. In 2001, kelp was dense, extensive, and healthy and was located beyond the 25-m depth contour on the north edge of the bed and out to 29 m on the offshore edge of the beds. The beds stayed large through 2002 and for most of 2003 (reaching 3.444 km^2), decreased in 2004 (1.029 km^2) to about one-third of their 2003 size, and decreased still further in 2005 (0.873 km^2) and 2006 (about 0.117 km^2). By the September 2006 survey, only a trace of kelp was visible from the air, and by December 2006, any recovery was limited. A diver survey in relatively shallow water (25 m) in a previously dense portion of the beds did not observe any kelp on bottom. Individual kelp were common, but no coherent canopy was present by late-July 2007. Kelp appeared stressed during the first three aerial surveys of 2007, but the beds increased greatly by the December 2007 survey to 2.750 km^2. The La Jolla kelp beds continued to increase and by the December 2008 aerial survey were larger (4.145 km^2) than they had been since 1989. Again, nutrient conditions by March 2009 were apparently not adequate, or there were losses from powerful storms that occurred in mid-February 2009; in any case canopy coverage decreased to 2.274 km^2 by March and remained 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 thereafter by the December survey. By the April 2011 survey, neither the upper nor lower section of the La Jolla Kelp bed were showing much canopy; they slowly increased by the August and October surveys, but they were still below average. By the 21 December 2011 survey, the bed had responded very favorably to nutrient pulses noted in Scripps Pier SST data and increased to 2.565 km^2. By 2012, the aerial surveys indicated there were distinct differences in the upper and lower 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 did not permit an October view of the bed, but based on the other beds in the region that ranked at well below average to below average, they probably did not fare well. However, by December 2012, the beds began to increase (especially in the lower 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 had been present recently as the surface fronds were a dark yellow. In 2012, the ABAPY for the La Jolla kelp beds (based on the La Jolla and Point Loma kelp bed averages) mirrored the average for the two beds (except for a few aberrant years such as 1970, 1993, 2002 and 2012 when the ABAPY was opposite that of the La Jolla kelp beds). This would suggest that, overall they are affected by the same oceanographic regime, but that micro-differences in bathymetry and currents can still make profound differences to kelp beds that otherwise appear very closely related (Figure 73).

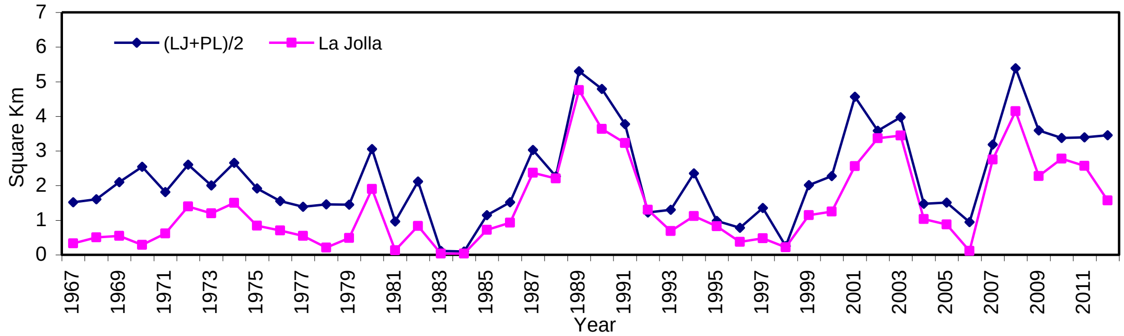


Figure 73. Comparisons between the (LJ+PL)/2 ABAPY and canopy coverages of the La Jolla kelp bed for the years shown.

Point Loma 2012. 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; they were very large in 1911 during Crandall's survey covering a linear distance of almost "eight nautical miles" and an area of 18.523 km^2 (Table 1, North and Jones 1991). That survey total was the exact amount recorded during a survey conducted in 1857, indicating that Crandall's perimeter measurements (other than the inability to see holes) were probably accurate (Table 1, SWQCB 1964, Neushul 1981, Appendix B). The canopy coverage was considerably smaller, but still very large in 1934 (11.465 km^2) and in 1941 (8.286 km^2), but apparently waned during some portion of the next 14 years, as by 1955 canopies only covered an area of 1.990 km^2. In a survey conducted in 1959, they were much smaller than observed in 1955 at 0.610 km^2, but by the time North (North and MBC 2001) began surveying in 1967, they had rebounded and covered 2.700 km^2, growing larger with a canopy coverage of 4.990 km^2 by 1970. By 1980, the beds ranged between 2.2 and 4.2 km^2, and averaged about 3.0 km^2. Following a low point with canopies covering less than 0.3 km^2 during the El Niño of 1997–1998, the kelp bed of Point Loma's peak (since 1941) canopy expanse of 6.6 km^2 occurred as a result of the La Niña of 1999–2000.

In 2001, the kelp canopies were substantially larger than in 2000, indicating that the La Niña probably had an effect on the growth of the bed equal to the 1989 La Niña. Kelp canopies grew well in 2001 during an exceptionally clear-water period of intense upwelling. After the peak of 2001, the kelp bed began to dissipate and was noticeably smaller during all of the 2002 surveys, retreating from deeper depths, but still covering 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 again increased in 2003 (covering 4.509 km^2). In early 2004, the bed at Point Loma began to decrease and was less than one half the size noted in 2003 by December 2004. Point Loma kelp bed lost a large amount of surface canopy, but the loss was mostly confined to the deeper water areas. Overall the bed increased slightly in 2005 (to 2.152 km^2). In 2006, the bed remained substantial, but was smaller bed than reported in 2005. Even though nutrients were again low in 2006 at nearby Scripps Pier, local upwelling apparently resulted in an ample supply of nutrients promoting good growth during a period when most of the beds typically lose canopy size. By the end of 2006, the kelp bed was only about 40% of the size recorded in 2003 (1.767 km^2). It appeared to be much reduced during the first three aerial surveys of 2007, but responded well to apparent increases in nutrients and was about double (3.616 km^2) the size noted in 2006 and was similar, though smaller, to the bed size last recorded in 2003. The Point Loma kelp bed continued to increase in 2008 and was much larger by June, decreased somewhat during the summer, and by December rebounded to the largest (a total canopy coverage of 6.623 km^2) it had been since 1941. Although very large in 2009, the Point Loma kelp bed decreased to 4.909 km^2 by March 2009, increased slightly in June 2009, and then decreased greatly throughout the remainder of 2009. In lockstep with La Jolla, this bed also peaked in August 2010 at a total canopy coverage of 3.977 km^2, but declined precipitously throughout the remainder of 2010. The April 16 survey indicated both the upper and lower portions of Point Loma kelp have very reduced canopies; however, by the August aerial survey small improvements were noted in the canopies (with better recovery in the lower portion), and by October the upper portion had improved. By the December 2011 survey, the upper portion of the bed exceeded the gains noted in the lower portion and the bed covered an area of 4.212 km^2. Responding to nutrient pulses that appeared to affect the upper portion of Point Loma more than the lower part (based on the quarterly surveys), the bed became very large covering 5.340 km^2 in 2012. The December 2012 survey noted that Upper Point Loma appeared well above the average while Lower Point Loma was above average, the difference resulting from variations in the local oceanographic regime. In 2012, the ABAPY for the Point Loma kelp beds (based on the La Jolla and Point Loma kelp bed averages) mirrored the average for the two beds, suggesting that they are affected by the same large- scale oceanographic regime (Figure 74).

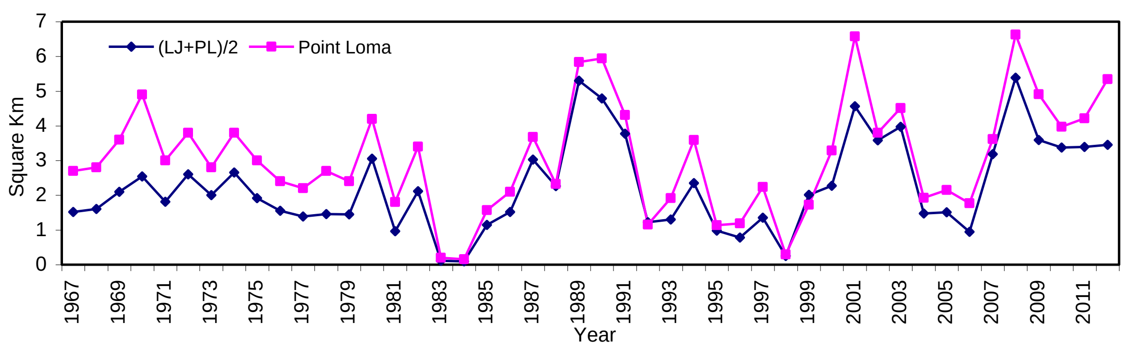


Figure 74. Comparisons between the (LJ+PL)/2 ABAPY and canopy coverages of the Point Loma kelp bed for the years shown.

Imperial Beach 2012. The Imperial Beach kelp bed canopies covered 0.984 km^2 during Crandall's survey of 1911, but 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; these beds had significant problems with urchins dominating the substrate 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, but only about one-third the size noted by Crandall in his 1911 survey. The beds were alternately small and then large through 1990. Their high point (0.727 km^2) in 1987 was atypical compared to the remainder of the San Diego beds, as those did not reach their highs until the 1989 La Niña. After 1991, the beds were relatively small until they disappeared in 1998, reformed as a single small bed in 1999 and 2000, but were farther south than their previous location off of the Imperial Beach Pier. The beds at Imperial Beach in 2005 became larger with each succeeding aerial survey. By late September they 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 that were prevalent in most of the region through 2006. 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 display of canopy was significantly increased with the aerial survey recording a larger bed (1.493 km^2) than had been recorded historically, far larger than Crandall (considered the baseline) recorded in 1911. The Imperial Beach kelp bed canopies continued to increase by the June 2008 aerial survey and by the December 2008 survey were extending farther south than noted in 2007. The December survey recorded a new high in canopy coverage for this bed with a canopy covering 1.895 km^2. The extremely large kelp canopies found in December 2008 did not last into March 2009, when a bed of only 0.862 km^2 was recorded (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 have been implicated in losses in the past at this bed; however, a diving survey that would have elicited information on urchin status was not conducted until the end of 2010. The other possible culprit (upon which information could be obtained post-event) was large swells. Upon examination of the swell record from the CDIP Point Loma South station that is offshore of Imperial Beach, it appears 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 had a deleterious effect on 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 noted in deeper water (18 m) was actually comprised almost exclusively of elkhorn kelp. The kelp was scattered over a wide area, but was mostly congregated in three disparate locations in 2012 and totaled 0.333 km^2. Boat observations revealed 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 outside patches of kelp. 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 in spite of 4 to 5 m visibility. Except for the period from 1967 to 1979 (when it was missing), the Imperial Beach kelp bed generally followed the ABAPY. In 2012, the ABAPY for the Imperial Beach kelp beds indicated that this bed followed the San Diego region kelp bed ABAPY by increasing in concert with most of the beds in the region (Figure 75).

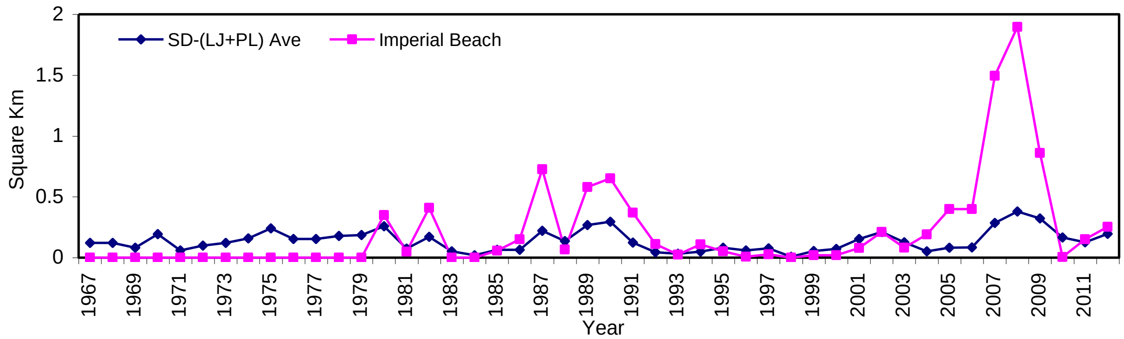


Figure 75. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Imperial Beach kelp bed for the years shown.

2013 UPDATE TO THE PRESENT

One aerial survey for 2013 has been conducted and critically evaluated. This survey was conducted on 13 May 2013. The daily pattern in temperature change tracked closely between the northern and southern automated sampling stations through May 2013 (the latest data available) with SSTs cooler than average at Point Dume, Newport Pier, and Scripps Pier through March, spiking upward briefly in early-April and staying very cool through the rest of April. In May temperatures became slightly higher than average in the region (Figure 10). At this early stage, it is unclear how the Central Region and Region Nine kelp beds will fare in 2013; however, based on the one aerial survey completed so far this year, it appears most of the kelp beds maintained coverage at a level similar to that observed in December 2012. In addition, boat surveys in the northern portion of the range indicated that those kelp beds were maintaining canopy sizes. The models being used to forecast El Niño suggest ENSO-neutral conditions developed in late-2012 and will continue into the second half of the Northern Hemisphere through summer 2013. There is no current discussion suggesting El Niño conditions will return during the remainder of the year; however, there is low confidence in the model predictions until we are actually into the summer months.

DISCUSSION

Based on the analysis of the aerial overflight surveys in 2012, kelp growth within the 50 kelp beds monitored as part of the CRKSC and RNKSC programs was above average for the year. Through April 2012 many canopies were actually larger than during the previous December, others were equally large, while most became smaller as the year progressed through at least October. Despite deterioration of the canopies into fall, kelp canopies reconstituted when typical late-fall/early-winter conditions returned and most of the kelp beds had their largest canopies in December. An analysis of the oceanographic data provides a perspective on why most of the kelp beds in the region increased. The prime factor that appeared to be influencing kelp health and growth in 2012 was nutrient availability that is generally caused by upwelling bringing cold, nutrient-rich waters to the surface. The upwelling index (33N 119W) indicated that May and June of 2012 had unusually strong upwelling compared to the 66-year average since 1946. The strong response of the kelp beds suggested that nutrients were available in the region and that variability observed in the kelp bed response was likely due to local upwelling that gave an impetus to the kelp canopies. Sea surface temperatures (as a surrogate for nutrient availability) indicated that cooler-than-average temperatures were found throughout most of the 355 km of coastline through April 2012 and then periodic upwelling (cold water from below the thermocline) spikes were prevalent (and nutrients theoretically available at least a portion of the time) from May through mid-September when SSTs returned to more average temperatures during the last three months of the year.

During the 2012–2013 nutrient season (beginning in July and ending in June the following year), the nutrient quotient for the waters off Point Dume was 26, Santa Monica Pier was 31, Palos Verdes N was 25, Palos Verdes S was 30, Newport Pier was 27, San Clemente Pier was 19, Scripps Pier was 25, but Point Loma was only 12 (20 is considered an average year). Most of the quotients indicated that above-average nutrients were theoretically available across most of the two regions with some differences apparently due to local bathymetry and current regimes. The quotient values were generally higher in the 2011–2012 and the 2010–2011 seasons, implying nutrient availability was slightly higher in the previous several years (during the La Niña).

Because of the variability in individual kelp bed response north of Point Dume, it was apparent that local variations in nutrient upwelling along the headlands from Deer Creek to Lechuza imparted growth to some kelp beds in the middle of that range, but resulted in a lack of nutrients and a loss of kelp at the two extreme ends. South of Point Dume kelp growth was excellent with kelp beds increasing from Point Dume to Sunset Kelp. At Santa Monica Pier, it appears that nutrients were available and contributing to growth in the Malibu to Ventura area. The Palos Verdes temperature monitoring station data were incomplete at the surface due to equipment loss, but the 2-m station data are typically only a few tenths of a degree cooler and were used to determine a clearer pattern of nutrient availability along the Palos Verdes headlands. Data from the northern Station PVN and southern Palos Verdes Station PVS temperature monitoring stations were very similar and temperatures were consistent with adequate nutrients to sustain the kelp beds; however the response to these apparent nutrients was mixed with the beds south of Point Inspiration slightly decreasing. This would again appear to indicate local variations in topography and current regimes are combining to reduce the apparent nutrient availability in some areas.

The Newport Pier temperature data suggested that the Newport region should have had adequate nutrients in the surrounding area; however, the Newport/Irvine Coast area actually marginally decreased, while the North Laguna Beach kelp bed increased and the South Laguna Beach kelp bed also slightly decreased, suggesting local variability around headlands. From Salt Creek/Dana Point south to Cardiff substantial increases were recorded in many of the beds, but Solana Beach decreased by about the same percentage that Cardiff increased. In this region, the San Clemente Pier data suggested nutrients were average, but The Scripps Pier data suggested that nutrients were higher than average, but Upper La Jolla decreased considerably. Lower La Jolla, Point Loma, and Imperial Beach kelp beds all increased in size in spite of Point Loma temperature data suggesting nutrients were only marginally adequate.

Large-scale phenomena, such as a La Niña, persisted through much of 2011 and gave an impetus to the kelp beds of the region that allowed most of the kelp beds in the region to persist with greater-than-average canopies into 2012. The ongoing discussion at the El Niño watch forum suggests the region transitioned to neutral conditions by May 2012 and in spite of some models predicting a transition to El Niño in late 2012, it did not occur and the region remains in a condition of El Niño Neutral through April 2013. 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 variables such as high swells, swell direction, turbidity from rain runoff and plankton blooms appeared from the data to have had minimal effects on the kelp beds of both regions during 2012. Swells were relatively mild with very few approaching the four-meter range from the west, where one would expect to see damage from breaking waves as they approach shallow coastal waters. None of the periods of intense swell lasted long enough to impart any lasting damage to the kelp bed resources. There were brief periods when the rivers and streams ran strongly and nearshore waters were turbid; however, these conditions did not persist for sustained periods. Rainfall was well below the long-term average at LAX of 14.46 inches with less than nine inches of rainfall at Los Angeles and seven inches in Orange and San Diego counties. There were periods of algal blooms (3,000 to 100,000 cells/liter), but they did not persist for sustained periods and they did not rise to the concentration levels (350,000 cells per liter) where they could occlude light.

CONCLUSION

Region-wide oceanographic influences including large-scale meteorological cycles such as the Pacific Decadal Oscillation (PDO), and Inter-decadal Pacific-Oscillation (IPO), as well as the better understood Southern Oscillation (ENSOs) (Power et al. 1999, Verdon et al. 2004, Verdon and Franks 2006) play an important role in structuring kelp bed communities off of southern California. For example, during 2012, a La Niña event continued to bathe the Southern California Bight in cool water temperatures and slightly elevated nutrient regimes. However, as has been typical (with a few atypical years such as 2009), the kelp beds in the region varied in their response to stimuli such as nutrient availability due to variability in flow regimes, bathymetry, locally and regionally determined sources of turbidity, the angle of the coastline, and exposure to swells.

Overall, giant kelp canopy coverage was maintained as observed in the April aerial survey of 2012, but by June many beds were shrinking in size likely due to a lack of nutrients, and were considerably reduced in size by the October survey. Region-wide temperature data were available and temperatures could be correlated with broad reductions or increases in kelp canopies over the region. The data collected showed that most areas in the region were subjected to similarly large temperature fluctuations synoptically, but that in isolated areas, responses were different enough to affect the local kelp beds. This illustrates that oceanographic conditions throughout the Central Region and Region Nine are influenced by differing regionally localized factors that reflect that variability.

The 2012 kelp study demonstrated that 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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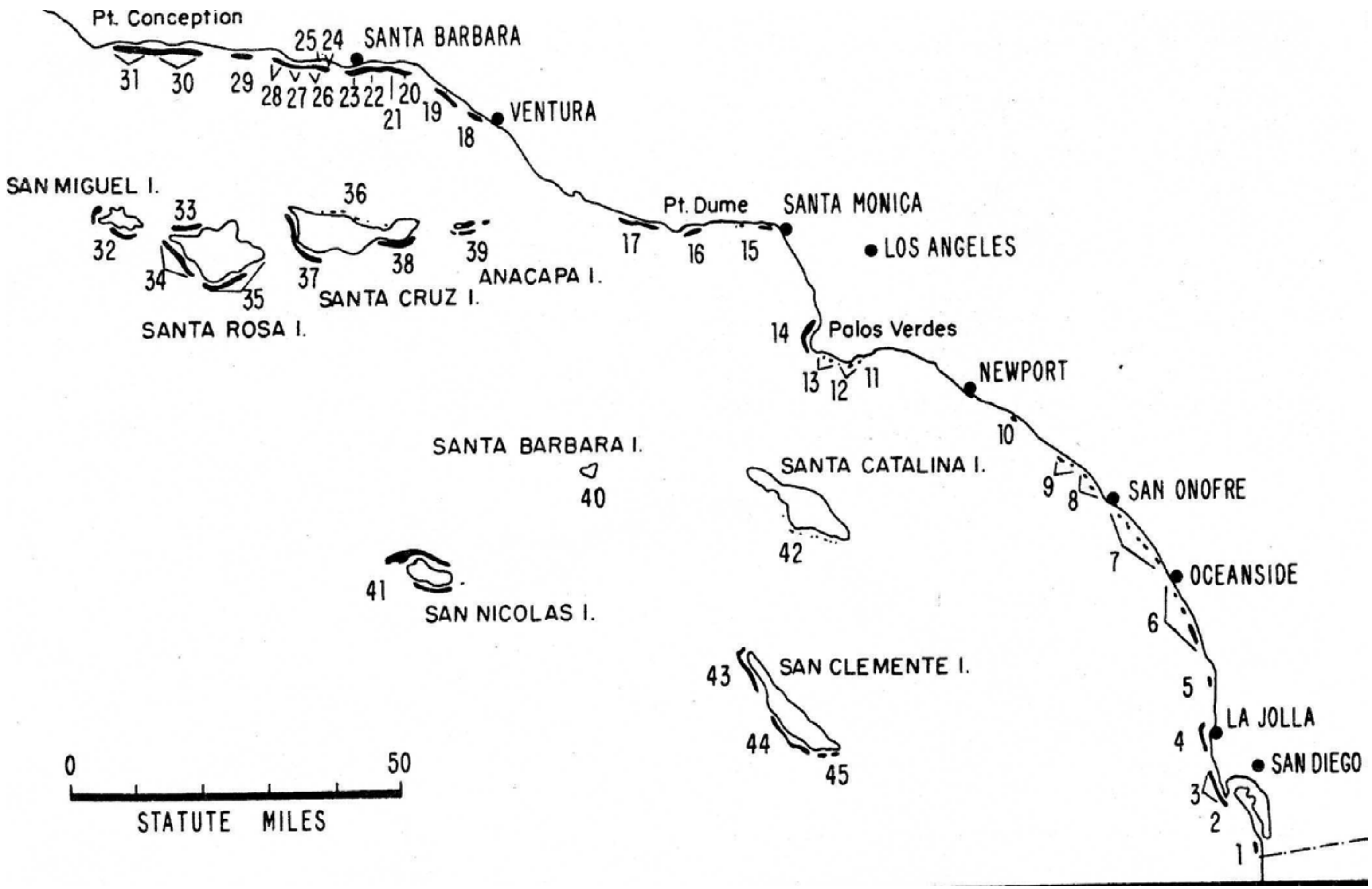
APPENDIX A

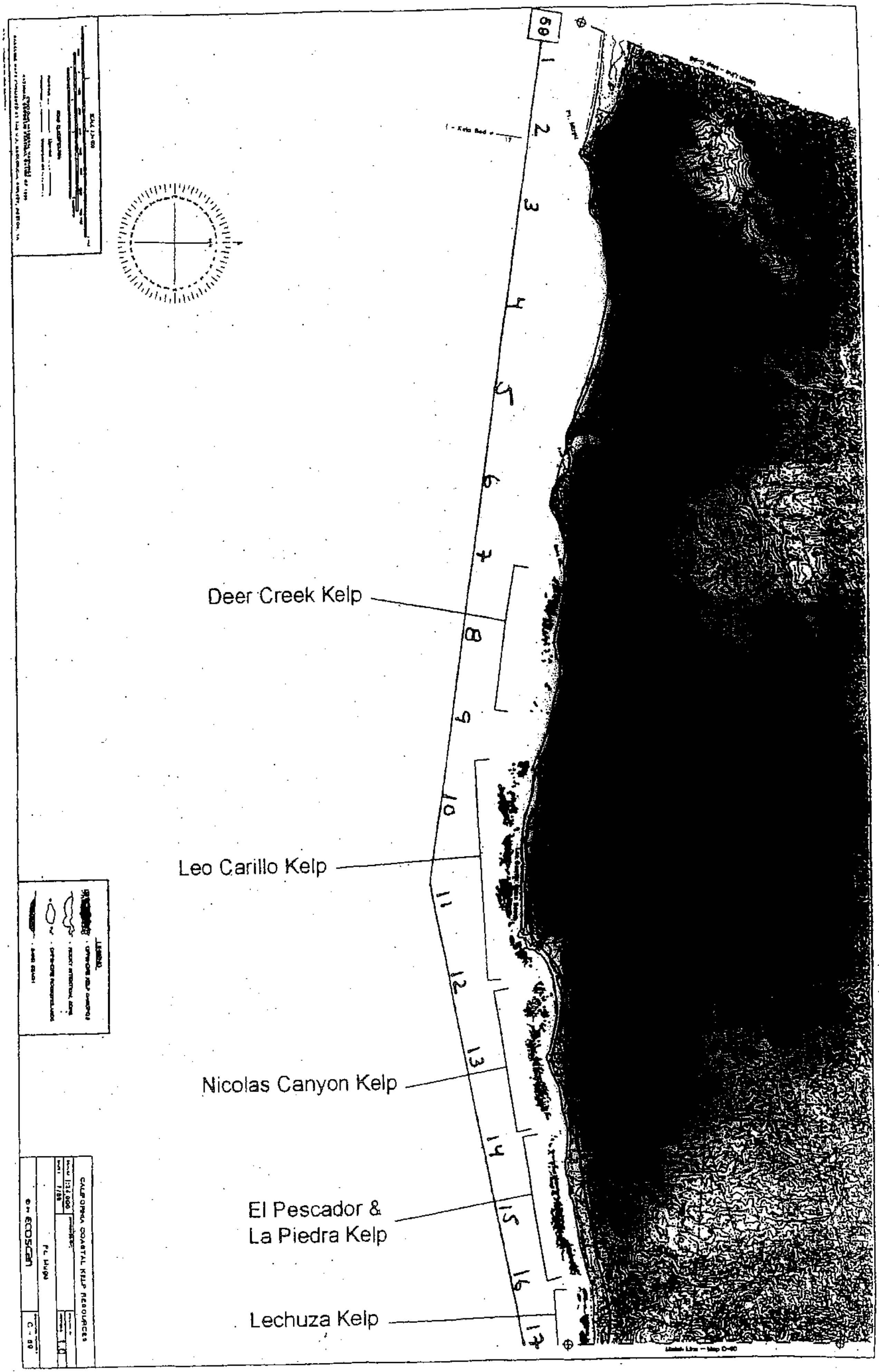
Kelp Canopy Maps



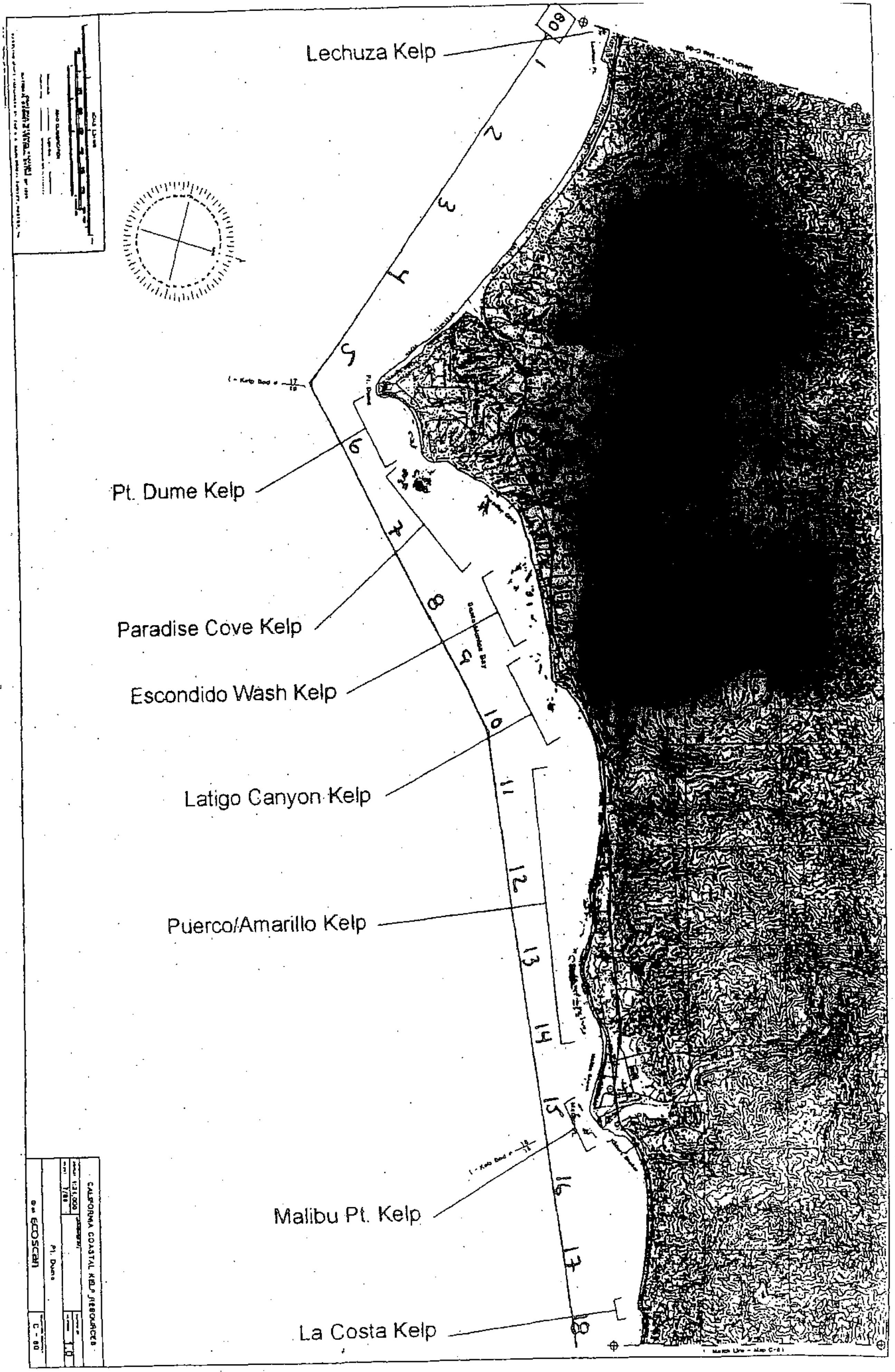
Appendix A. Fish and Game designated kelp bed numbers in the Southern California Bight.

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



59
Deer Creek Kelp
Leo Carillo Kelp
Nicolas Canyon Kelp
El Pescador &
La Piedra Kelp
Lechuza Kelp
CALIFORNIA COASTAL KELP RESOURCES
C-59


Lechuza Kelp
Pt. Dume Kelp
Paradise Cove Kelp
Escondido Wash Kelp
Latigo Canyon Kelp
Puerco/Amarillo Kelp
Malibu Pt. Kelp
La Costa Kelp
80
1
2
3
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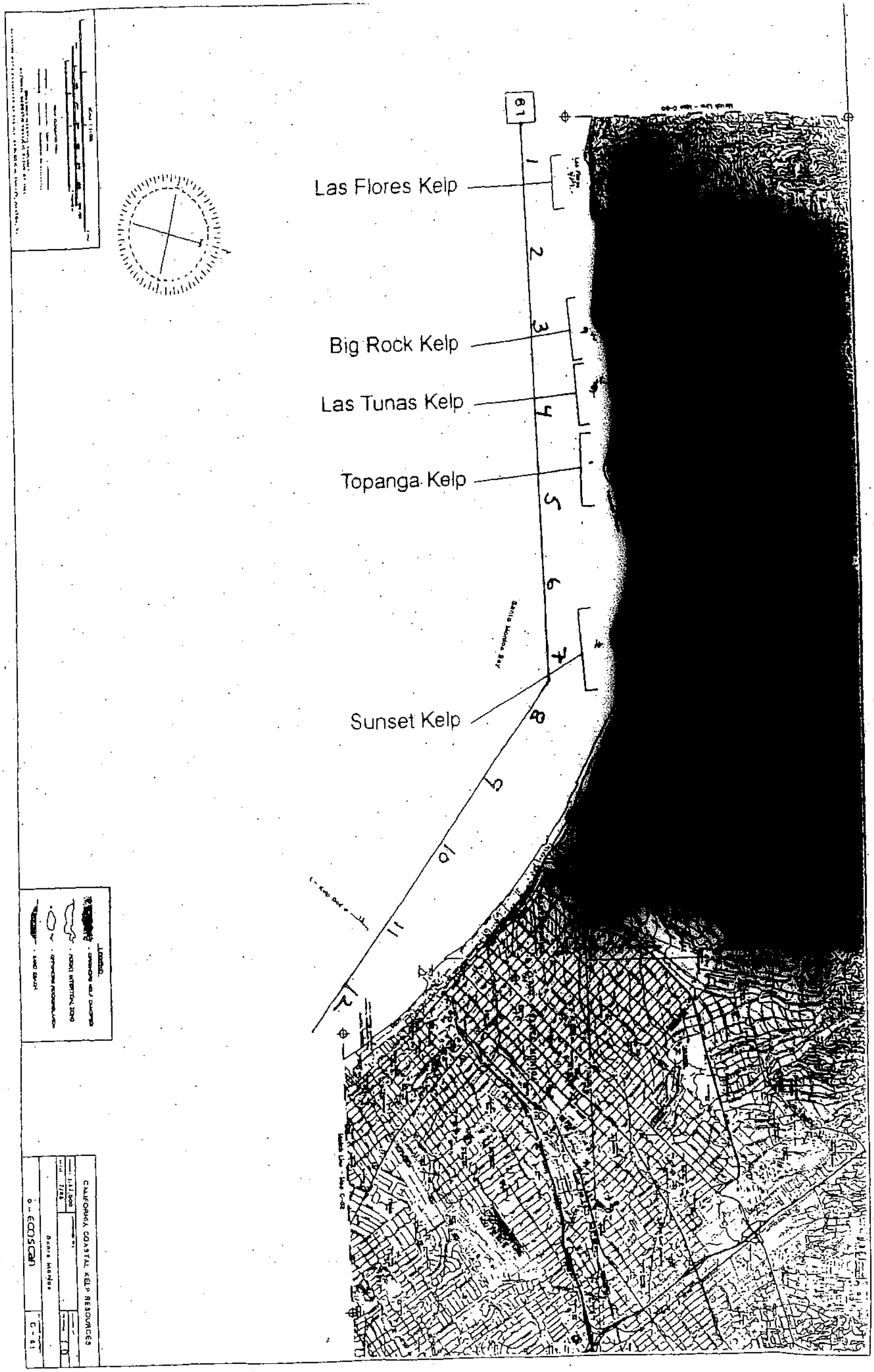
18
CALIFORNIA COASTAL KELP RESOURCES
Pt. Dume
ECOSCAN
C - 80


61
Las Flores Kelp
Big Rock Kelp
Las Tunas Kelp
Topanga Kelp
Sunset Kelp
1
2
3
4
5
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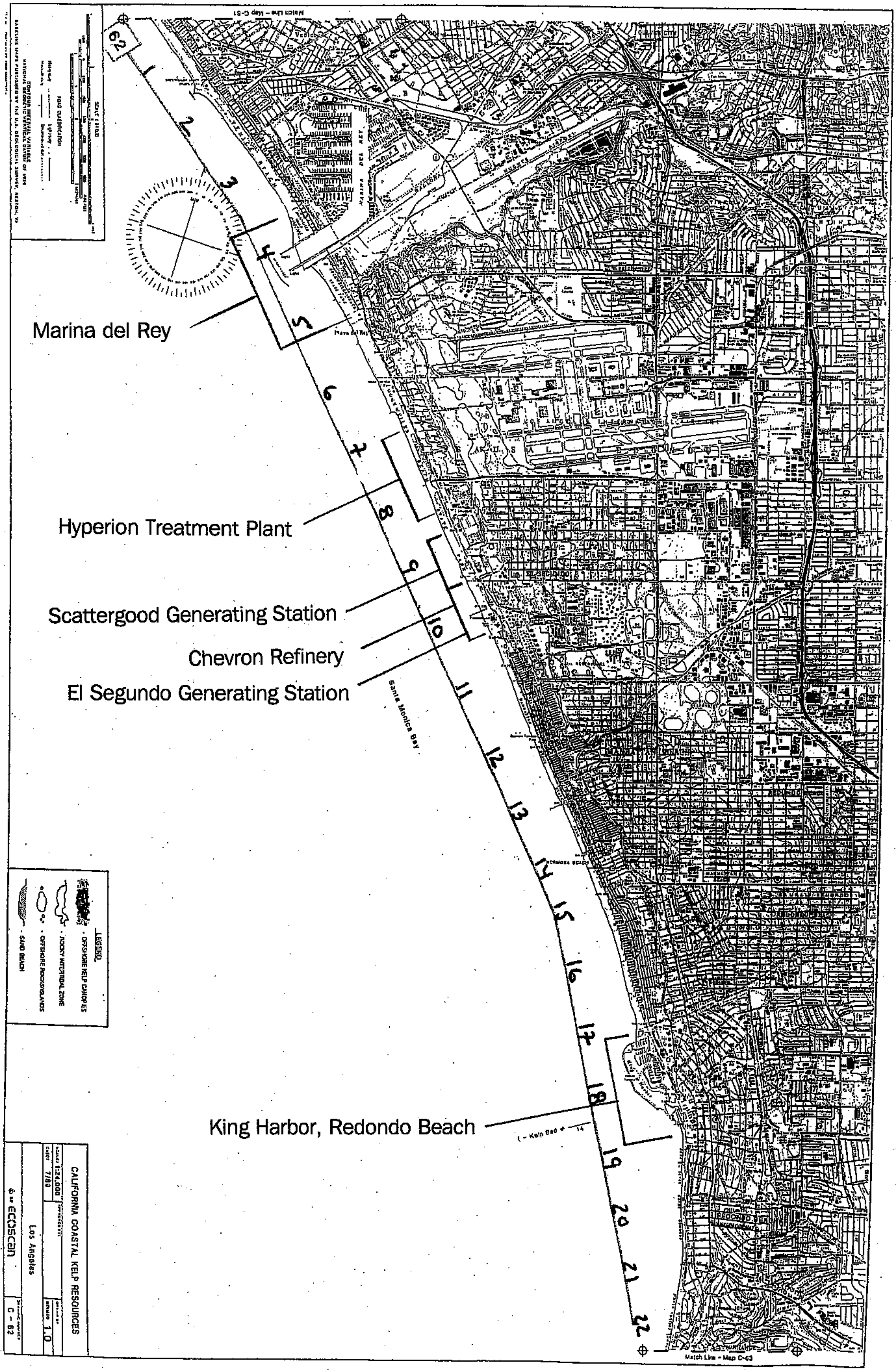
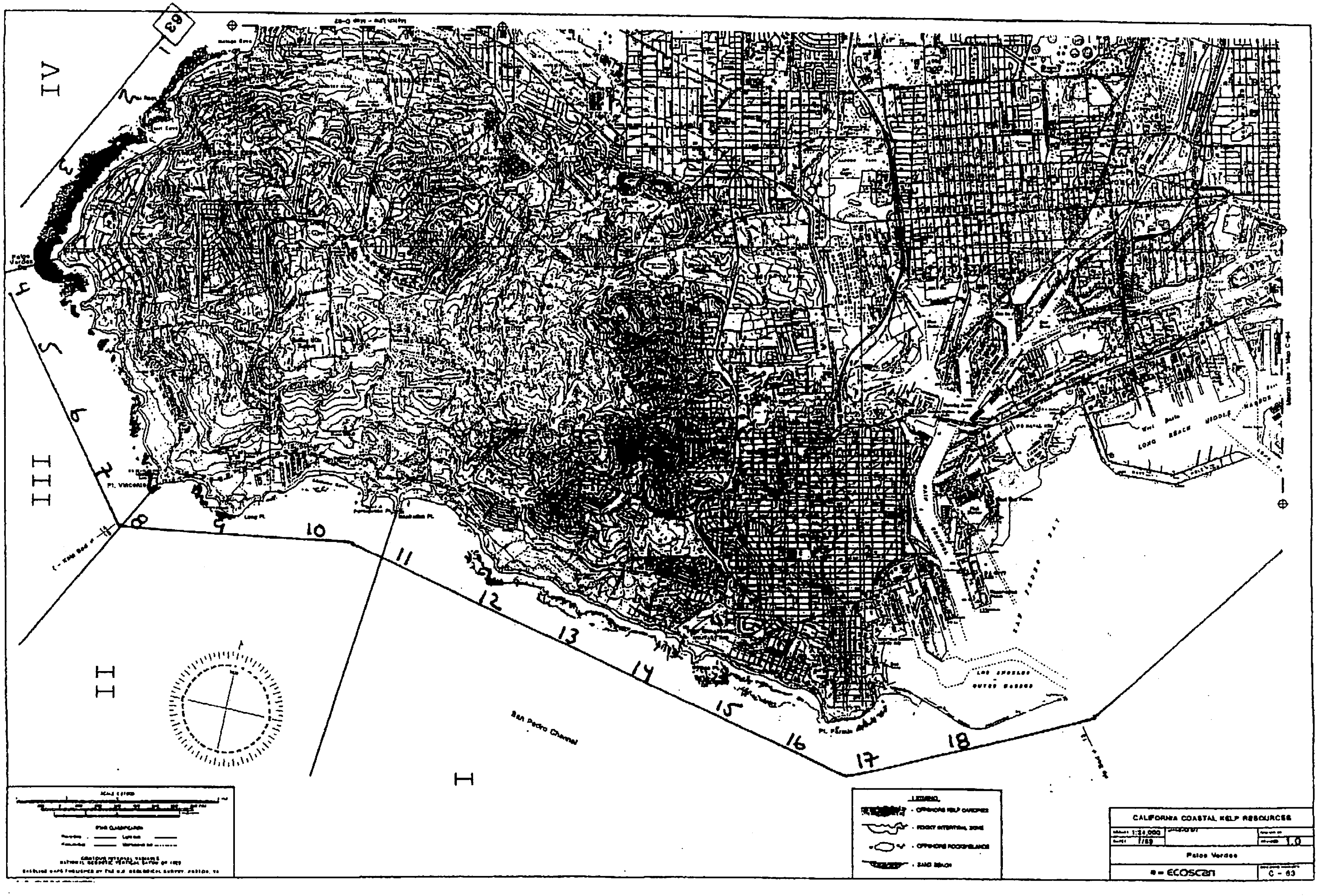
9
10
11
12
Santa Monica Bay
CALIFORNIA COASTAL KELP RESOURCES
ECOSCAN
C-61



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



CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Palos Verdes
ECOSCAN
C - 63
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
San Pedro Channel
Pt. Vicente
Long Pt.
Pt. Fermin
Palos Verdes
LOS ANGELES OUTER HARBOR
LONG BEACH MIDDLE HARBOR
SAN PEDRO BAY
Match Line - Map C-64
Match Line - Map C-62
I
II
III
IV
63
1
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7
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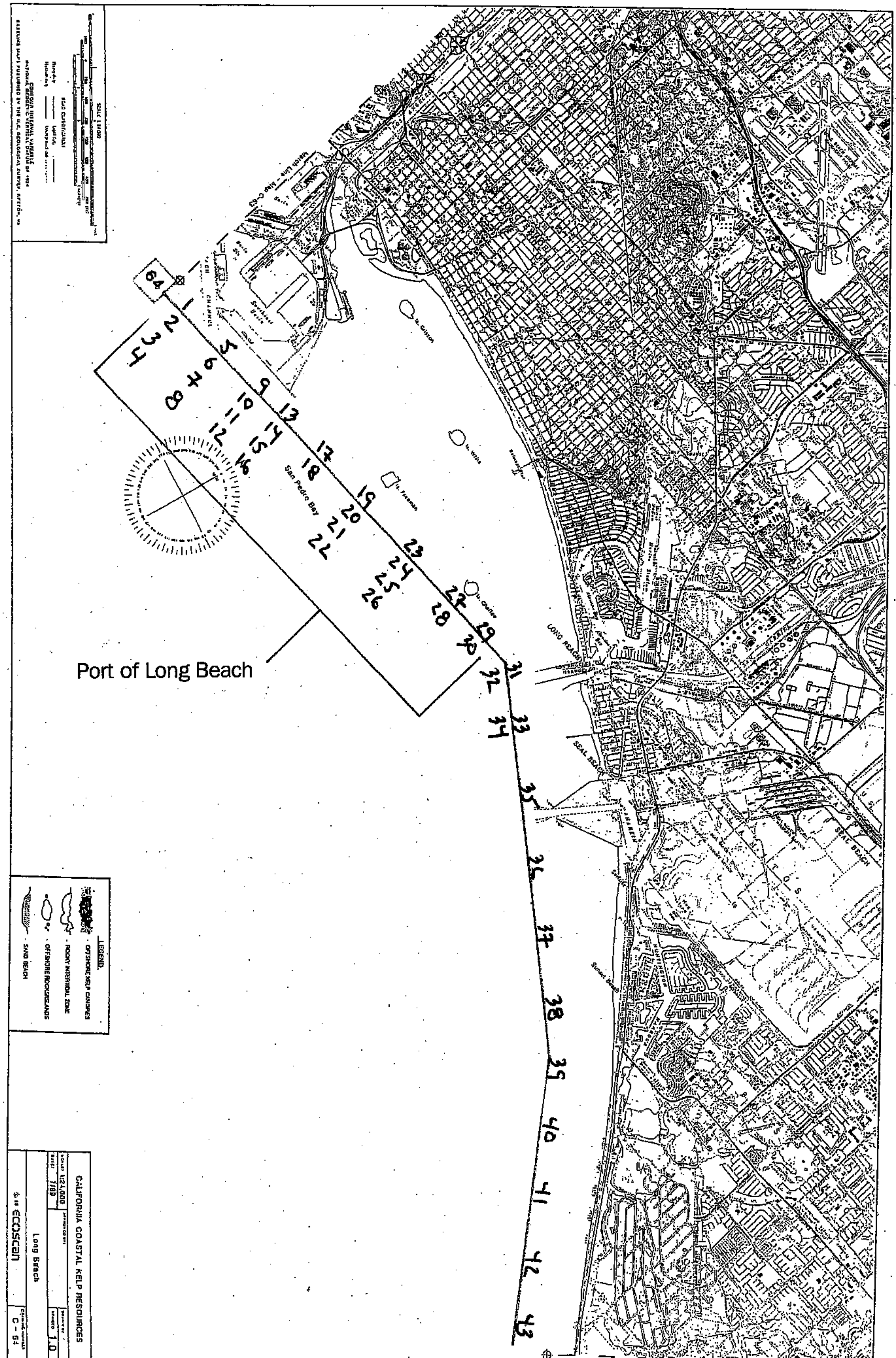
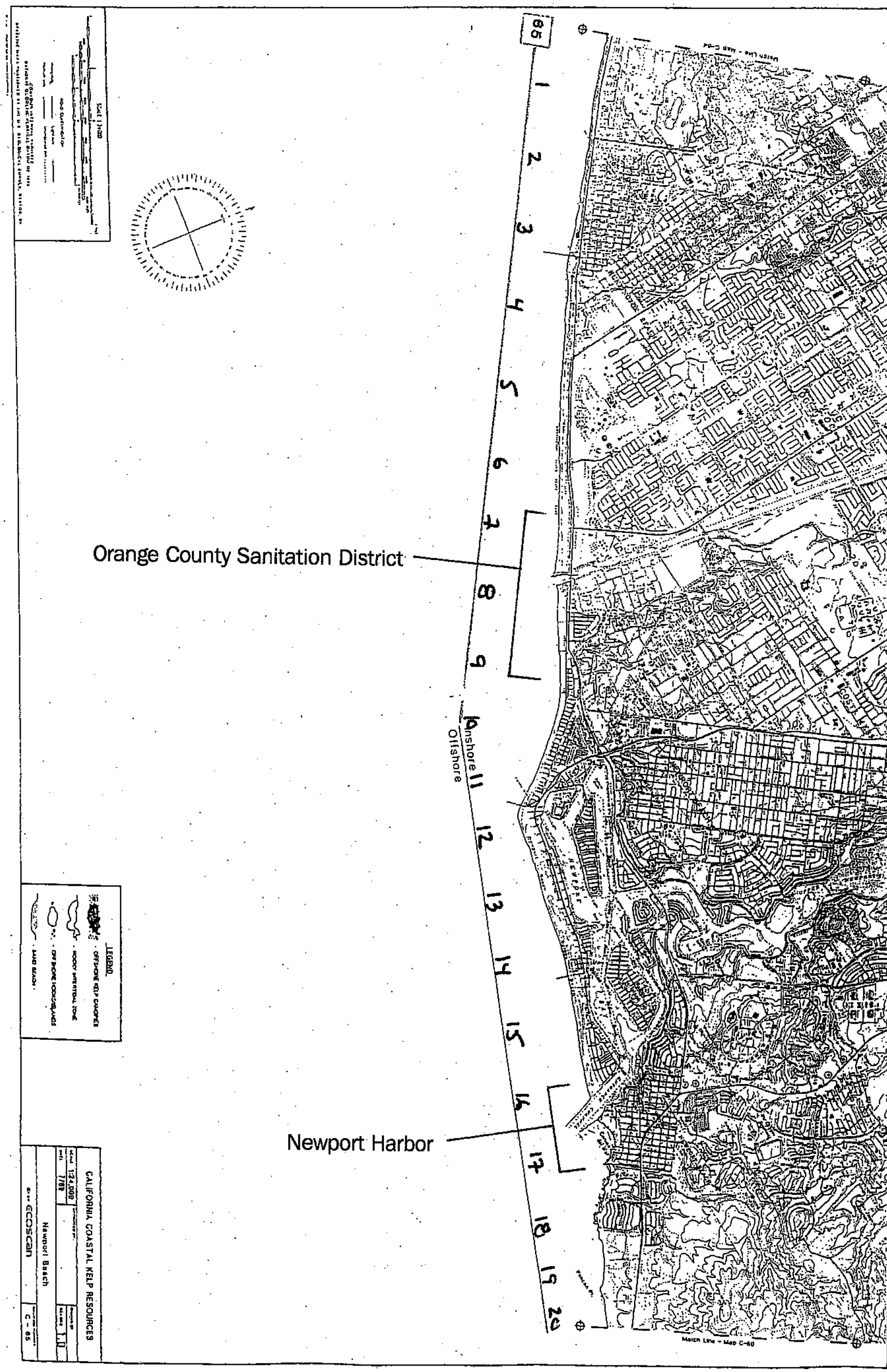
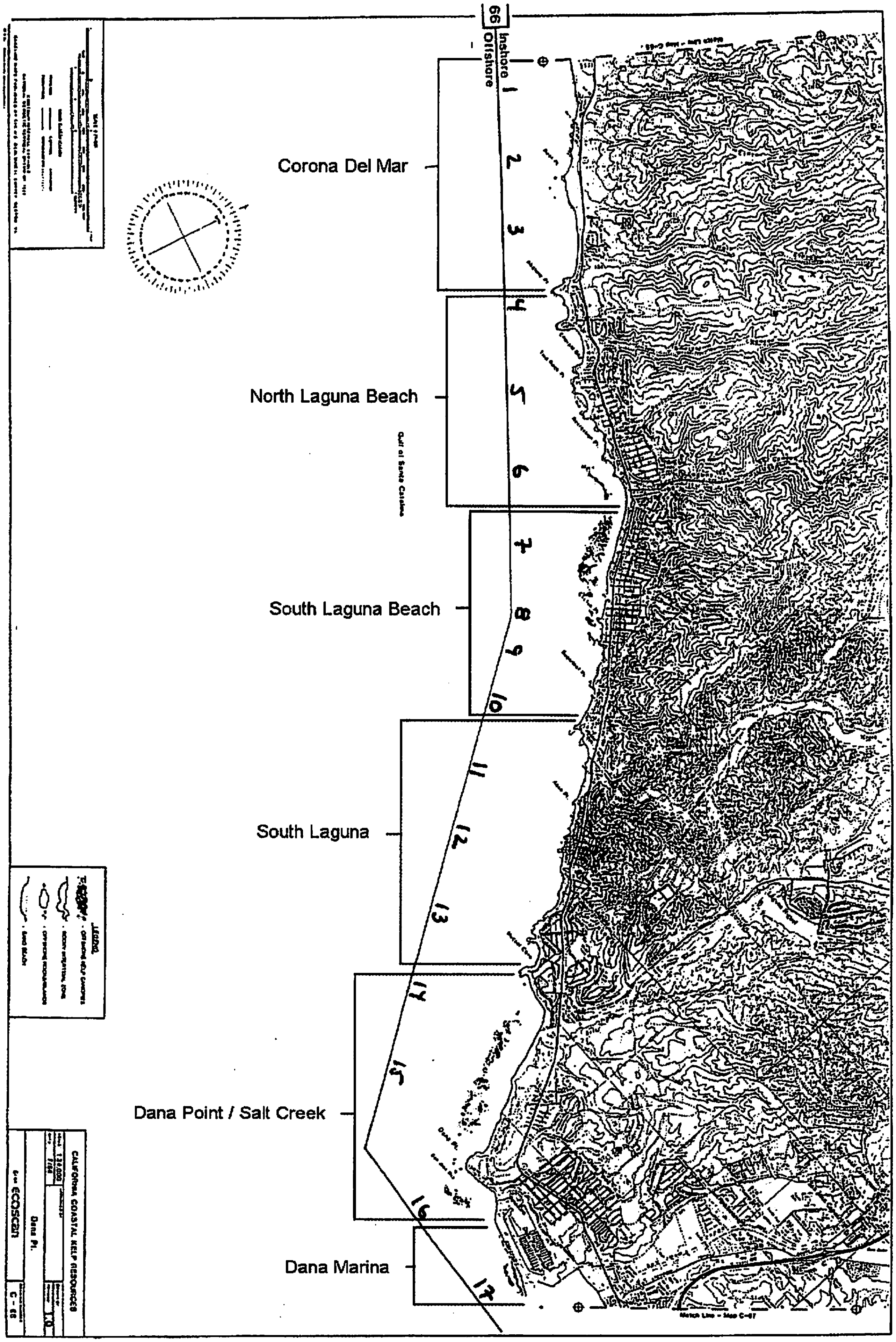


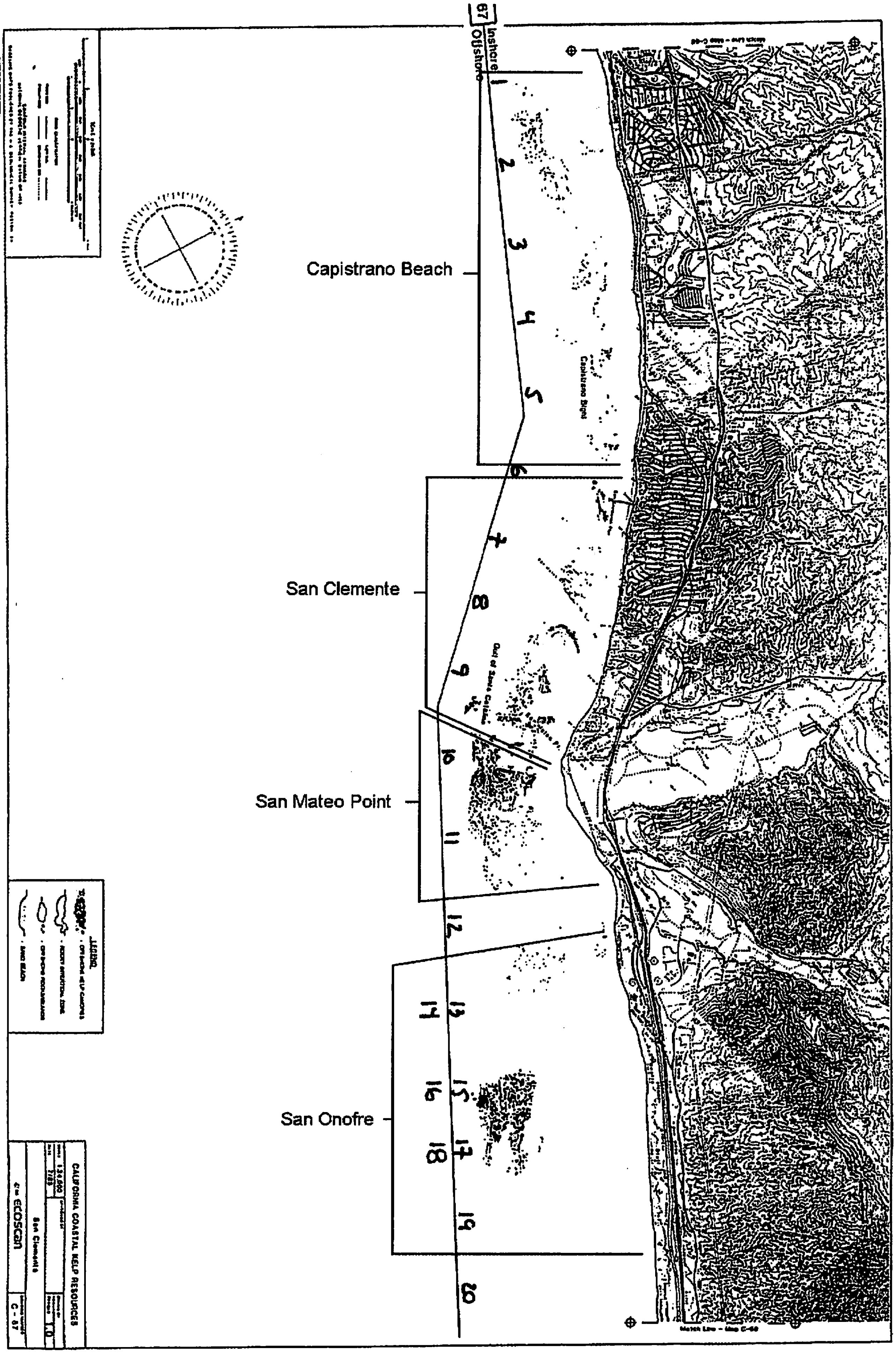
Port of Long Beach
San Pedro Bay
LONG BEACH
SEAL BEACH
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
Long Beach
C - 64
ecoscan
Match Line - Map C-65
64

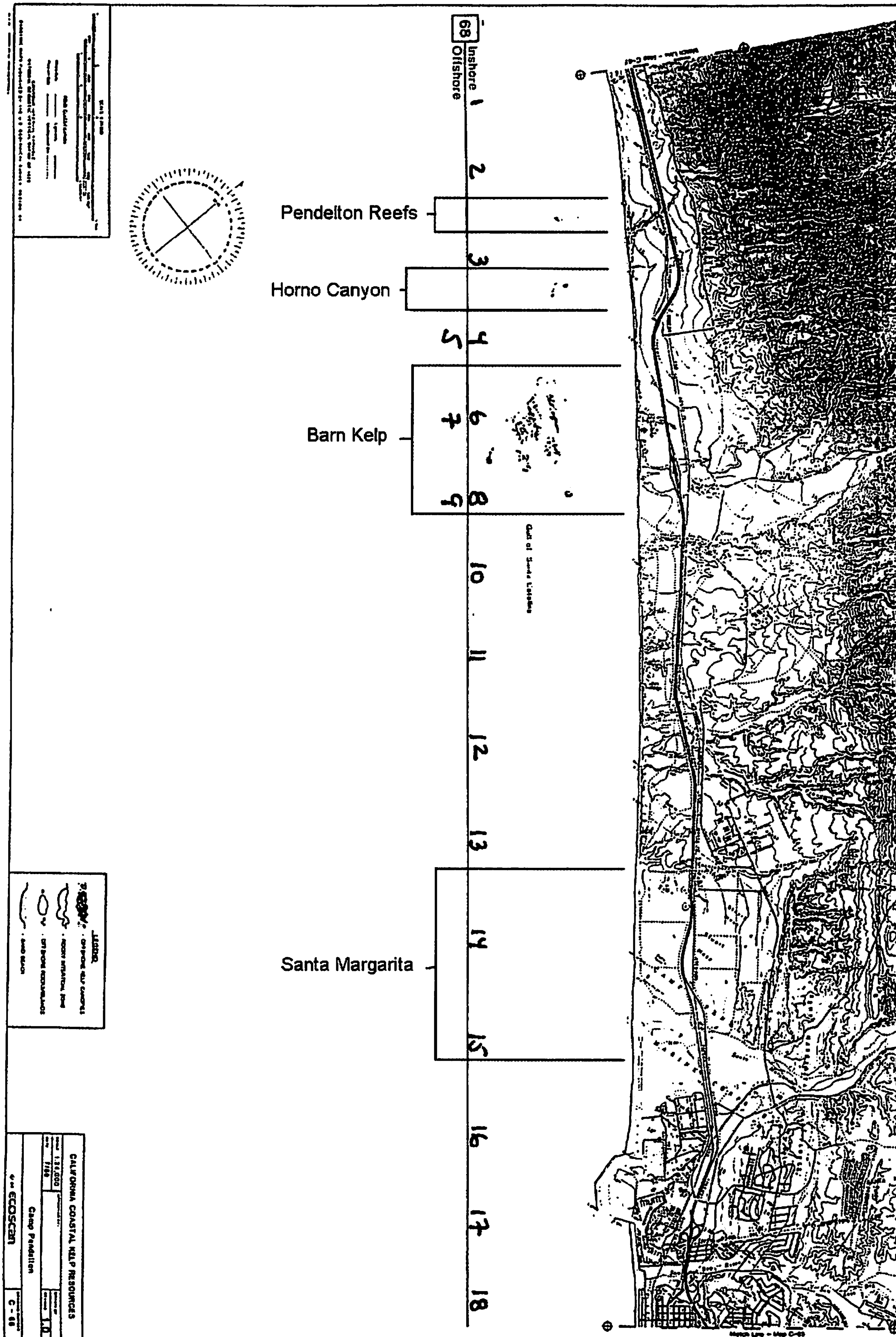


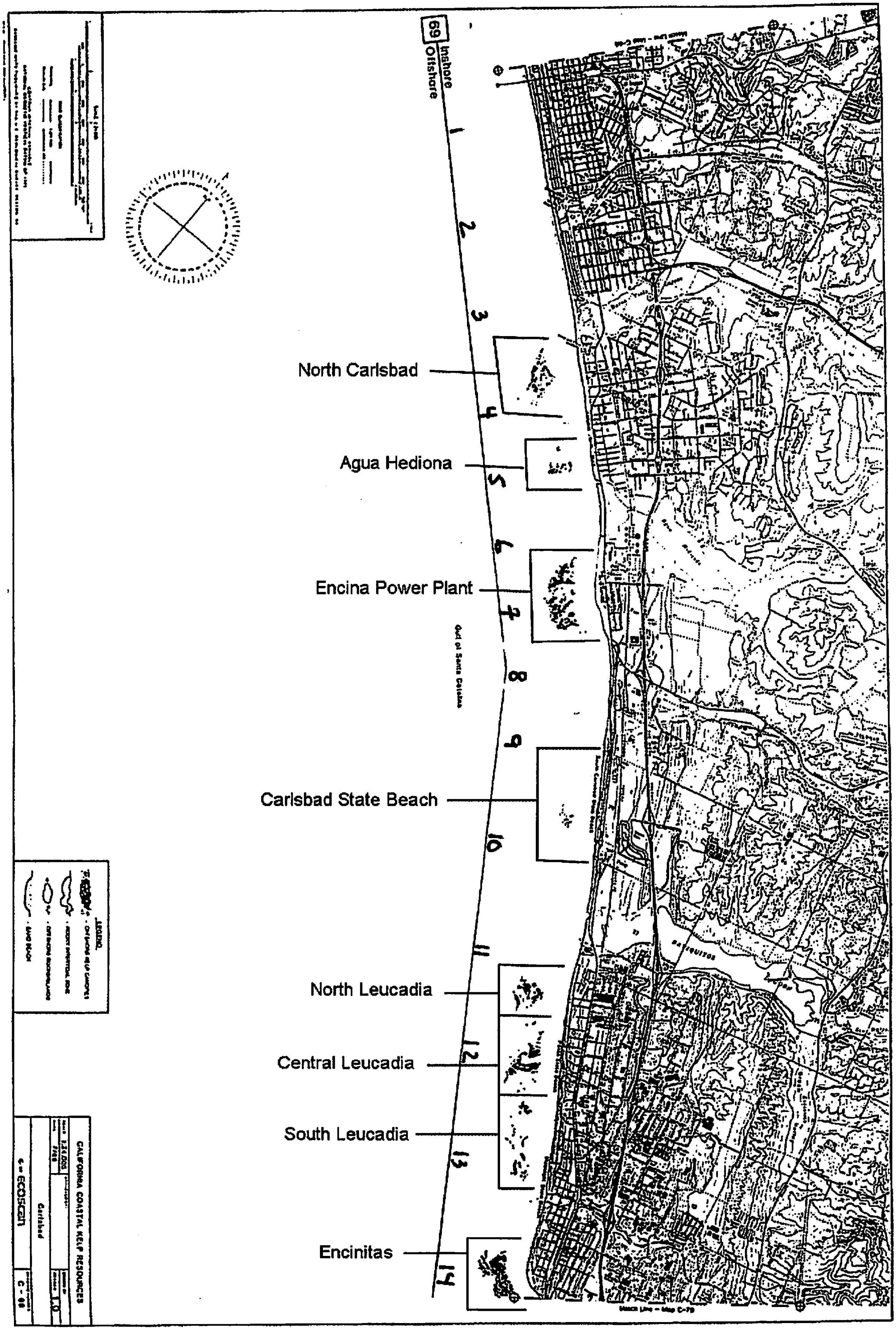
85
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Inshore
Offshore
Orange County Sanitation District
Newport Harbor
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Newport Beach
ecoscan
C - 85



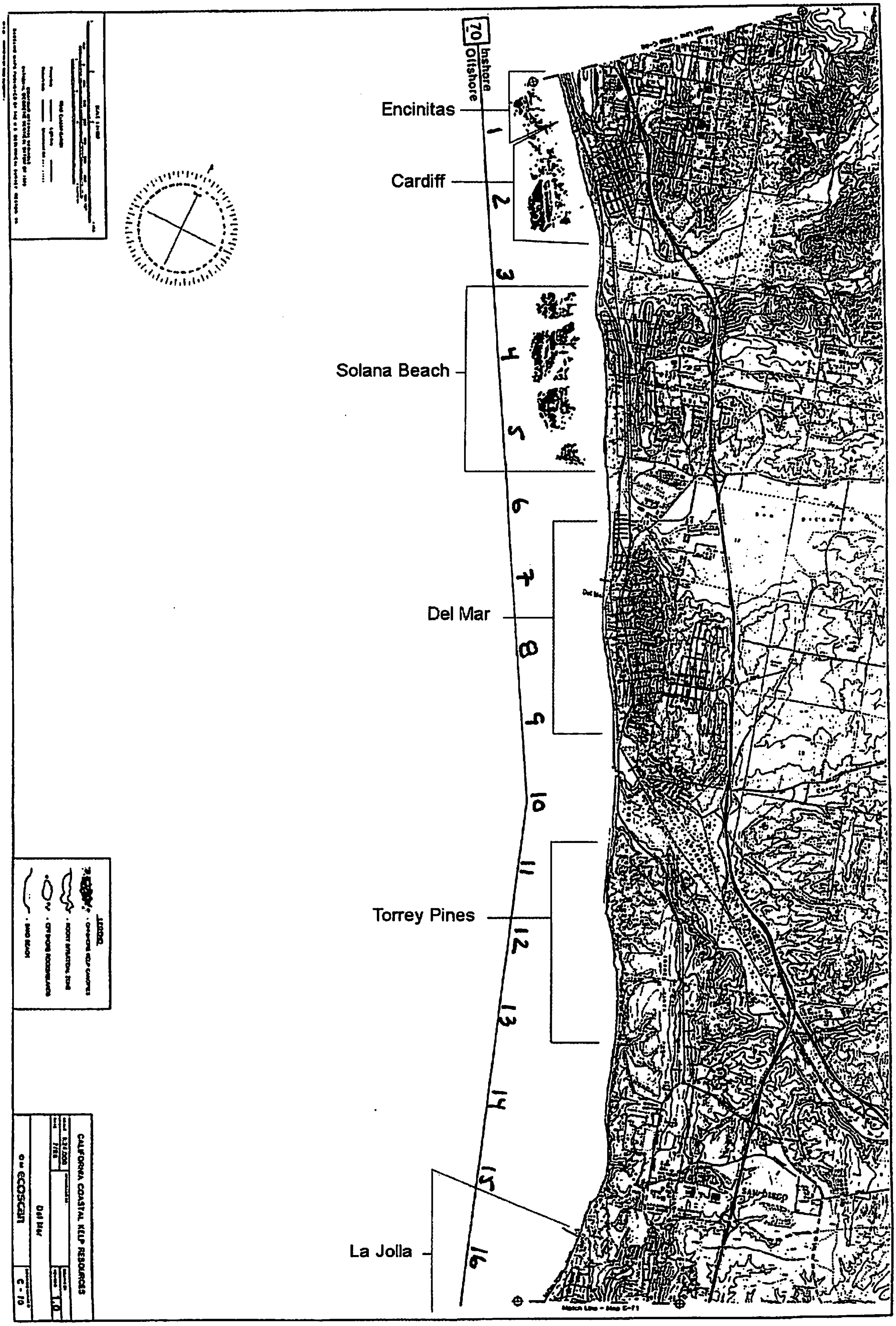
99
Inshore
Offshore
Corona Del Mar
North Laguna Beach
South Laguna Beach
South Laguna
Dana Point / Salt Creek
Dana Marina
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
CALIFORNIA COASTAL KELP RESOURCES
Dana Pt.
ECOSCAN
C - 68


67
Inshore
Offshore
Capistrano Beach
San Clemente
San Mateo Point
San Onofre
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Capistrano Bight
CALIFORNIA COASTAL KELP RESOURCES
San Clemente
ECOSCAN
C - 67

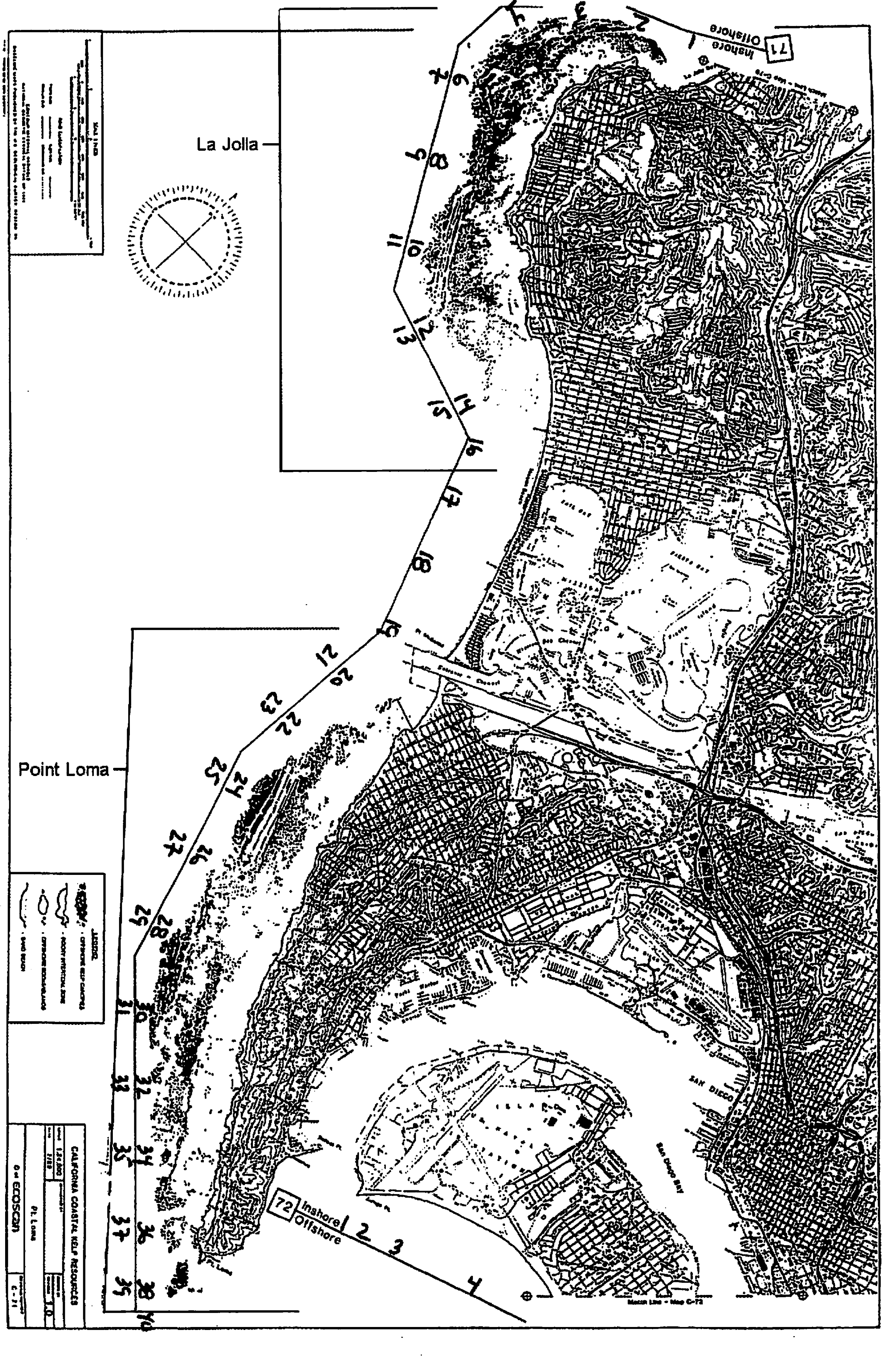

Pendelton Reefs
Horno Canyon
Barn Kelp
Santa Margarita
68
Inshore
Offshore
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
CALIFORNIA COASTAL KELP RESOURCES
Camp Pendelton
ecoscan
C-68

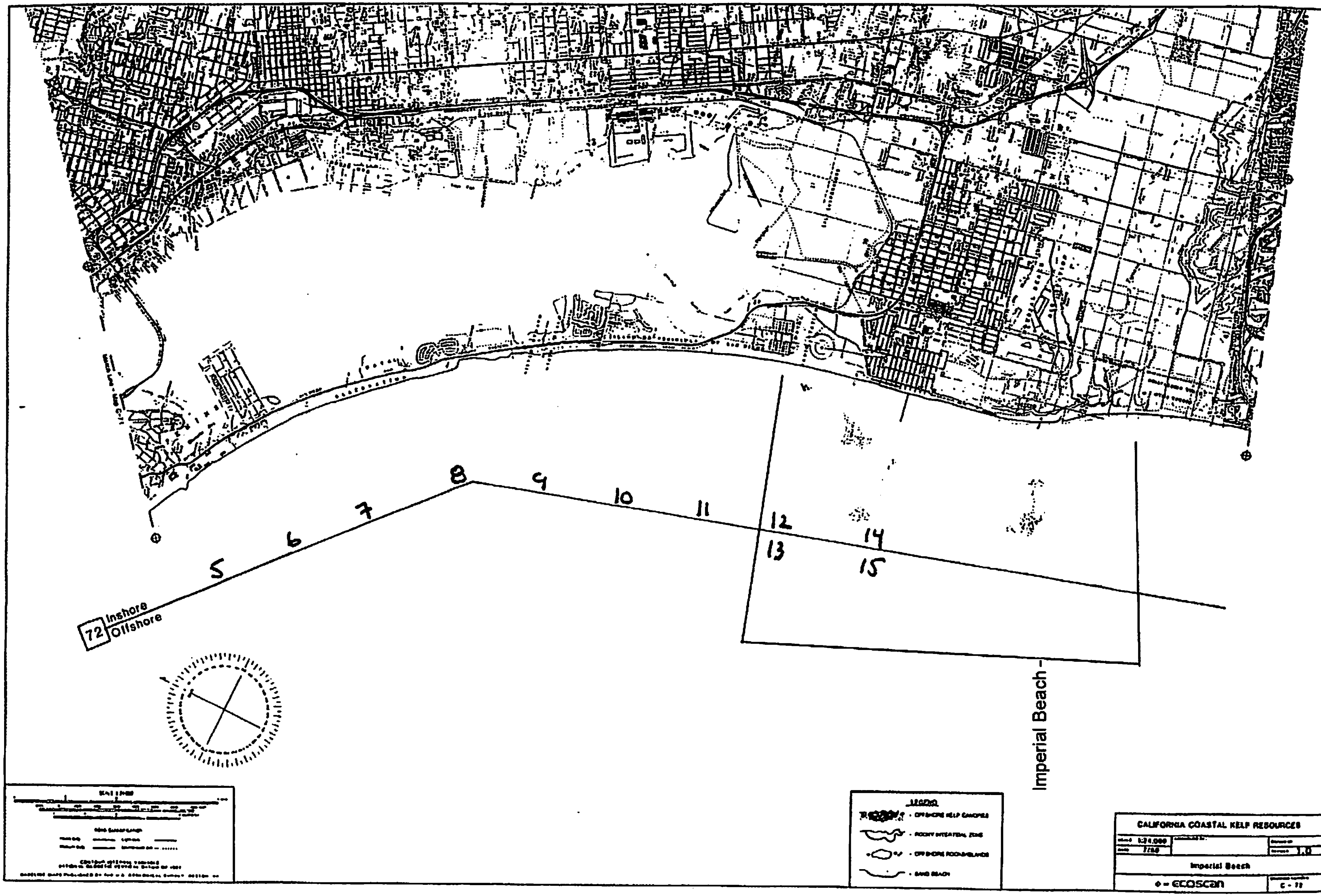


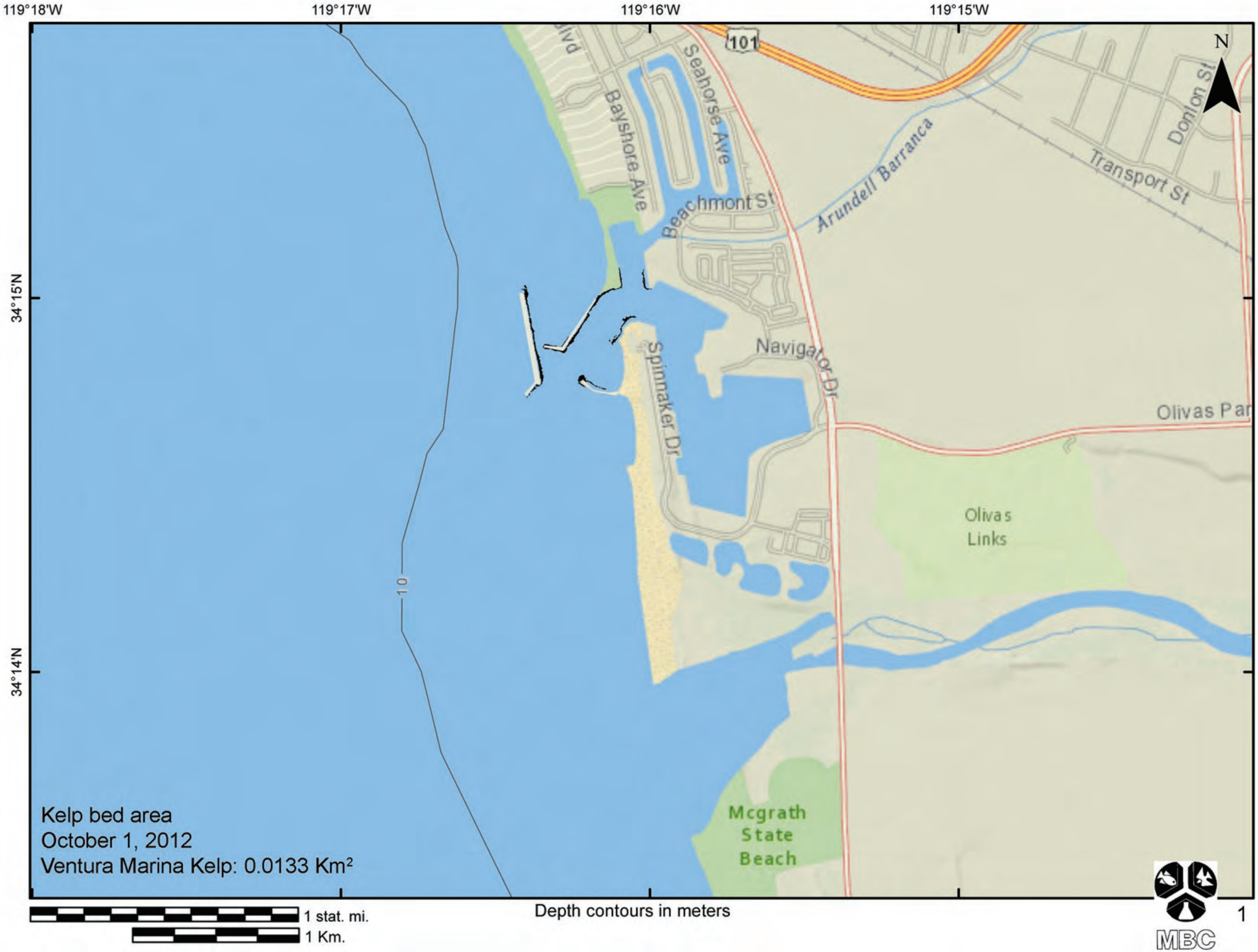
69 Inshore Offshore
North Carlsbad
Agua Hediona
Encina Power Plant
Carlsbad State Beach
North Leucadia
Central Leucadia
South Leucadia
Encinitas
1
2
3
4
5
6
7
8
9
10
11
12
13
14
CALIFORNIA COASTAL KELP RESOURCES
Carlsbad
ECOSCAN
C - 08

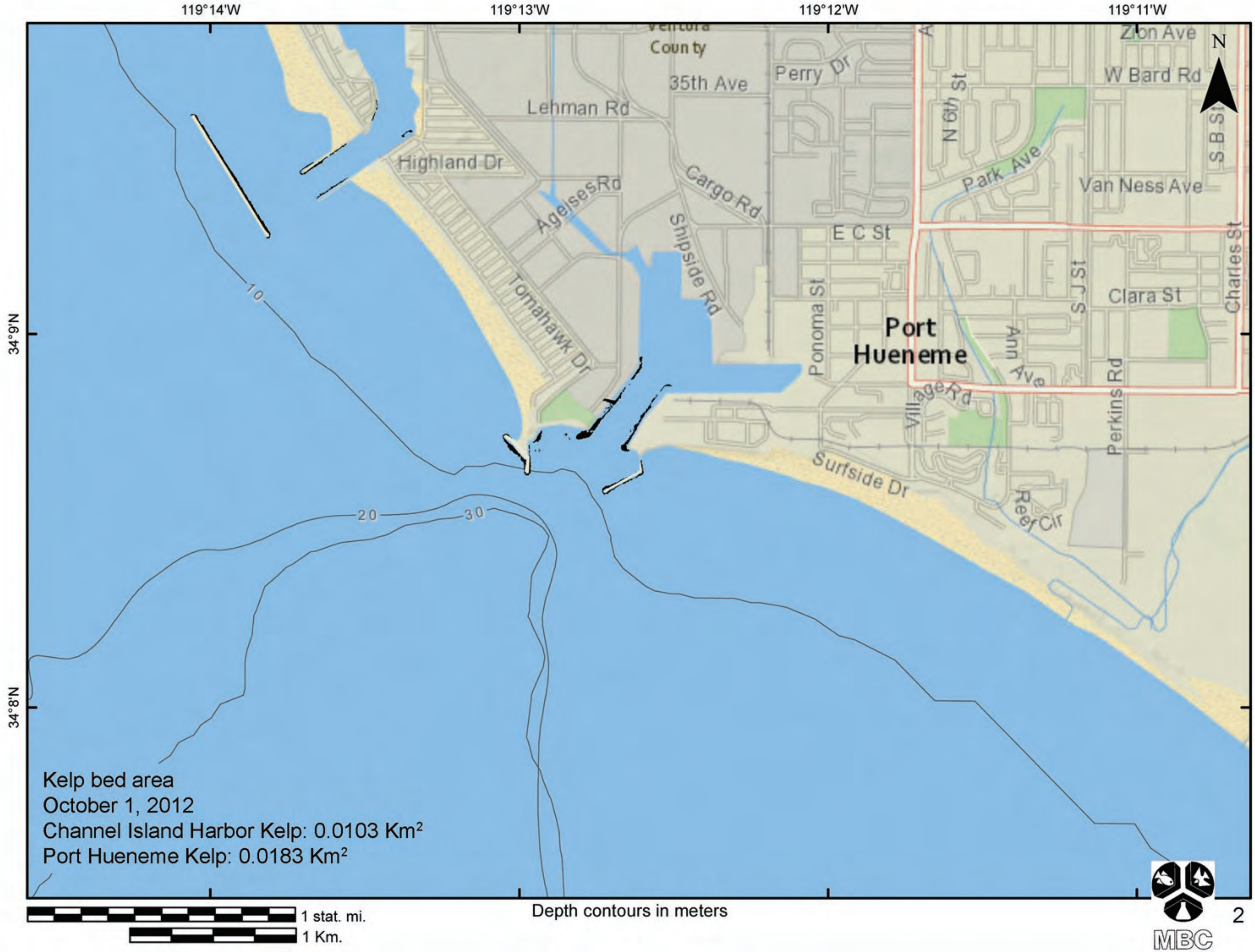


70
Inshore
Offshore
Encinitas
Cardiff
Solana Beach
Del Mar
Torrey Pines
La Jolla
CALIFORNIA COASTAL KELP RESOURCES
Del Mar

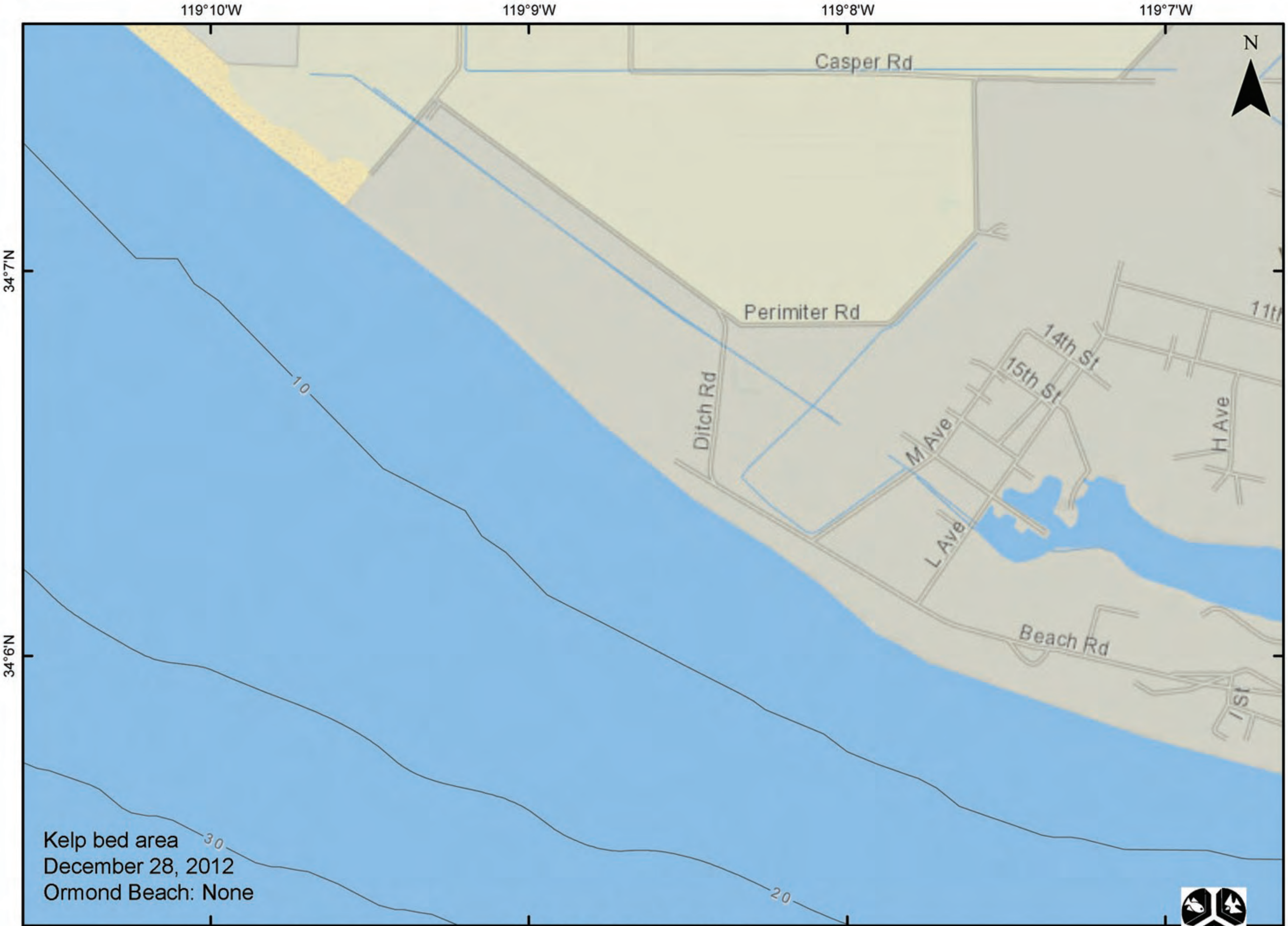

La Jolla
Point Loma
71 Inshore Offshore
72 Inshore Offshore
SAN DIEGO
San Diego Bay
ECOSCAN
CALIFORNIA COASTAL KELP RESOURCES
Pt. Loma


72
Inshore
Offshore
5
6
7
8
9
10
11
12
13
14
15
Imperial Beach -
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
Imperial Beach
ECOSCAN


119°18'W
119°17'W
119°16'W
119°15'W
34°15'N
34°14'N
N
101
Blvd
Bayshore Ave
Seahorse Ave
Beachmont St
Arundell Barranca
Transport St
Donlon St
Spinnaker Dr
Navigator Dr
Olivas Par
Olivas Links
Mcgrath State Beach
10
Kelp bed area
October 1, 2012
Ventura Marina Kelp: 0.0133 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC



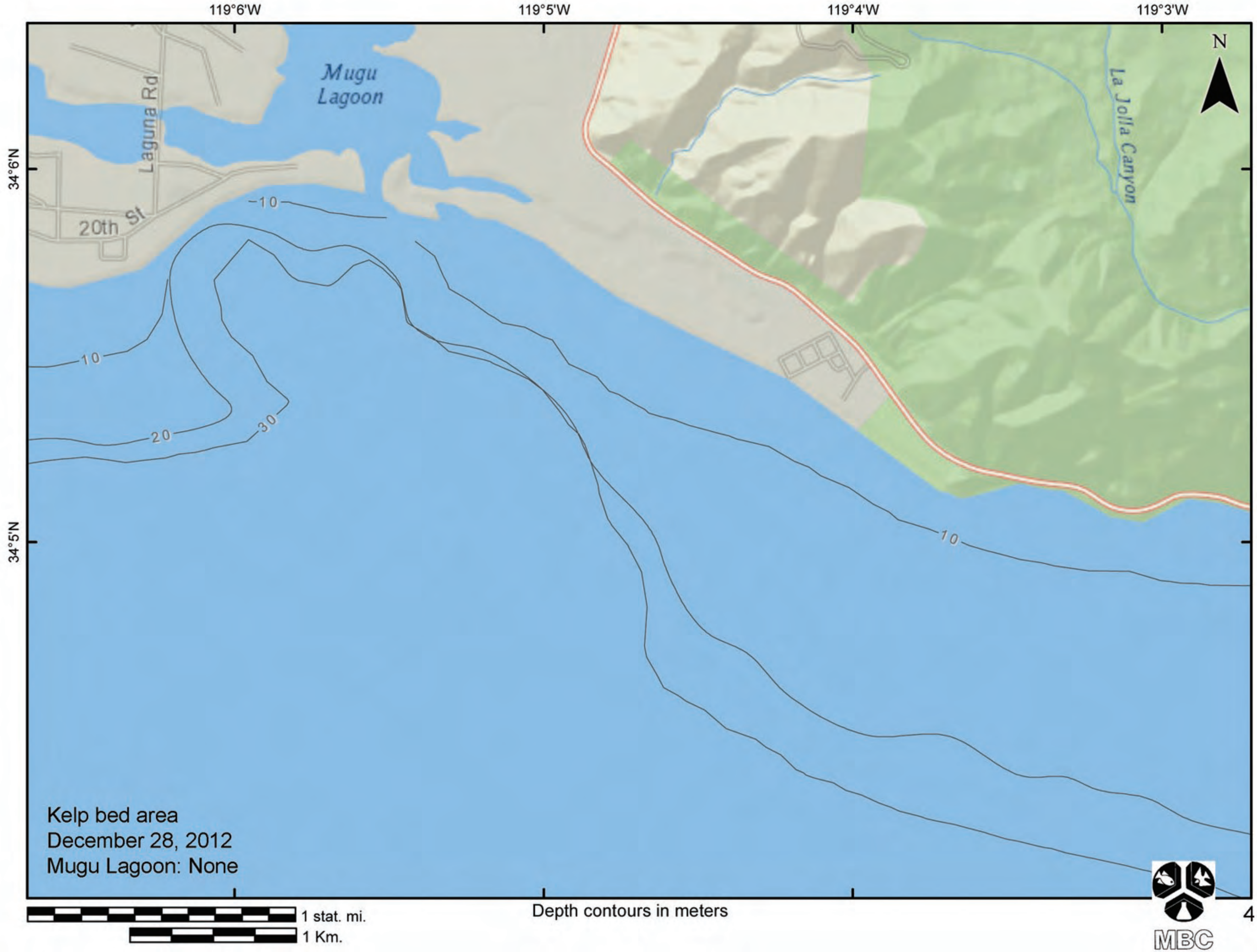
Depth contours in meters



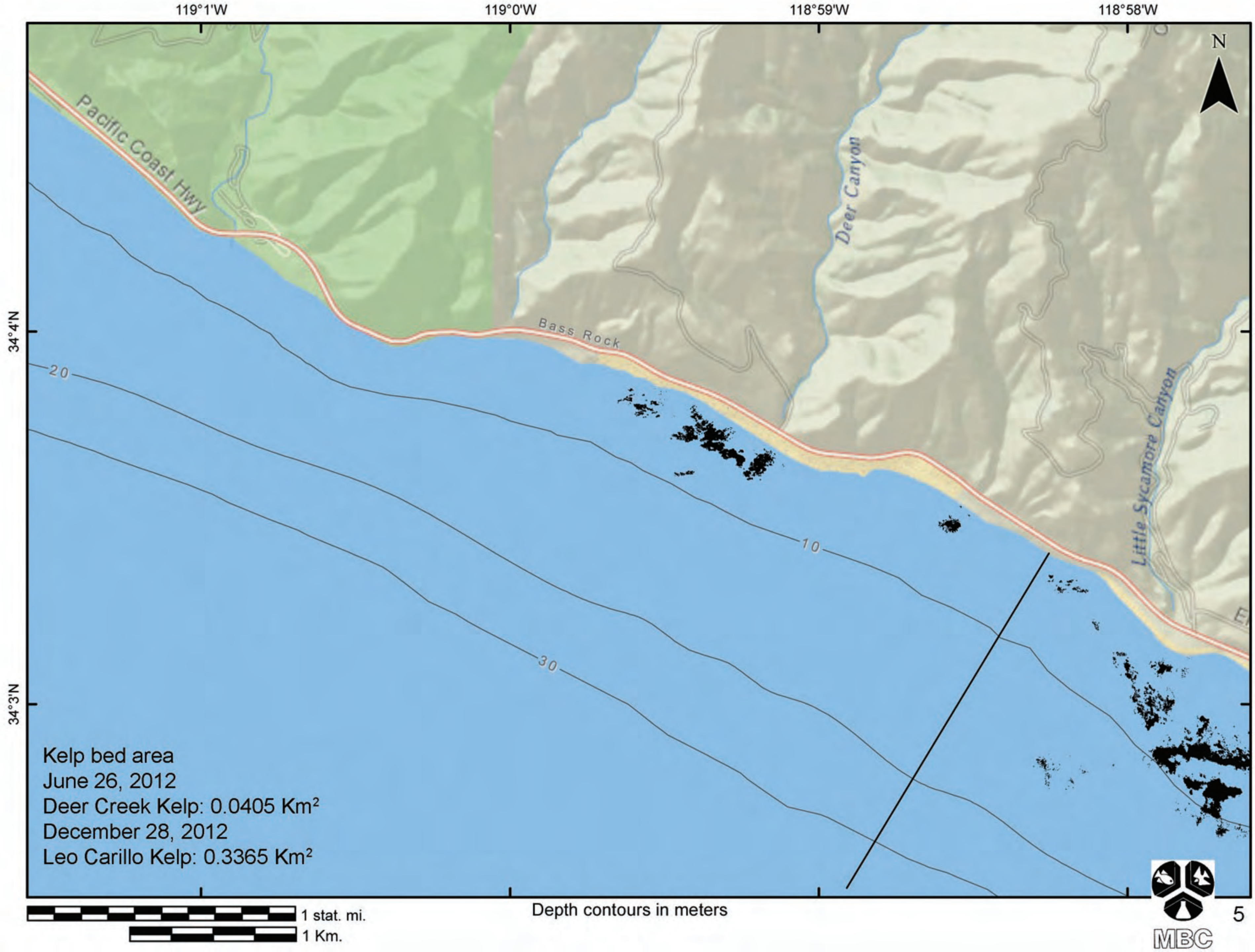
1 stat. mi.
1 Km.

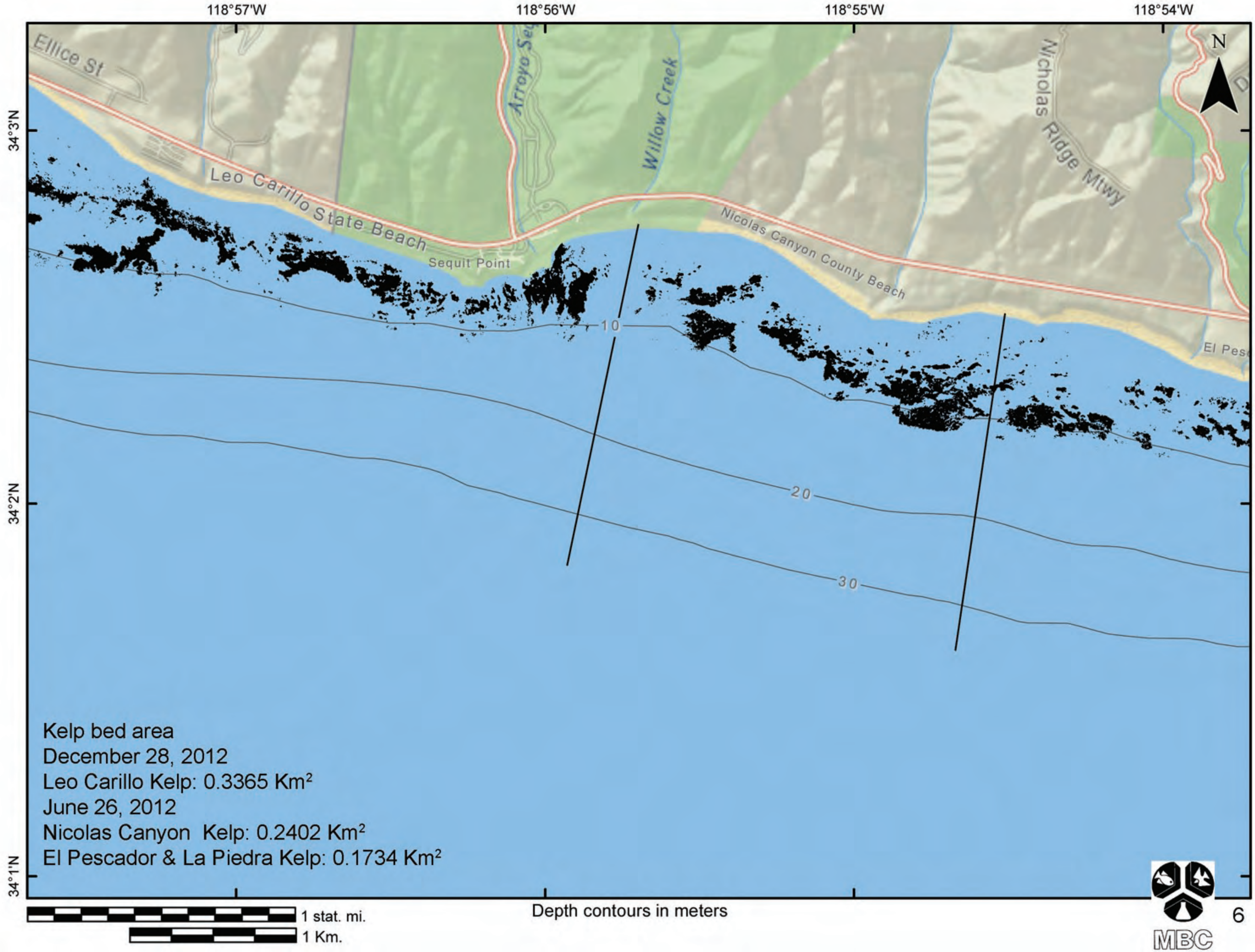
Depth contours in meters

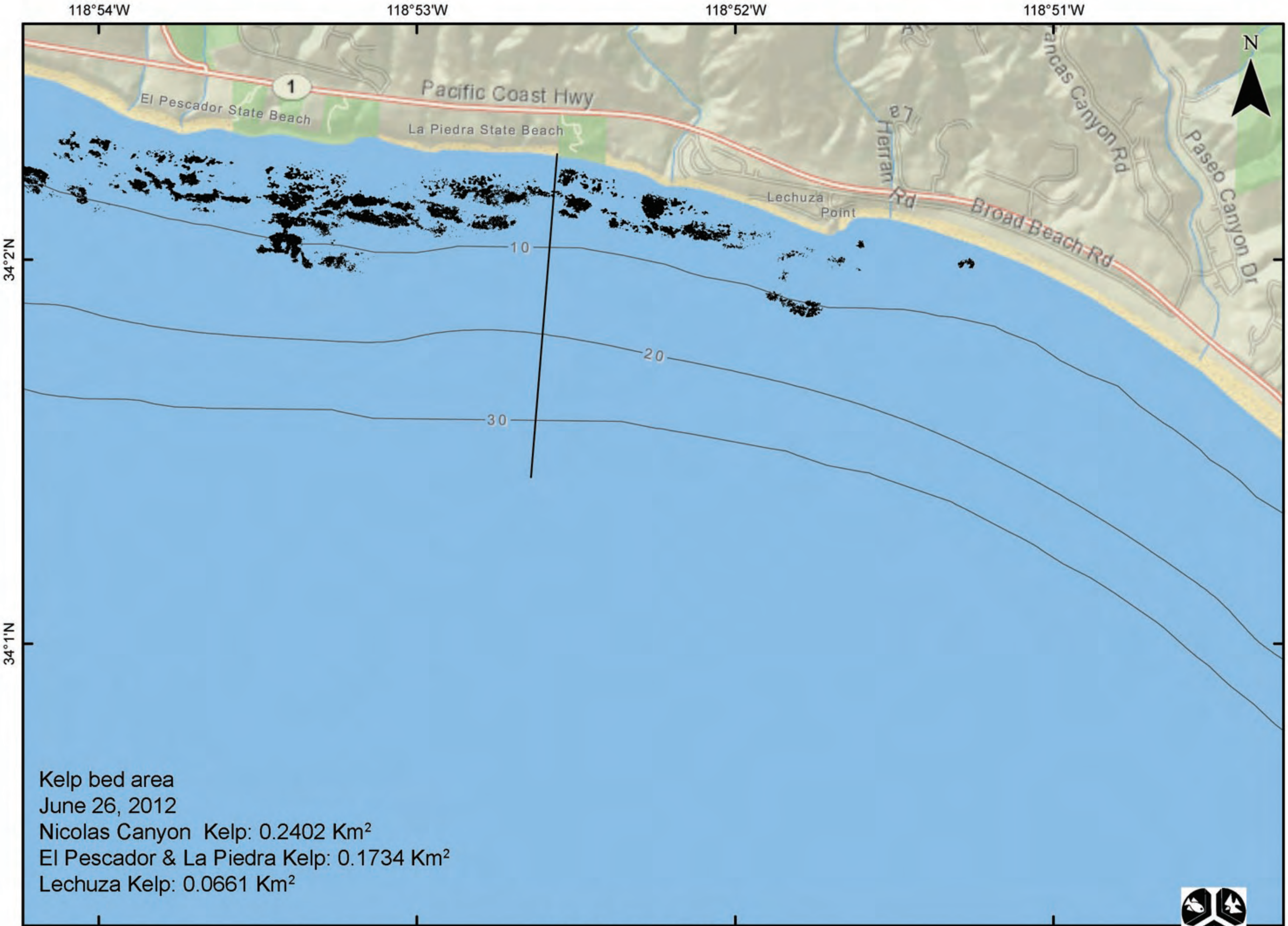
MBC



Depth contours in meters

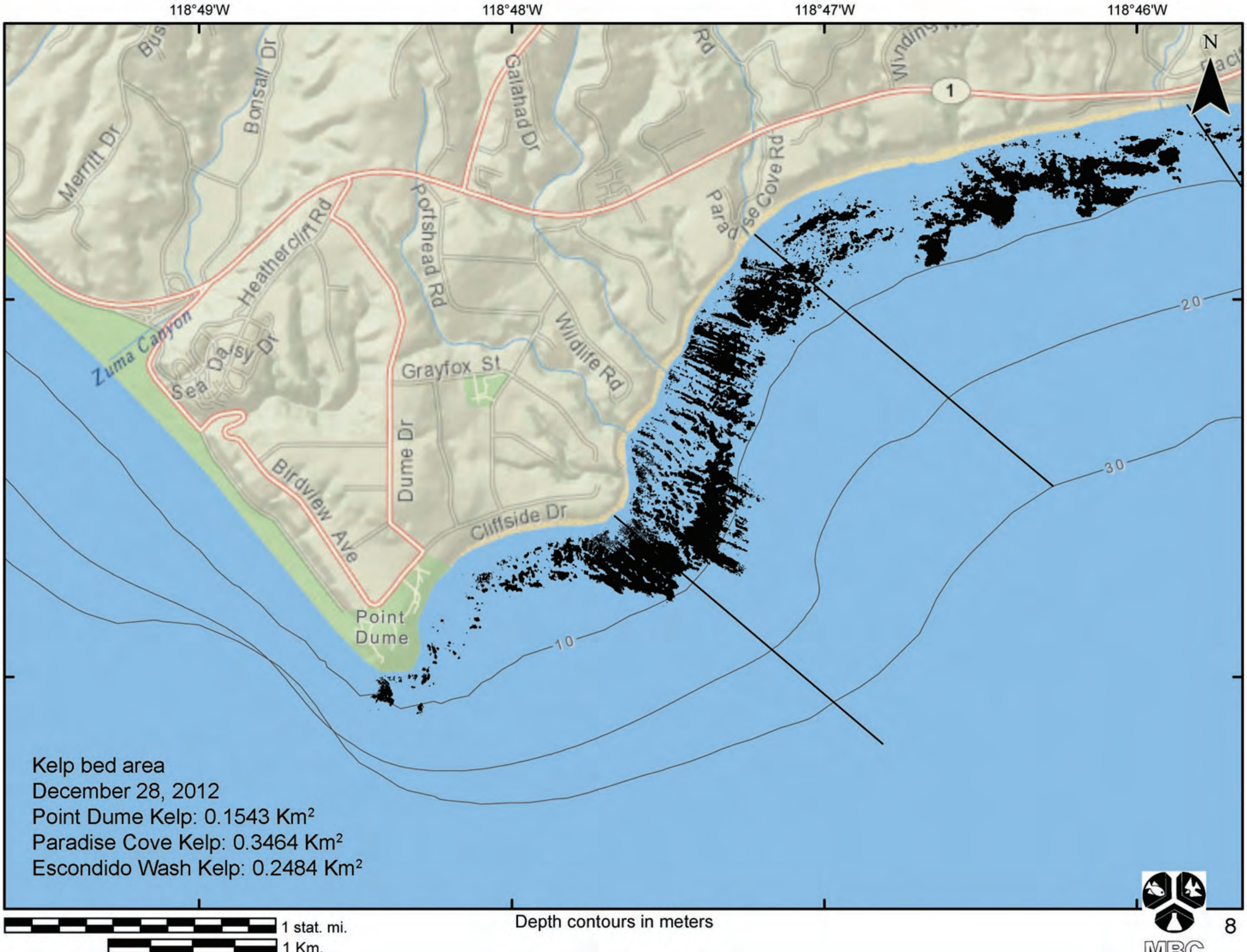

119°1'W
119°0'W
118°59'W
118°58'W
34°4'N
34°3'N
N
Pacific Coast Hwy
Bass Rock
Deer Canyon
Little Sycamore Canyon
20
10
30
Kelp bed area
June 26, 2012
Deer Creek Kelp: 0.0405 Km²
December 28, 2012
Leo Carillo Kelp: 0.3365 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

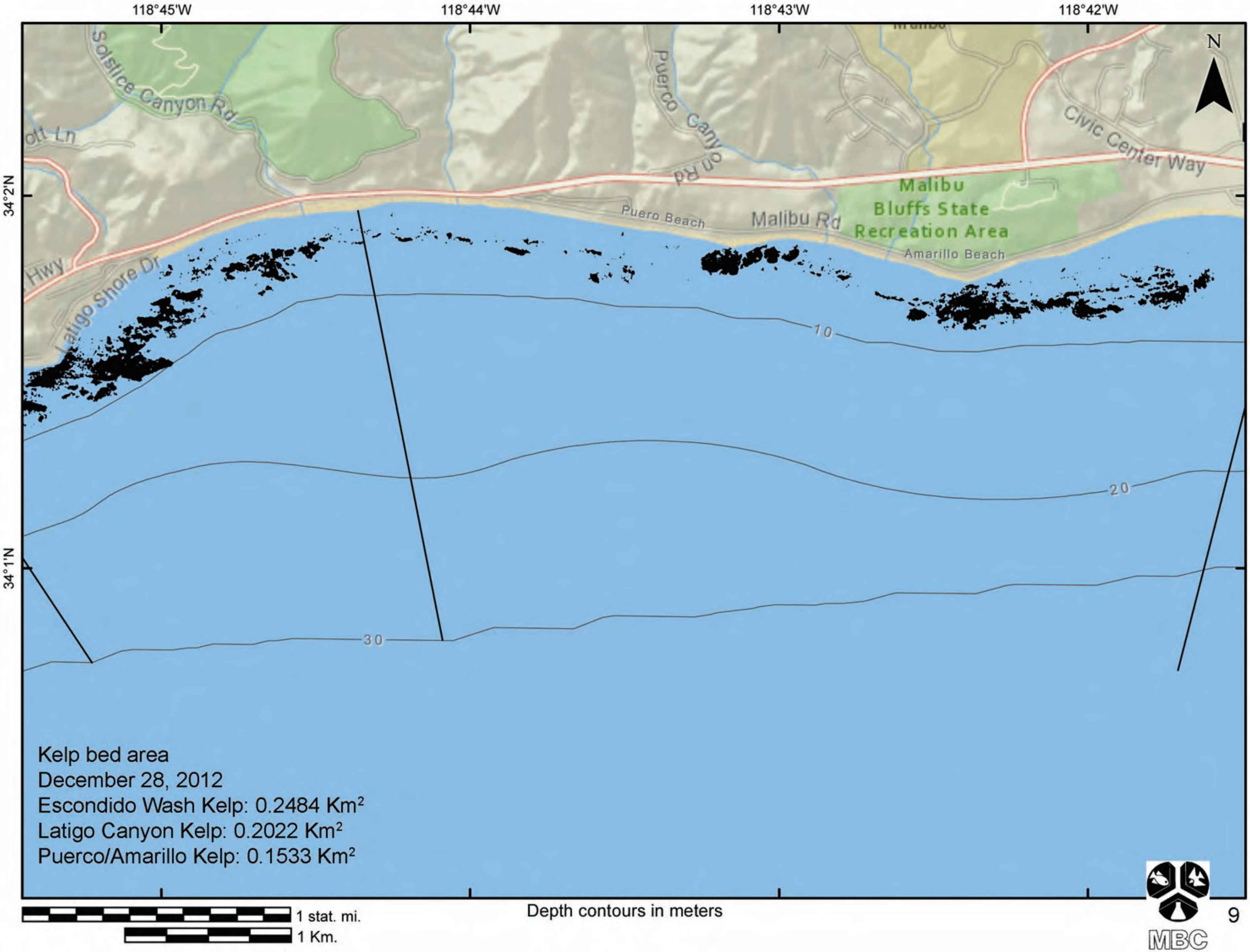

118°57'W
118°56'W
118°55'W
118°54'W
34°3'N
34°2'N
34°1'N
N
Ellice St
Arroyo Sequit
Willow Creek
Nicholas Ridge Mtwy
Leo Carillo State Beach
Sequit Point
Nicolas Canyon County Beach
El Pesc
10
20
30
Kelp bed area
December 28, 2012
Leo Carillo Kelp: 0.3365 Km²
June 26, 2012
Nicolas Canyon Kelp: 0.2402 Km²
El Pescador & La Piedra Kelp: 0.1734 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC



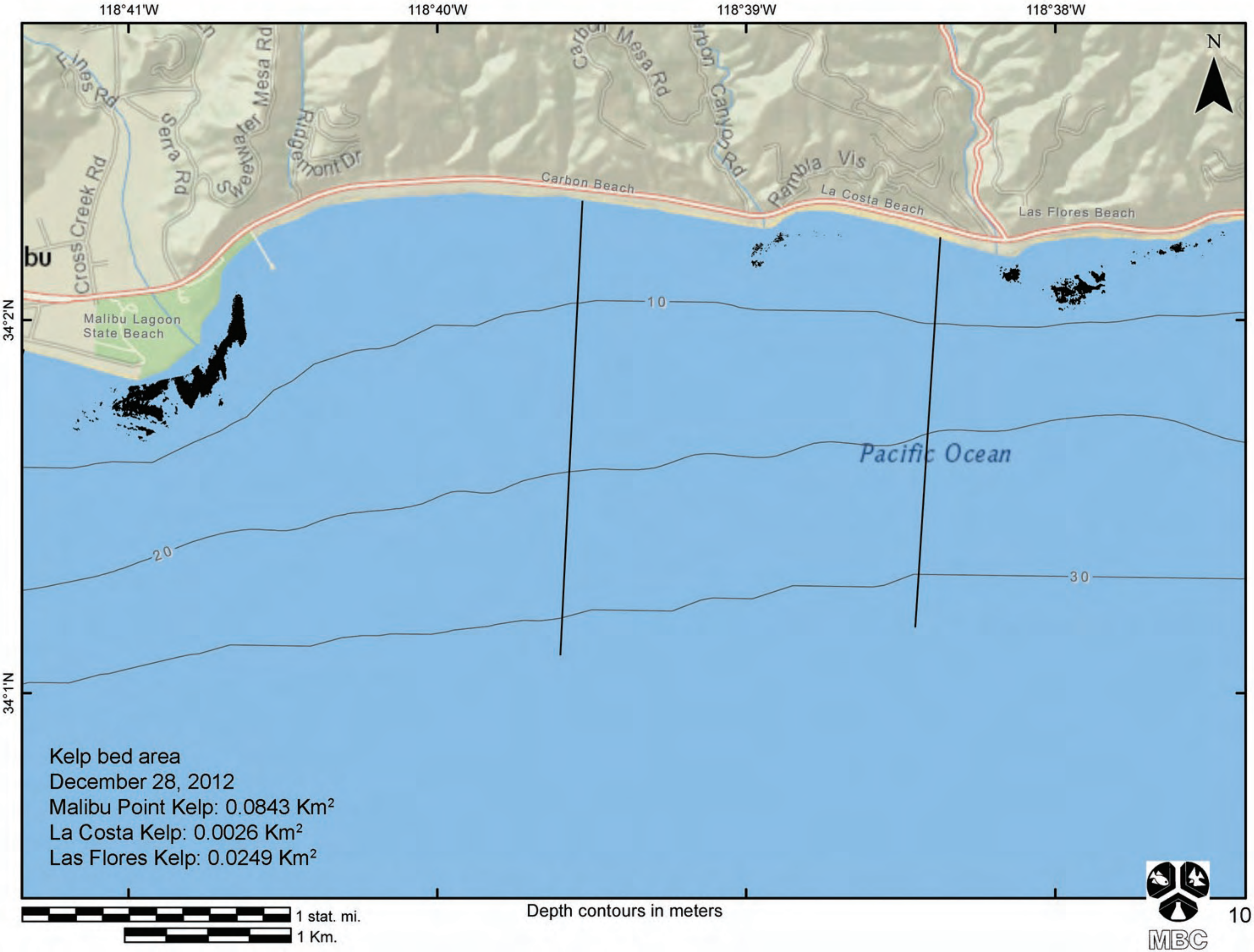
1 stat. mi.
1 Km.

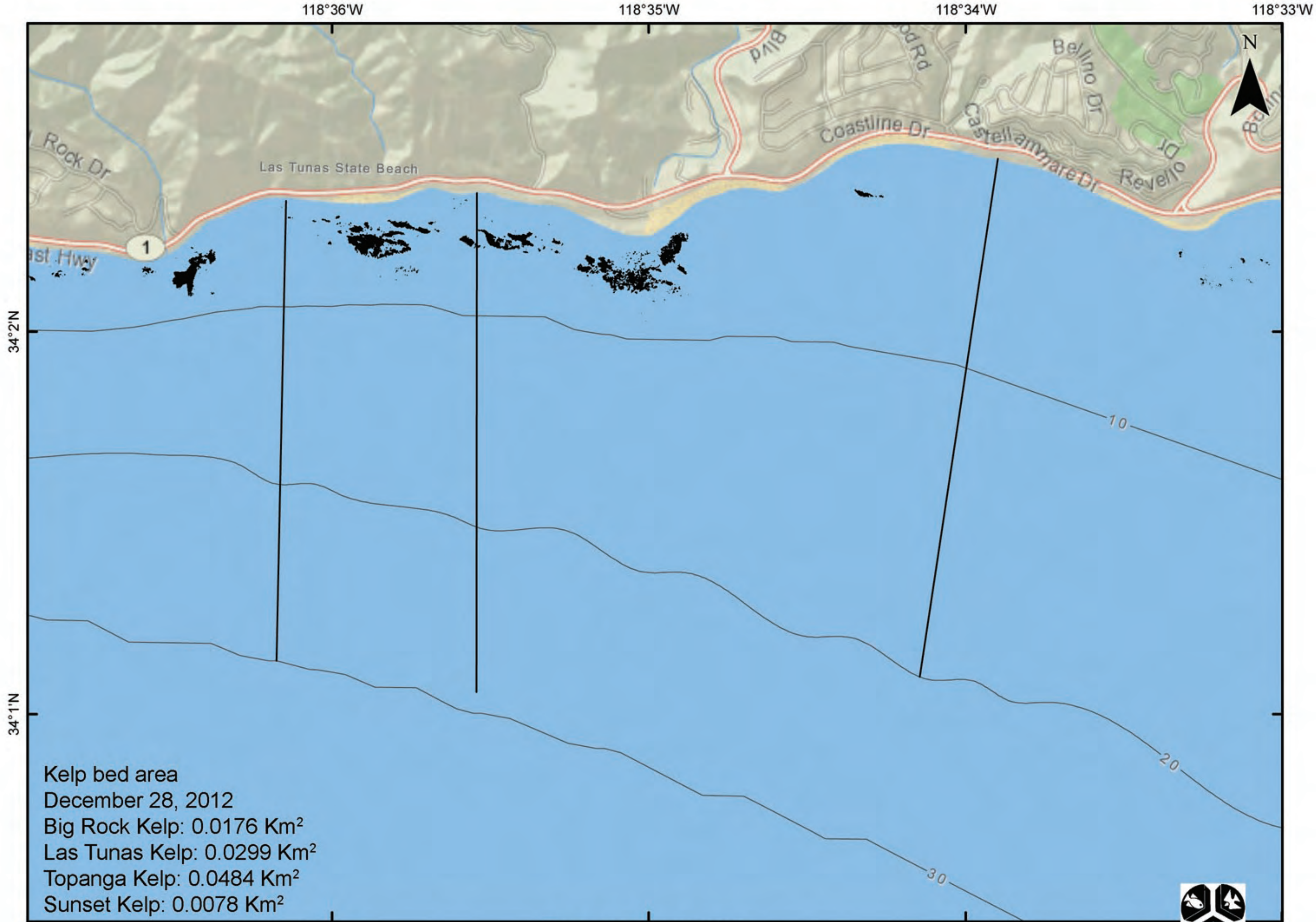
Depth contours in meters


118°49'W
118°48'W
118°47'W
118°46'W
34°1'N
34°0'N
N
Merritt Dr
Bonsall Dr
Galahad Dr
Paradise Cove Rd
Heathercliff Rd
Portshead Rd
Zuma Canyon
Sea Daisy Dr
Grayfox St
Wildlife Rd
Dume Dr
Birdview Ave
Cliffside Dr
Point Dume
1
10
20
30
Kelp bed area
December 28, 2012
Point Dume Kelp: 0.1543 Km²
Paradise Cove Kelp: 0.3464 Km²
Escondido Wash Kelp: 0.2484 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC



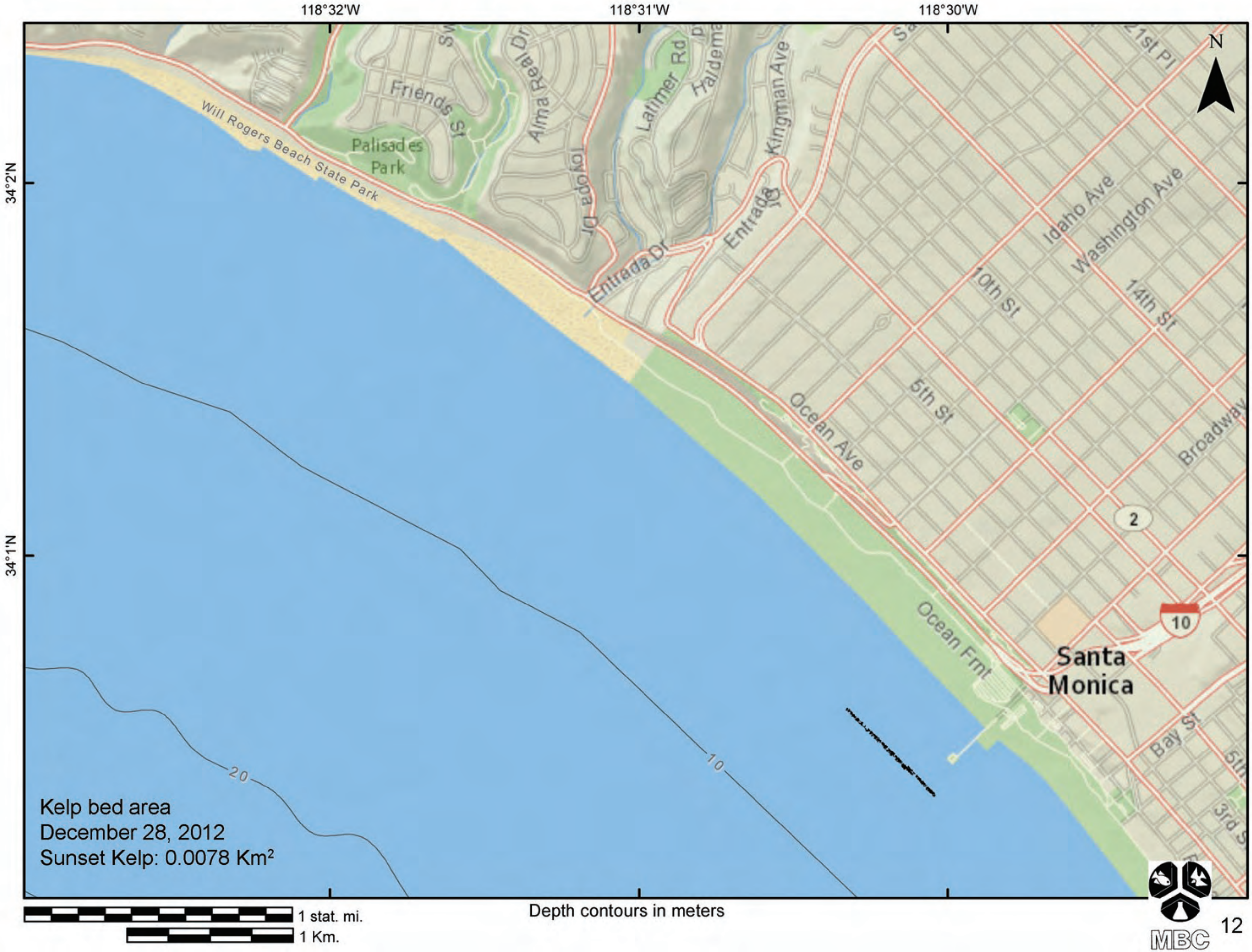
Depth contours in meters


118°41'W
118°40'W
118°39'W
118°38'W
34°2'N
34°1'N
N
Malibu Lagoon State Beach
Carbon Beach
La Costa Beach
Las Flores Beach
Pacific Ocean
10
20
30
Kelp bed area
December 28, 2012
Malibu Point Kelp: 0.0843 Km²
La Costa Kelp: 0.0026 Km²
Las Flores Kelp: 0.0249 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

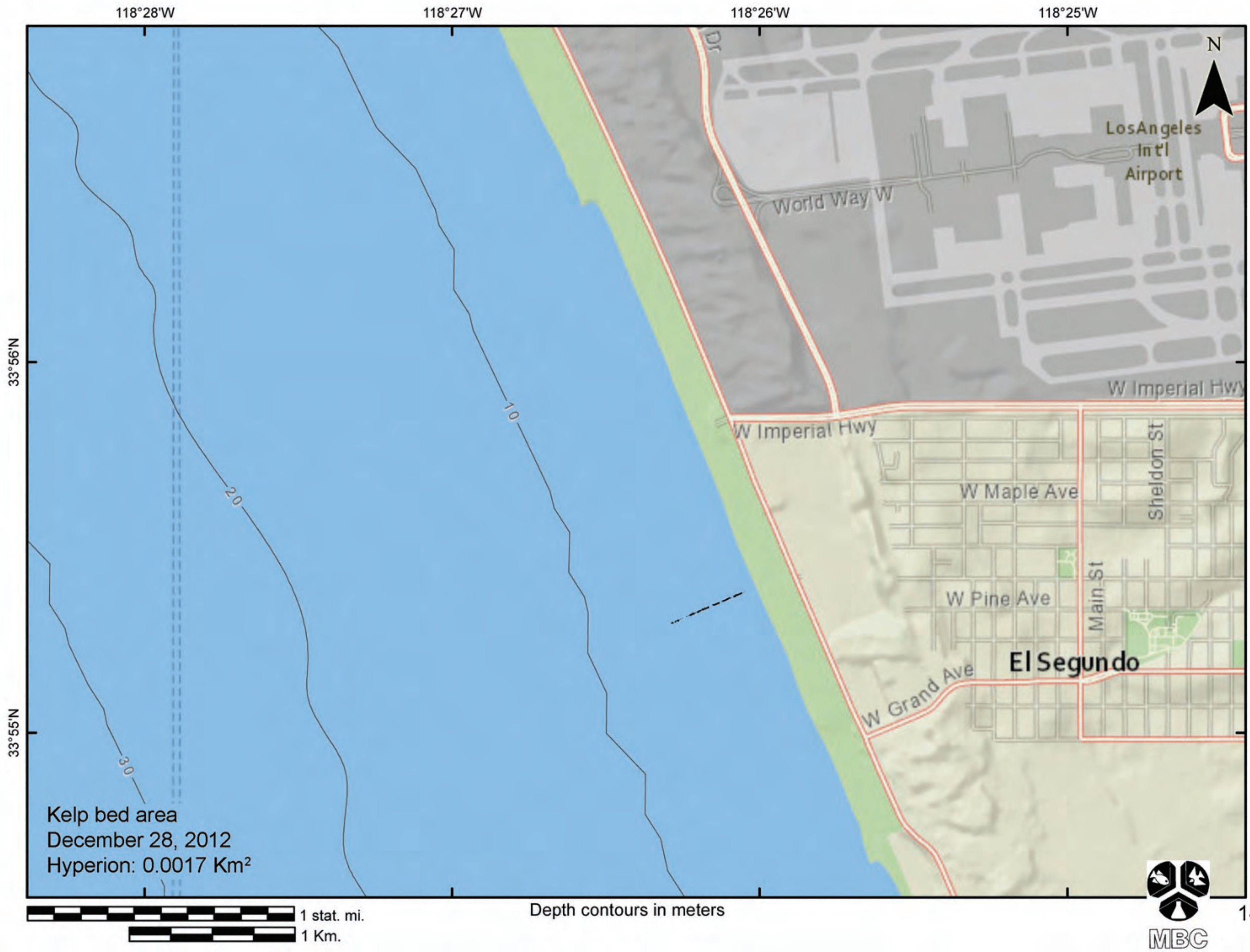


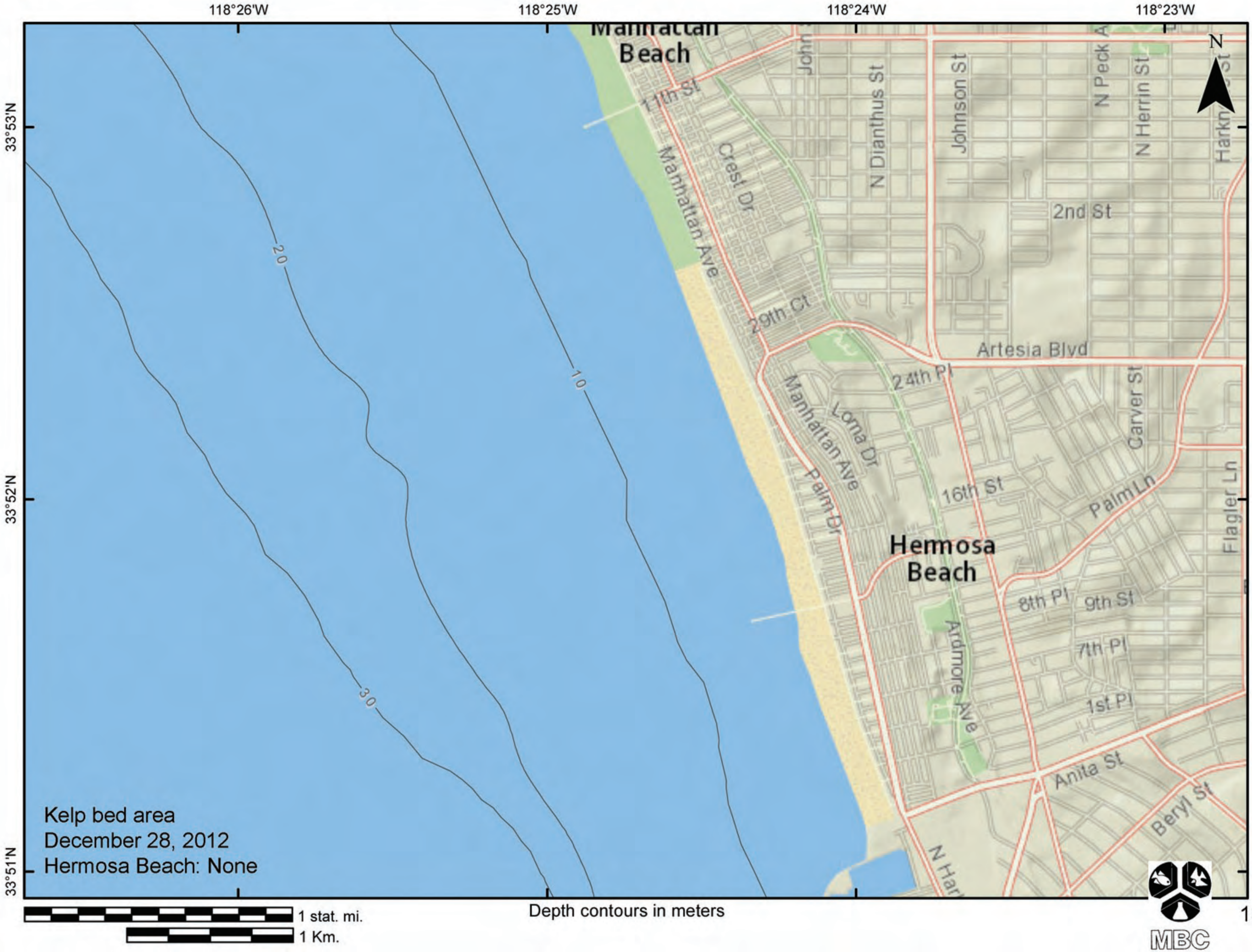
1 stat. mi.
1 Km.

Depth contours in meters


118°32'W
118°31'W
118°30'W
34°2'N
34°1'N
N
Will Rogers Beach State Park
Palisades Park
Friends St
Alma Real Dr
Loyola Dr
Latimer Rd
Haldeman
Kingman Ave
Entrada Dr
Entrada Dr
21st Pl
Idaho Ave
Washington Ave
10th St
14th St
5th St
Ocean Ave
Broadway
2
10
Ocean Frnt
Santa Monica
Bay St
3rd St
10
20
Kelp bed area
December 28, 2012
Sunset Kelp: 0.0078 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

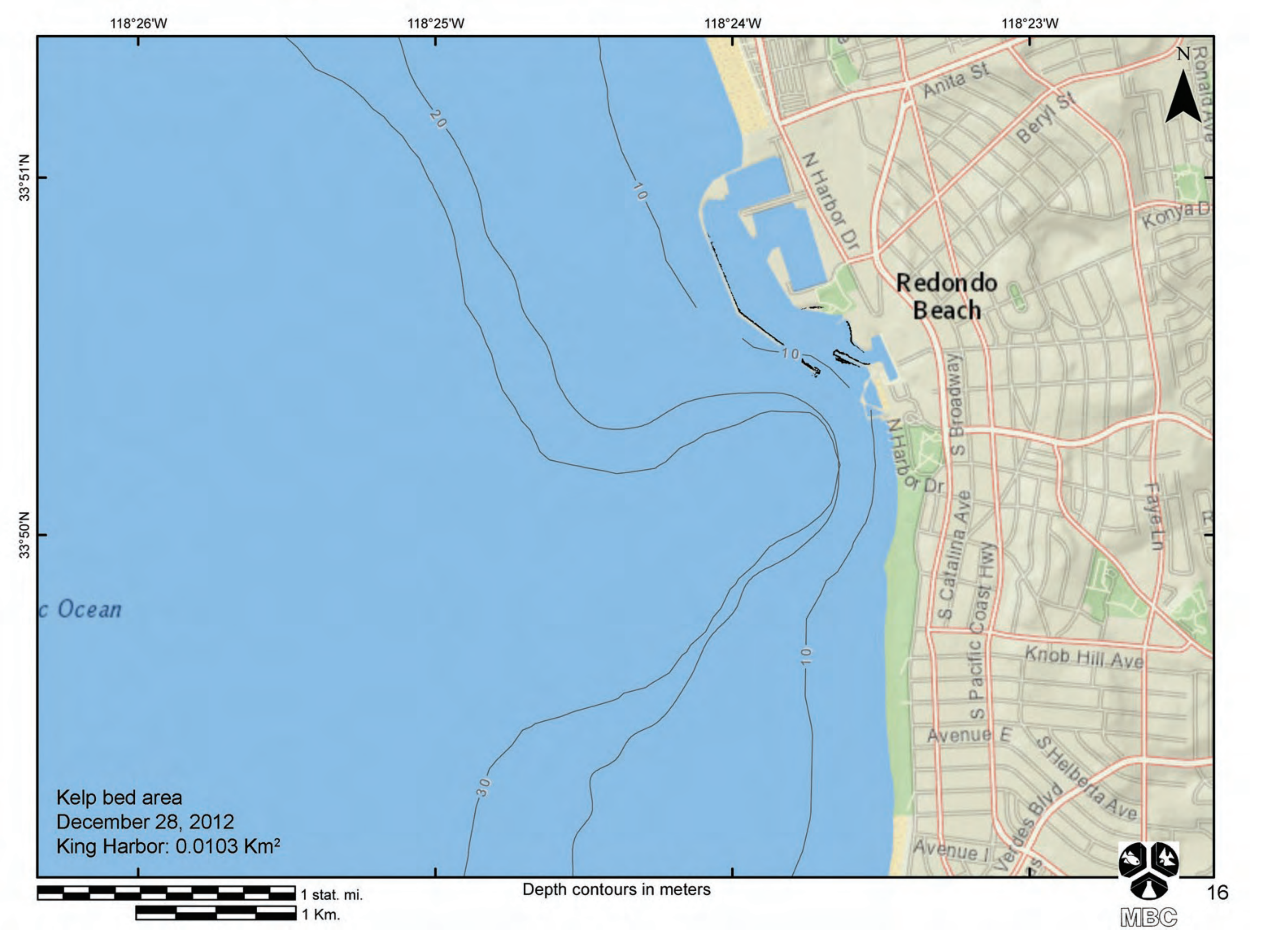

118°29'W
118°28'W
118°27'W
118°26'W
33°59'N
33°58'N
N
Venice
Marina Del Rey
Playa Del Rey
Electric Ave
Rialto Ave
Marr St
Del Rey Ave
Glencoe Ave
Mindanao Way
Carroll Canal
S Grand Cl
Via Marina
Palawan Way
Marina Del Rey
Fiji Way
Fleet St
Speedway
Tahiti Way
Ballona Creek
S Ponte
Avalon Marina Del Rey Fry
W Cabot
Zitola Ter
Falmouth Ave
Ridge
10
20
Kelp bed area
December 28, 2012
Marina Del Rey: 0.014 Km²
1 stat. mi.
1 Km.
Depth contours in meters


118°28'W
118°27'W
118°26'W
118°25'W
33°56'N
33°55'N
N
Los Angeles Int'l Airport
World Way W
W Imperial Hwy
W Imperial Hwy
W Maple Ave
Sheldon St
W Pine Ave
Main St
El Segundo
W Grand Ave
10
20
30
Kelp bed area
December 28, 2012
Hyperion: 0.0017 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

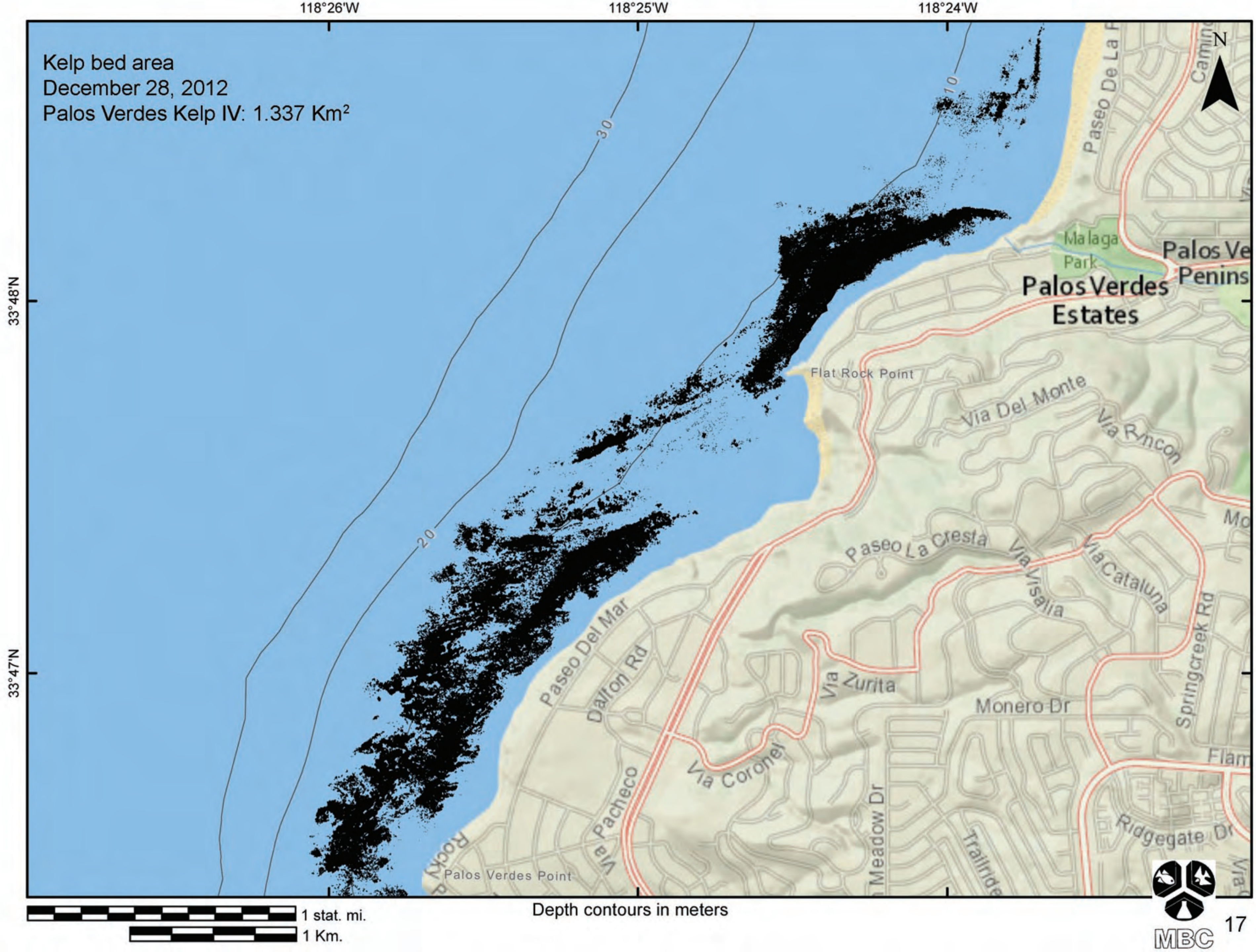


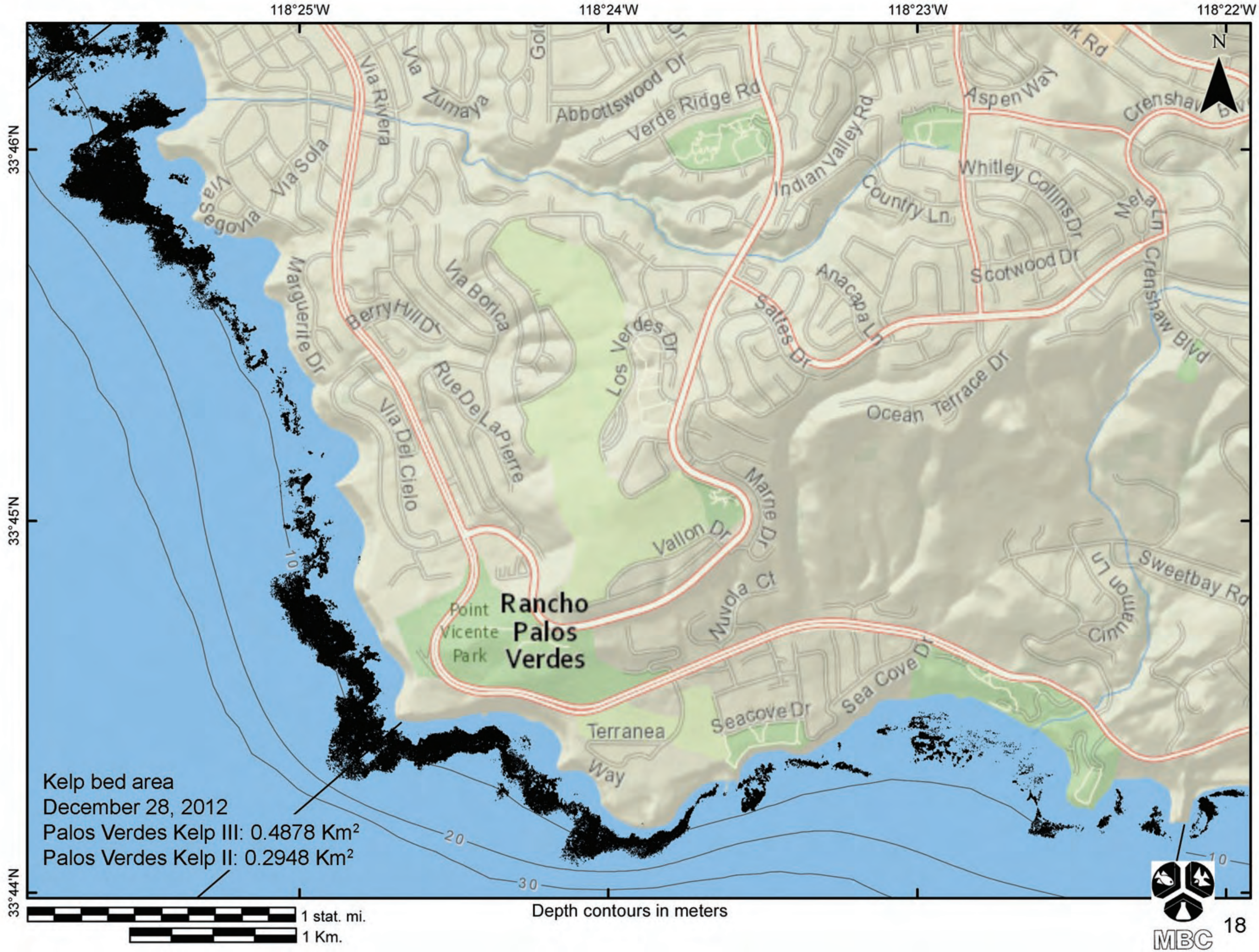
Depth contours in meters

MBC

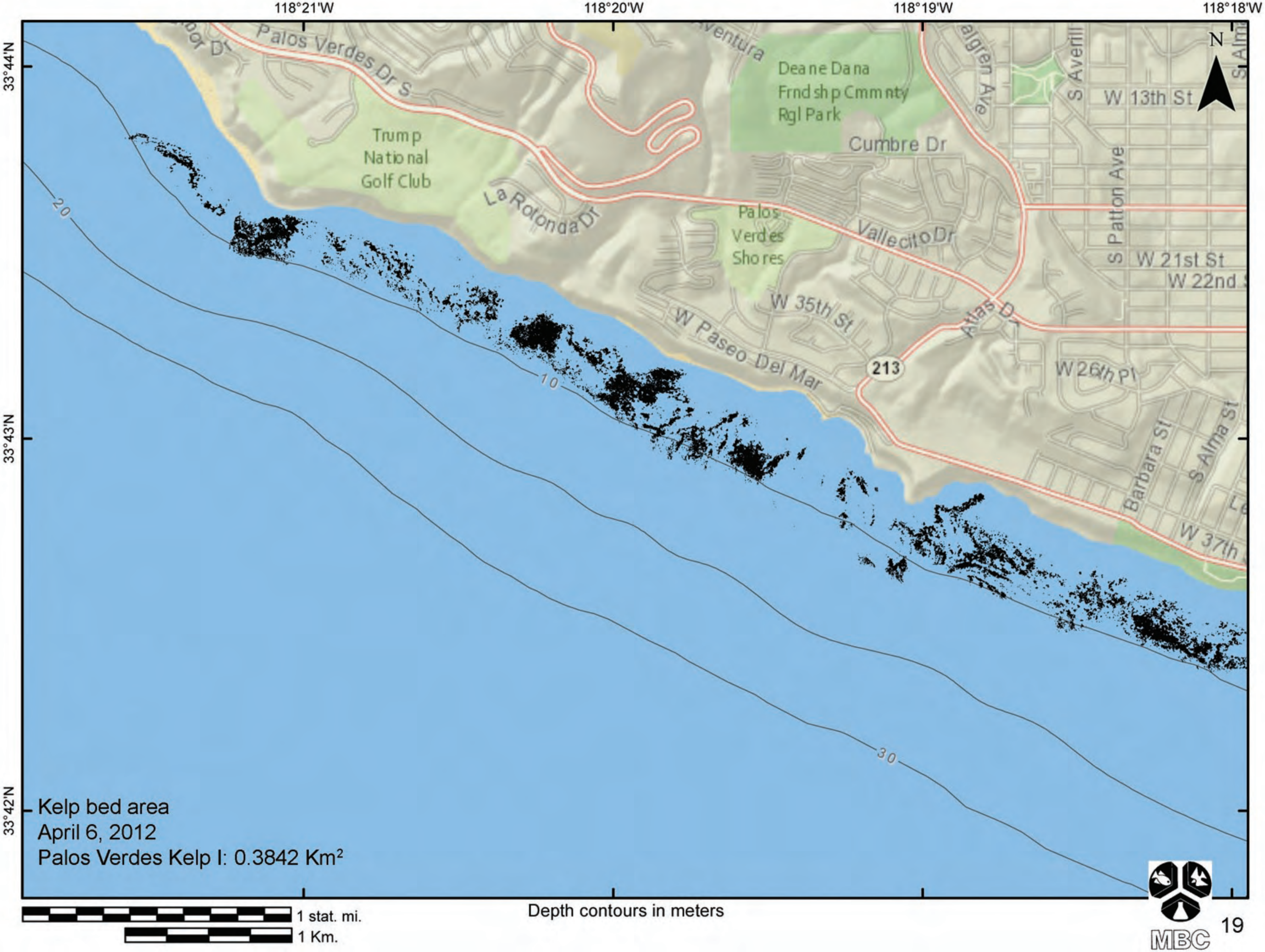


118°26'W
118°25'W
118°24'W
118°23'W
33°51'N
33°50'N
N
c Ocean
Redondo Beach
Anita St
Beryl St
Ronald Ave
Konya Dr
N Harbor Dr
S Broadway
S Catalina Ave
S Pacific Coast Hwy
Faye Ln
Knob Hill Ave
Avenue E
S Helberta Ave
Avenue I
Verdes Blvd
10
20
30
Kelp bed area
December 28, 2012
King Harbor: 0.0103 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

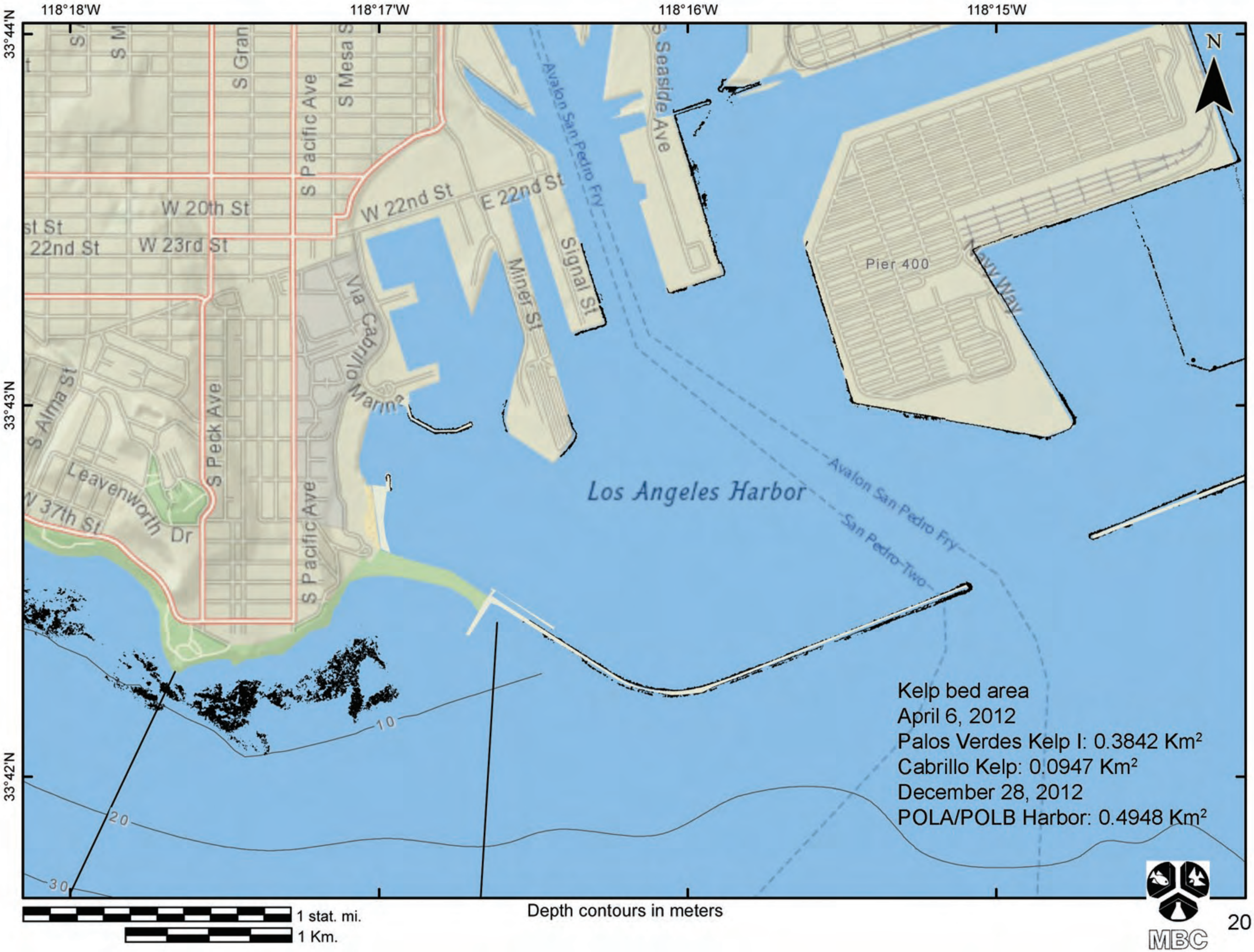

118°26'W
118°25'W
118°24'W
33°48'N
33°47'N
Kelp bed area
December 28, 2012
Palos Verdes Kelp IV: 1.337 Km²
N
30
20
10
Malaga Park
Palos Verdes Estates
Flat Rock Point
Via Del Monte
Via Rincon
Paseo La Cresta
Via Visalia
Via Cataluna
Springcreek Rd
Paseo Del Mar
Dalton Rd
Via Zurita
Monero Dr
Via Coronel
Via Pacheco
Meadow Dr
Ridgegate Dr
Palos Verdes Point
1 stat. mi.
1 Km.
Depth contours in meters
MBC

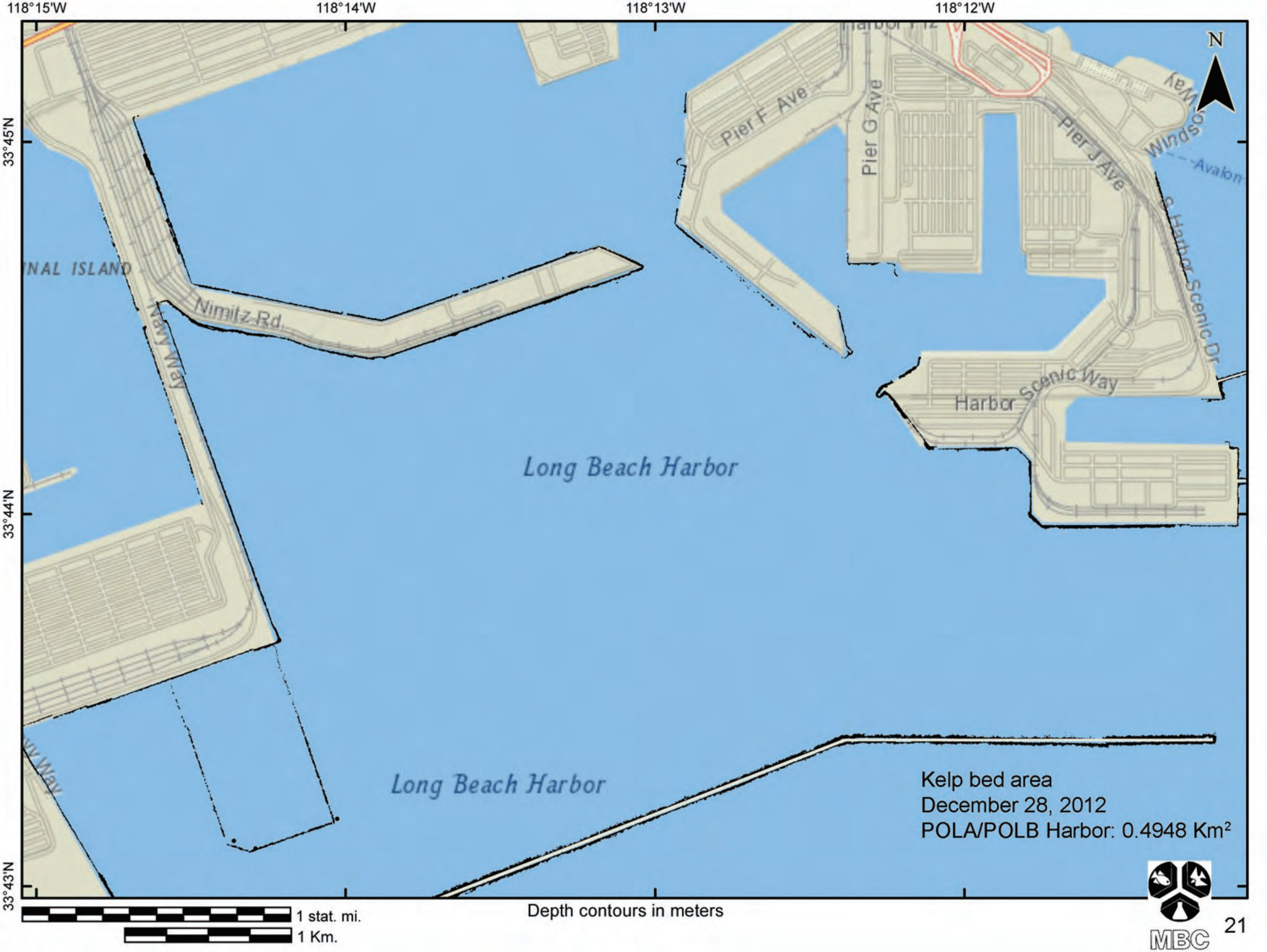


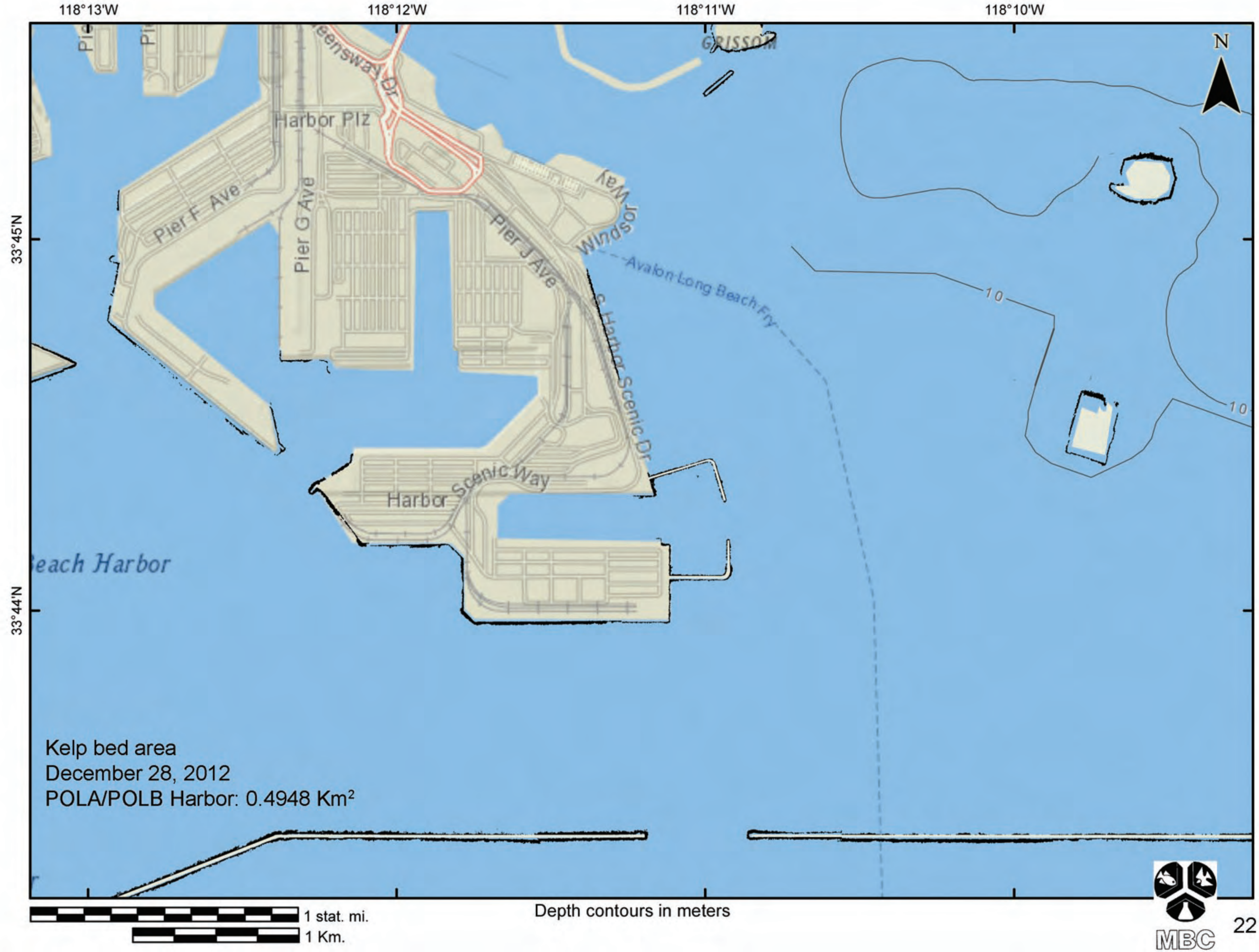
118°25'W
118°24'W
118°23'W
118°22'W
33°46'N
33°45'N
33°44'N
N
Via Rivera
Via Zumaya
Abbottswood Dr
Verde Ridge Rd
Indian Valley Rd
Aspen Way
Crenshaw Blvd
Whitley Collins Dr
Country Ln
Via Sola
Via Segovia
Marguerite Dr
Berry Hill Dr
Via Borica
Los Verdes Dr
Sattes Dr
Anacapa Ln
Scotwood Dr
Mela Ln
Crenshaw Blvd
Ocean Terrace Dr
Rue De La Pierre
Via Del Cielo
Marne Dr
Vallon Dr
Nuvola Ct
Sweetbay Rd
Cinnamon Ln
Point Vicente Park
Rancho Palos Verdes
Sea Cove Dr
Seacove Dr
Terranea Way
10
20
30
Kelp bed area
December 28, 2012
Palos Verdes Kelp III: 0.4878 Km²
Palos Verdes Kelp II: 0.2948 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC



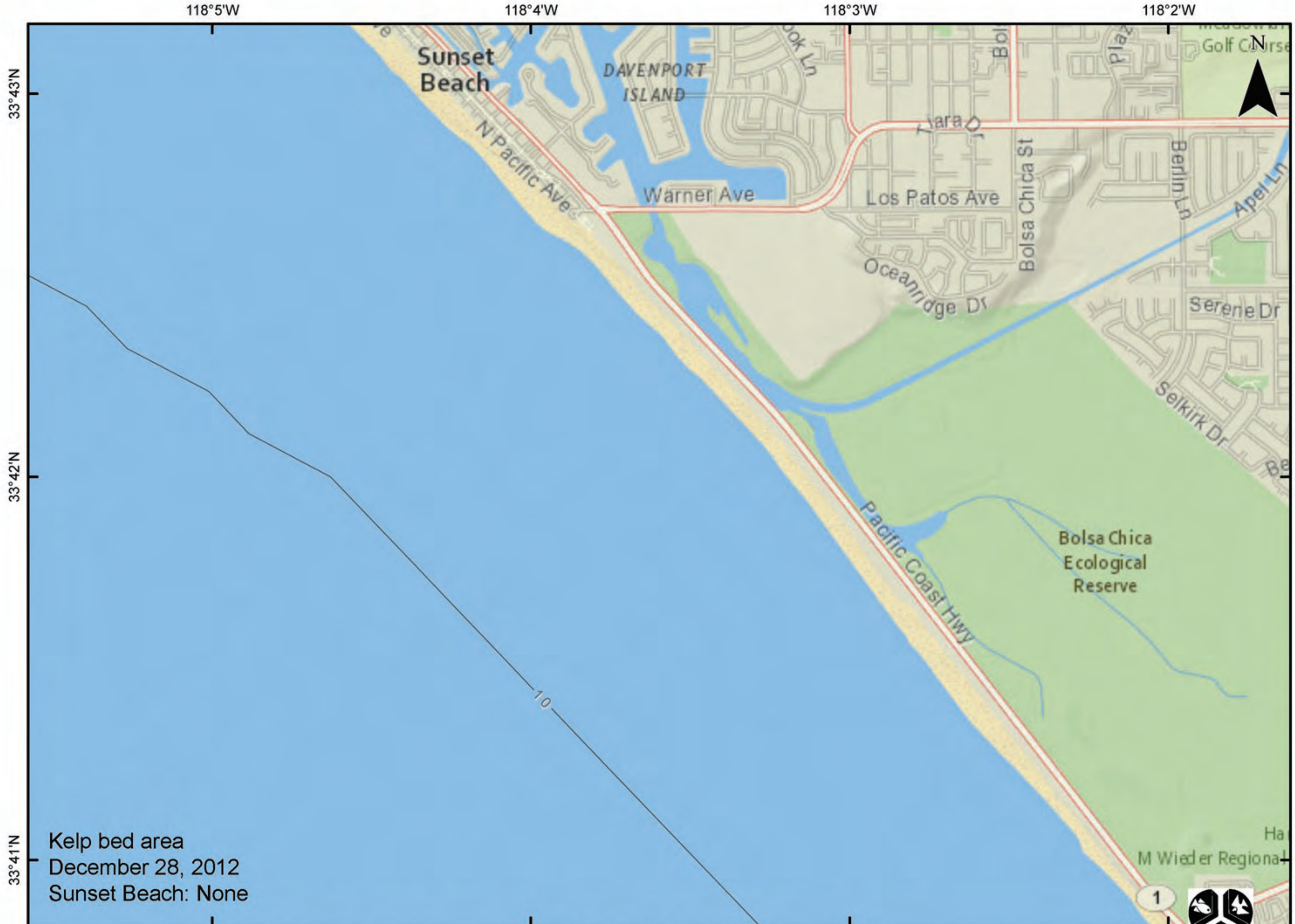
118°21'W
118°20'W
118°19'W
118°18'W
33°44'N
33°43'N
33°42'N
N
Palos Verdes Dr S
Trump National Golf Club
Deane Dana Frnd shp Cmmnty Rgl Park
Cumbre Dr
La Rotonda Dr
Palos Verdes Shores
Vallecito Dr
W 35th St
W Paseo Del Mar
213
W 13th St
S Patton Ave
W 21st St
W 22nd
W 26th Pl
Barbara St
S Alma St
W 37th
20
10
30
Kelp bed area
April 6, 2012
Palos Verdes Kelp I: 0.3842 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


118°18'W
118°17'W
118°16'W
118°15'W
33°44'N
33°43'N
33°42'N
N
Los Angeles Harbor
Pier 400
W 22nd St
E 22nd St
W 20th St
W 23rd St
S Pacific Ave
S Mesa St
Signal St
Miner St
Seaside Ave
Navy Way
Via Cabrillo Marina
S Peck Ave
S Alma St
Leavenworth Dr
W 37th St
Avalon San Pedro Fry
San Pedro Two
10
20
30
Kelp bed area
April 6, 2012
Palos Verdes Kelp I: 0.3842 Km²
Cabrillo Kelp: 0.0947 Km²
December 28, 2012
POLA/POLB Harbor: 0.4948 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


118°15'W
118°14'W
118°13'W
118°12'W
33°45'N
33°44'N
33°43'N
N
Pier F Ave
Pier G Ave
Pier J Ave
Windsor Way
Avalon
S Harbor Scenic Dr
Harbor Scenic Way
Nimitz Rd
Navy Way
INAL ISLAND
Long Beach Harbor
Long Beach Harbor
Kelp bed area
December 28, 2012
POLA/POLB Harbor: 0.4948 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

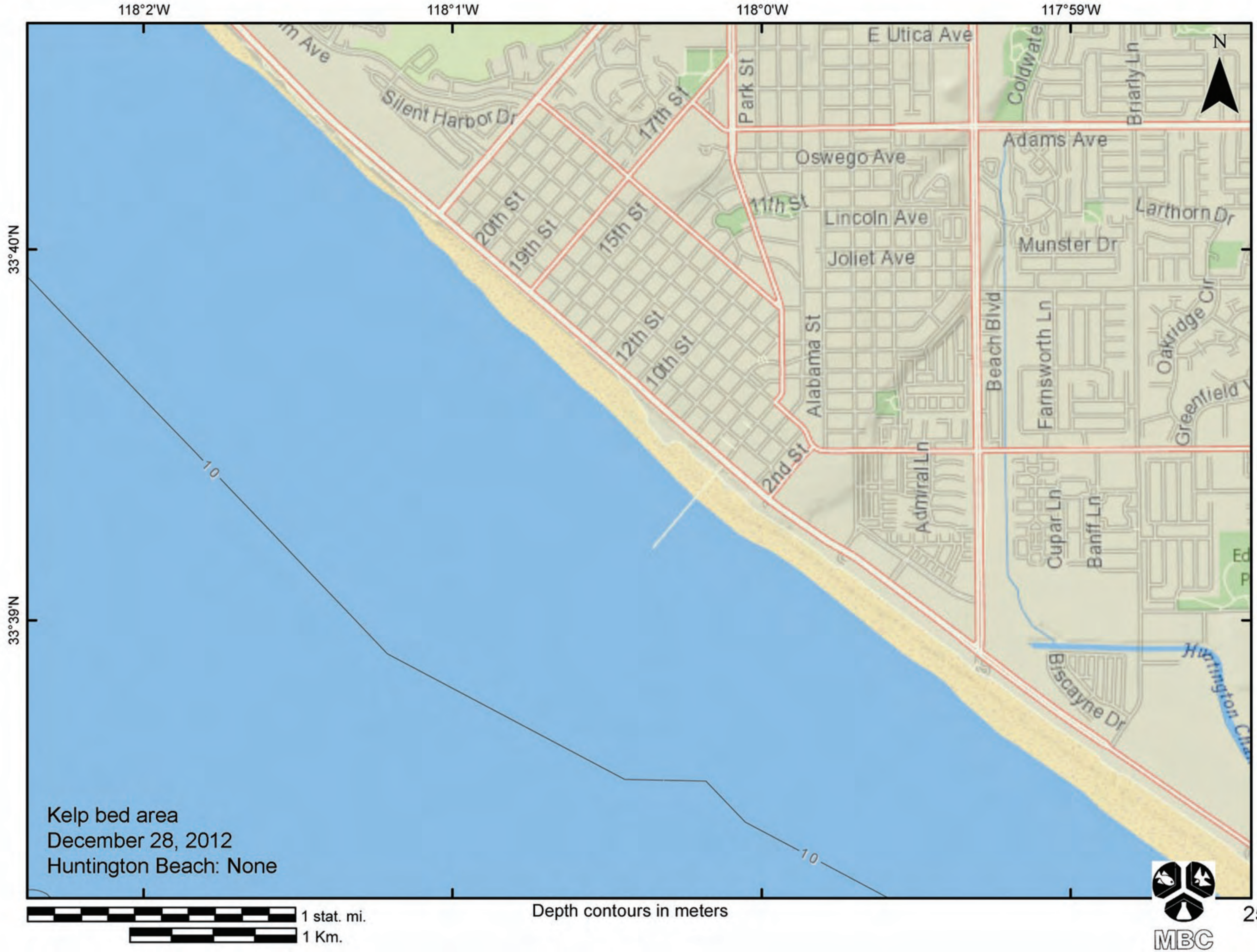

118°13'W
118°12'W
118°11'W
118°10'W
33°45'N
33°44'N
N
GRISSOM
Harbor Plz
Pier F Ave
Pier G Ave
Pier J Ave
Windsor Way
Avalon-Long Beach Fry
S Harbor Scenic Dr
Harbor Scenic Way
10
Beach Harbor
Kelp bed area
December 28, 2012
POLA/POLB Harbor: 0.4948 Km²
1 stat. mi.
1 Km.
Depth contours in meters


118°8'W
118°7'W
118°6'W
118°5'W
33°45'N
33°44'N
33°43'N
N
E Ocean Blvd
Lido Ln
61st Pl
66th Pl
Anaheim Bay
N Marina Dr
Gum Grove Park
Seal Beach
2nd St
Ocean Ave
Electric Ave
Landing Ave
Seal Way
Bolsa Ave
Pelorus Ave
Hussey Rd
Seal Beach Blvd
Huntington Harbor
Pacific Ocean
Surfside
ISLAND CHAFFEE
10
Kelp bed area
December 28, 2012
POLA/POLB Harbor: 0.4948 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

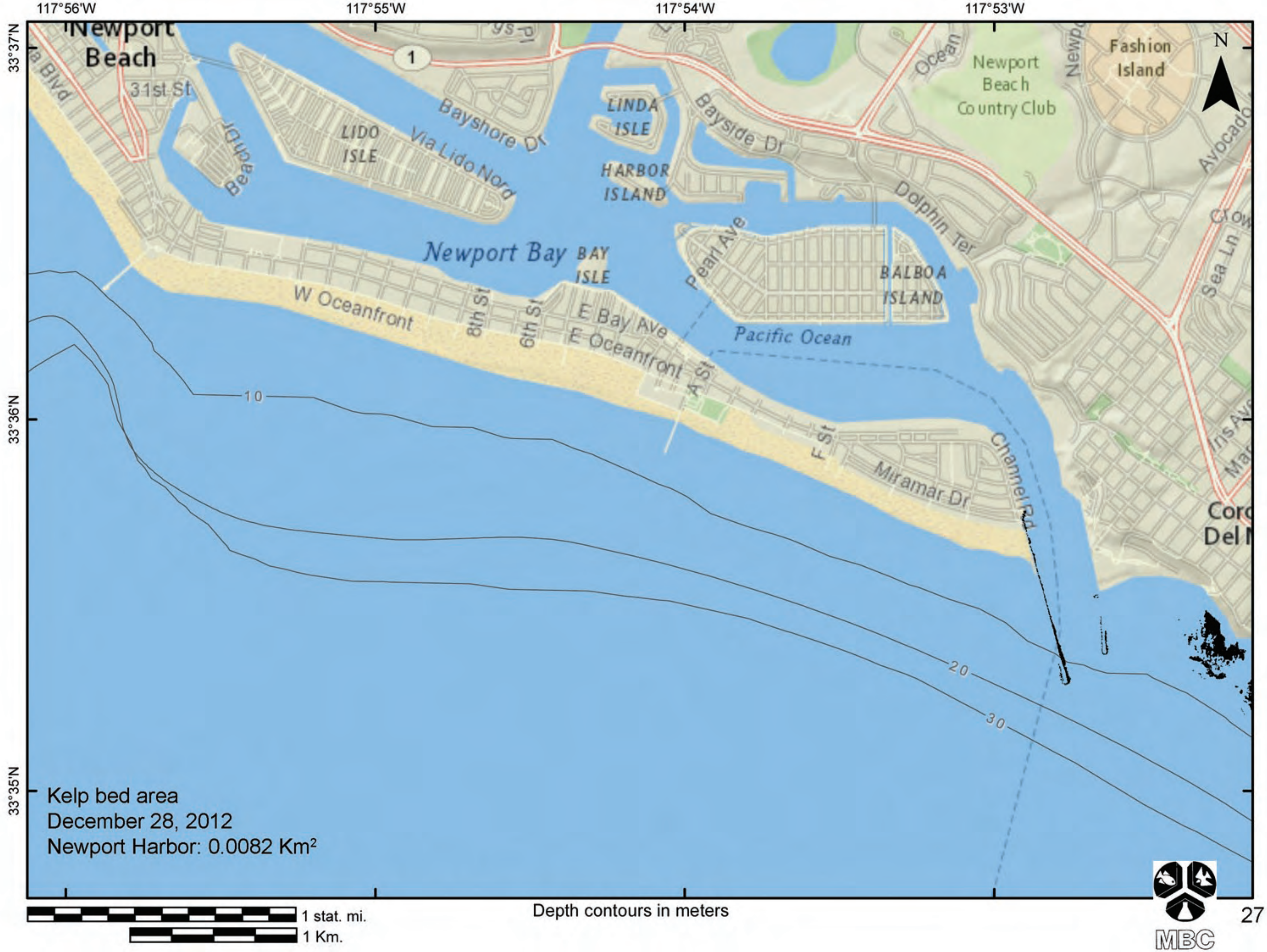


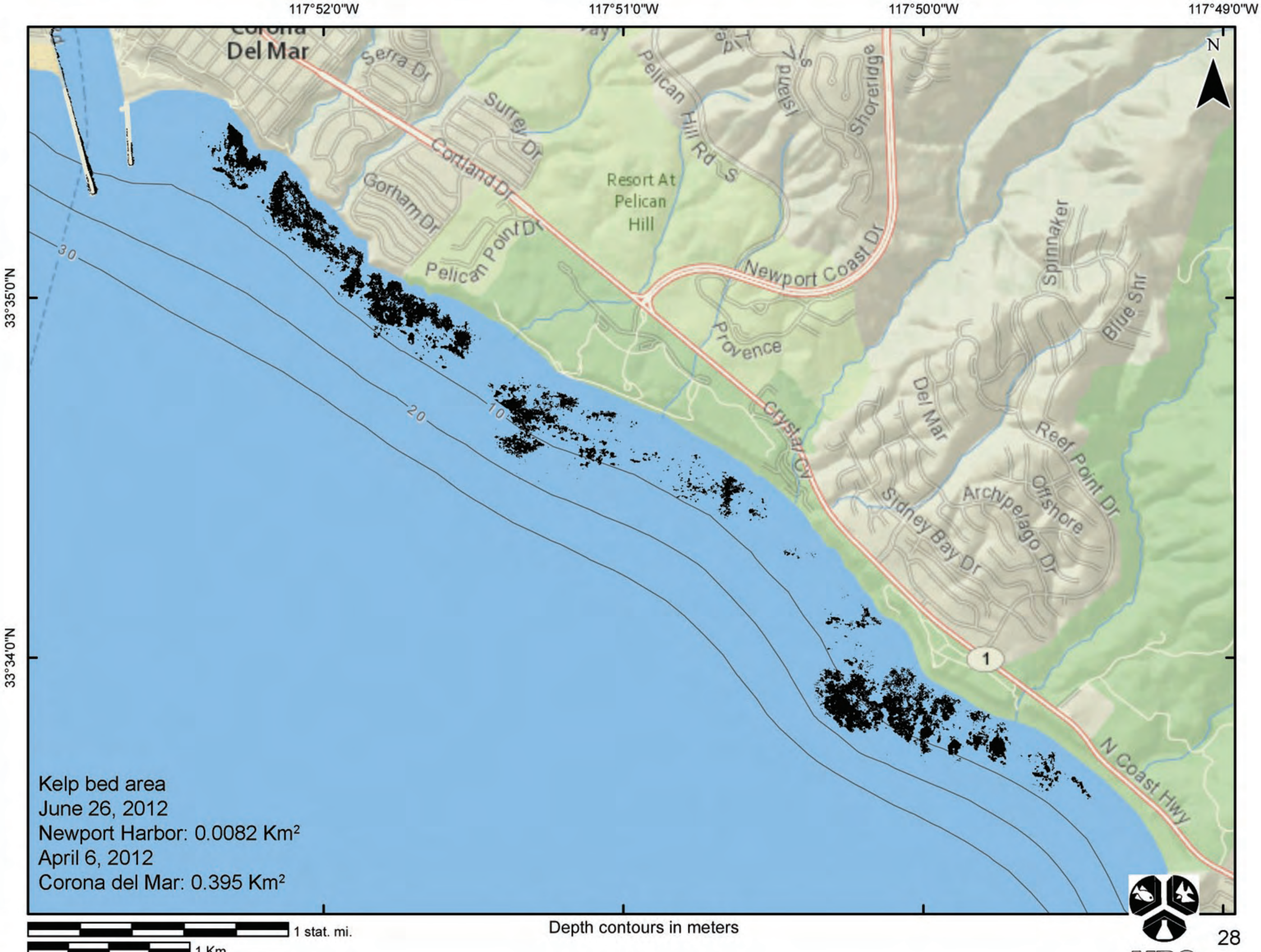
1 stat. mi.
1 Km.

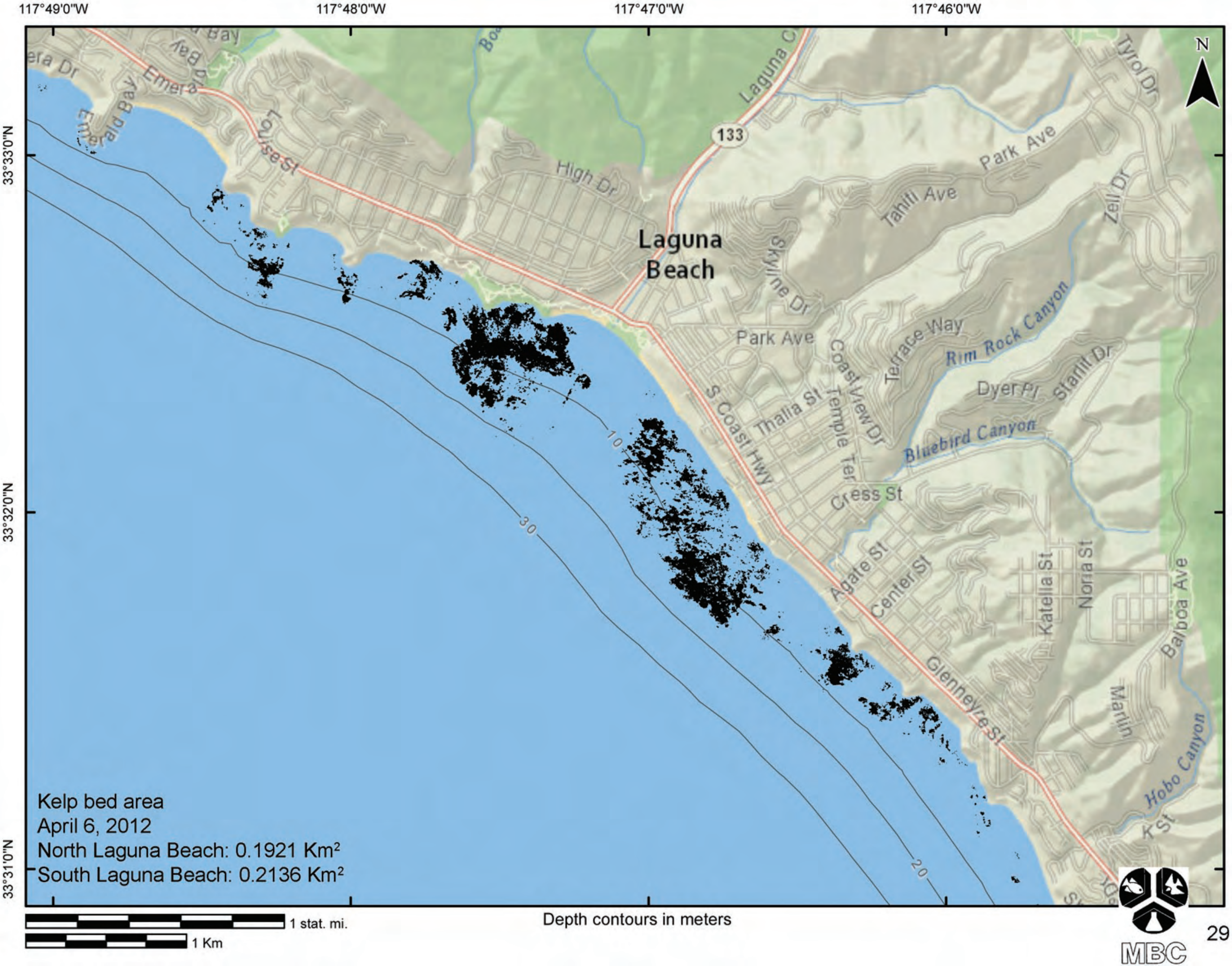
Depth contours in meters


118°2'W
118°1'W
118°0'W
117°59'W
33°40'N
33°39'N
N
E Utica Ave
Silent Harbor Dr
17th St
Park St
Coldwate
Briarly Ln
Adams Ave
Oswego Ave
11th St
Lincoln Ave
Larthorn Dr
20th St
19th St
15th St
Munster Dr
Joliet Ave
12th St
10th St
Alabama St
Beach Blvd
Farnsworth Ln
Oakridge Cir
Greenfield
2nd St
Admiral Ln
Cupar Ln
Banff Ln
10
Biscayne Dr
Kelp bed area
December 28, 2012
Huntington Beach: None
1 stat. mi.
1 Km.
Depth contours in meters
MBC


117°58'W
117°57'W
117°56'W
117°55'W
33°38'N
33°37'N
N
Talbert Channel
Whittier Ave
Park Dr
Cabrillo St
Colton St
W 16th St
W 15th St
Knox St
Ogle St
Catalina Dr
Clay St
Aliso Ave
River Ave
NEWPORT ISLE
Newport Beach
W Balboa Blvd
31st St
1
LIDO ISLE
Beach Dr
W Oceanfront
10
20
30
Kelp bed area
December 28, 2012
Newport Beach: None
1 stat. mi.
1 Km.
Depth contours in meters
MBC


117°56'W
117°55'W
117°54'W
117°53'W
33°37'N
33°36'N
33°35'N
Newport Beach
31st St
Beach Dr
LIDO ISLE
Via Lido Nord
Bayshore Dr
LINDA ISLE
HARBOR ISLAND
Bayside Dr
Newport Beach Country Club
Fashion Island
Dolphin Ter
Newport Bay
BAY ISLE
Pearl Ave
BALBOA ISLAND
W Oceanfront
8th St
6th St
E Bay Ave
E Oceanfront
A St
Pacific Ocean
F St
Miramar Dr
Channel Rd
10
20
30
N
Kelp bed area
December 28, 2012
Newport Harbor: 0.0082 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


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
Resort At Pelican Hill
Pelican Hill Rd S
Island
Shoreridge
Newport Coast Dr
Provence
Crystal Cv
Spinnaker
Blue Shr
Del Mar
Reef Point Dr
Offshore
Archipelago Dr
Sidney Bay Dr
N Coast Hwy
1
30
20
10
Kelp bed area
June 26, 2012
Newport Harbor: 0.0082 Km²
April 6, 2012
Corona del Mar: 0.395 Km²
1 stat. mi.
1 Km
Depth contours in meters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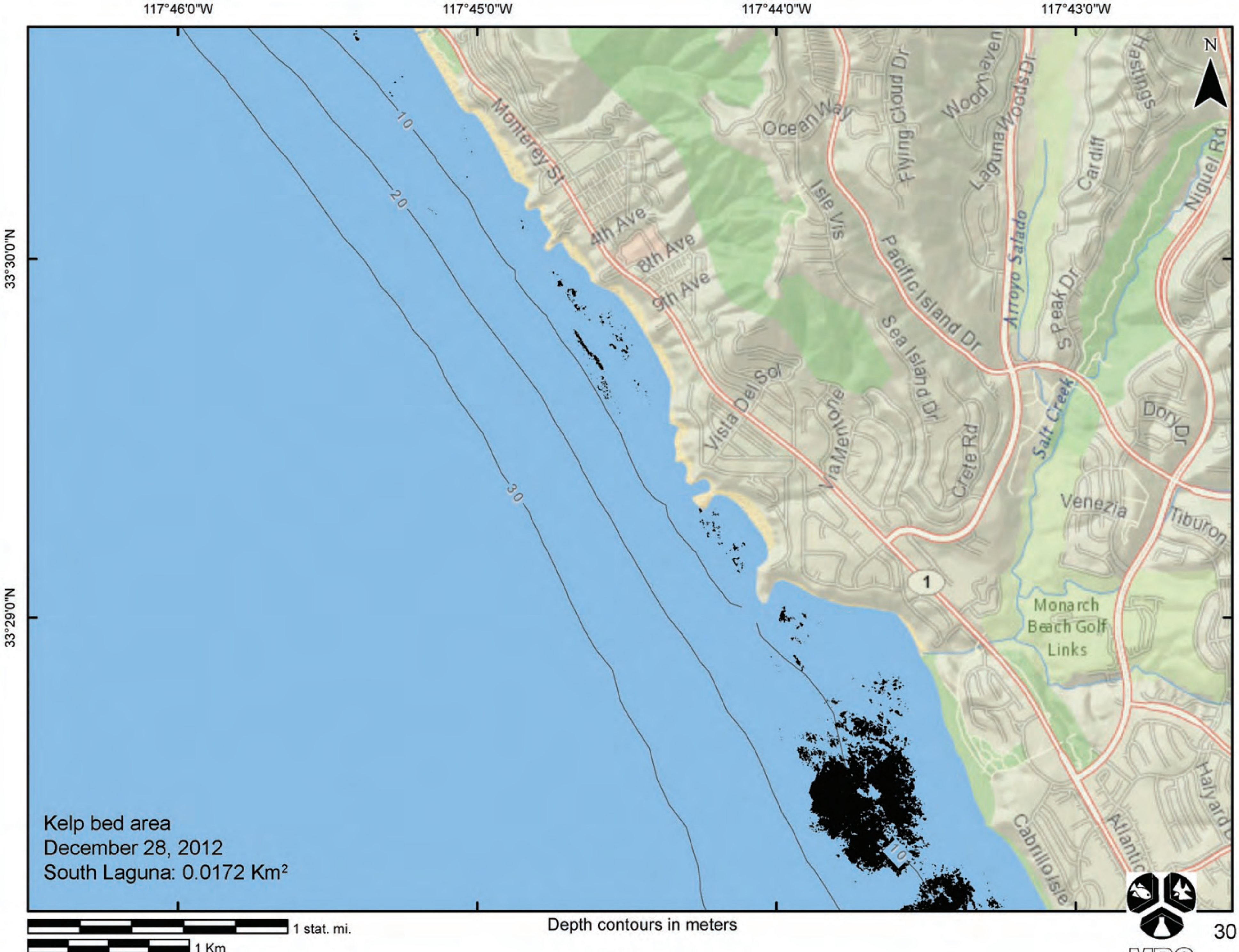
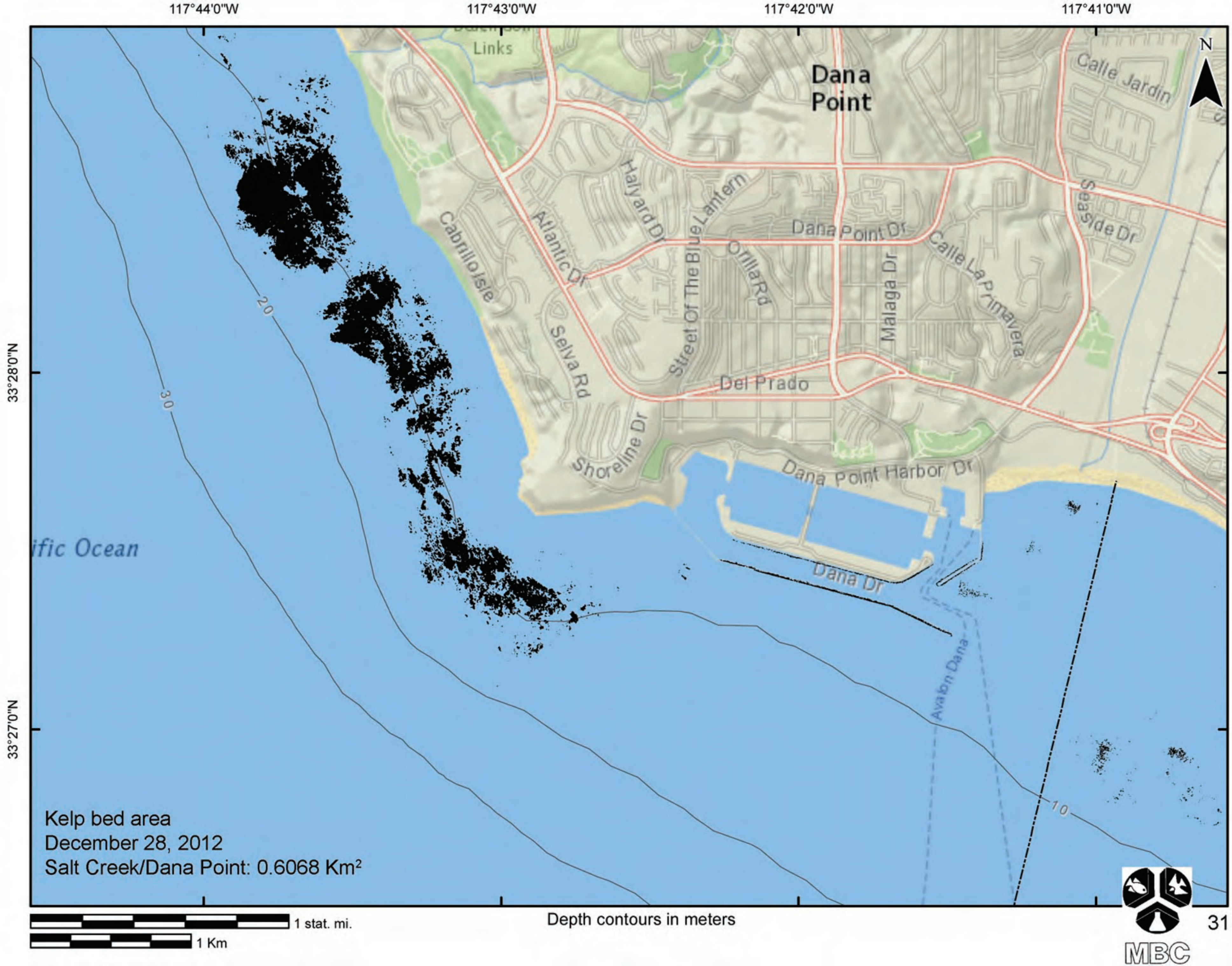
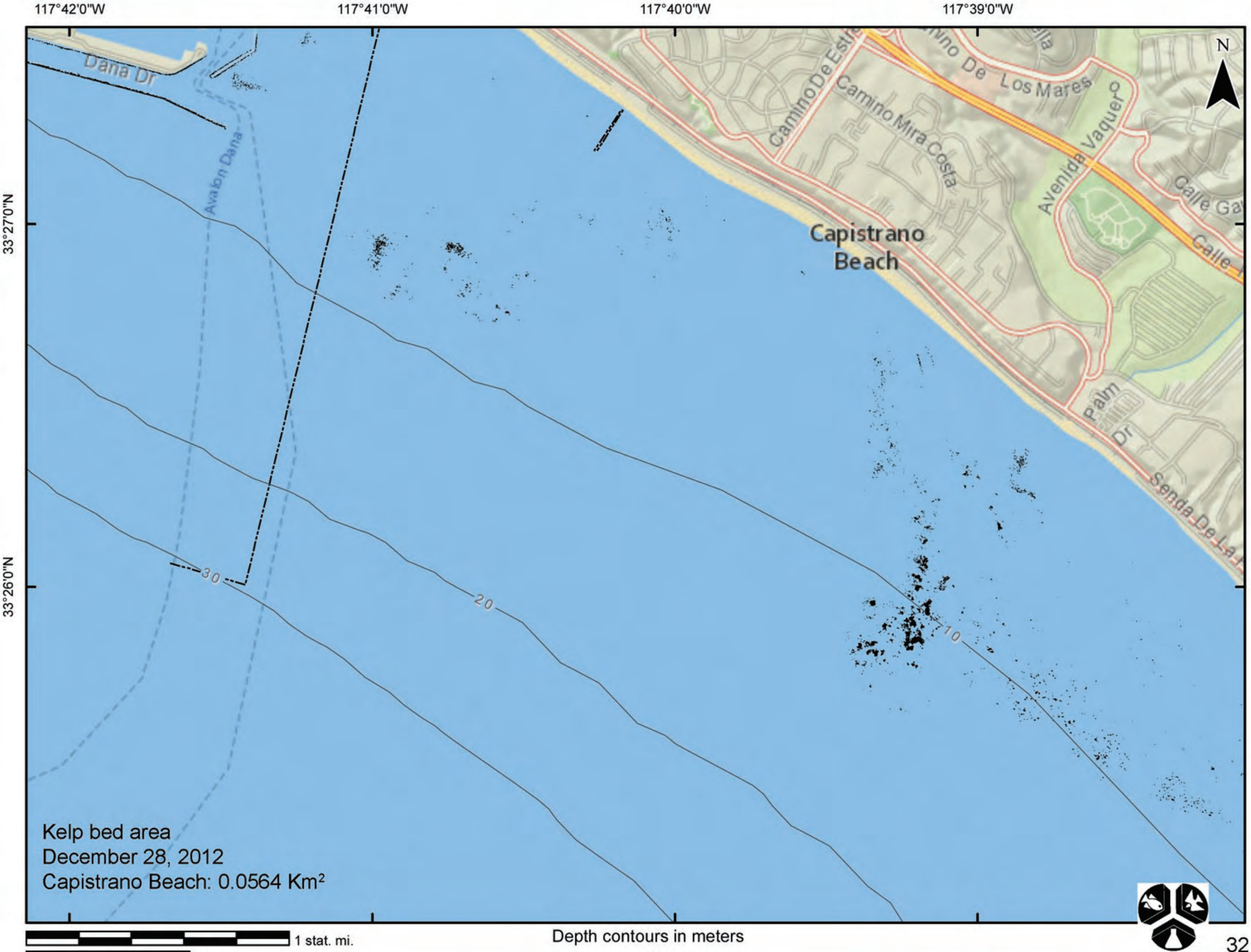
117°48'0"W
117°47'0"W
117°46'0"W
33°33'0"N
33°32'0"N
33°31'0"N
N
Laguna Beach
133
High Dr
Louise St
Emerald Bay
Park Ave
Tahiti Ave
Skyline Dr
Terrace Way
Rim Rock Canyon
Coast View Dr
Temple Ter
Thalia St
S Coast Hwy
Dyer Pl
Starlit Dr
Bluebird Canyon
Cress St
Agate St
Center St
Katella St
Noria St
Balboa Ave
Glenneyre St
Marlin
Hobo Canyon
K St
Tyrol Dr
Zell Dr
10
20
30
Kelp bed area
April 6, 2012
North Laguna Beach: 0.1921 Km²
South Laguna Beach: 0.2136 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

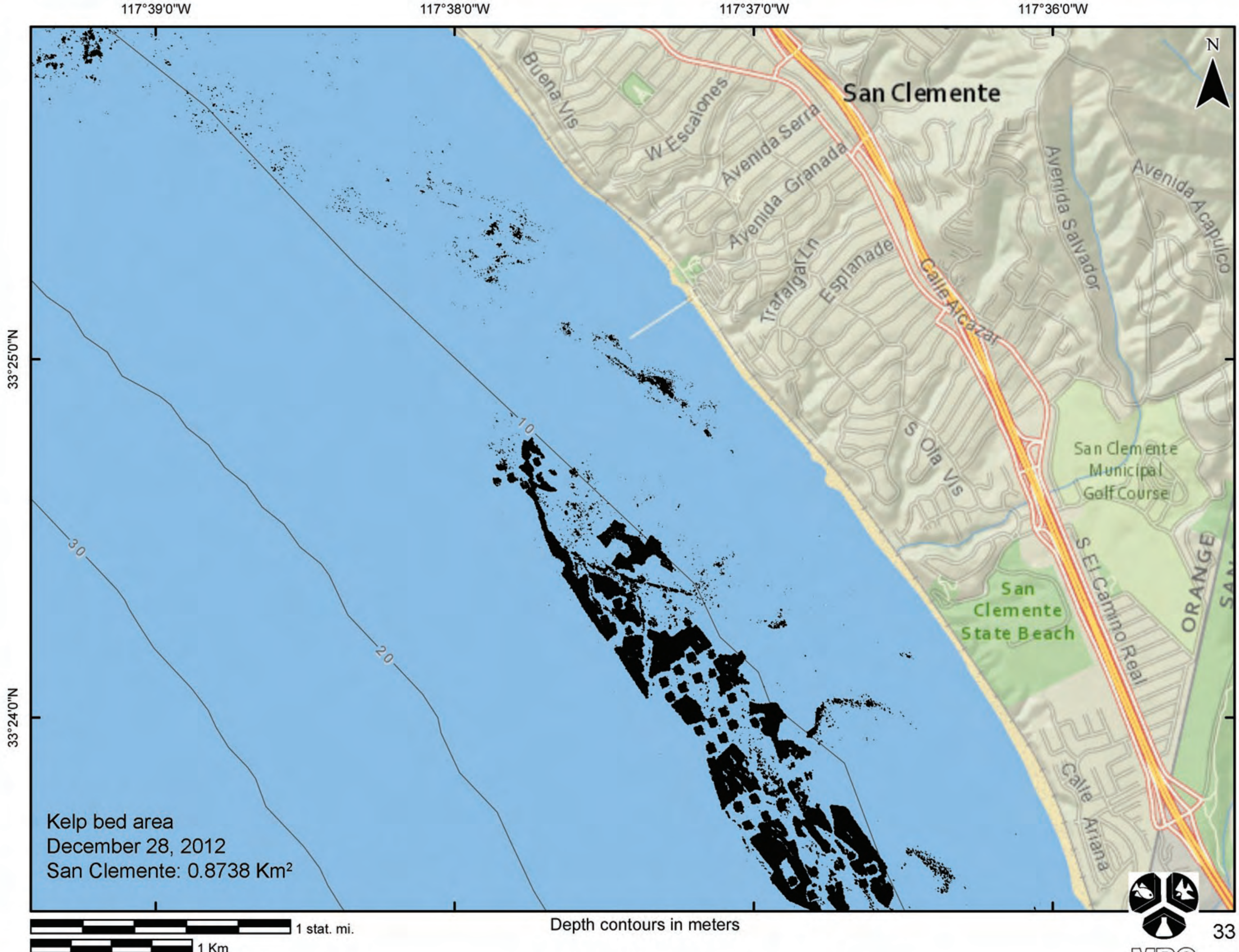

117°46'0"W
117°45'0"W
117°44'0"W
117°43'0"W
33°30'0"N
33°29'0"N
N
10
20
30
Monterey St
4th Ave
8th Ave
9th Ave
Ocean Way
Flying Cloud Dr
Woodhaven
Laguna Woods Dr
Hastings
Cardiff
Niguel Rd
Isle Vis
Pacific Island Dr
Arroyo Salado
S Peak Dr
Sea Island Dr
Vista Del Sol
Via Mentone
Crete Rd
Salt Creek
Dory Dr
Venezia
Tiburon
1
Monarch
Beach Golf
Links
Cabrillo Isle
Atlantic
Kelp bed area
December 28, 2012
South Laguna: 0.0172 Km²
1 stat. mi.
1 Km
Depth contours in meters

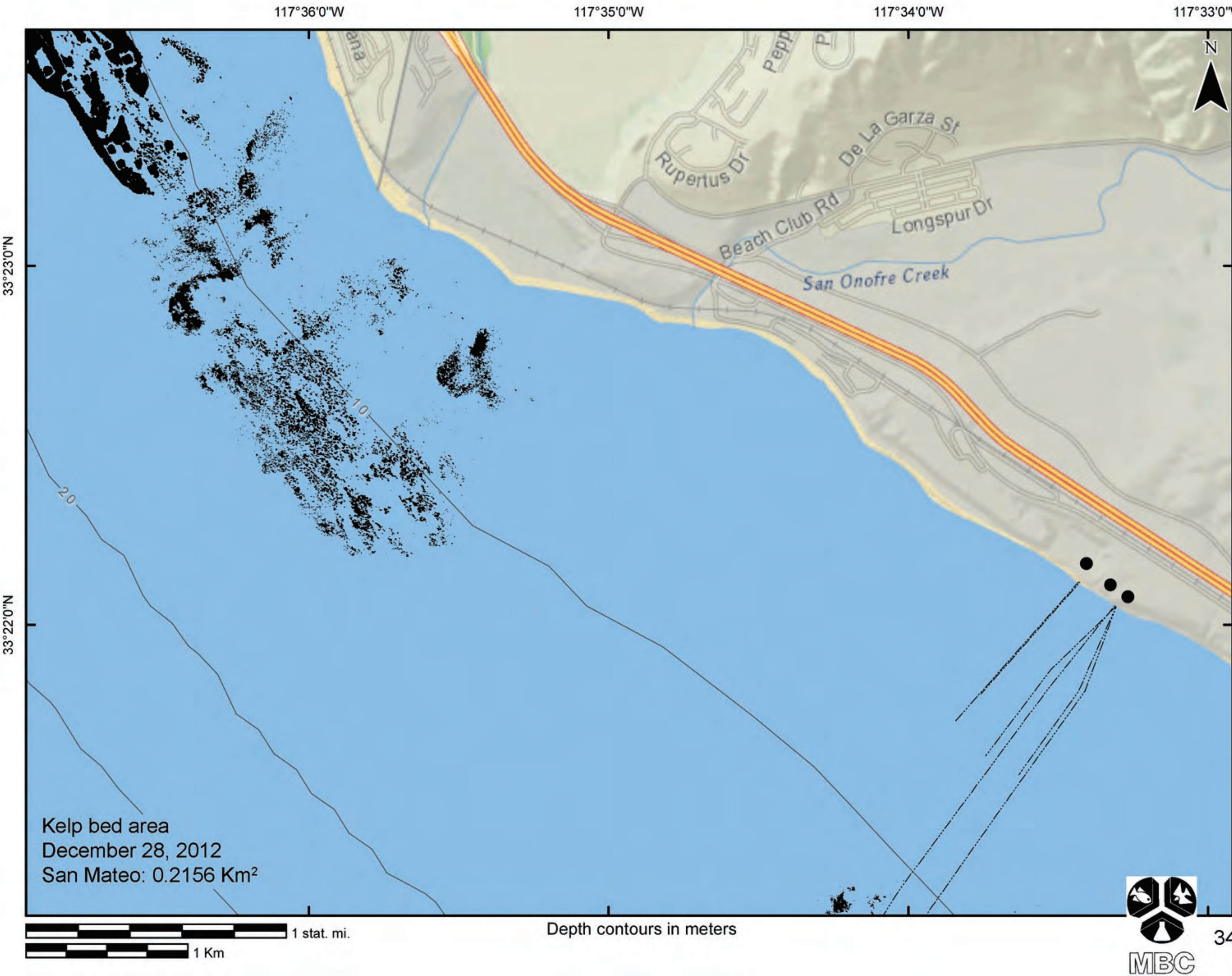
MBC

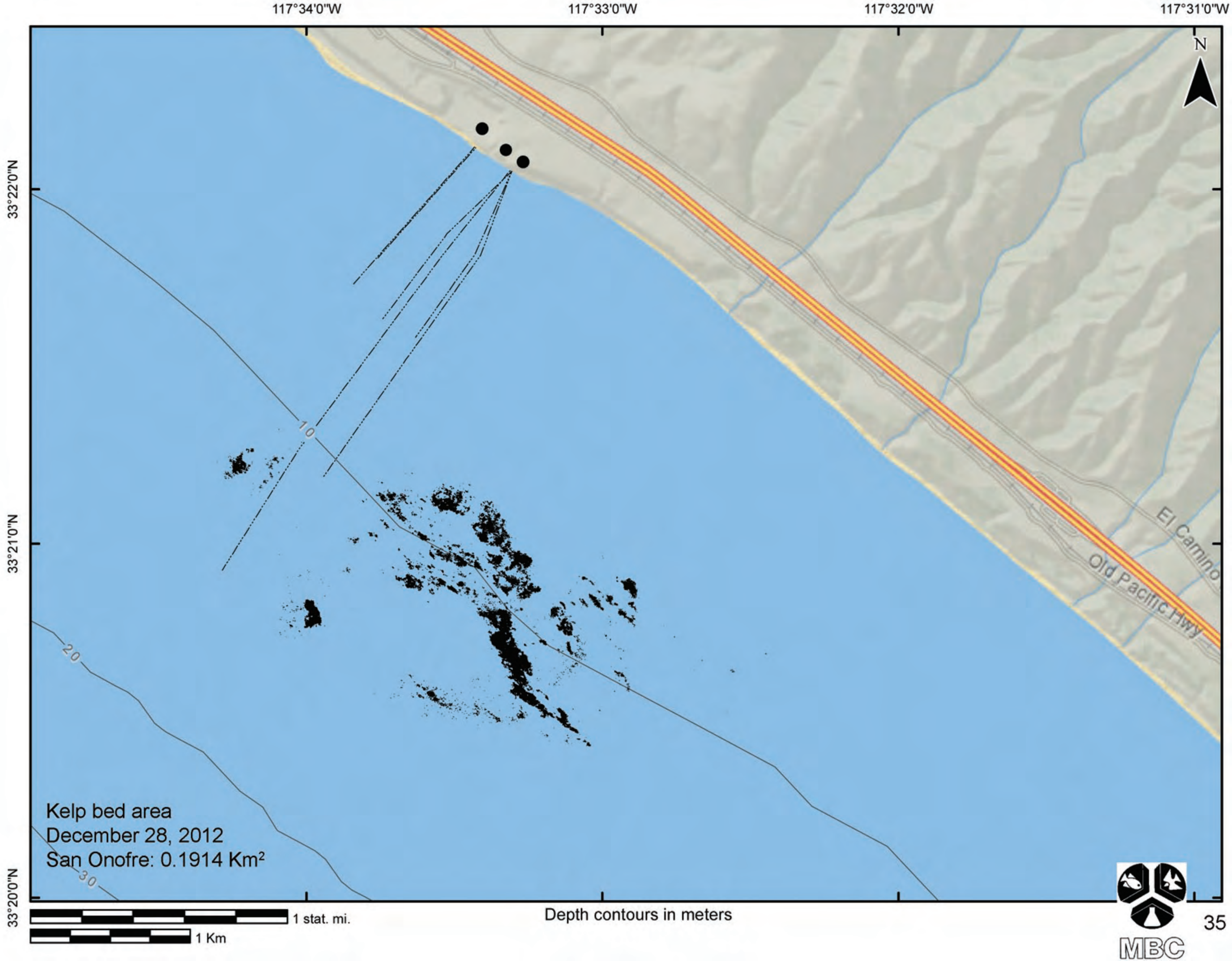


117°44'0"W
117°43'0"W
117°42'0"W
117°41'0"W
33°28'0"N
33°27'0"N
N
Links
Dana
Point
Calle Jardin
Halyard Dr
Street Of The Blue Lantern
Dana Point Dr
Calle La Primavera
Sea Side Dr
Cabrillo Isle
Atlantic Dr
Orilla Rd
Malaga Dr
Selva Rd
Del Prado
Shoreline Dr
Dana Point Harbor Dr
Dana Dr
Avalon Dana
ific Ocean
20
30
10
Kelp bed area
December 28, 2012
Salt Creek/Dana Point: 0.6068 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

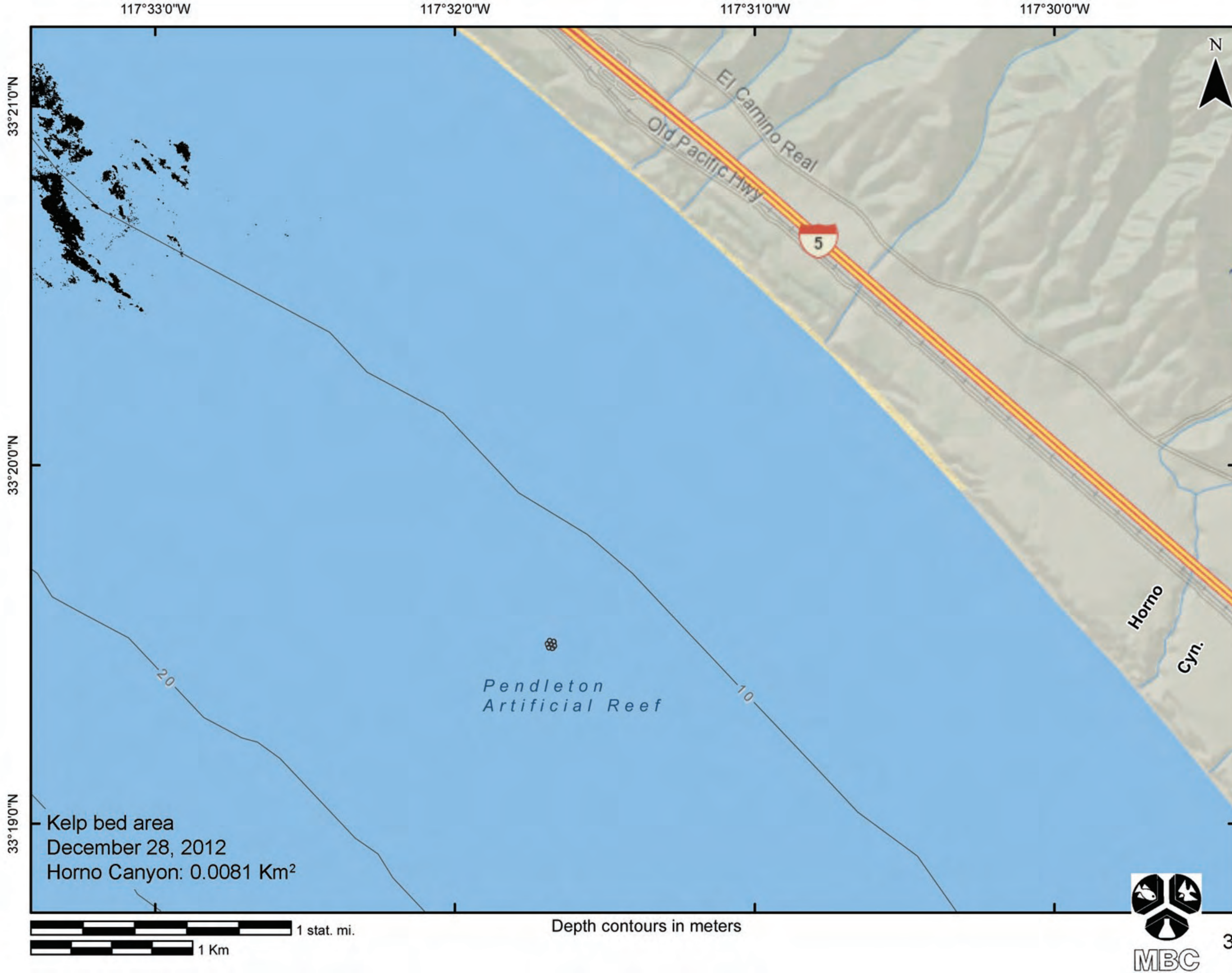

117°42'0"W
117°41'0"W
117°40'0"W
117°39'0"W
33°27'0"N
33°26'0"N
N
Dana Dr
Avalon Dana
Camino De Estrella
Camino De Los Mares
Camino Mira Costa
Avenida Vaquero
Calle Gaviota
Capistrano Beach
Palm Dr
Senda De La Playa
30
20
10
Kelp bed area
December 28, 2012
Capistrano Beach: 0.0564 Km²
1 stat. mi.
1 Km
Depth contours in meters

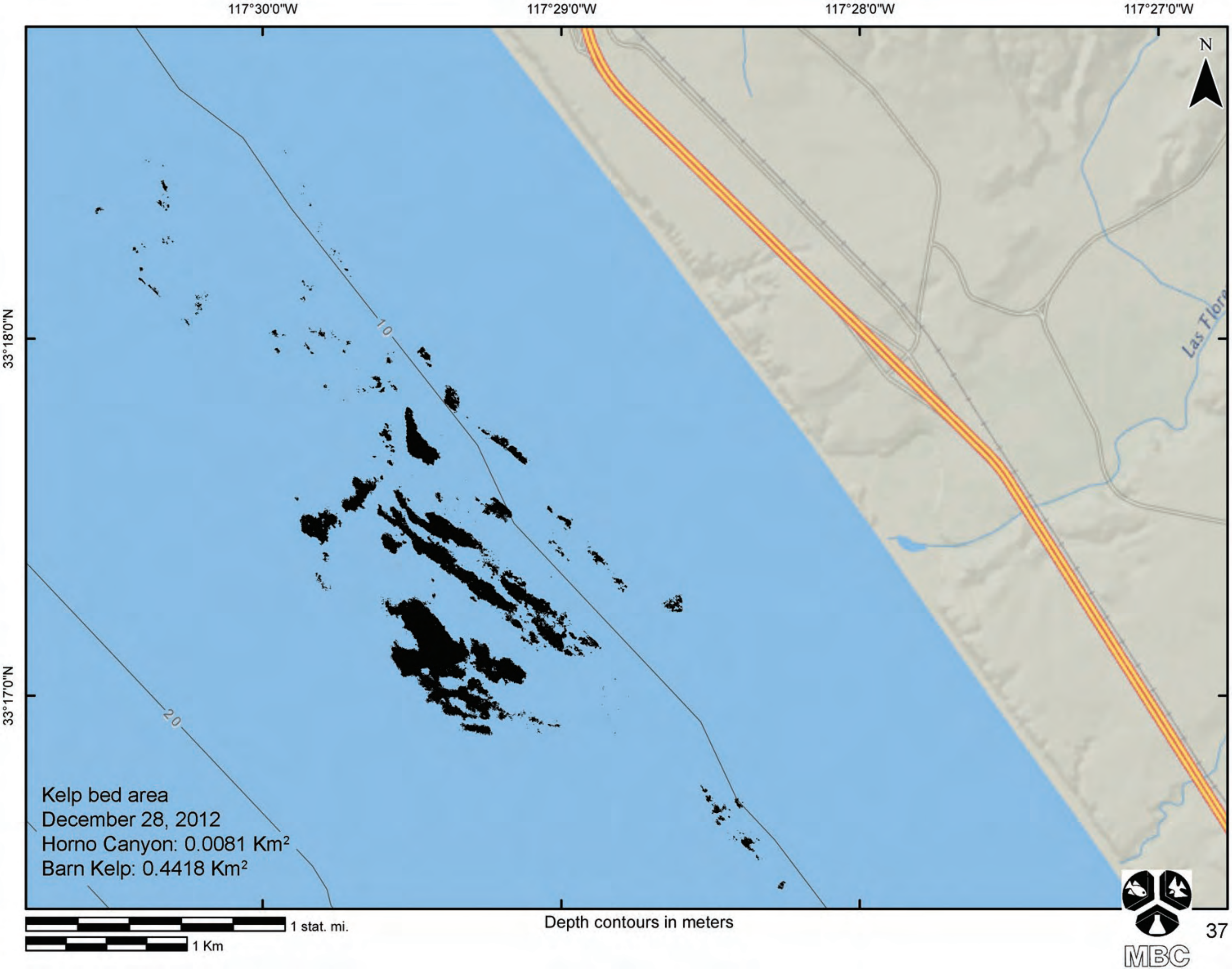

117°39'0"W
117°38'0"W
117°37'0"W
117°36'0"W
33°25'0"N
33°24'0"N
N
San Clemente
Buena Vis
W Escalones
Avenida Serra
Avenida Granada
Avenida
Trafalgar Ln
Esplanade
Calle Alcazar
Avenida Salvador
Avenida Acapulco
S Ola Vis
San Clemente Municipal Golf Course
San Clemente State Beach
S El Camino Real
ORANGE
Calle Ariana
10
20
30
Kelp bed area
December 28, 2012
San Clemente: 0.8738 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

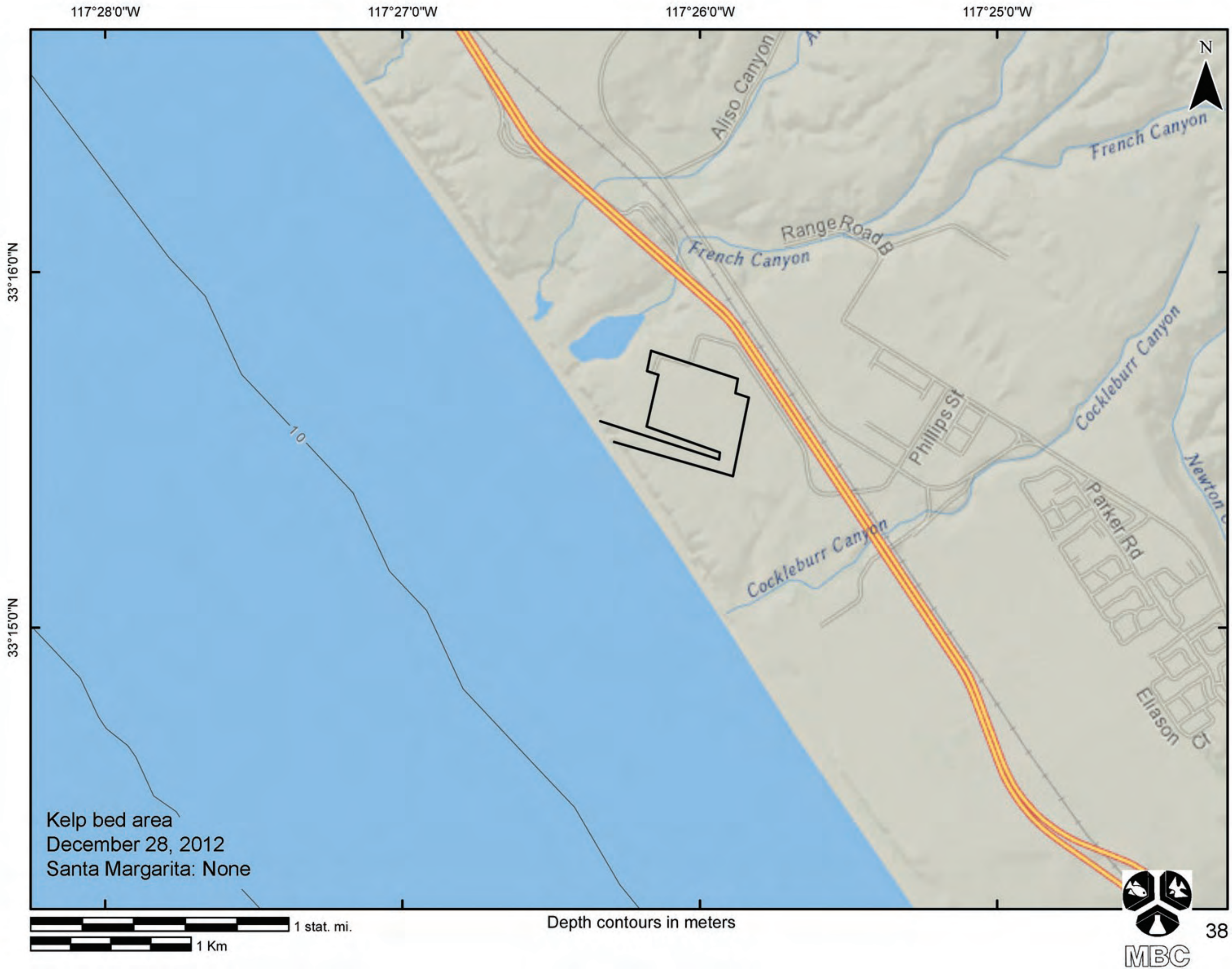

117°36'0"W
117°35'0"W
117°34'0"W
117°33'0"W
33°23'0"N
33°22'0"N
N
De La Garza St
Rupertus Dr
Beach Club Rd
Longspur Dr
San Onofre Creek
10
20
Kelp bed area
December 28, 2012
San Mateo: 0.2156 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

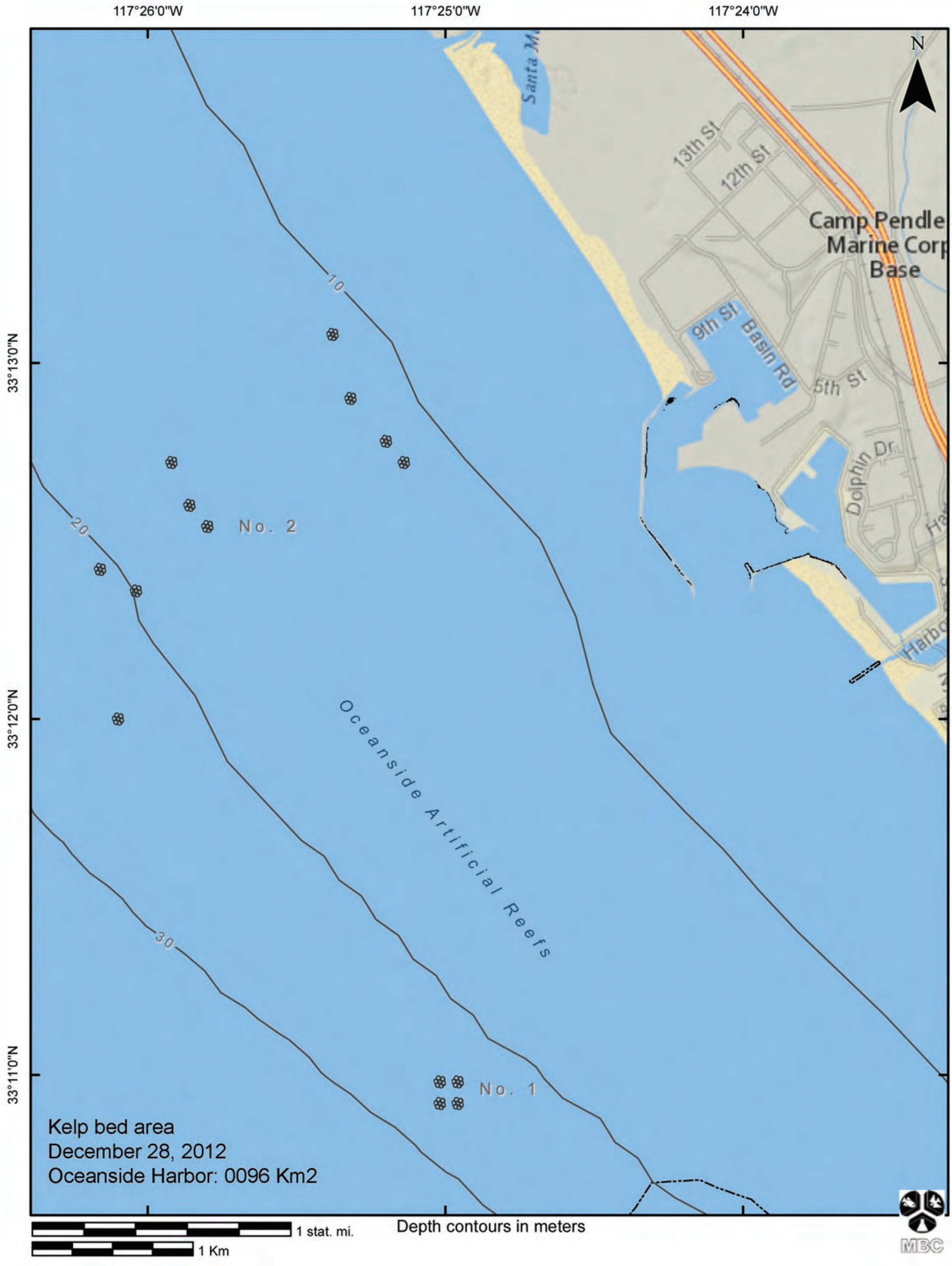


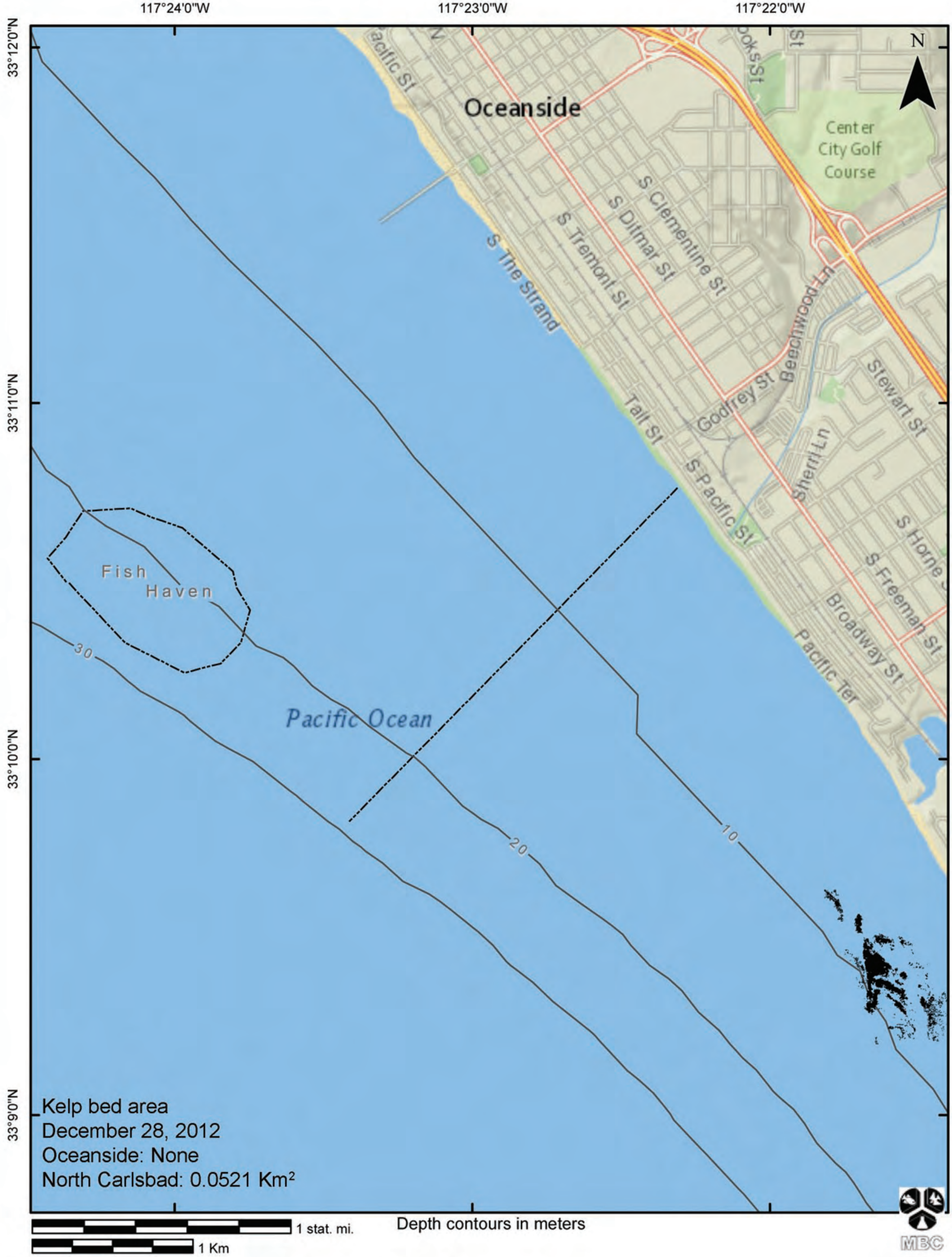
117°34'0"W
117°33'0"W
117°32'0"W
117°31'0"W
33°22'0"N
33°21'0"N
33°20'0"N
N
10
20
30
El Camino
Old Pacific Hwy
Kelp bed area
December 28, 2012
San Onofre: 0.1914 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

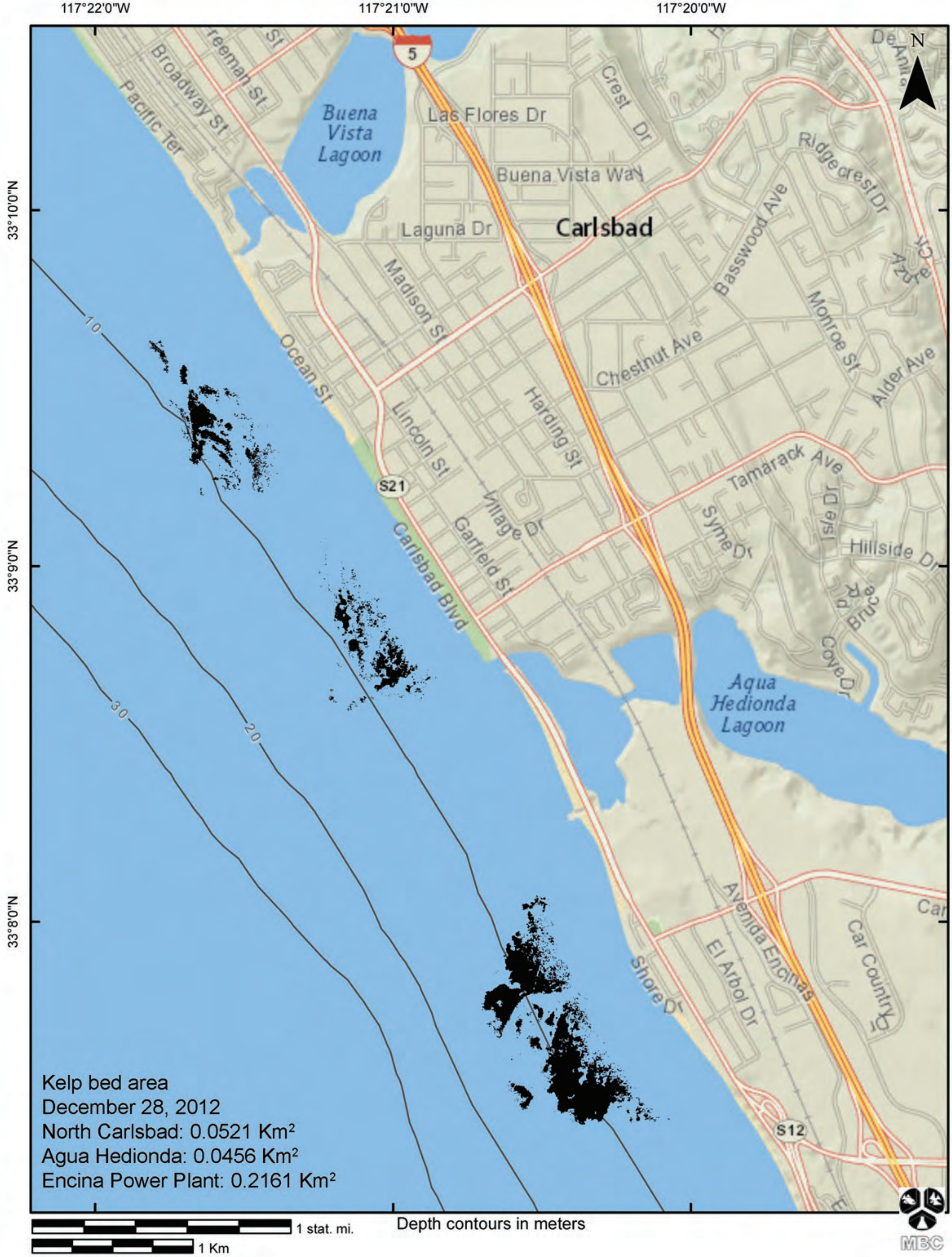

117°33'0"W
117°32'0"W
117°31'0"W
117°30'0"W
33°21'0"N
33°20'0"N
33°19'0"N
N
El Camino Real
Old Pacific Hwy
5
Horno
Cyn.
Pendleton
Artificial Reef
20
10
Kelp bed area
December 28, 2012
Horno Canyon: 0.0081 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

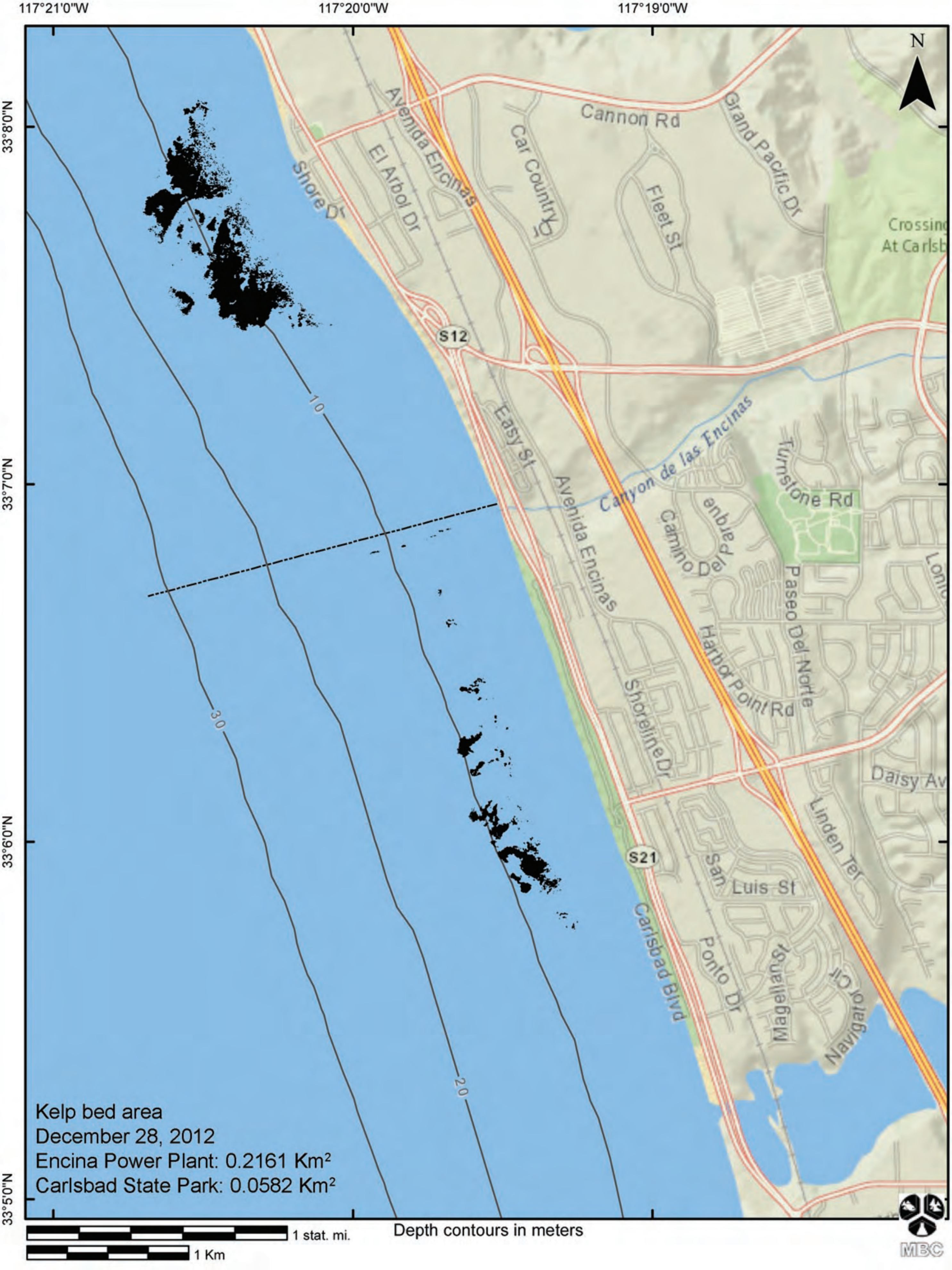

117°30'0"W
117°29'0"W
117°28'0"W
117°27'0"W
33°18'0"N
33°17'0"N
N
10
20
Las Flore
Kelp bed area
December 28, 2012
Horno Canyon: 0.0081 Km²
Barn Kelp: 0.4418 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°28'0"W
117°27'0"W
117°26'0"W
117°25'0"W
33°16'0"N
33°15'0"N
N
Aliso Canyon
French Canyon
Range Road B
French Canyon
Cockleburr Canyon
Phillips St
Newton
Parker Rd
Cockleburr Canyon
Eliason
Ct
10
Kelp bed area
December 28, 2012
Santa Margarita: None
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°26'0"W
117°25'0"W
117°24'0"W
33°13'0"N
33°12'0"N
33°11'0"N
N
Santa Ma
13th St
12th St
Camp Pendle
Marine Corp
Base
9th St
Basin Rd
5th St
Dolphin Dr
10
20
30
No. 2
No. 1
Oceanside Artificial Reefs
Kelp bed area
December 28, 2012
Oceanside Harbor: 0096 Km2
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°24'0"W
117°23'0"W
117°22'0"W
33°12'0"N
33°11'0"N
33°10'0"N
33°9'0"N
N
Oceanside
Center City Golf Course
S Clementine St
S Ditmar St
S Tremont St
S The Strand
Pacific St
Beechwood Ln
Godfrey St
Stewart St
Tait St
S Pacific St
Sherri Ln
S Horne St
S Freeman St
Broadway St
Pacific Ter
Fish Haven
Pacific Ocean
10
20
30
Kelp bed area
December 28, 2012
Oceanside: None
North Carlsbad: 0.0521 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°22'0"W
117°21'0"W
117°20'0"W
33°10'0"N
33°9'0"N
33°8'0"N
N
5
Buena Vista Lagoon
Las Flores Dr
Buena Vista Way
Laguna Dr
Carlsbad
Broadway St
Pacific Ter
Crest Dr
Ridgecrest Dr
Basswood Ave
Madison St
Ocean St
Chestnut Ave
Monroe St
Alder Ave
Harding St
Lincoln St
Tamarack Ave
S21
Carlsbad Blvd
Garfield St
Village Dr
Syme Dr
Isle Dr
Hillside Dr
Bruce Rd
Cove Dr
Aqua Hedionda Lagoon
10
20
30
Avenida Encinas
El Arbol Dr
Car Country Dr
Shore Dr
S12
Kelp bed area
December 28, 2012
North Carlsbad: 0.0521 Km²
Agua Hedionda: 0.0456 Km²
Encina Power Plant: 0.2161 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC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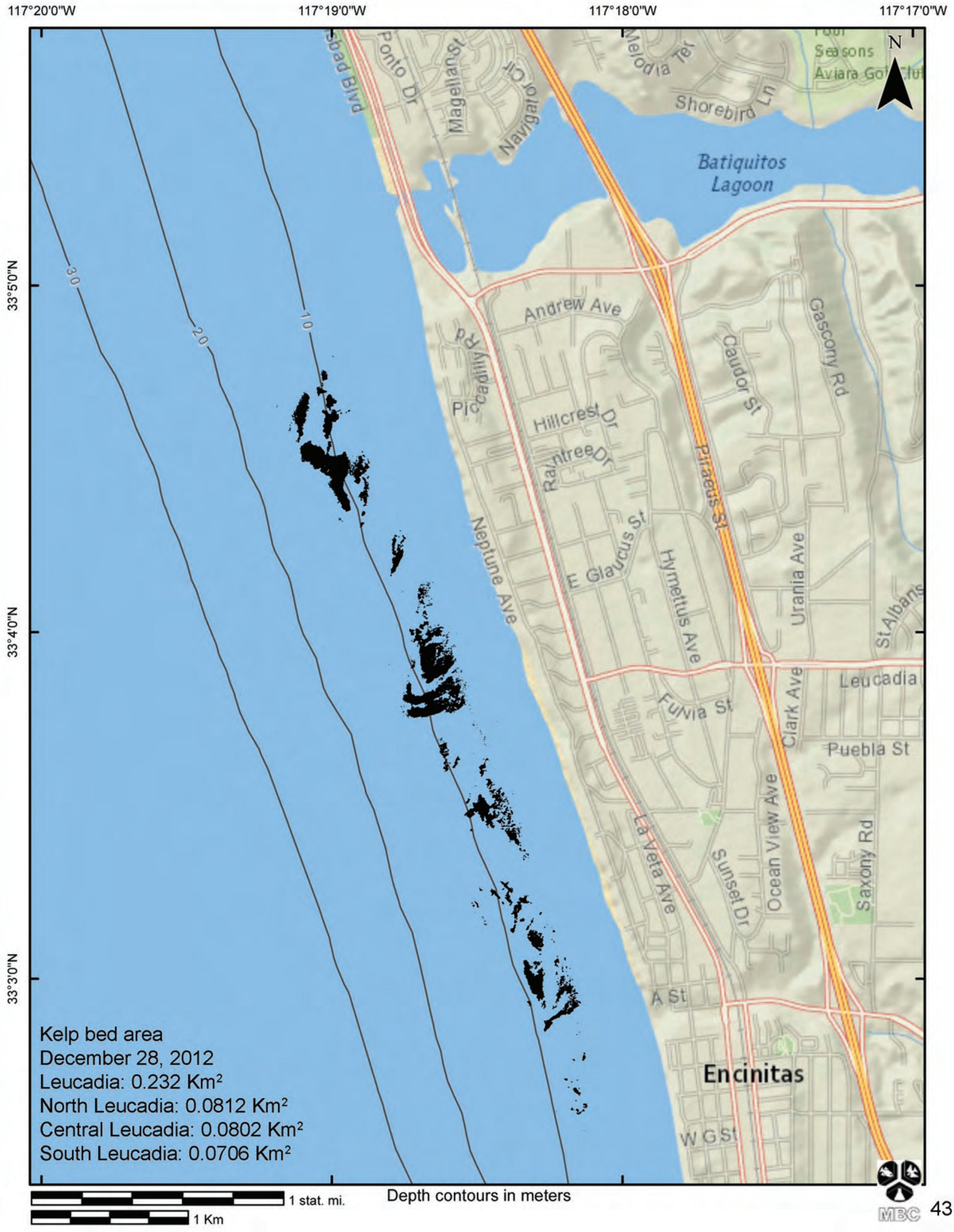
117°20'0"W
117°19'0"W
33°8'0"N
33°7'0"N
33°6'0"N
33°5'0"N
N
Cannon Rd
Grand Pacific Dr
Avenida Encinas
El Arbol Dr
Car Country Dr
Fleet St
Shore Dr
Crossings At Carlsbad
S12
10
20
30
Easy St
Canyon de las Encinas
Turnstone Rd
Camino Del Parque
Avenida Encinas
Paseo Del Norte
Harbor Point Rd
Shoreline Dr
Daisy Av
Linden Ter
S21
San Luis St
Carlsbad Blvd
Ponto Dr
Magellan St
Navigator Cir
Kelp bed area
December 28, 2012
Encina Power Plant: 0.2161 Km²
Carlsbad State Park: 0.0582 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC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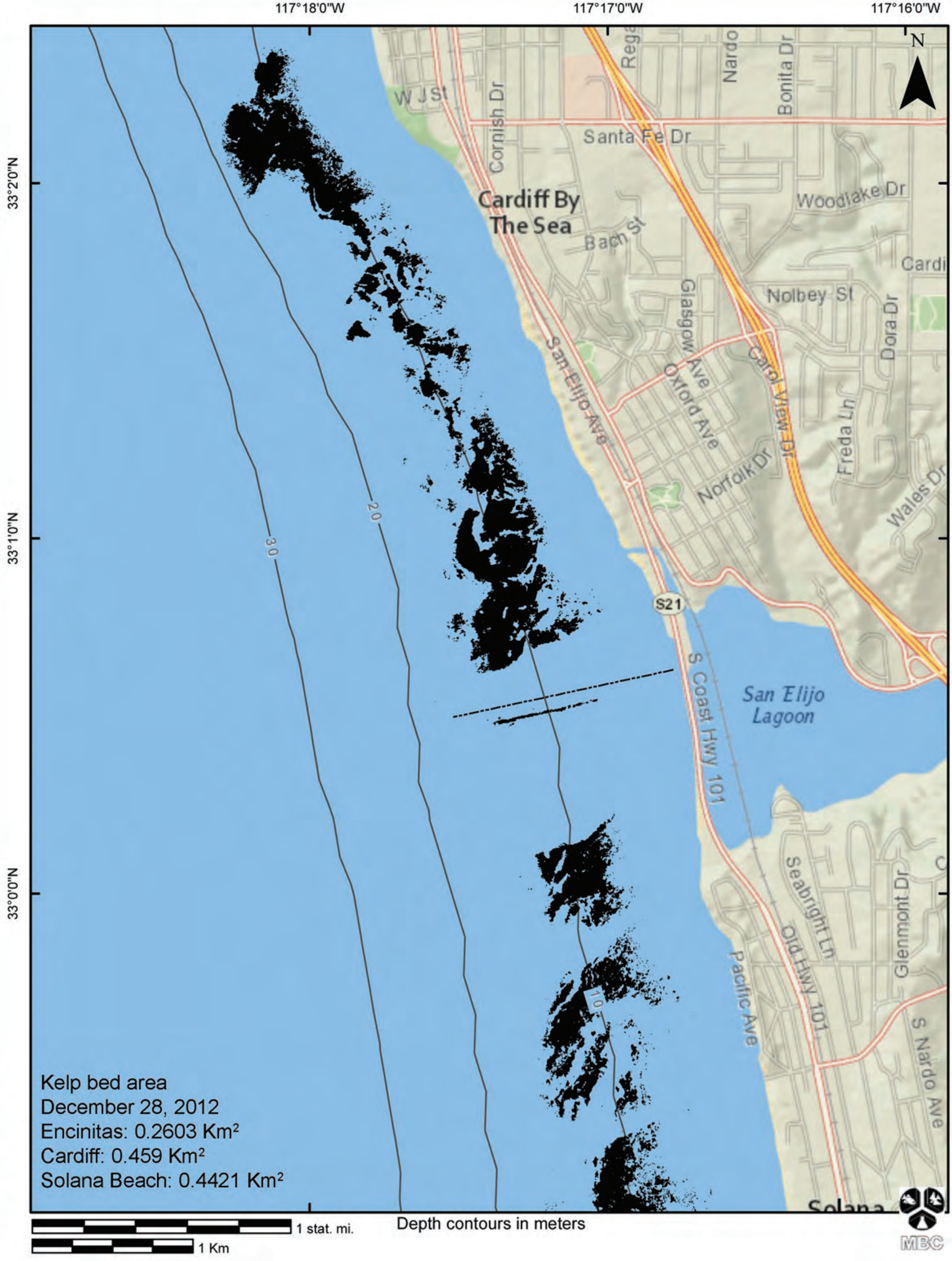
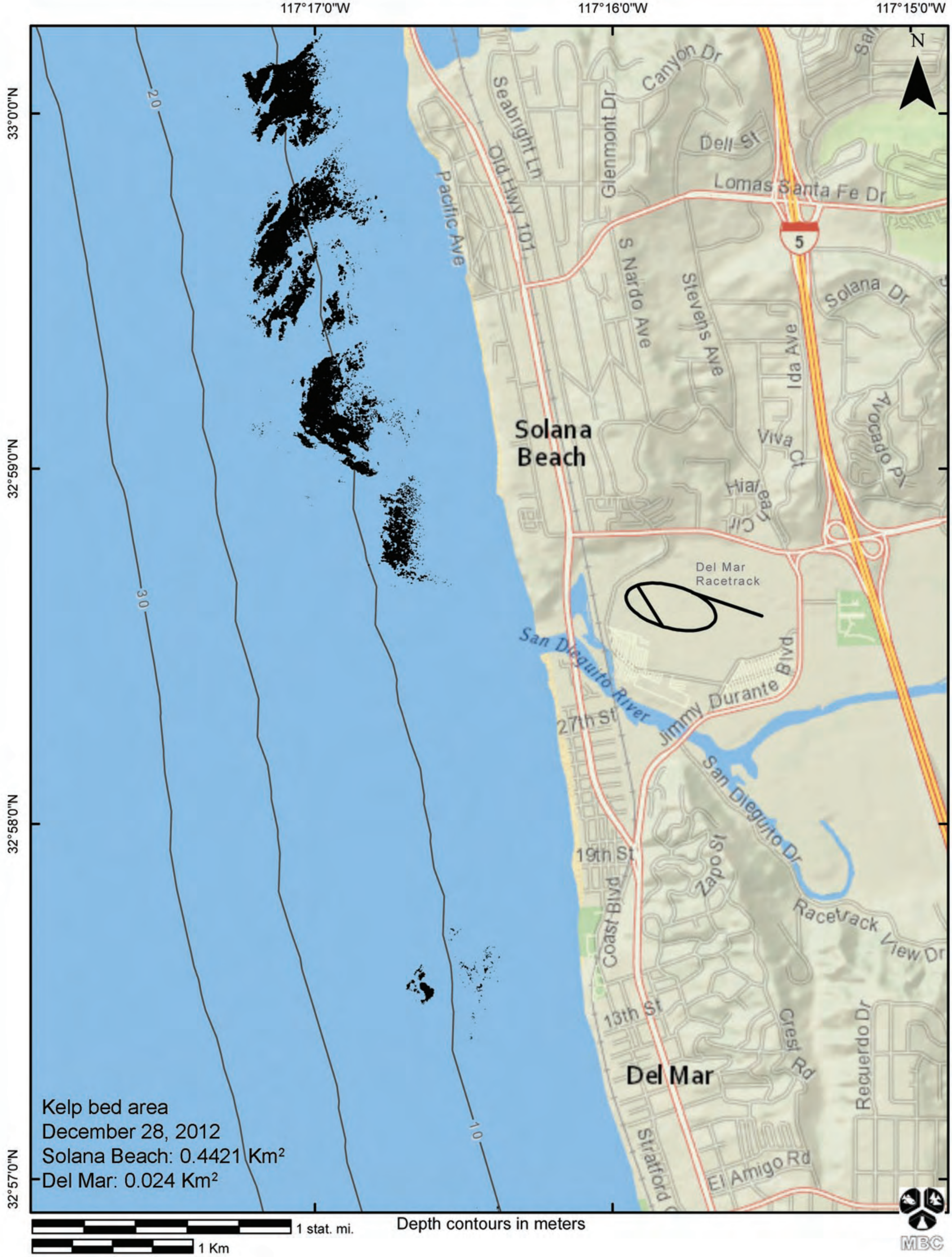
117°18'0"W
117°17'0"W
33°5'0"N
33°4'0"N
33°3'0"N
N
Batiquitos Lagoon
Encinitas
30
20
10
Kelp bed area
December 28, 2012
Leucadia: 0.232 Km²
North Leucadia: 0.0812 Km²
Central Leucadia: 0.0802 Km²
South Leucadia: 0.0706 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°18'0"W
117°17'0"W
117°16'0"W
33°2'0"N
33°1'0"N
33°0'0"N
N
W J St
Cornish Dr
Rega
Nardo
Bonita Dr
Santa Fe Dr
Woodlake Dr
Cardiff By The Sea
Bach St
Cardi
Nolbey St
Glasgow Ave
Dora Dr
San Elijo Ave
Oxford Ave
Carol View Dr
Freda Ln
Norfolk Dr
Wales Dr
S21
S Coast Hwy 101
San Elijo Lagoon
Seabright Ln
Glenmont Dr
Old Hwy 101
Pacific Ave
S Nardo Ave
Solana
30
20
10
Kelp bed area
December 28, 2012
Encinitas: 0.2603 Km²
Cardiff: 0.459 Km²
Solana Beach: 0.4421 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC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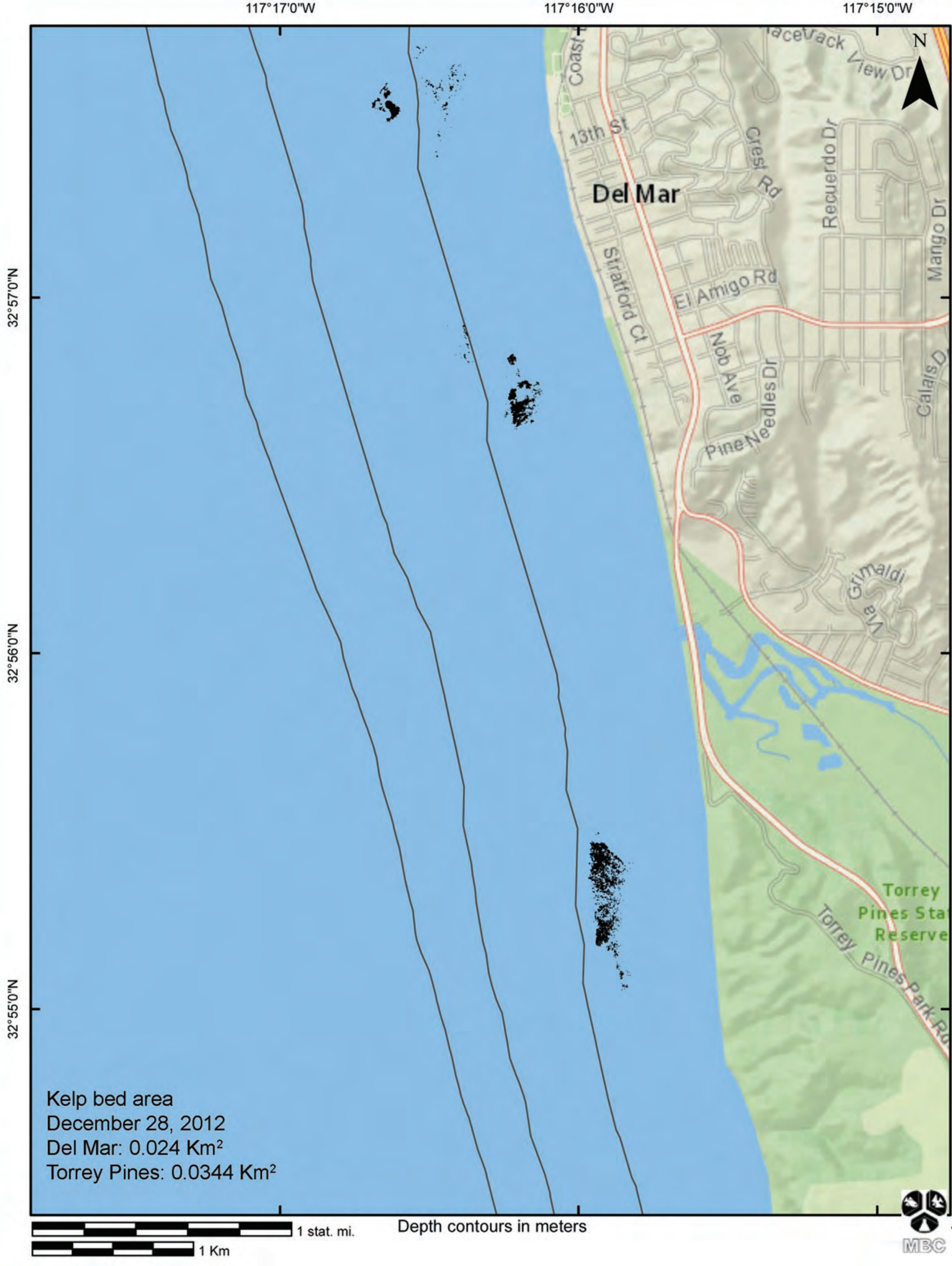
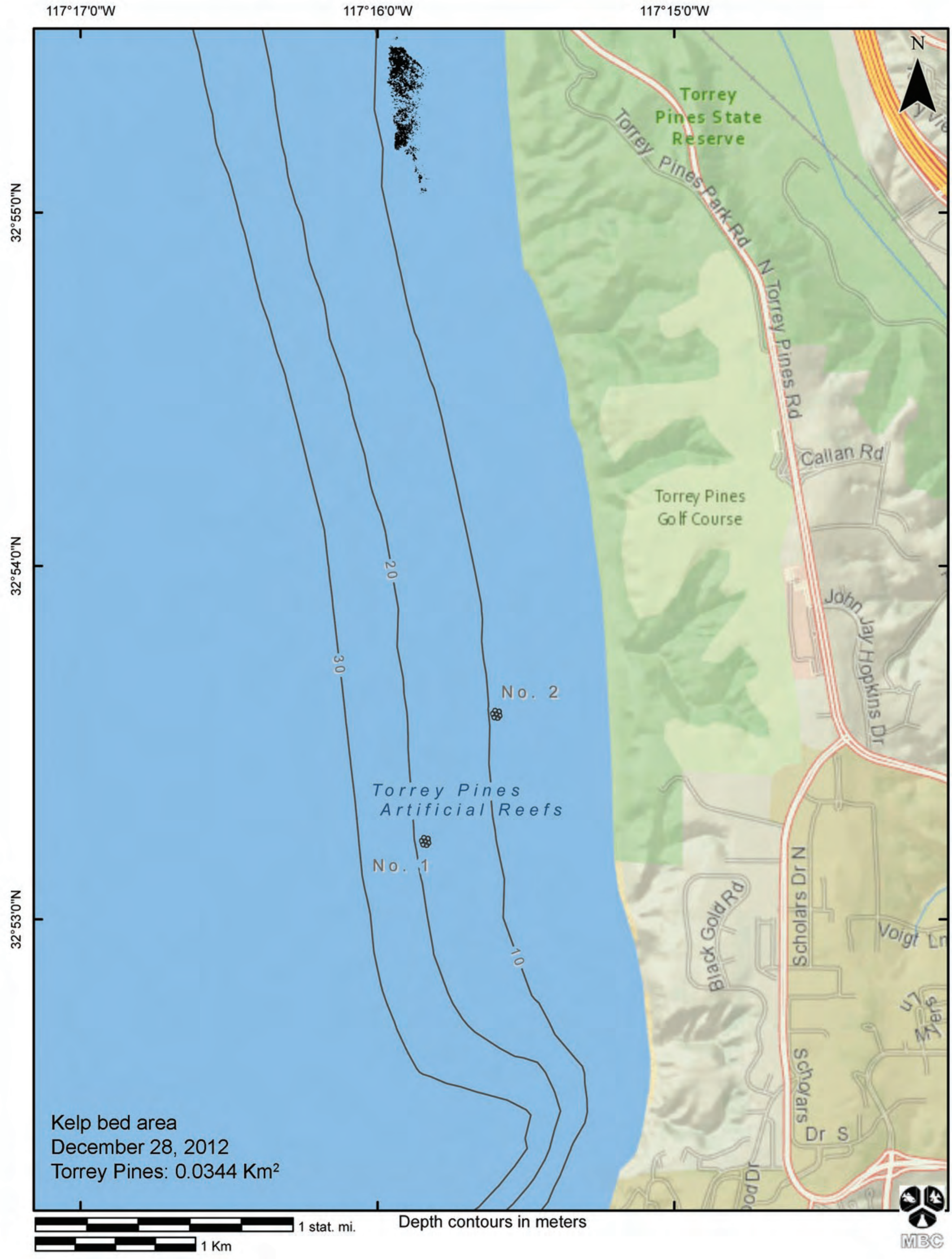
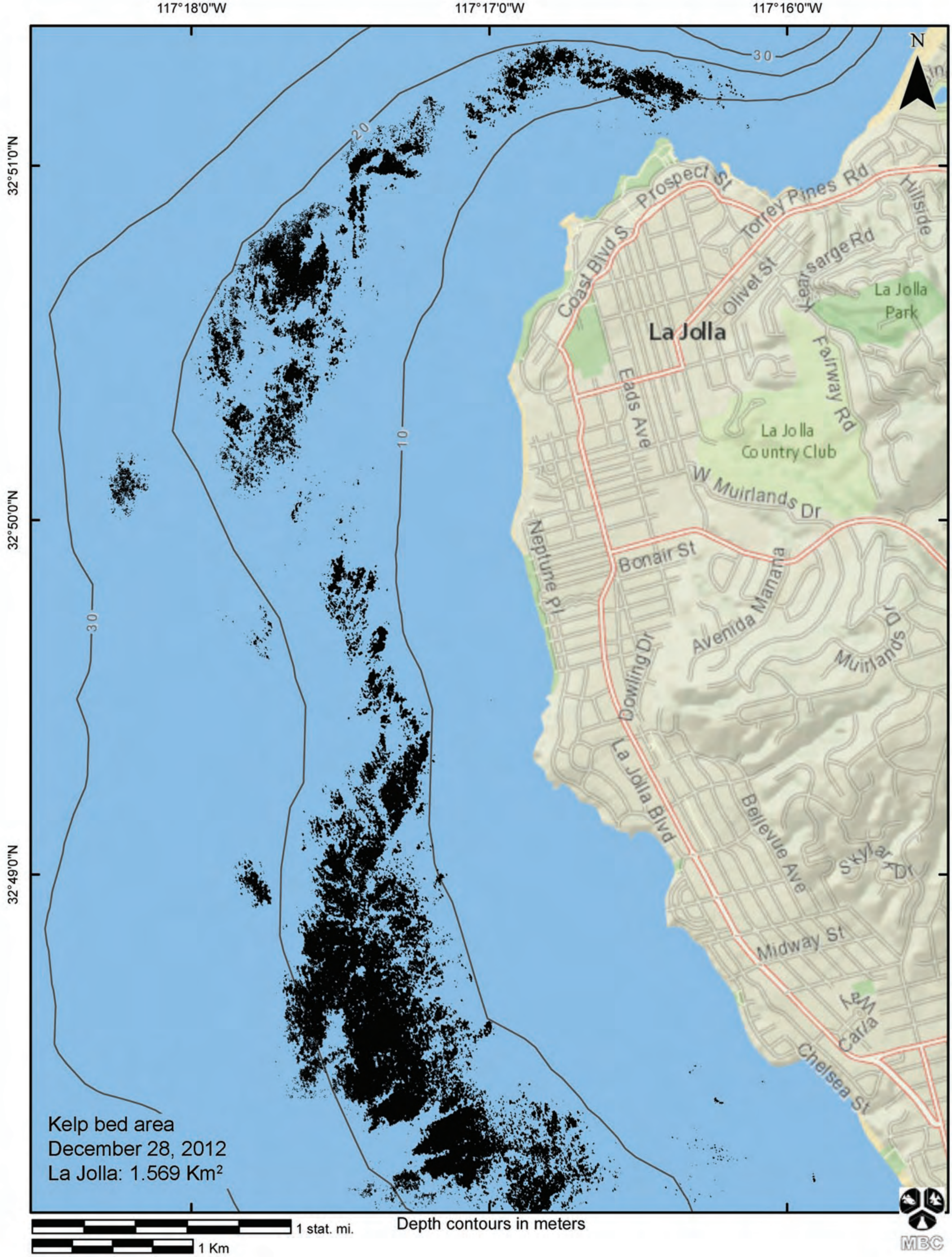
117°15'0"W
33°0'0"N
32°59'0"N
32°58'0"N
32°57'0"N
N
20
30
10
Canyon Dr
Seabright Ln
Glenmont Dr
Dell St
Old Hwy 101
Pacific Ave
Lomas Santa Fe Dr
5
S Nardo Ave
Stevens Ave
Solana Dr
Ida Ave
Avocado Pl
Viva Ct
Hialeah Cir
Solana Beach
Del Mar Racetrack
San Dieguito River
Jimmy Durante Blvd
27th St
San Dieguito Dr
Zapo St
19th St
Coast Blvd
Racetrack View Dr
13th St
Crest Rd
Recuerdo Dr
Del Mar
Stratford
El Amigo Rd
Kelp bed area
December 28, 2012
Solana Beach: 0.4421 Km²
Del Mar: 0.024 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°17'0"W
117°16'0"W
117°15'0"W
N
32°57'0"N
32°56'0"N
32°55'0"N
Coast
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
Kelp bed area
December 28, 2012
Del Mar: 0.024 Km²
Torrey Pines: 0.0344 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°17'0"W
117°16'0"W
117°15'0"W
32°55'0"N
32°54'0"N
32°53'0"N
N
Torrey Pines State Reserve
Torrey Pines Park Rd
N Torrey Pines Rd
Callan Rd
Torrey Pines Golf Course
John Jay Hopkins Dr
Scholars Dr N
Scholars Dr S
Black Gold Rd
Voigt Ln
Myers Ln
20
30
10
No. 2
No. 1
Torrey Pines Artificial Reefs
Kelp bed area
December 28, 2012
Torrey Pines: 0.0344 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC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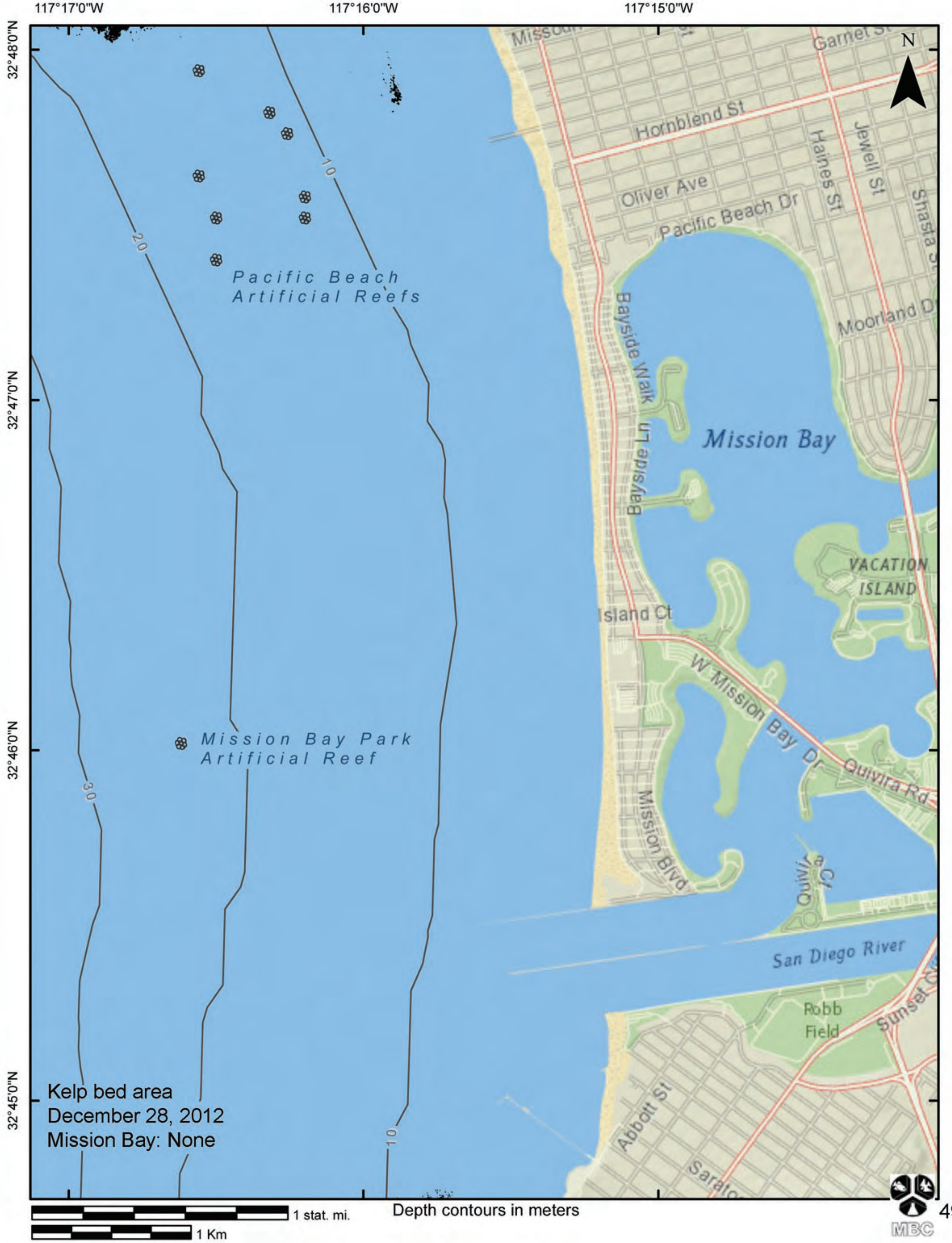
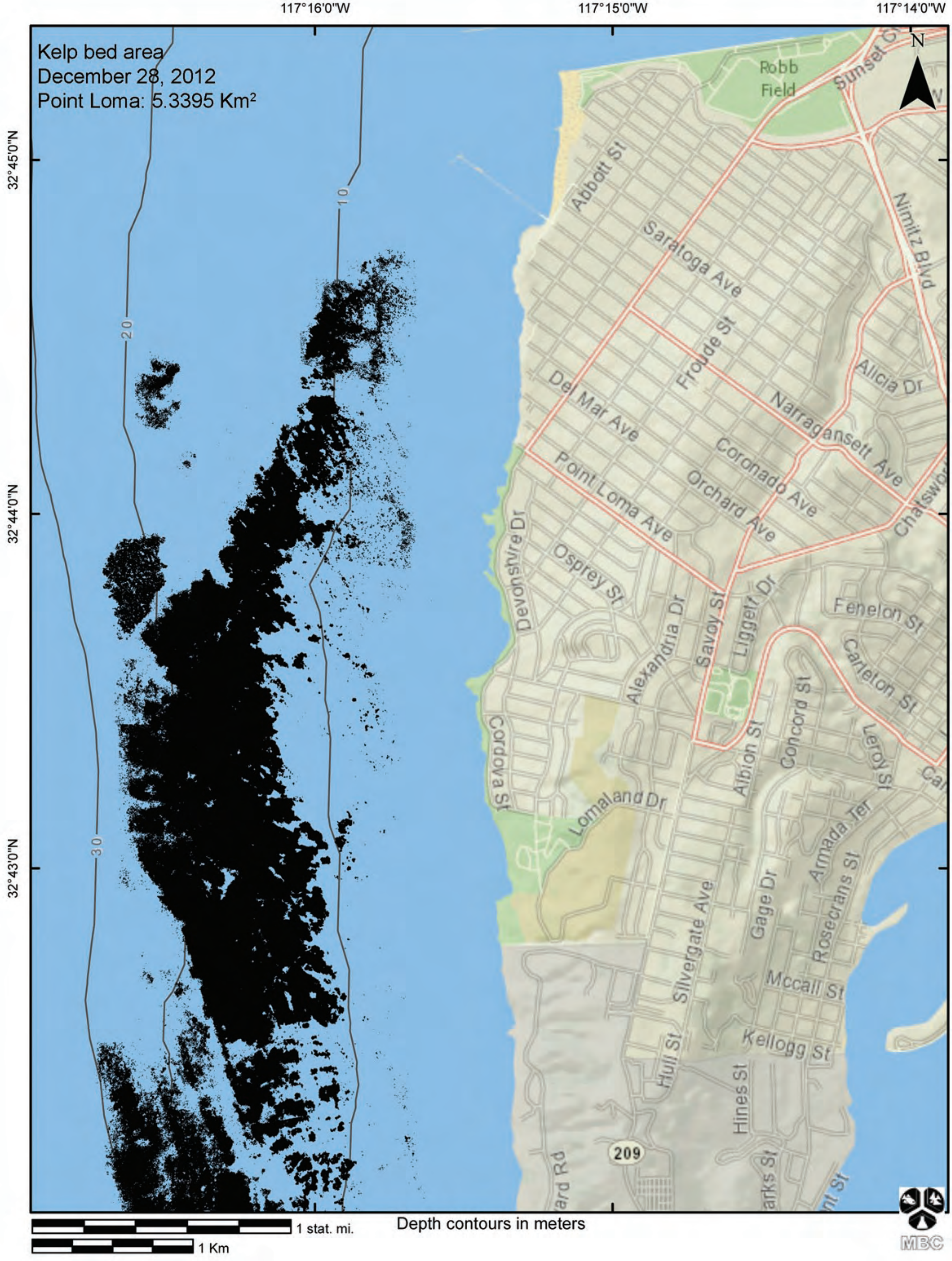
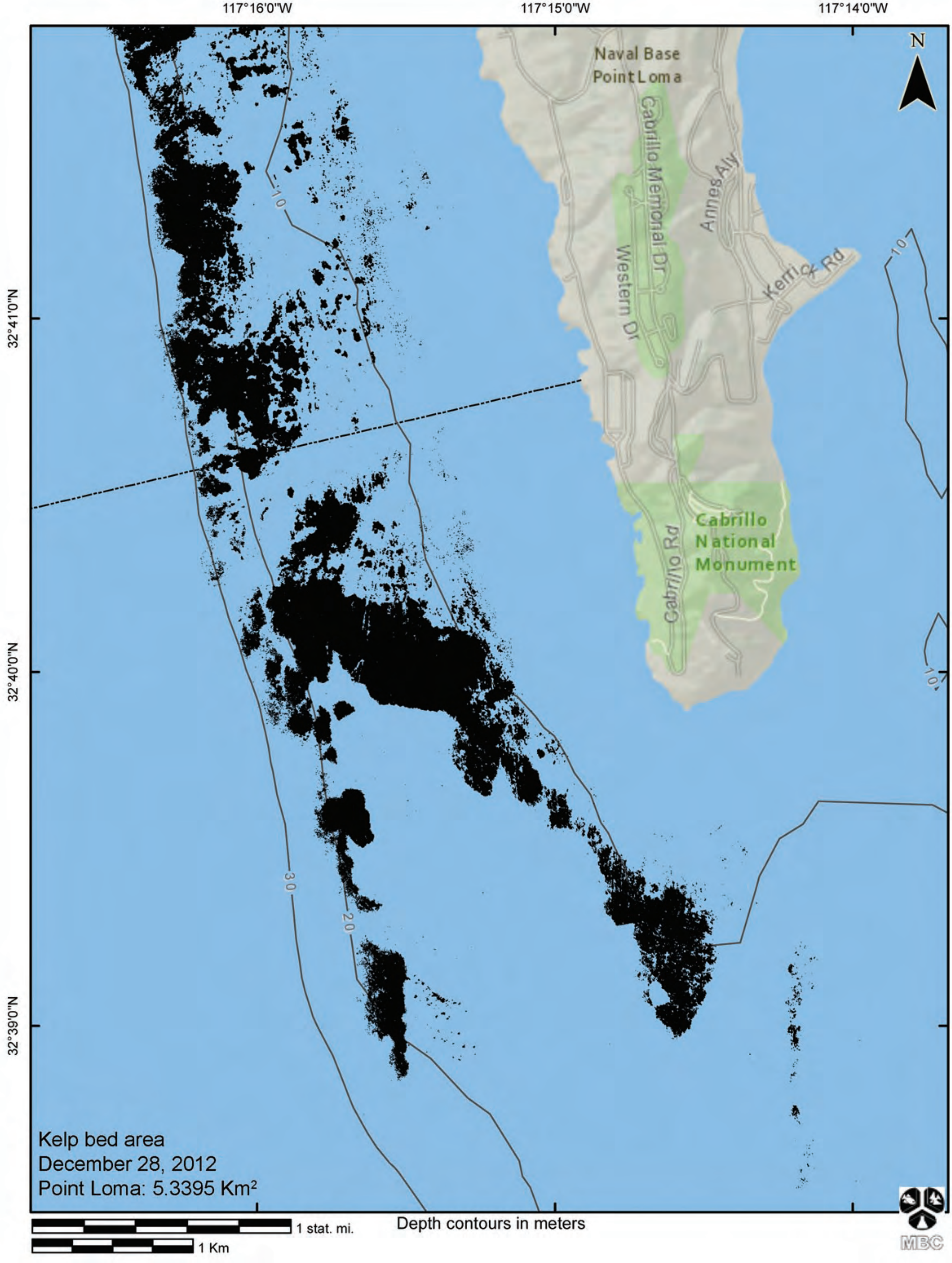
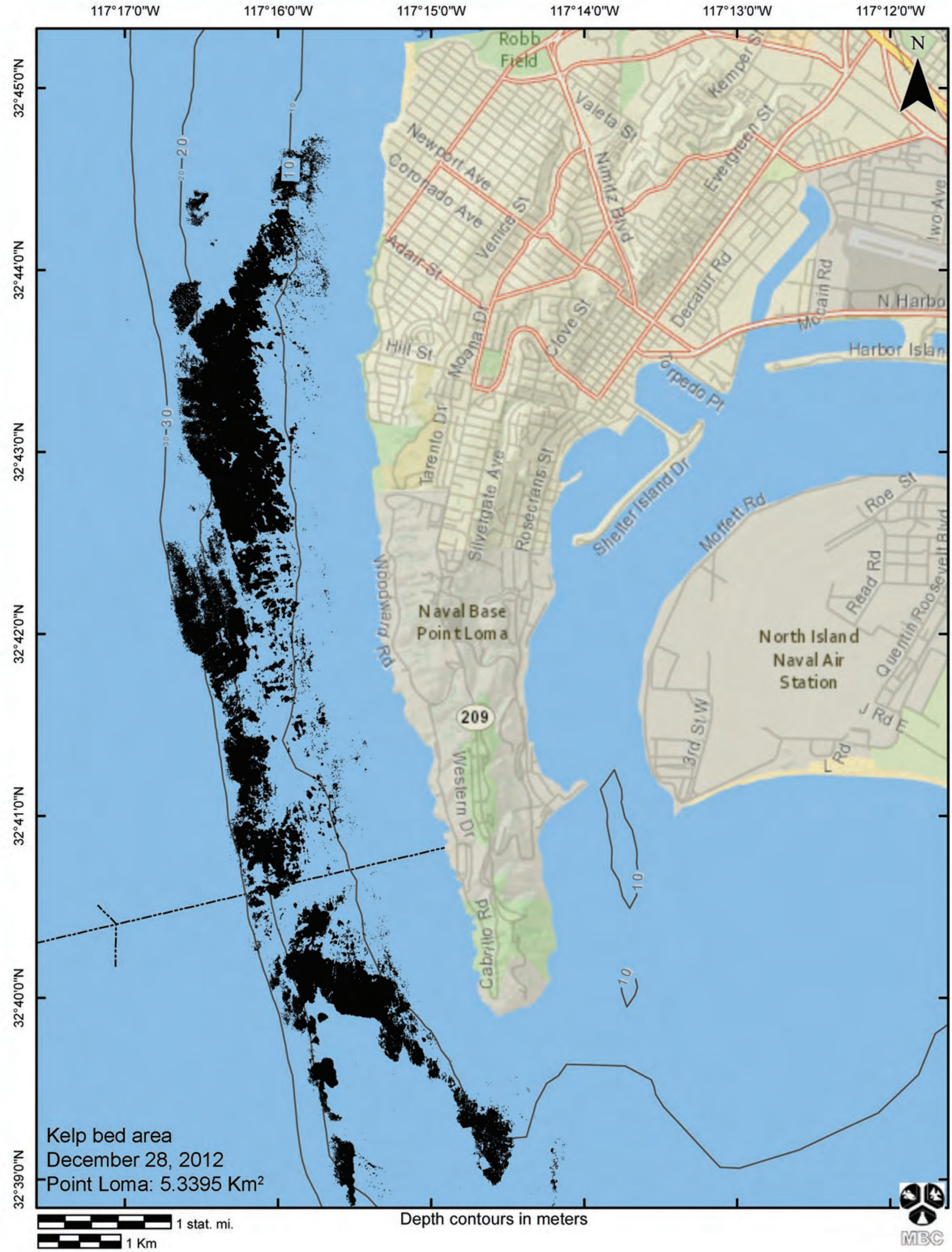
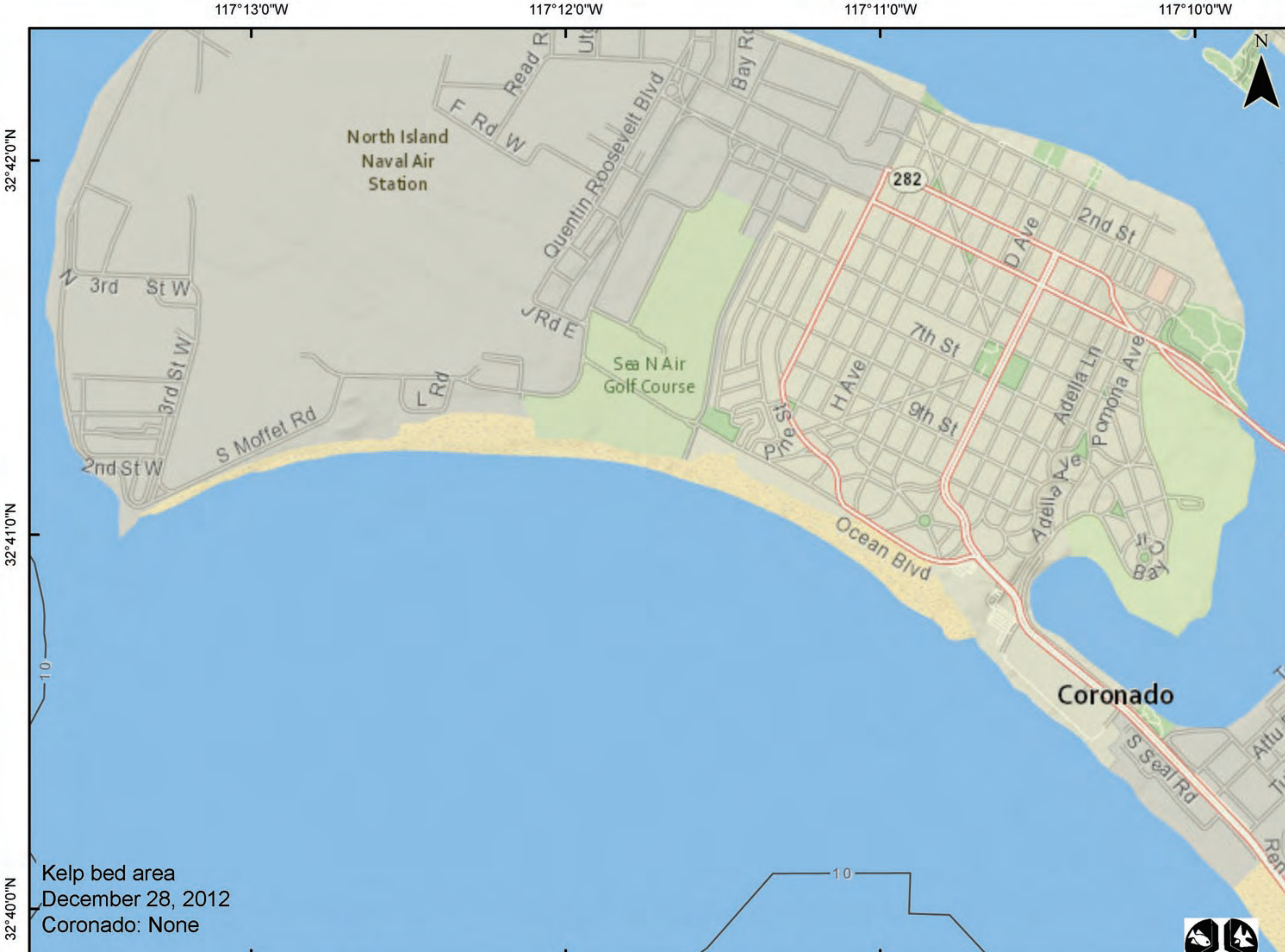
117°17'0"W
117°16'0"W
32°51'0"N
32°50'0"N
32°49'0"N
N
30
20
10
30
Prospect St
Torrey Pines Rd
Hillside
Coast Blvd S
Kearsarge Rd
Olivet St
La Jolla
La Jolla Park
Fairway Rd
Eads Ave
La Jolla Country Club
W Muirlands Dr
Neptune Pl
Bonair St
Avenida Manana
Muirlands Dr
Dowling Dr
La Jolla Blvd
Bellevue Ave
Skylark Dr
Midway St
Carla Way
Chelsea St
Kelp bed area
December 28, 2012
La Jolla: 1.569 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°17'0"W
117°16'0"W
117°15'0"W
32°48'0"N
32°47'0"N
32°46'0"N
32°45'0"N
N
Pacific Beach
Artificial Reefs
Mission Bay Park
Artificial Reef
10
20
30
Mission Bay
VACATION ISLAND
San Diego River
Hornblend St
Garnet St
Oliver Ave
Pacific Beach Dr
Haines St
Jewell St
Moorland Dr
Bayside Walk
Bayside Ln
Island Ct
W Mission Bay Dr
Quivira Rd
Quivira Ct
Mission Blvd
Robb Field
Abbott St
Kelp bed area
December 28, 2012
Mission Bay: None
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°16'0"W
117°15'0"W
117°14'0"W
Kelp bed area
December 28, 2012
Point Loma: 5.3395 Km²
32°45'0"N
32°44'0"N
32°43'0"N
10
20
30
N
Robb Field
Sunset Cl
Abbott St
Saratoga Ave
Nimitz Blvd
Froude St
Alicia Dr
Del Mar Ave
Narragansett Ave
Coronado Ave
Point Loma Ave
Orchard Ave
Chatsworth
Devonshire Dr
Osprey St
Liggett Dr
Fenelon St
Alexandria Dr
Savoy St
Carleton St
Cordova St
Albion St
Concord St
Leroy St
Lomaland Dr
Armada Ter
Silvergate Ave
Gage Dr
Rosecrans St
Mccall St
Hull St
Kellogg St
Hines St
209
1 stat. mi.
1 Km
Depth contours in meters
MBC


117°16'0"W
117°15'0"W
117°14'0"W
N
Naval Base
Point Loma
Cabrillo Memorial Dr
Annes Aly
Western Dr
Kerrick Rd
Cabrillo Rd
Cabrillo
National
Monument
32°41'0"N
32°40'0"N
32°39'0"N
10
20
30
Kelp bed area
December 28, 2012
Point Loma: 5.3395 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

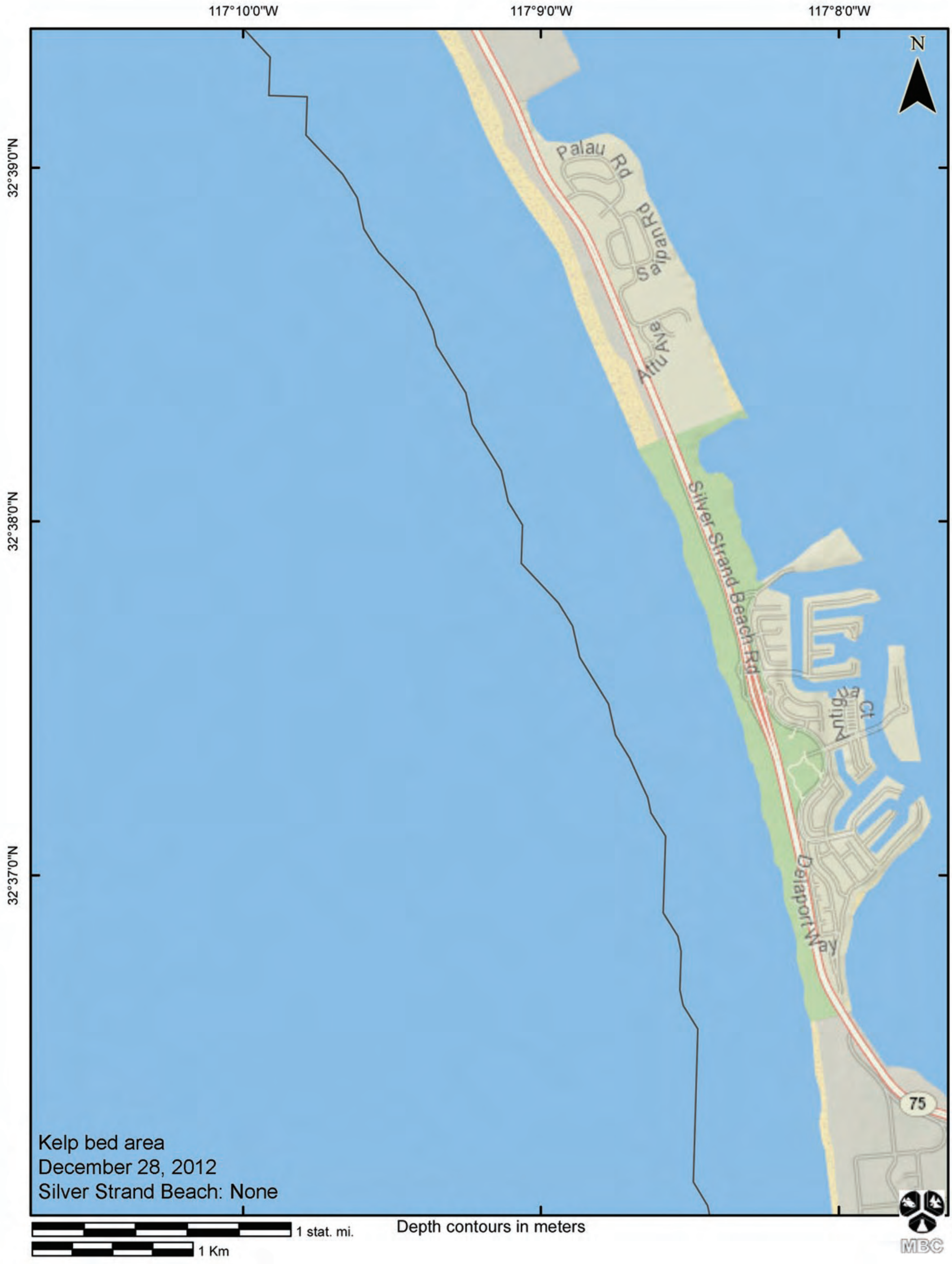

117°17'0"W
117°16'0"W
117°15'0"W
117°14'0"W
117°13'0"W
117°12'0"W
32°45'0"N
32°44'0"N
32°43'0"N
32°42'0"N
32°41'0"N
32°40'0"N
32°39'0"N
N
Robb Field
Newport Ave
Coronado Ave
Adair St
Venice St
Valeta St
Nimitz Blvd
Kemper St
Evergreen St
Decatur Rd
Iwo Ave
Mccain Rd
N Harbo
Harbor Islan
Hill St
Moana Dr
Clove St
Torpedo Pt
Tarento Dr
Silvergate Ave
Rosecrans St
Shelter Island Dr
Moffett Rd
Roe St
Woodward Rd
Naval Base Point Loma
North Island Naval Air Station
Read Rd
Quentin Roosevelt Blvd
209
J Rd E
3rd St W
L Rd
Western Dr
Cabrillo Rd
10
20
30
Kelp bed area
December 28, 2012
Point Loma: 5.3395 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC



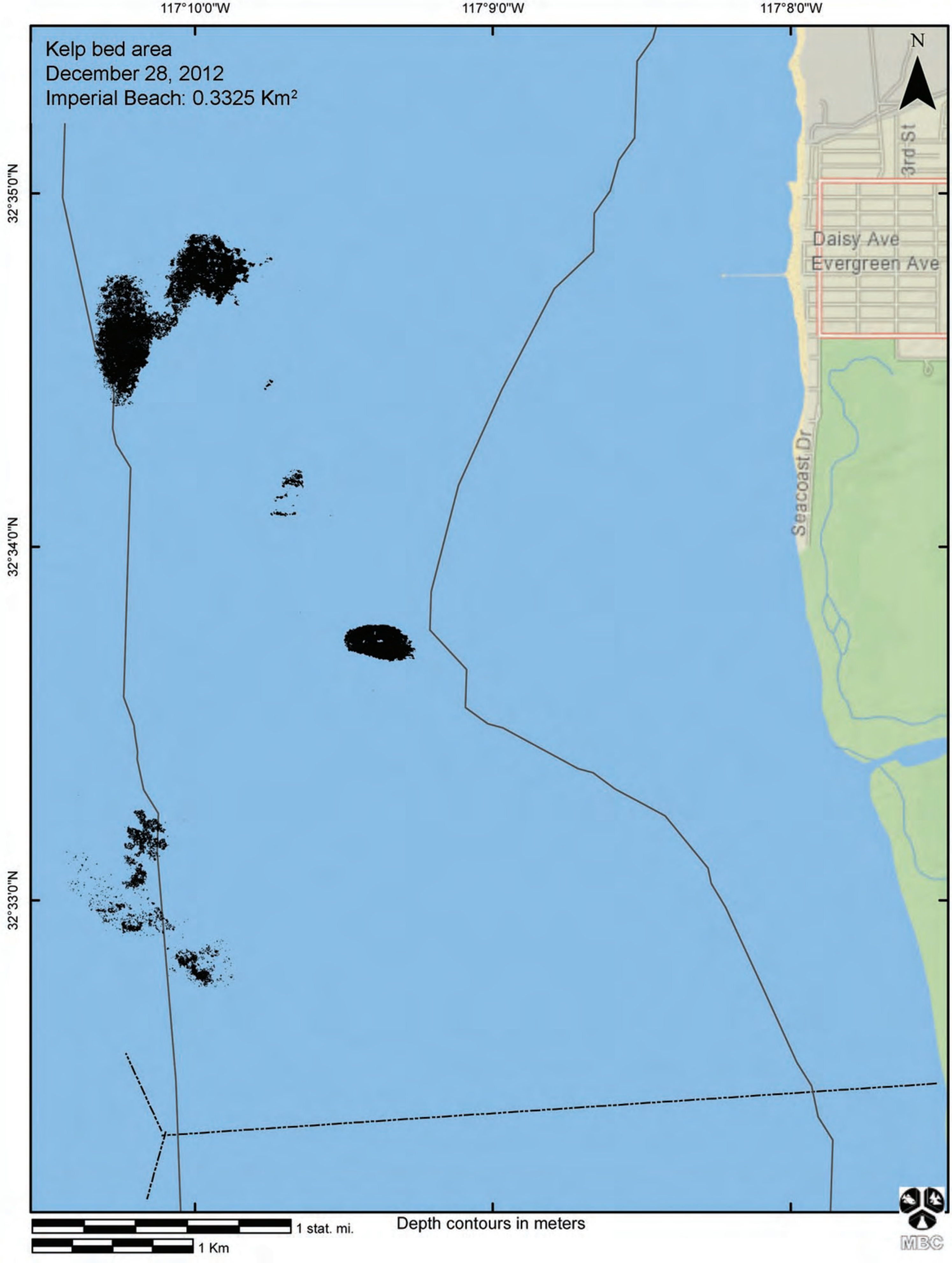
1 stat. mi.

1 Km

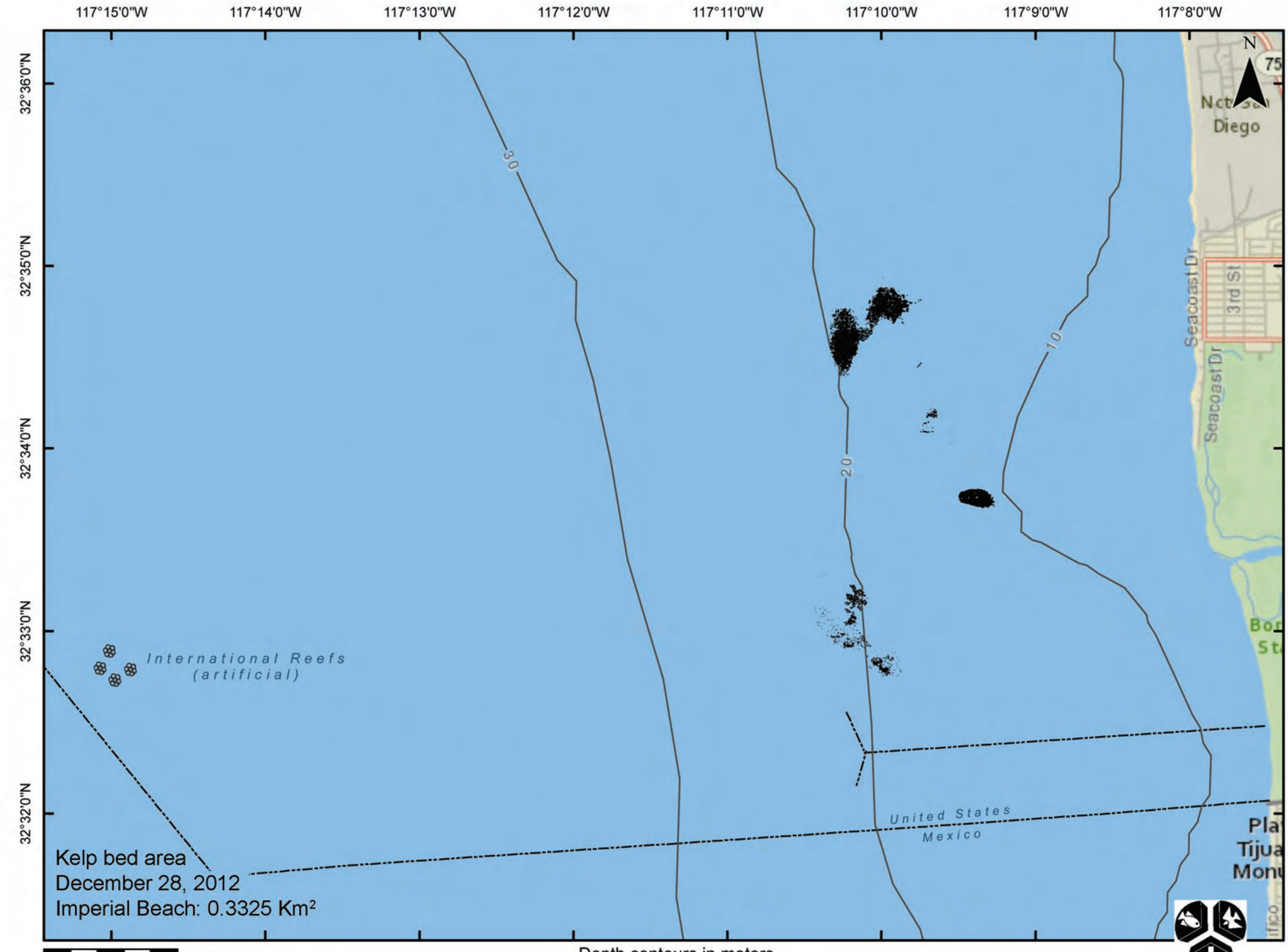
Depth contours in meters



Kelp bed area
December 28, 2012
Silver Strand Beach: None



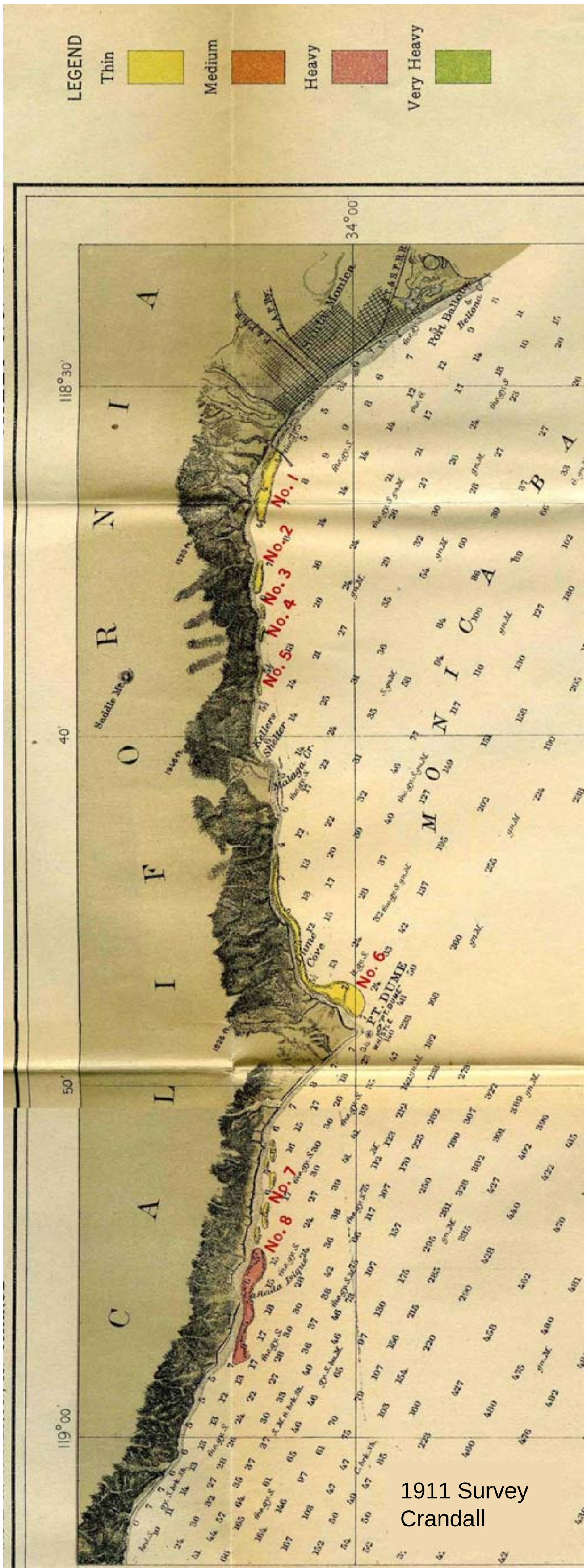
Kelp bed area
December 28, 2012
Imperial Beach: 0.3325 Km²
117°10'0"W
117°9'0"W
117°8'0"W
32°35'0"N
32°34'0"N
32°33'0"N
N
3rd St
Daisy Ave
Evergreen Ave
Seacoast Dr
1 stat. mi.
1 Km
Depth contours in meters
MBC



117°15'0"W
117°14'0"W
117°13'0"W
117°12'0"W
117°11'0"W
117°10'0"W
117°9'0"W
117°8'0"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
International Reefs (artificial)
United States
Mexico
Diego
Seacoast Dr
3rd St
Kelp bed area
December 28, 2012
Imperial Beach: 0.3325 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC

APPENDIX B

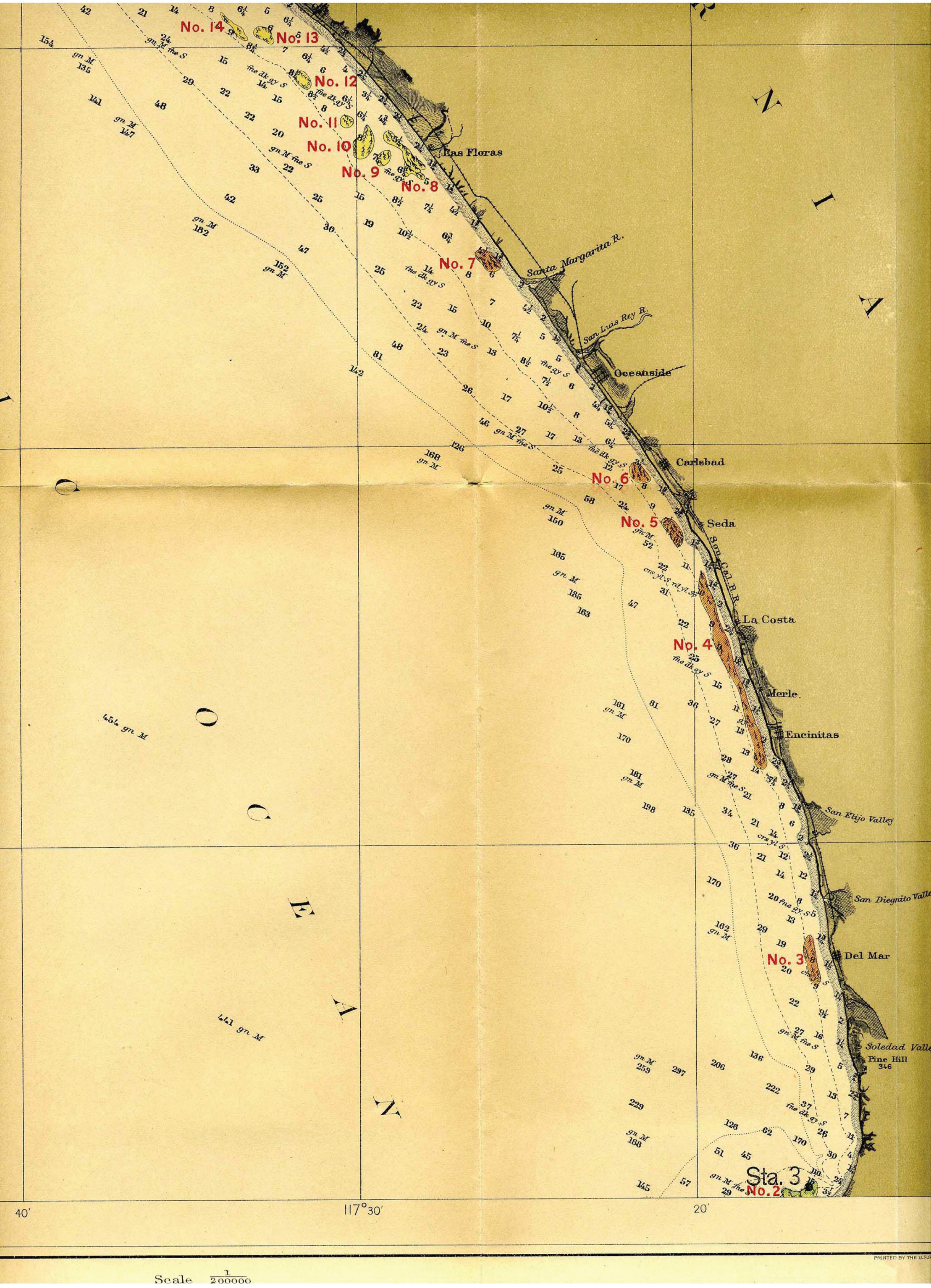
Historic Coverage Area of Kelp Canopies



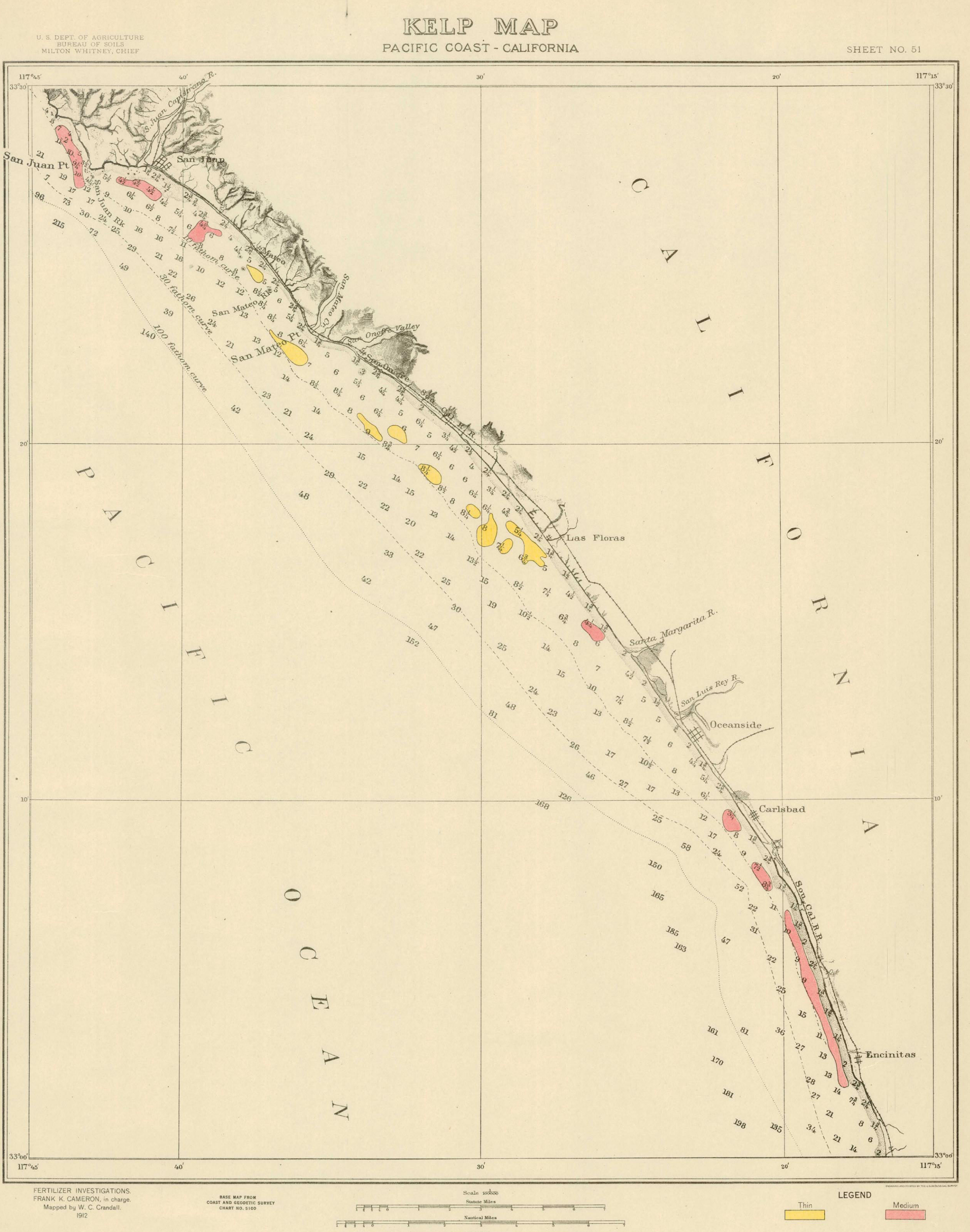
1911 Survey
Crandall


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. 24
No. 23
No. 22
No. 21
118° 24'
118° 20'
118° 16'
33° 46'
33° 42'
1911 Survey
Crandall
Mapped by
W. C. Crandall
BASE MAP FROM
COAST AND GEODETIC
SURVEY CHART NO. 5143
Statute Miles
Nautical Miles
SOUNDINGS
The soundings are in fathoms and show the depth at mean lower low water.
Senate Doc. 190; 62d Cong., 2d Sess.
LEG
Th
Med

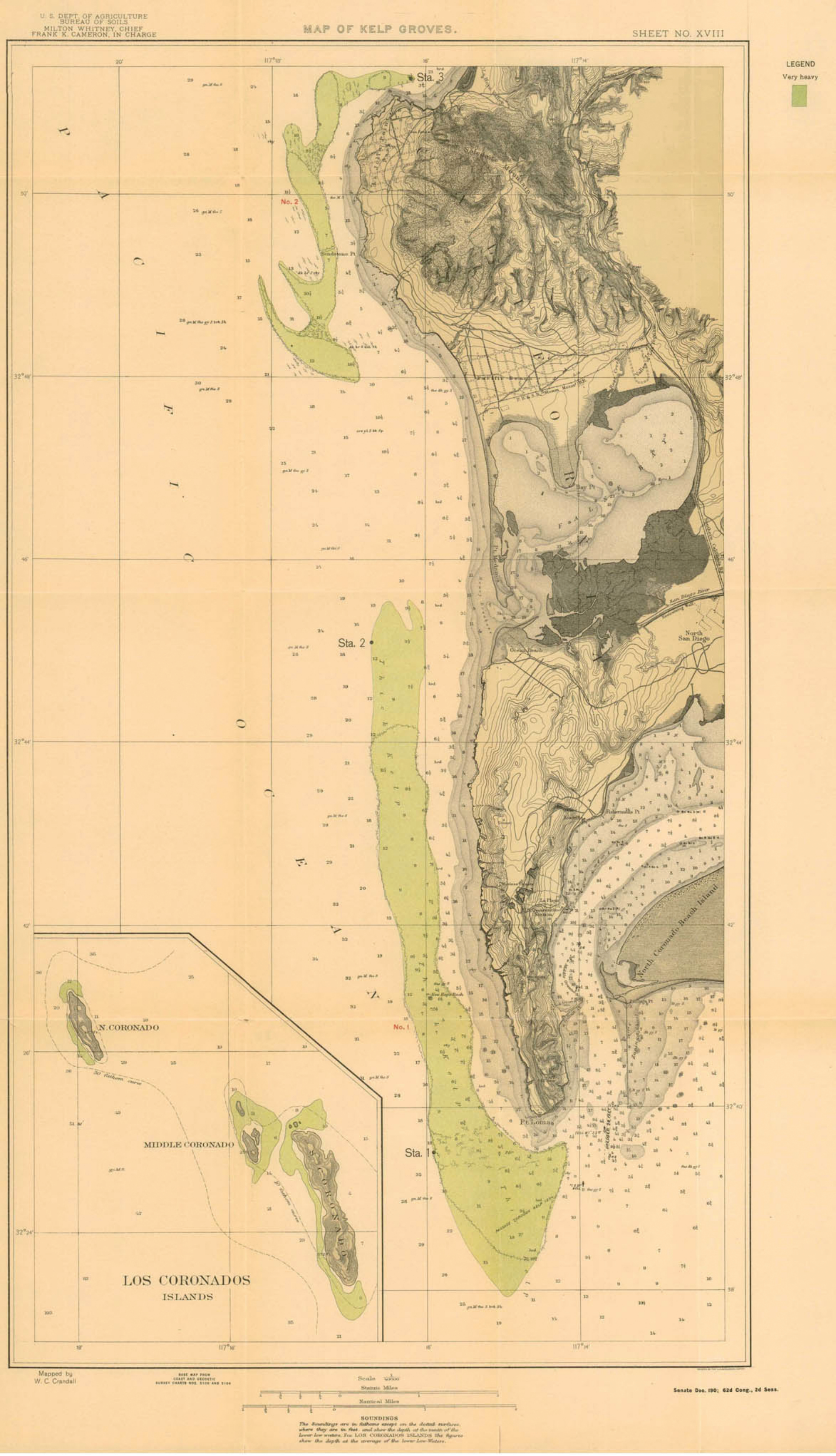
1911 Crandall kelp bed survey, Newport to San Onofre



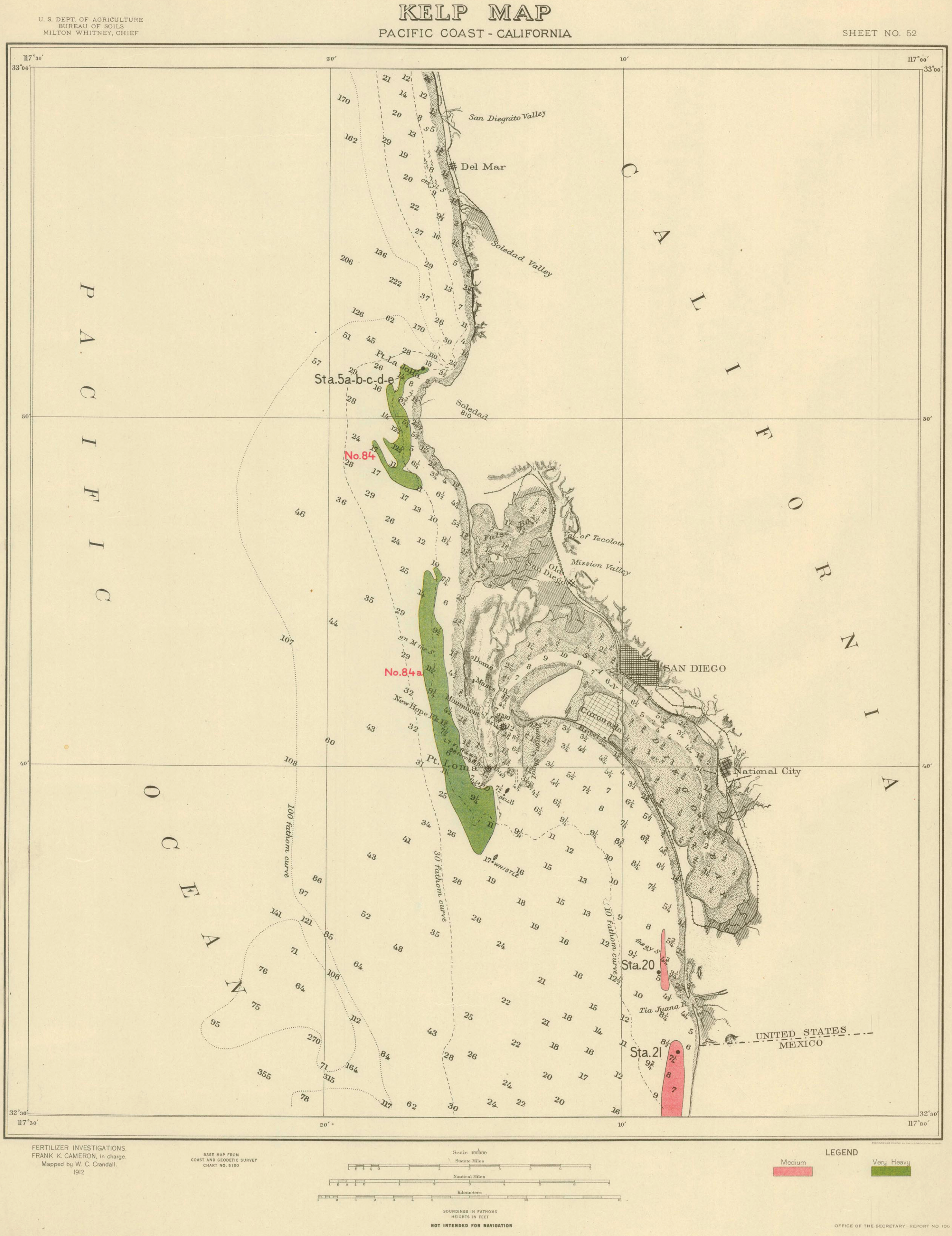
1911 Crandall kelp bed survey, San Onofre to Del Mar



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

Flight Data Reports

Quarterly Kelp Survey Flight Schedule

Mid-March to Mid-April	Tide (Scripps Pier)	Sea/Swell (feet)	Wind (knots)	Weather (NOAA)	Flight Status	Reason/Comments
16-Mar-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover
17-Mar-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover
18-Mar-12	Less than 1' MLLW	6-9 Feet	Greater than 10 kts.	Overcast entire range, rain	Survey Cancelled	Cloud cover, seas, wind
19-Mar-12	Less than 1' MLLW	6-9 Feet	Greater than 10 kts.	Overcast entire range, rain	Survey Cancelled	Cloud cover, seas, wind
20-Mar-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
21-Mar-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
22-Mar-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
23-Mar-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
24-Mar-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
25-Mar-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, tide
26-Mar-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, tide
27-Mar-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, tide
28-Mar-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, tide
29-Mar-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, tide
30-Mar-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, tide
31-Mar-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, tide
1-Apr-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
2-Apr-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
3-Apr-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
4-Apr-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
5-Apr-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
6-Apr-12	**0.8 (+) to 0.1' (+) MLLW**	**5 Feet**	**Calm**	**Clear**	**Survey Flown**	**Optimum Conditions**
Mid-June to Mid July	**Tide (Scripps Pier)**	**Sea/Swell (feet)**	**Wind (knots)**	**Weather**	**Flight Status**	**Reason/Comments**
15-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
16-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
17-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
18-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
19-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
20-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
21-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
22-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
23-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
24-Jun-12	More than 1.0' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
25-Jun-12	Less than 1.0' MLLW (AM)	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
26-Jun-12	**4.6' (+) to 4.1' (+) MLLW**	**3 Feet**	**5 knots**	**Clear**	**Survey Flown**	**Excellent Conditions**

Quarterly Kelp Survey Flight Schedule

Mid-Sept. - Mid Oct.	Tide (Scripps Pier)	Sea/Swell (feet)	Wind (knots)	Weather	Flight Status	Reason/Comments
15-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
16-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
17-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
18-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
19-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
20-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
21-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
22-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
23-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
24-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
25-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
26-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
27-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
28-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
29-Sep-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
30-Sep-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
1-Oct-12	**3.1' (+) to 1.1' (+) MLLW**	**3 Feet**	**Calm**	**Clear, fog S of Del Mar**	**Survey Flown**	**Optimum ConditionsexFog**
11-Oct-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcas entire range, rain	Survey Cancelled	Cloud cover, rain
15-Oct-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, fog	Survey Cancelled	Cloud cover, fog
30-Oct-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, fog	Survey Cancelled	Cloud cover, fog
Mid-December-End December	**Tide (Scripps Pier)**	**Sea/Swell (feet)**	**Wind (knots)**	**Weather**	**Flight Status**	**Reason/Comments**
15-Dec-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
16-Dec-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
17-Dec-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
18-Dec-12	More than 1' MLLW	**6-9 Feet**	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain, tide, seas
19-Dec-12	More than 1' MLLW	**6-9 Feet**	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover, rain, tide, seas
20-Dec-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Clear	Survey Cancelled	Tide
21-Dec-12	More than 1' MLLW	Less than 5 Feet	Less than 10 knots	Clear	Survey Cancelled	Tide
22-Dec-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
23-Dec-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
24-Dec-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
25-Dec-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
26-Dec-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range, rain	Survey Cancelled	Cloud cover, rain
27-Dec-12	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy partial range	Survey Cancelled	Cloud cover
28-Dec-12	**1.1' (+) to 0.2' (-) MLLW**	**5 Feet**	**Calm**	**Clear**	**Survey Flown**	**Optimum Conditions**

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:**	3/12
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	4/6/12
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	4/2012

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

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach - April 6, 2012**
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:		April 6, 2012			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear (some patchy fog)
	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:	Calm
	Videography	Lenses:	30mm (see note)	Sea/Swell:	6-8 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1403-1540
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	1.0' (+) to 0.1' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	Low-medium glare present
	Other 3:	Photographer:	Van Wagenen	Comments:	Good/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 good to 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

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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:**	6/12
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	6/26/12
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	6/2012

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

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach - June 26, 2012**
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:		**June 26, 2012**			
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:	35mm (see note)	Sea/Swell:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1535-1720
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	4.7' (+) to 4.2' (+) 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	35mm (digital SLR camera) is similiar focal length to 52mm (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:**	9/12
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	10/1/12
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	11/12

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

Project Title		**California Coastal Kelp Resources - Ventura to Oceanside- October 1, 2012**
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:		**October 1, 2012**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear to coastal fog
	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:	1437-1554
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	1.7' (+) to 0.4' (+) 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 Oceanside - Coastal fog was present south of Buena Vista Lagoon (map 69) to Imperial Beach and prevented imagery acquisition within this range (maps 69-72).	
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
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:**	12/12
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	12/28/12
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	1/13

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

Project Title		**California Coastal Kelp Resources - Ventura to Oceanside- December 28, 2012**
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 28, 2012**			
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:	4-6 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1300-1432
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	1.4' (+) to 0.4' (-) 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:**	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)

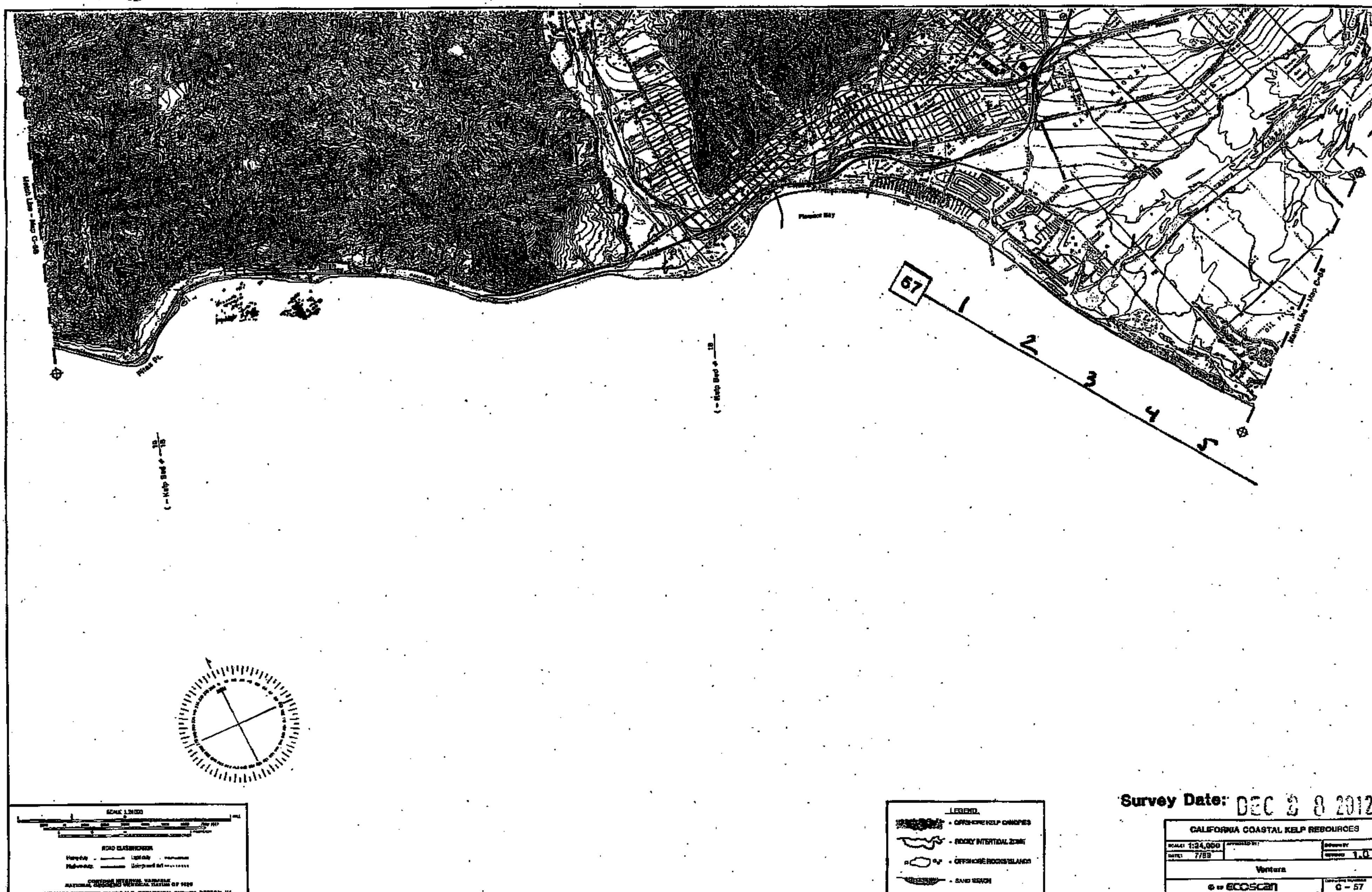
Aerial Resource Survey Flight Data for:		May 13, 2013			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic 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)

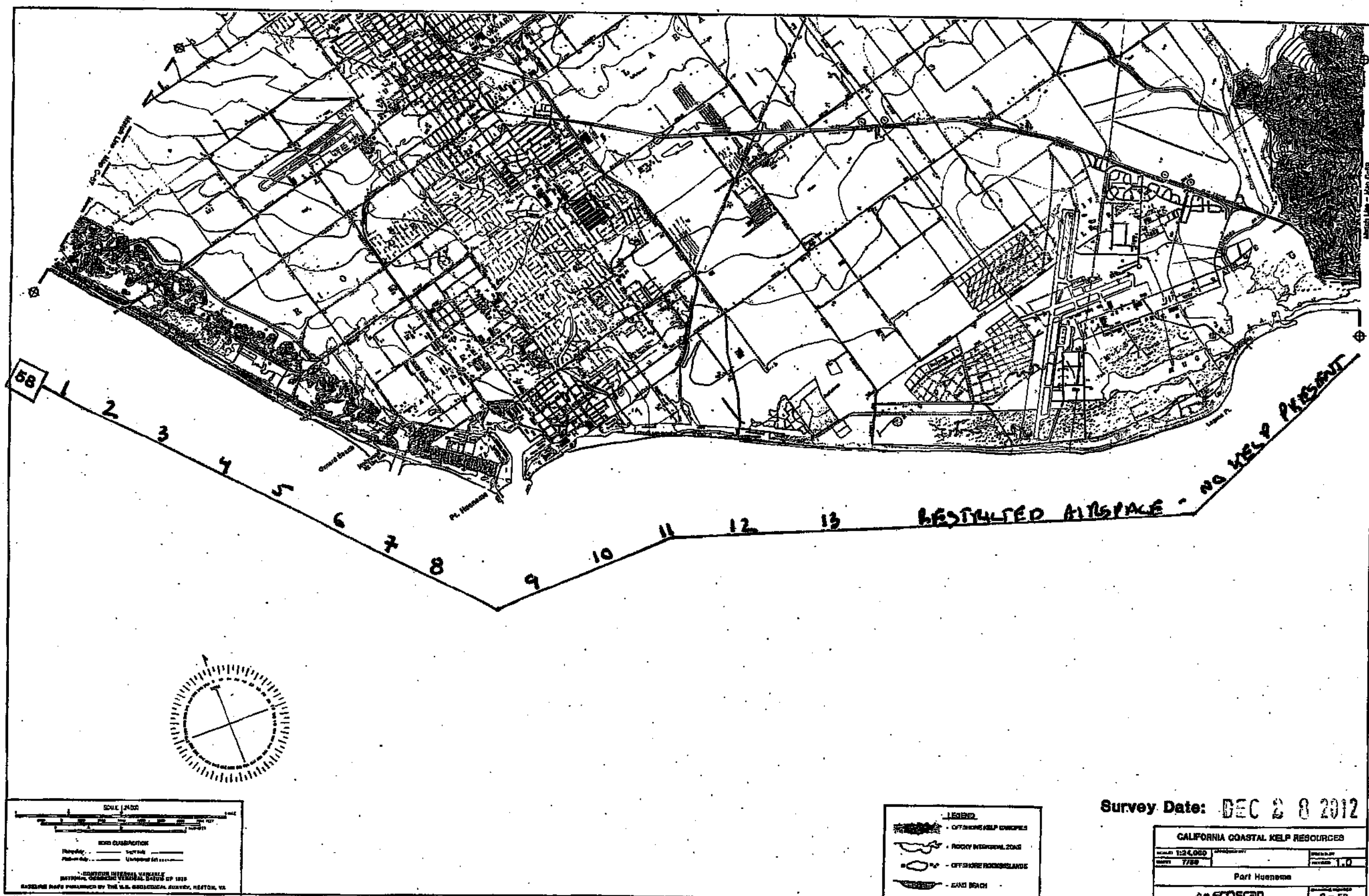
Ecoscan Resource Data
143 Browns Valley Rd.
Watsonville, CA 95076
(831) 728-5900 (ph./fax)

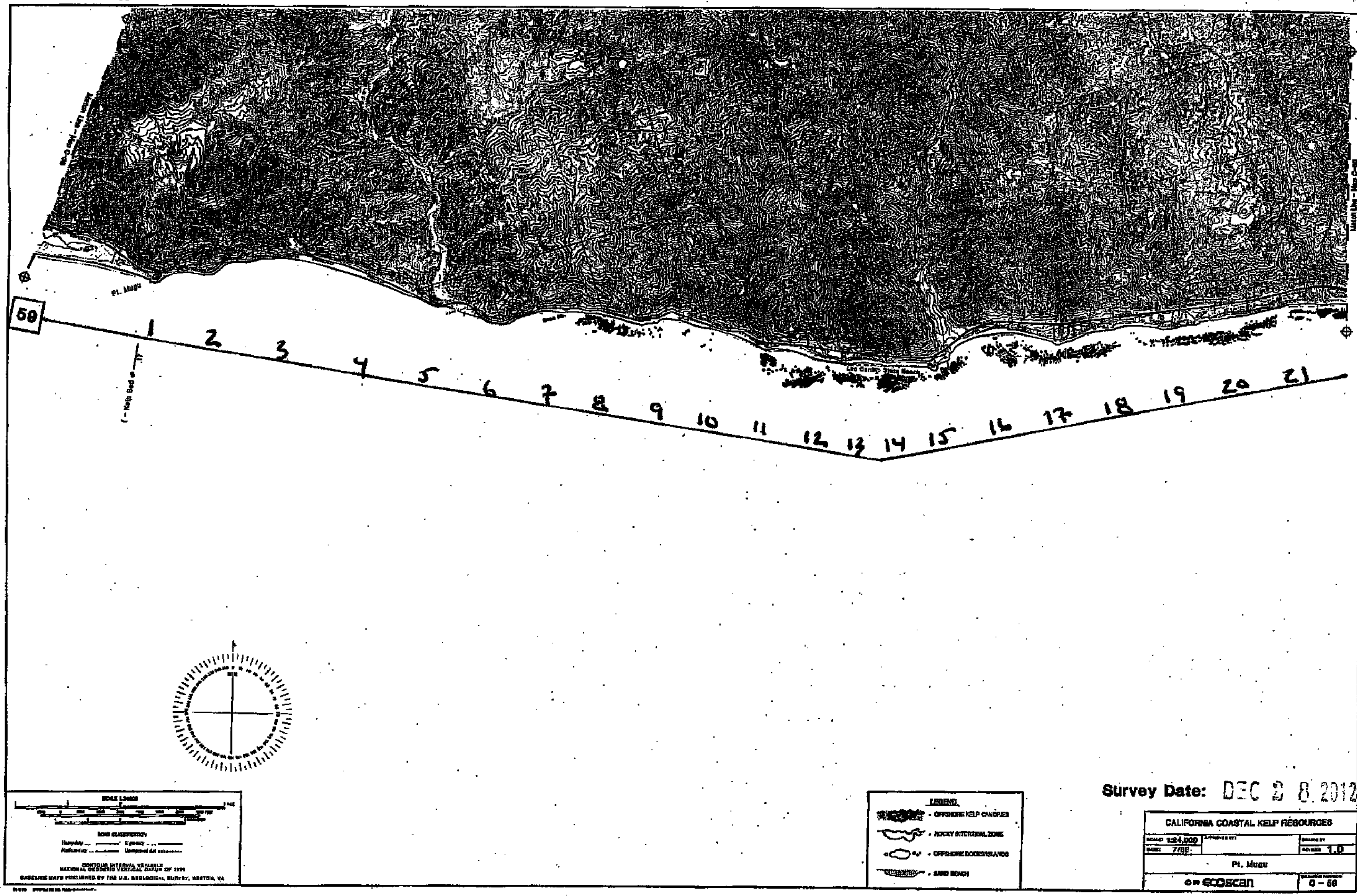
Signed: ______________________ Bob Van Wagenen, Director

Copy To:

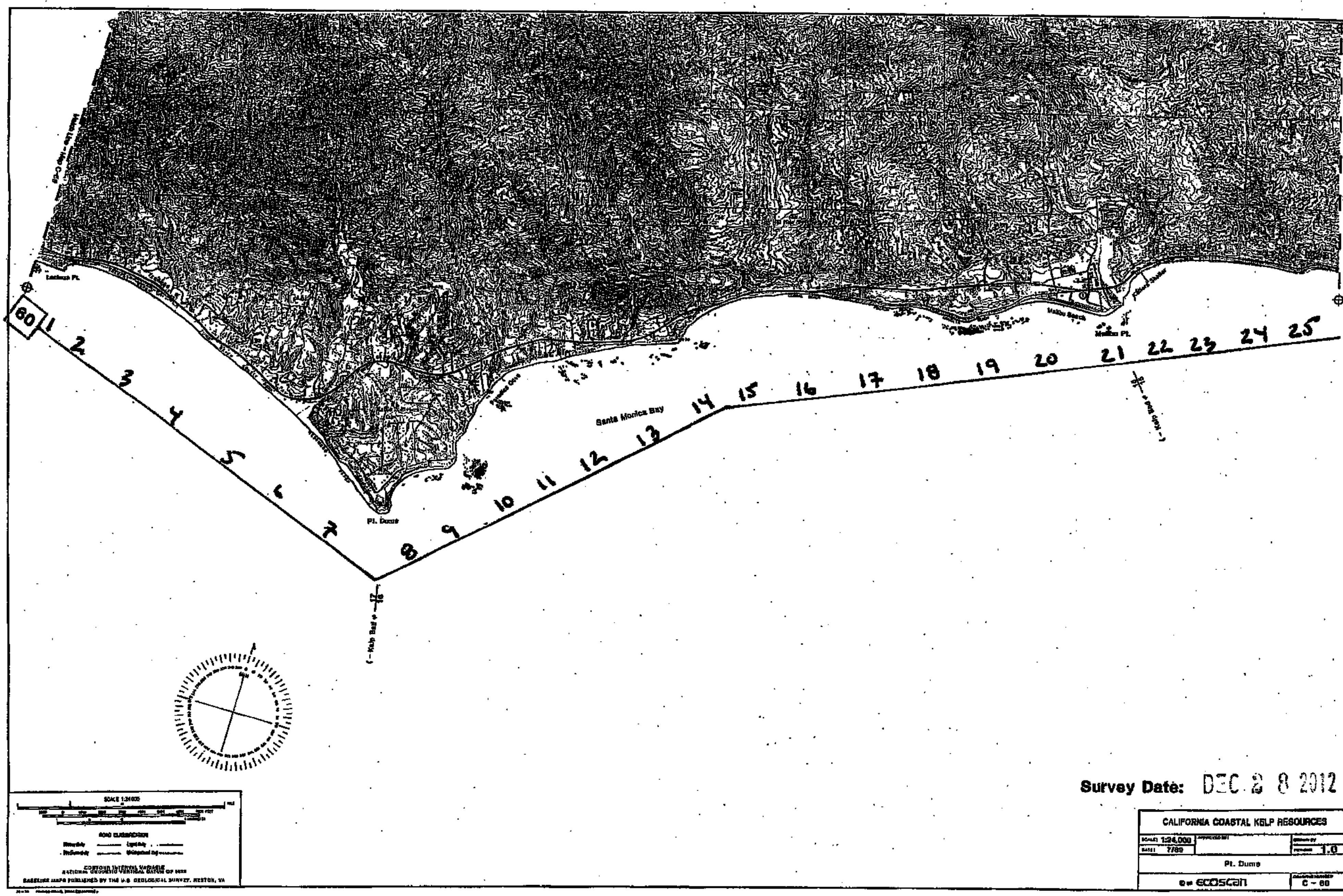


57
1
2
3
4
5
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
SCALE: 1:24,000
DATE: 7/89
1.0
Ventura
ECOSCAN
C - 57
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
ROAD CLASSIFICATION
Match Line - Map C-56
Match Line - Map C-58


58
1
2
3
4
5
6
7
8
9
10
11
12
13
RESTRICTED AIRSPACE - NO KELP PRESENT
Pt. Hueneme
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
SCALE 1:24,000
DATE 7/89
1.0
Port Hueneme
ECOSCAN
C - 58



59
Pt. Mugu
Leo Carrillo State Beach
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/88
1.0
Pt. Mugu
ecoscan
C - 59



Santa Monica Bay
Pt. Dume
Malibu Beach
Malibu Pt.
Leo Carrillo
60
1
2
3
4
5
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7
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11
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13
14
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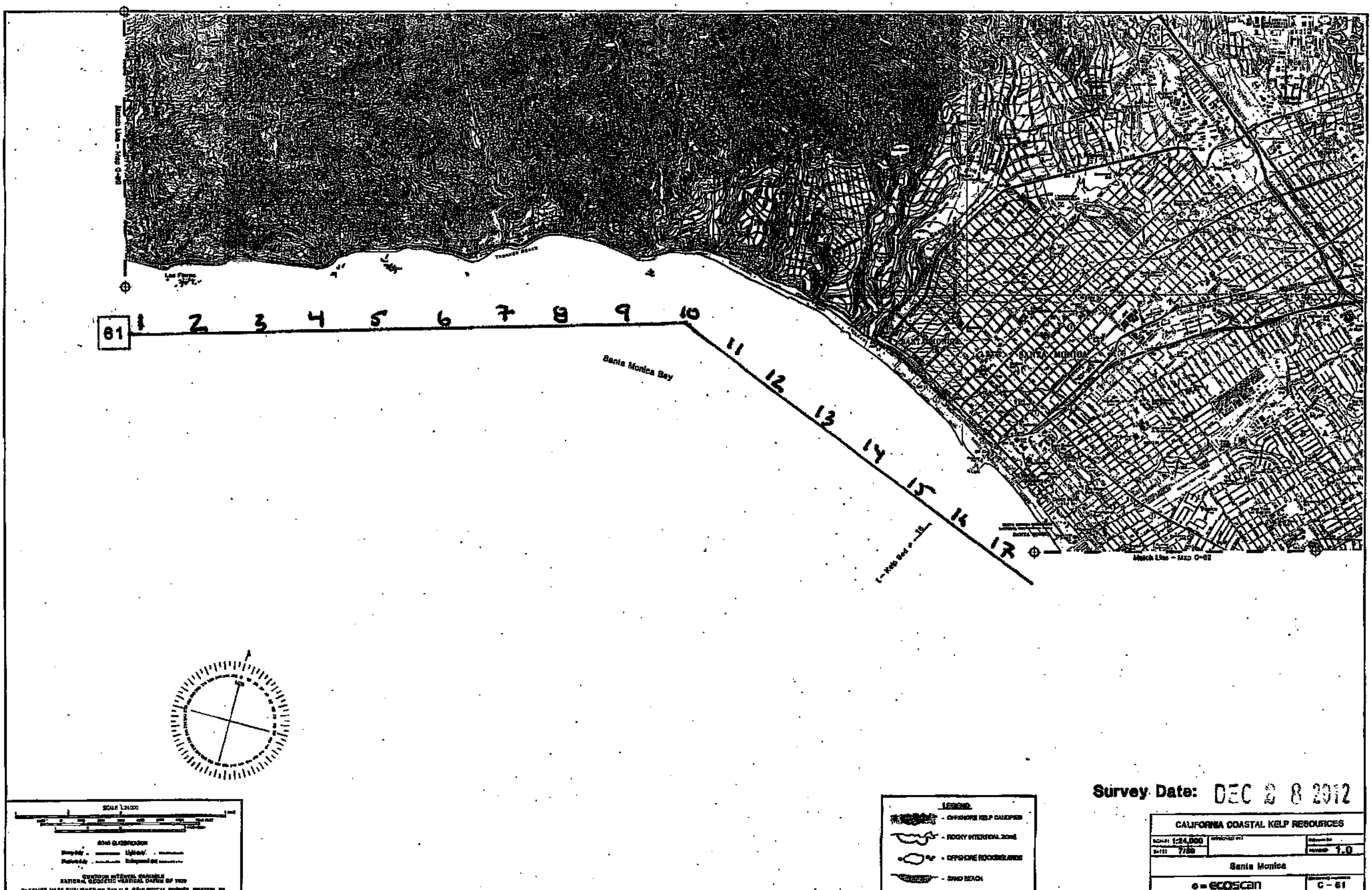
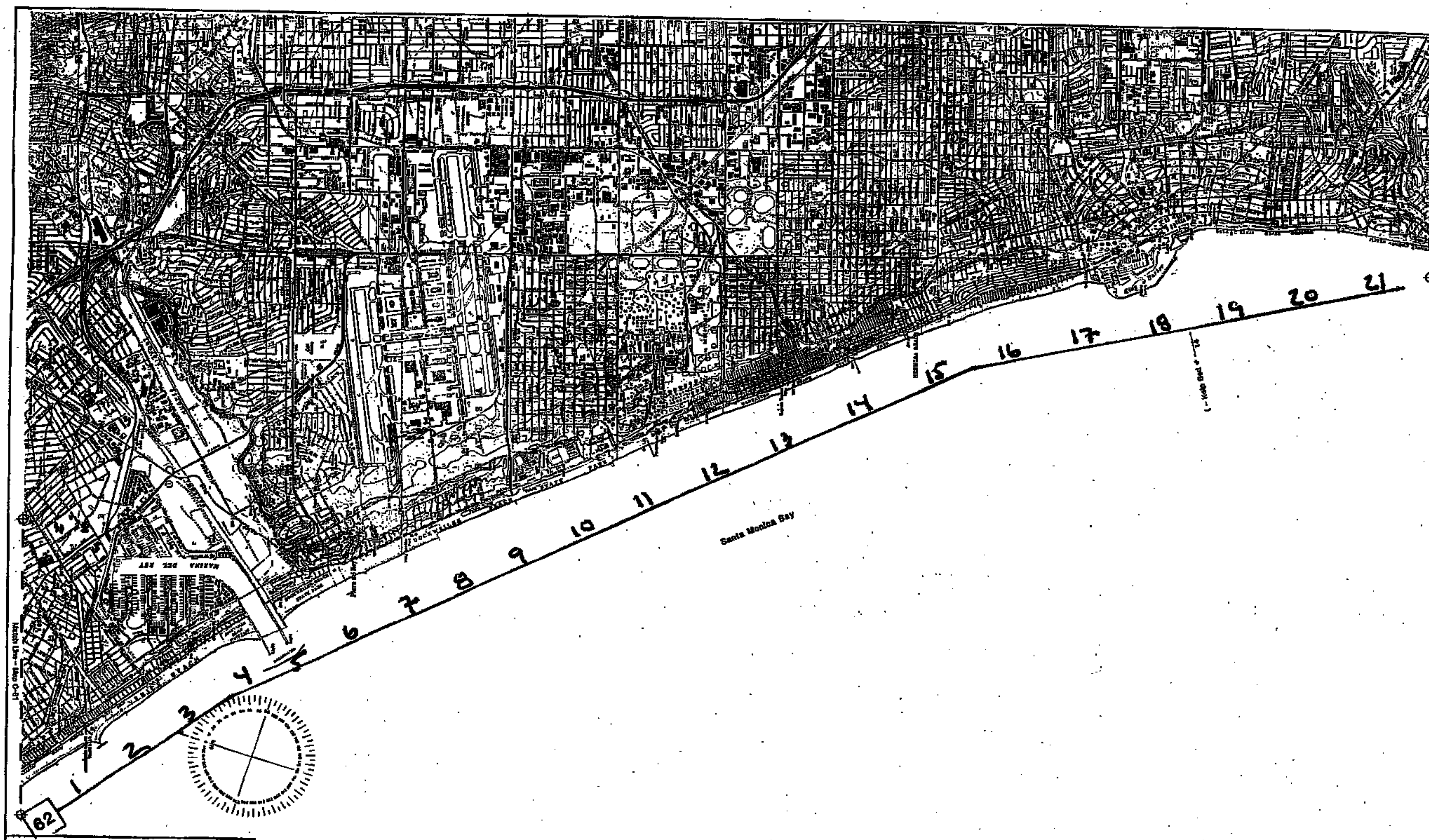
19
20
21
22
23
24
25
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Pt. Dume
ecoscan
C - 60


Match Line - Map C-62
61
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Santa Monica Bay
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
1.0
Santa Monica
ecoscan
C - 61
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA

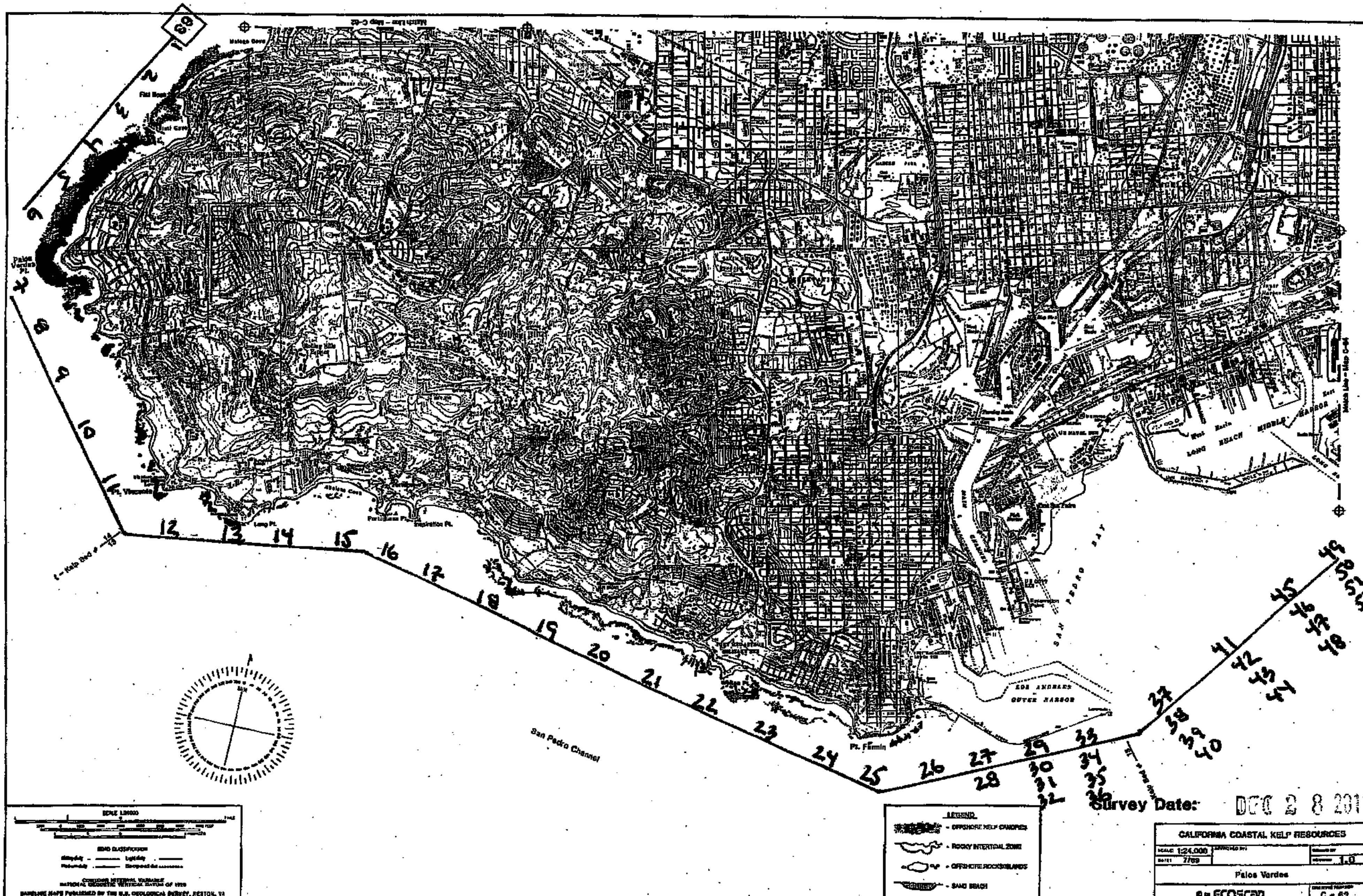


Survey Date: DEC 2 8 2012

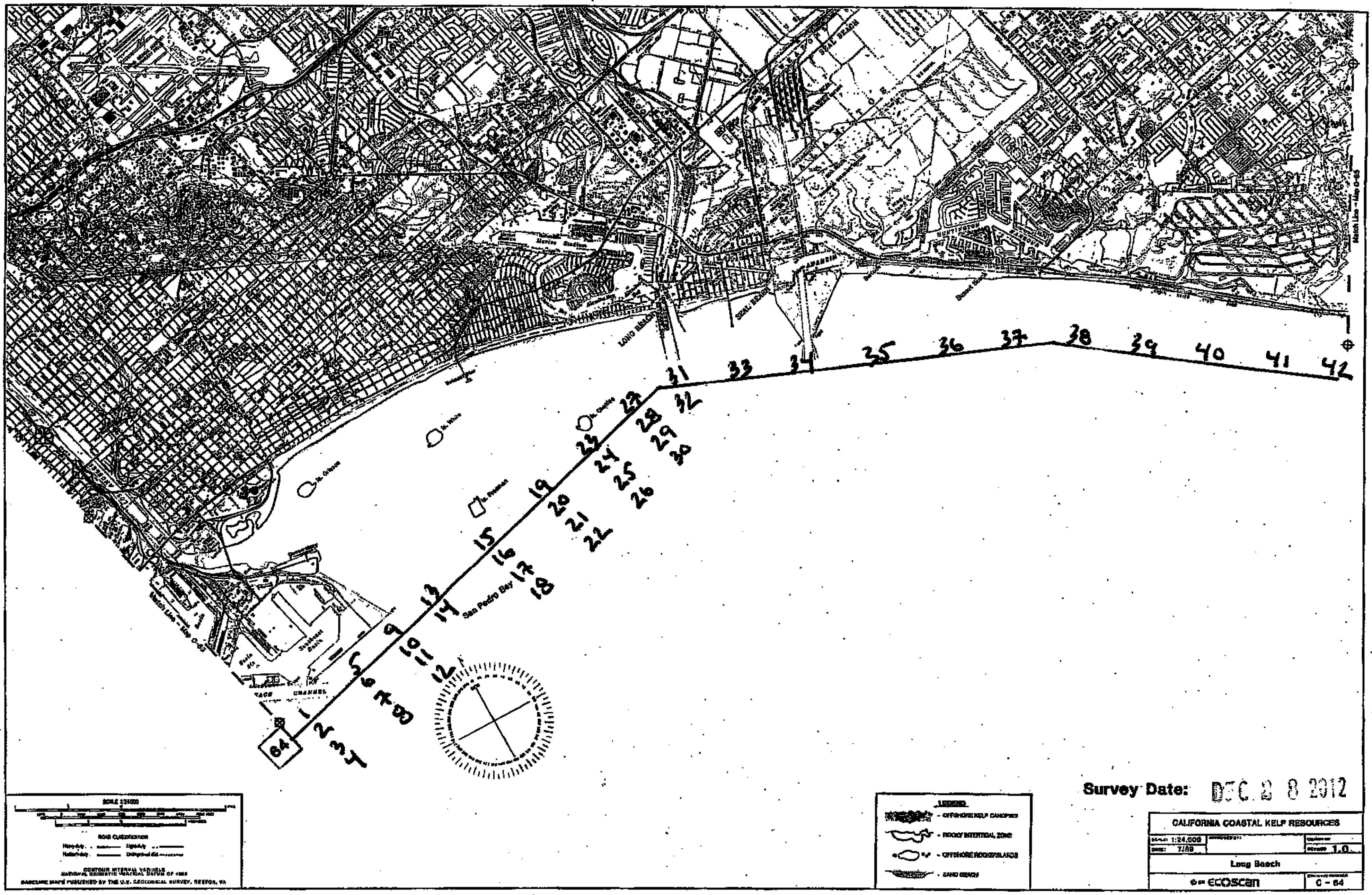
LEGEND

- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH

CALIFORNIA COASTAL KELP RESOURCES		
SCALE: 1:24,000 DATE: 7/88		1.0
Los Angeles		
ECOSCAN		C - 62



Match Line – Map C-62
Malaga Cove
Palos Verdes Pt.
Pt. Vicente
Long Pt.
Portuguese Pt.
Inspiration Pt.
Abalone Cove
San Pedro Channel
Pt. Fermin
SAN PEDRO BAY
LOS ANGELES OUTER HARBOR
LONG BEACH MIDDLE HARBOR
Match Line – Map C-64
Survey Date:
DEC 2 8 2012
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


Long Beach
Seal Beach
San Pedro Bay
Survey Date: DEC 2 8 2012
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Long Beach
ECOSCAN
C - 64
64
1
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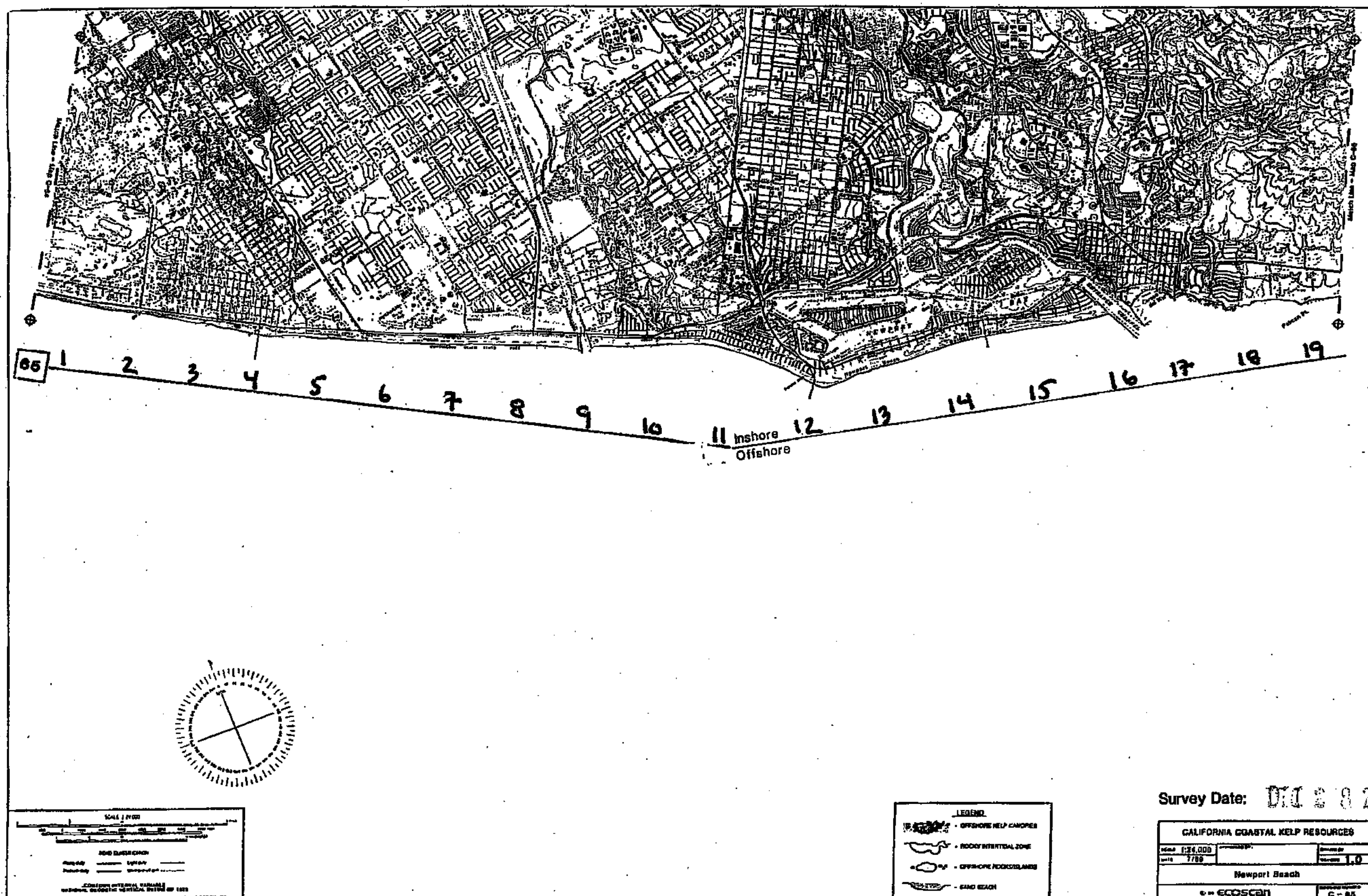
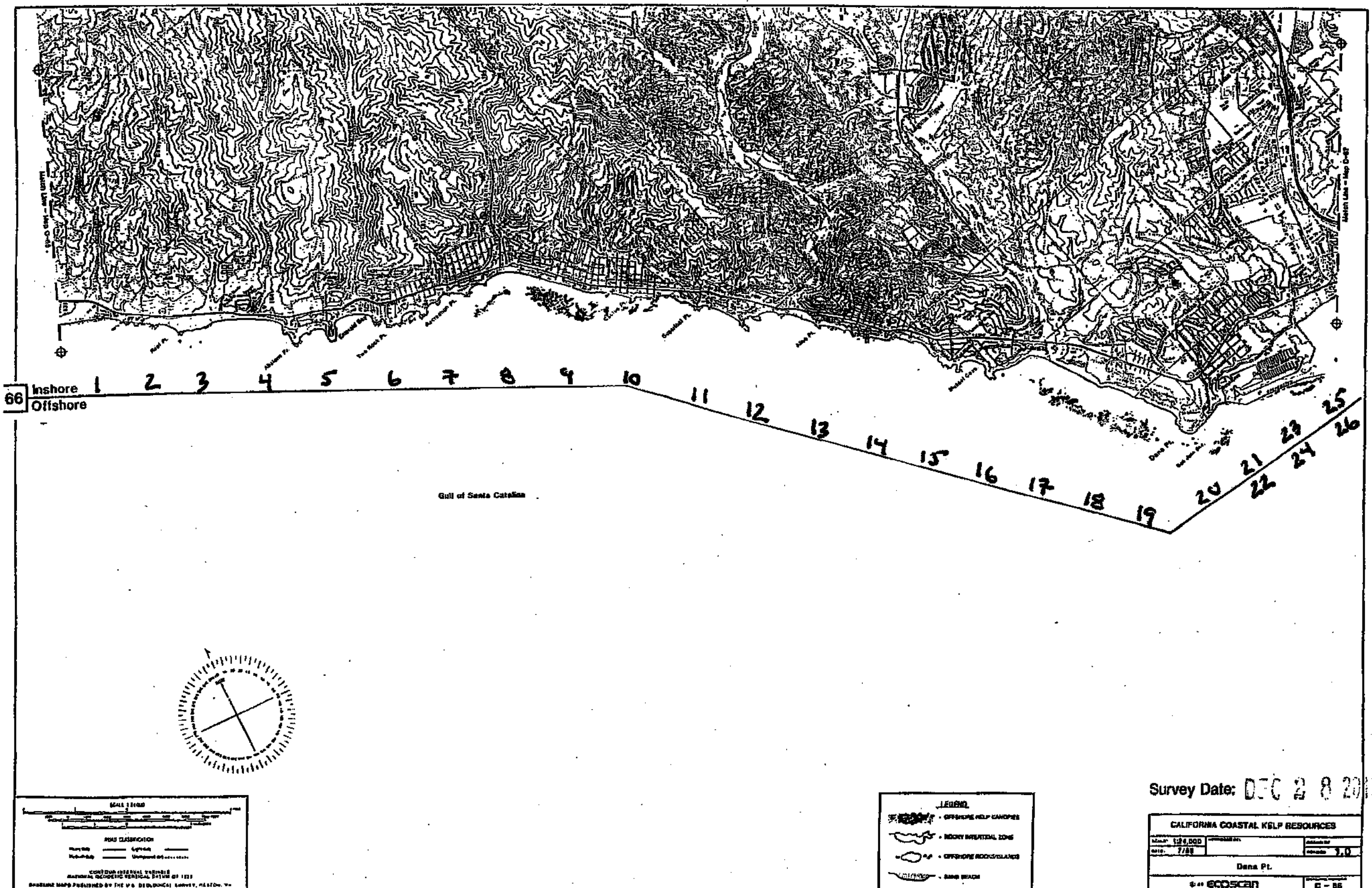
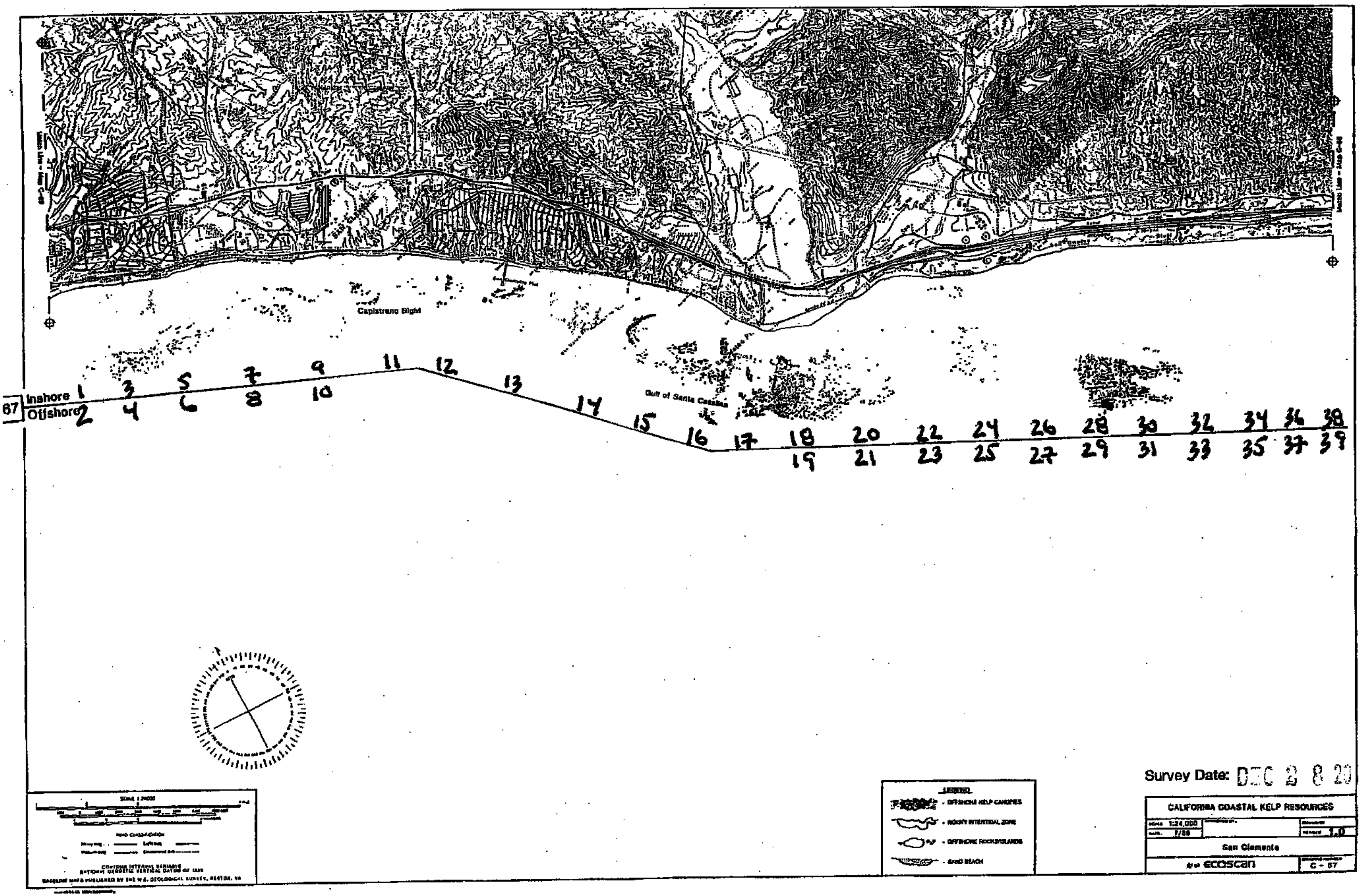
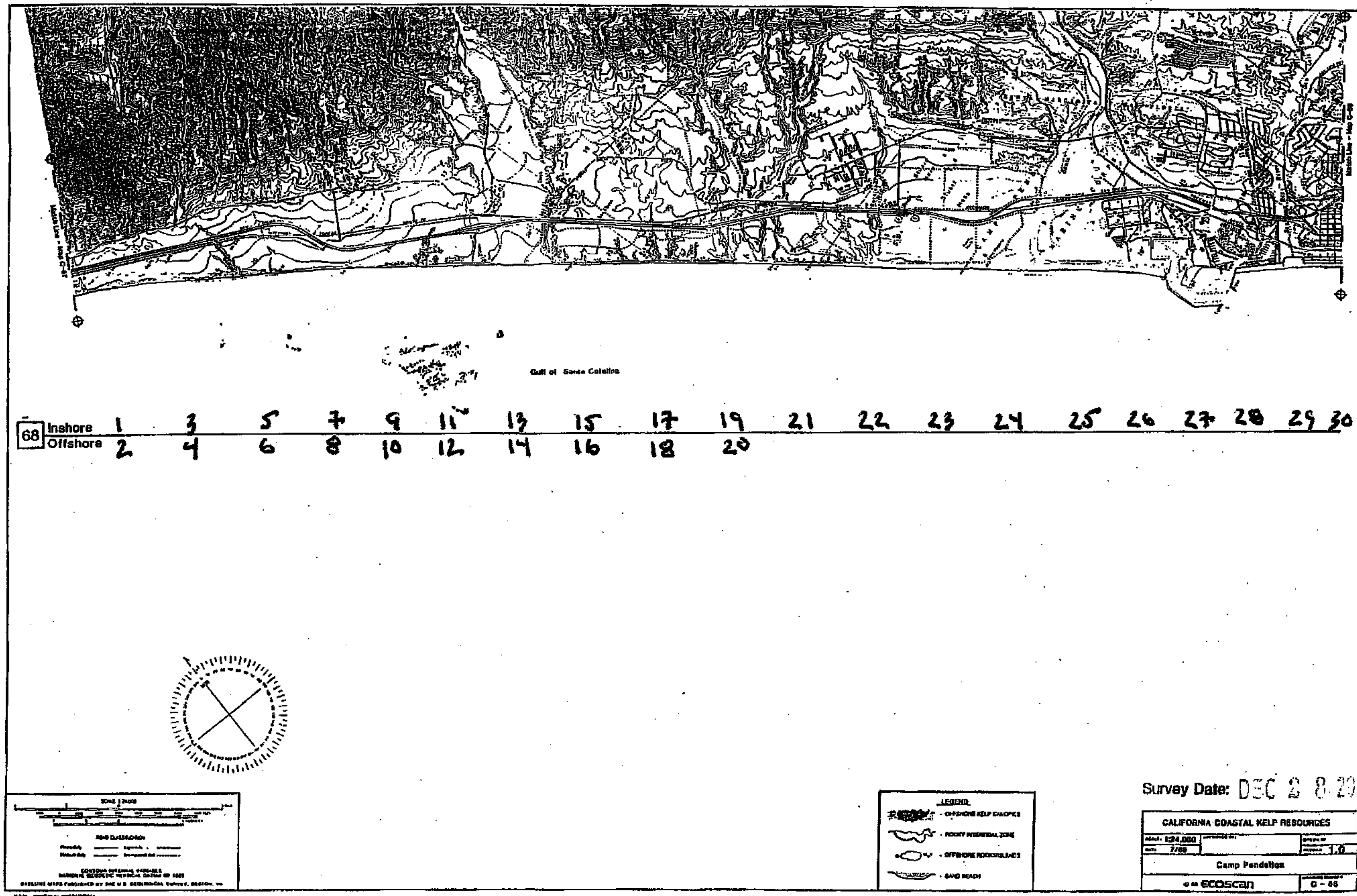
41
42


65
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Inshore
Offshore
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Newport Beach
ECOSCAN
C - 65

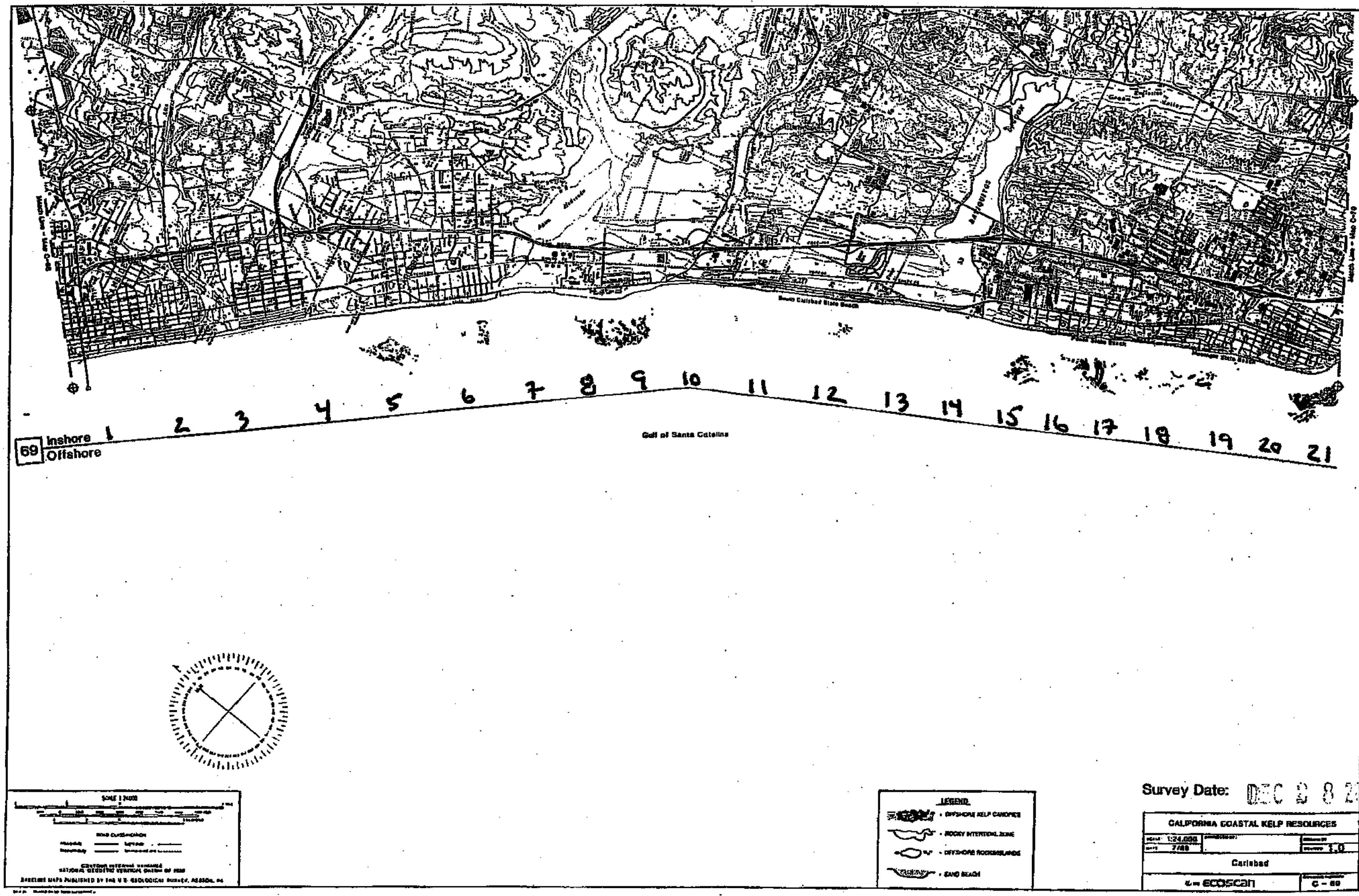

66
Inshore
Offshore
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Gulf of Santa Catalina
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/88
Dana Pt.
ecoscan
C - 66

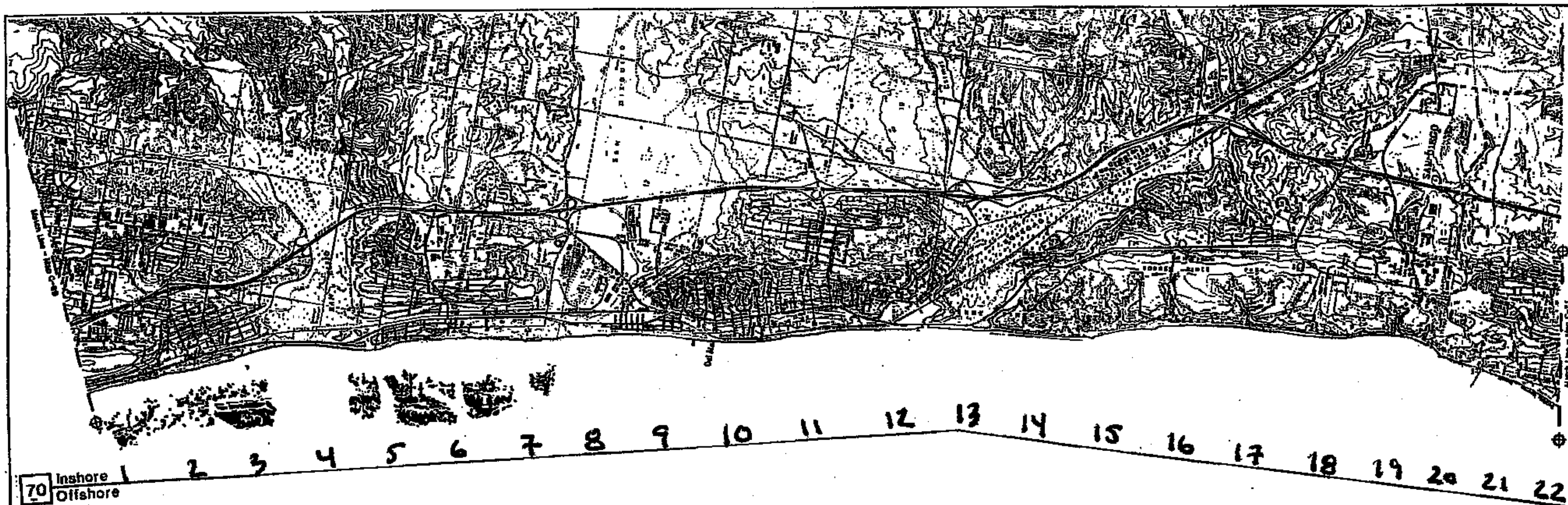


Capistrano Bight
Gulf of Santa Catalina
67
Inshore 1 3 5 7 9 11 12 13 14 15 16 17 18 20 22 24 26 28 30 32 34 36 38
Offshore 2 4 6 8 10 19 21 23 25 27 29 31 33 35 37 39
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
San Clemente
ecoscan
C - 67
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH



Gulf of Santa Catalina
68 Inshore 1 3 5 7 9 11 13 15 17 19 21 22 23 24 25 26 27 28 29 30
Offshore 2 4 6 8 10 12 14 16 18 20
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Camp Pendleton
ecoscan
C - 68


69 Inshore
Offshore
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Gulf of Santa Catalina
South Carlsbad State Beach
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/88
Carlsbad
ECOSCAN
C - 69



Survey Date: DEC 2 8 2012

LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH

CALIFORNIA COASTAL KELP RESOURCES

SCALE 1:24,000
DATE 7/89
REVISION 1.0

Del Mar

ECOSCAN

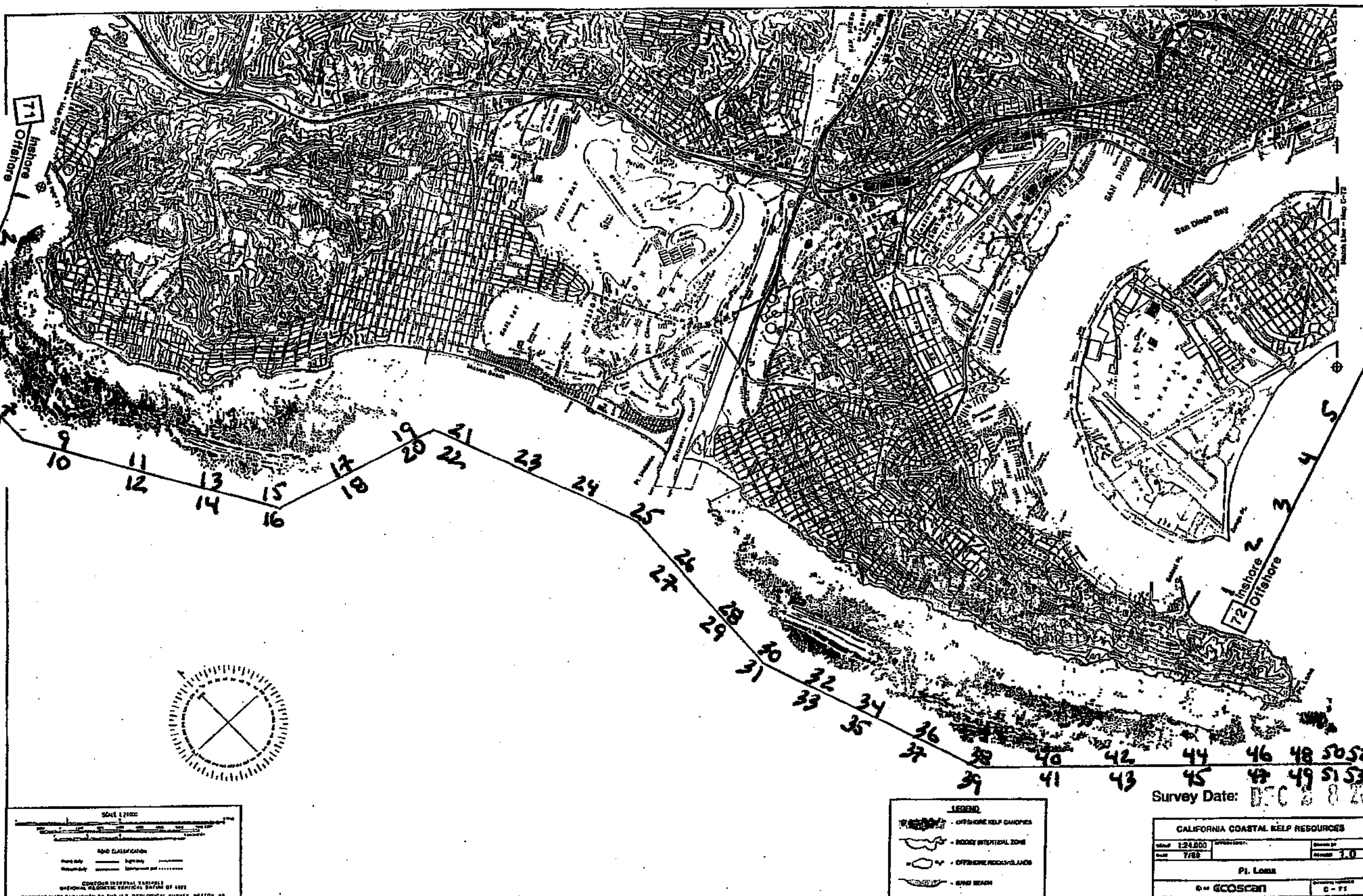
C - 70

SCALE 1:24000

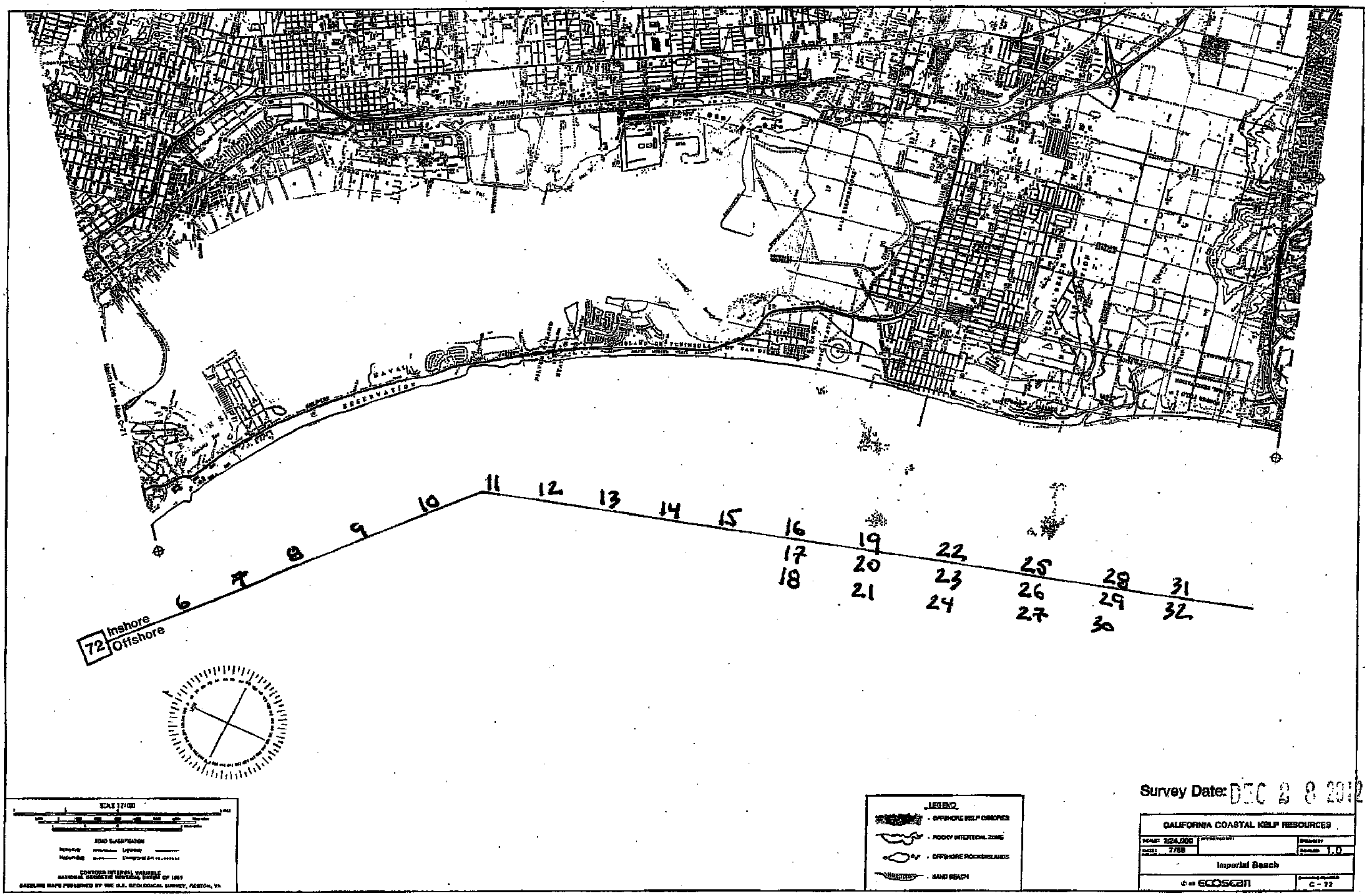
ROAD CLASSIFICATION

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA



71
Inshore
Offshore
72
Inshore
Offshore
San Diego Bay
Survey Date:
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Pt. Loma
ECOSCAN
C-71
ROAD CLASSIFICATION



Match Line — Map C-71
72 Inshore
Offshore
6
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8
9
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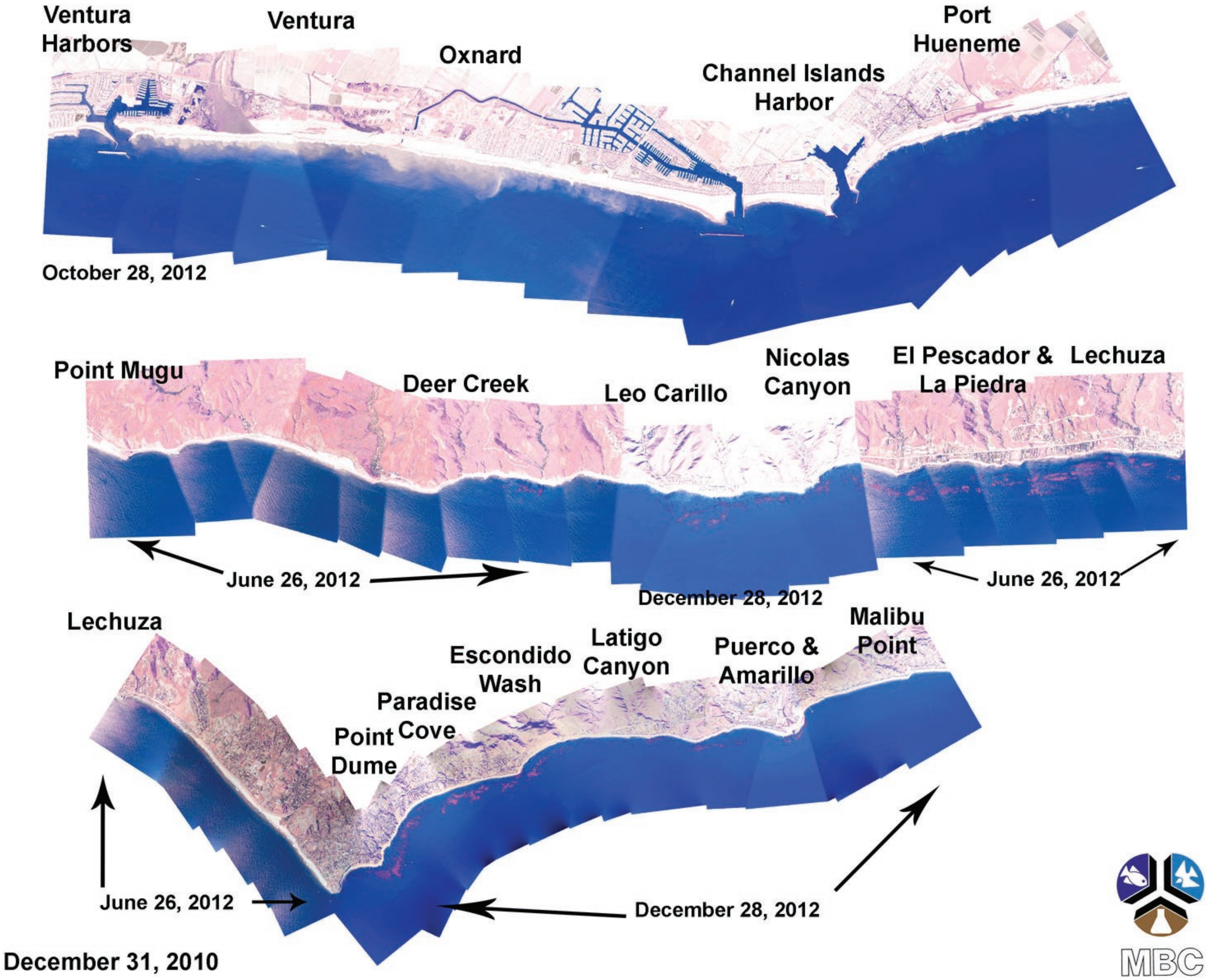
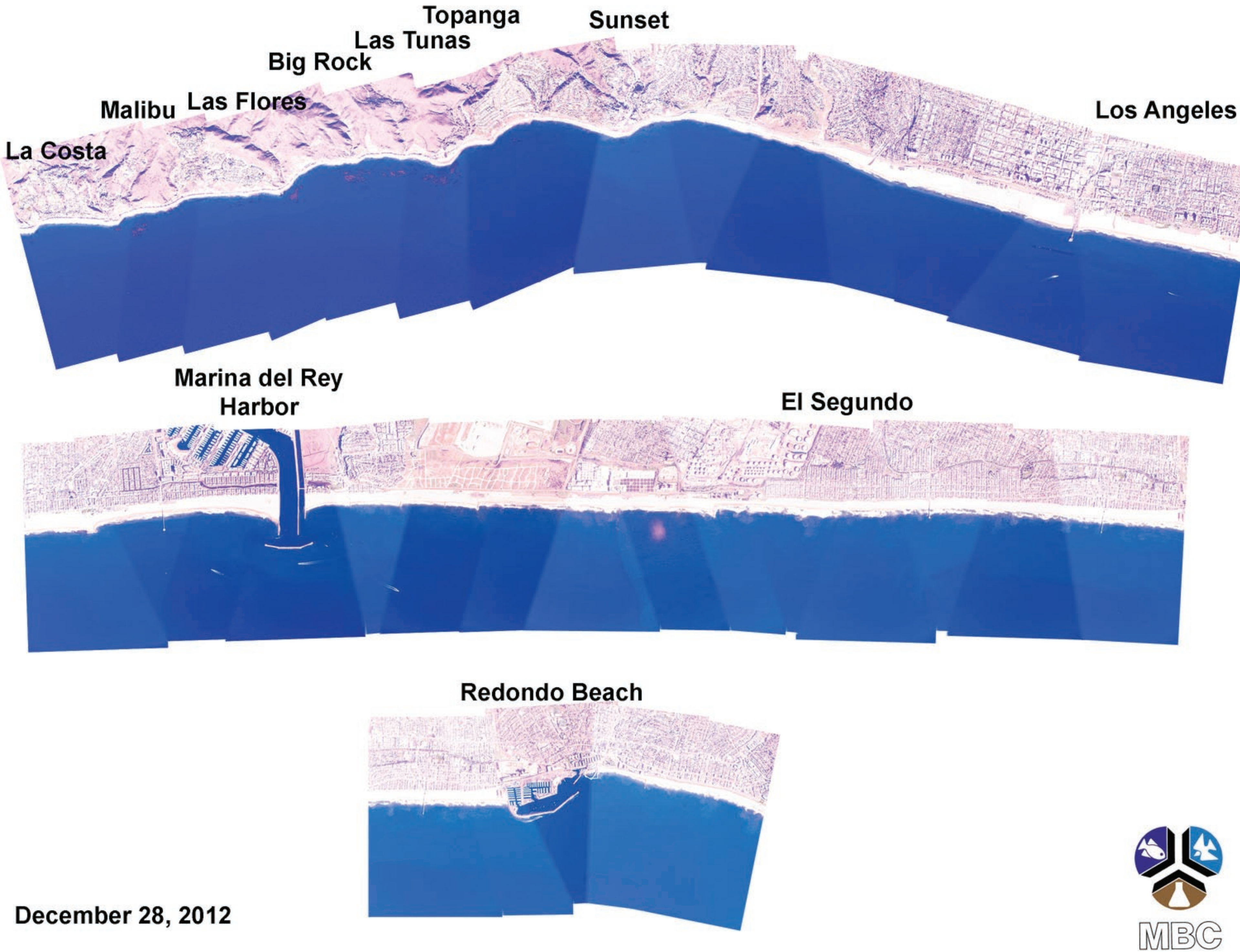
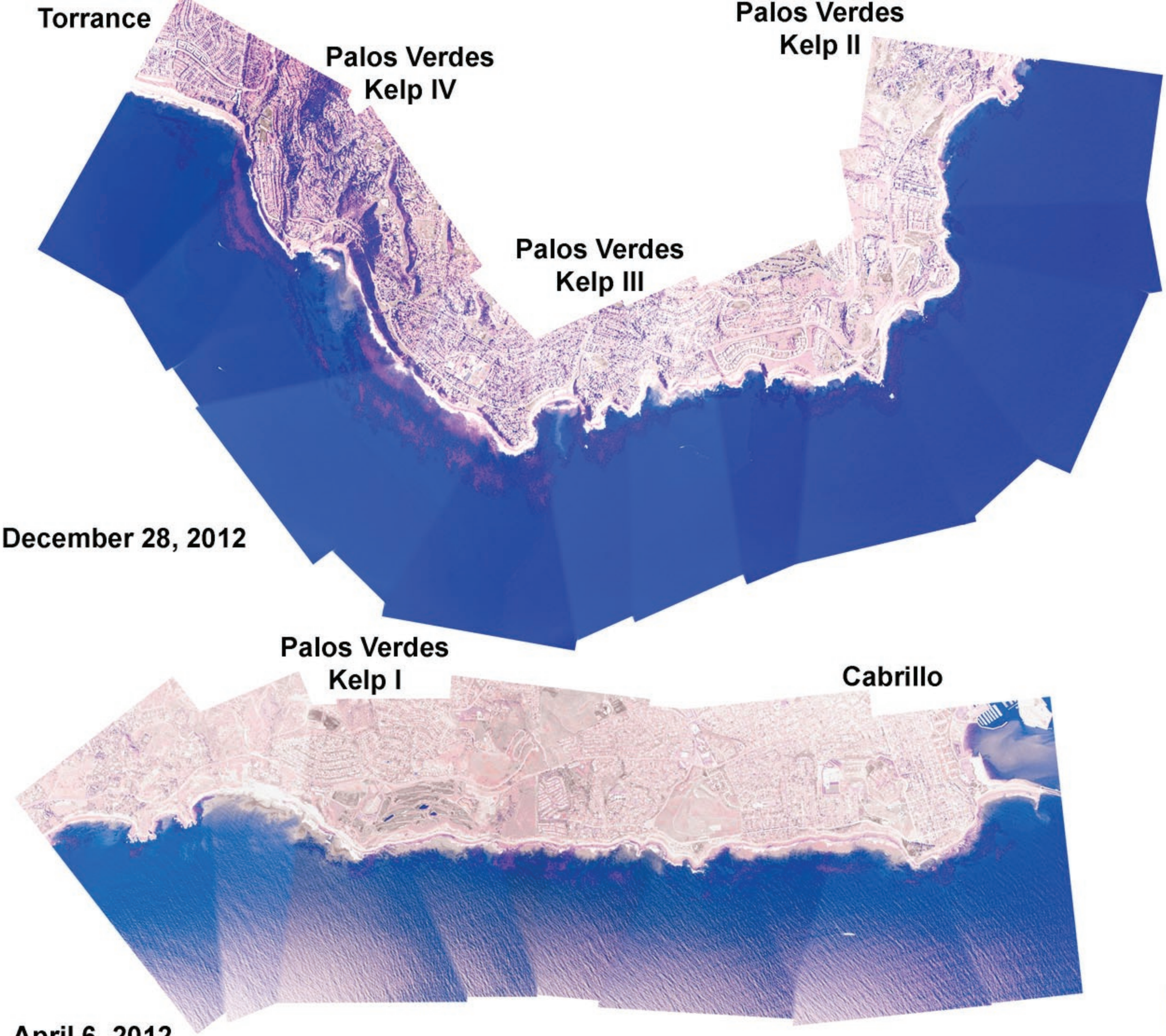
24
25
26
27
28
29
30
31
32
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 8 2012
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
1.0
Imperial Beach
ECOSCAN
C - 72

APPENDIX D

Kelp Canopy Aerial Photographs


Ventura Harbors
Ventura
Oxnard
Channel Islands Harbor
Port Hueneme
October 28, 2012
Point Mugu
Deer Creek
Leo Carillo
Nicolas Canyon
El Pescador & La Piedra
Lechuza
June 26, 2012
December 28, 2012
June 26, 2012
Lechuza
Point Dume
Paradise Cove
Escondido Wash
Latigo Canyon
Puerco & Amarillo
Malibu Point
June 26, 2012
December 28, 2012
December 31, 2010
MBC


La Costa
Malibu
Las Flores
Big Rock
Las Tunas
Topanga
Sunset
Los Angeles
Marina del Rey
Harbor
El Segundo
Redondo Beach
December 28, 2012
MBC

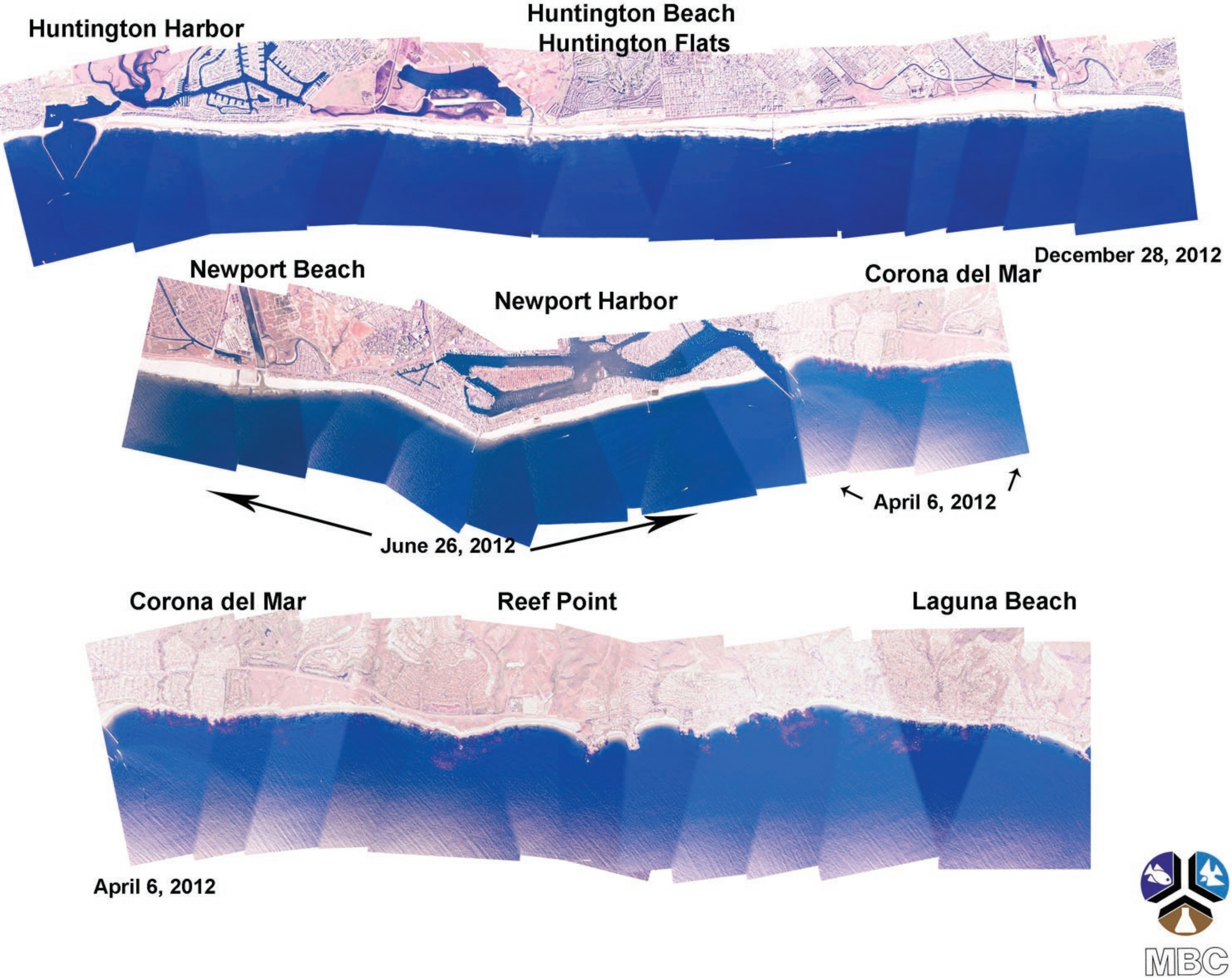


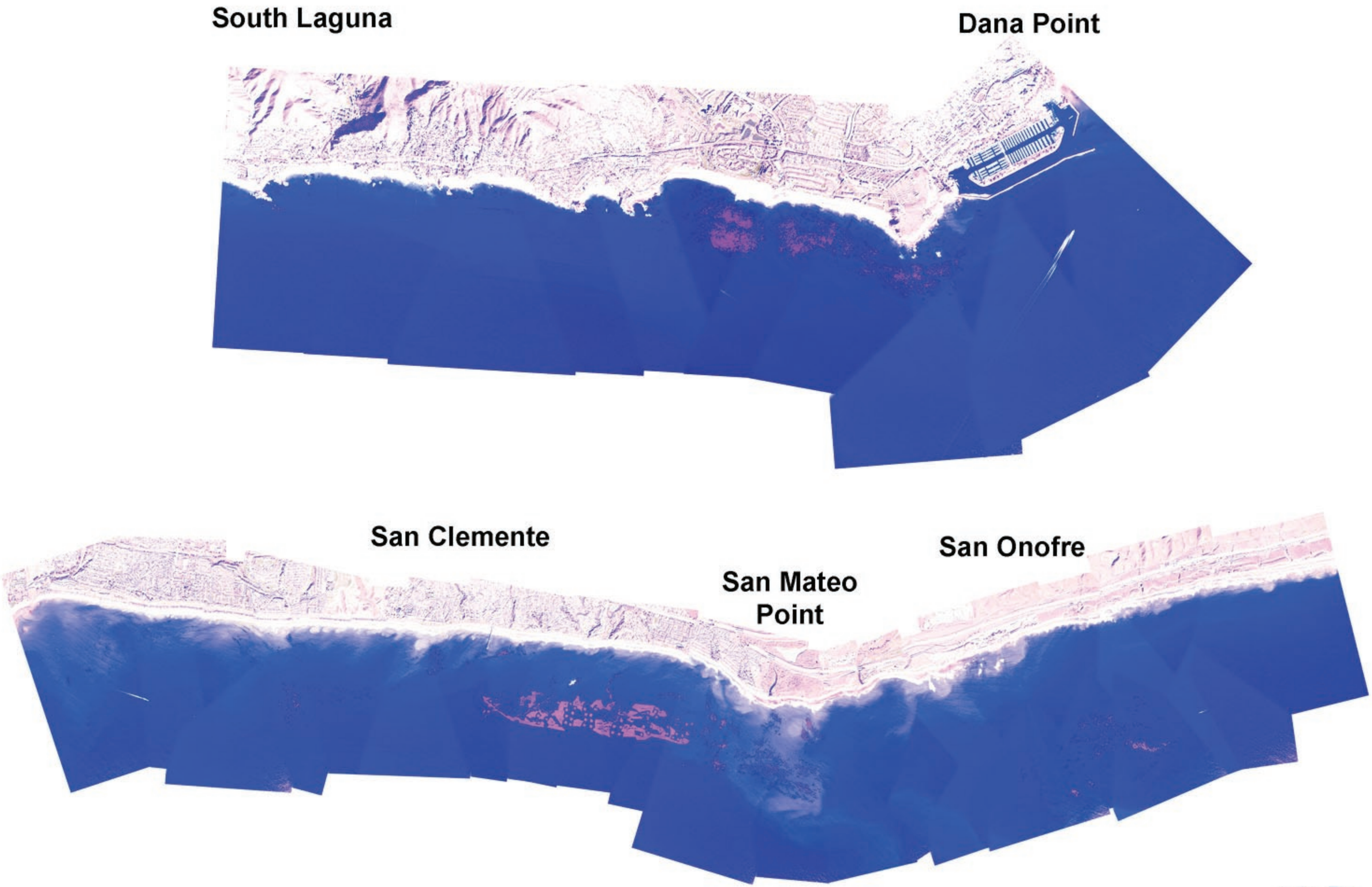
Torrance
Palos Verdes Kelp IV
Palos Verdes Kelp II
Palos Verdes Kelp III
December 28, 2012
Palos Verdes Kelp I
Cabrillo
April 6, 2012

POLA/POLB Harbors

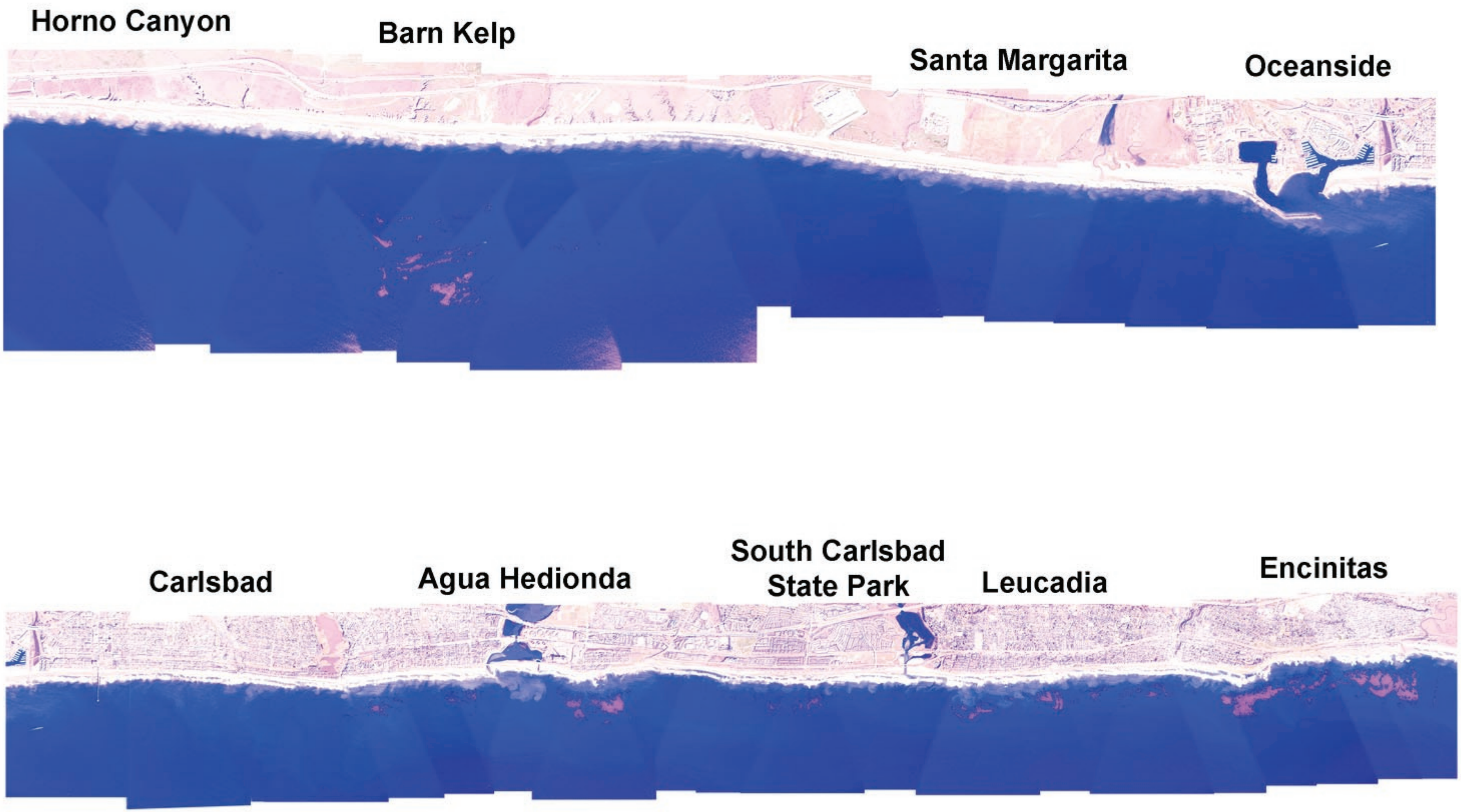
December 28, 2012

MBC

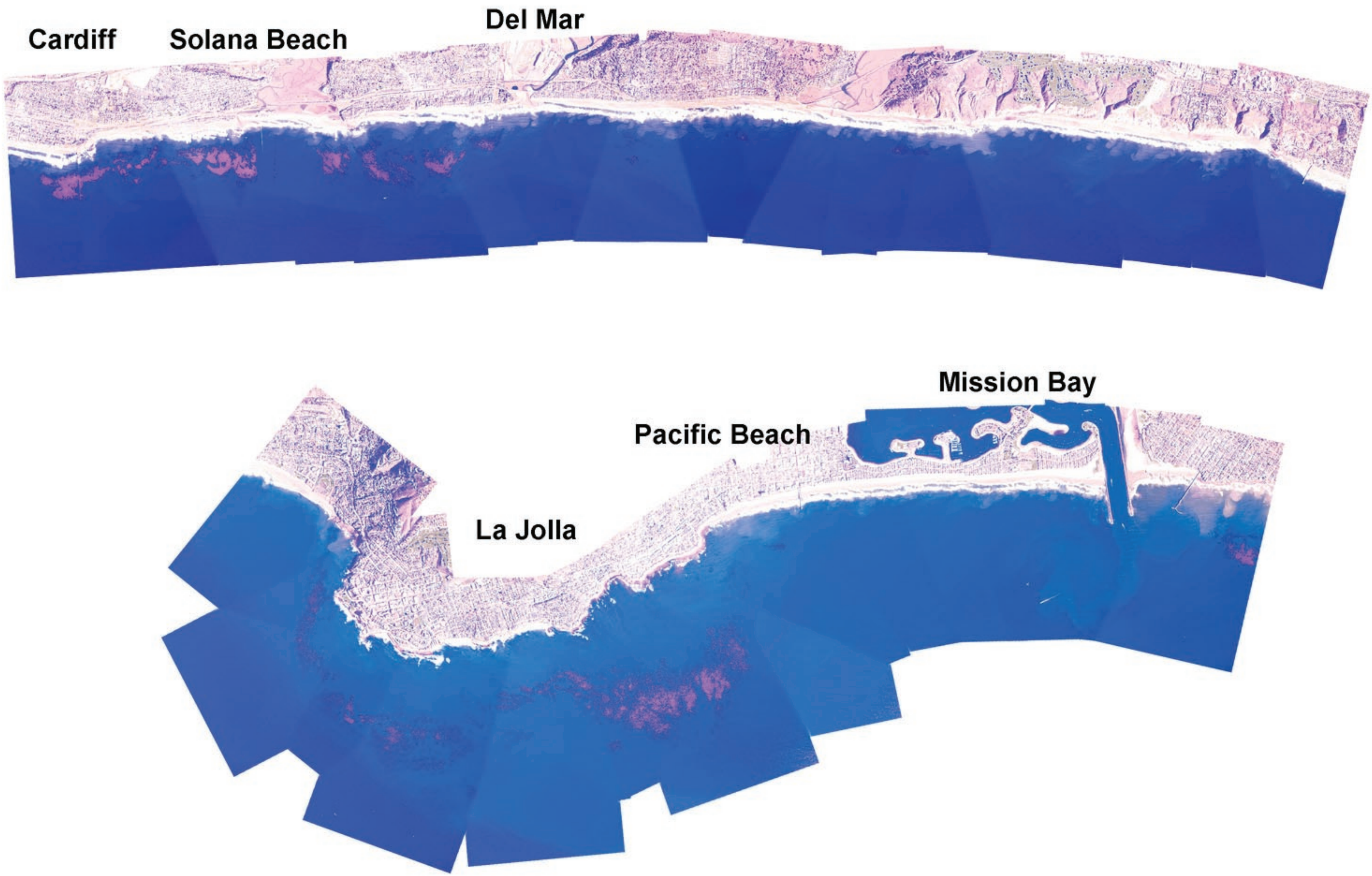

Huntington Harbor
Huntington Beach
Huntington Flats
December 28, 2012
Newport Beach
Newport Harbor
Corona del Mar
June 26, 2012
April 6, 2012
Corona del Mar
Reef Point
Laguna Beach
April 6, 2012
MBC



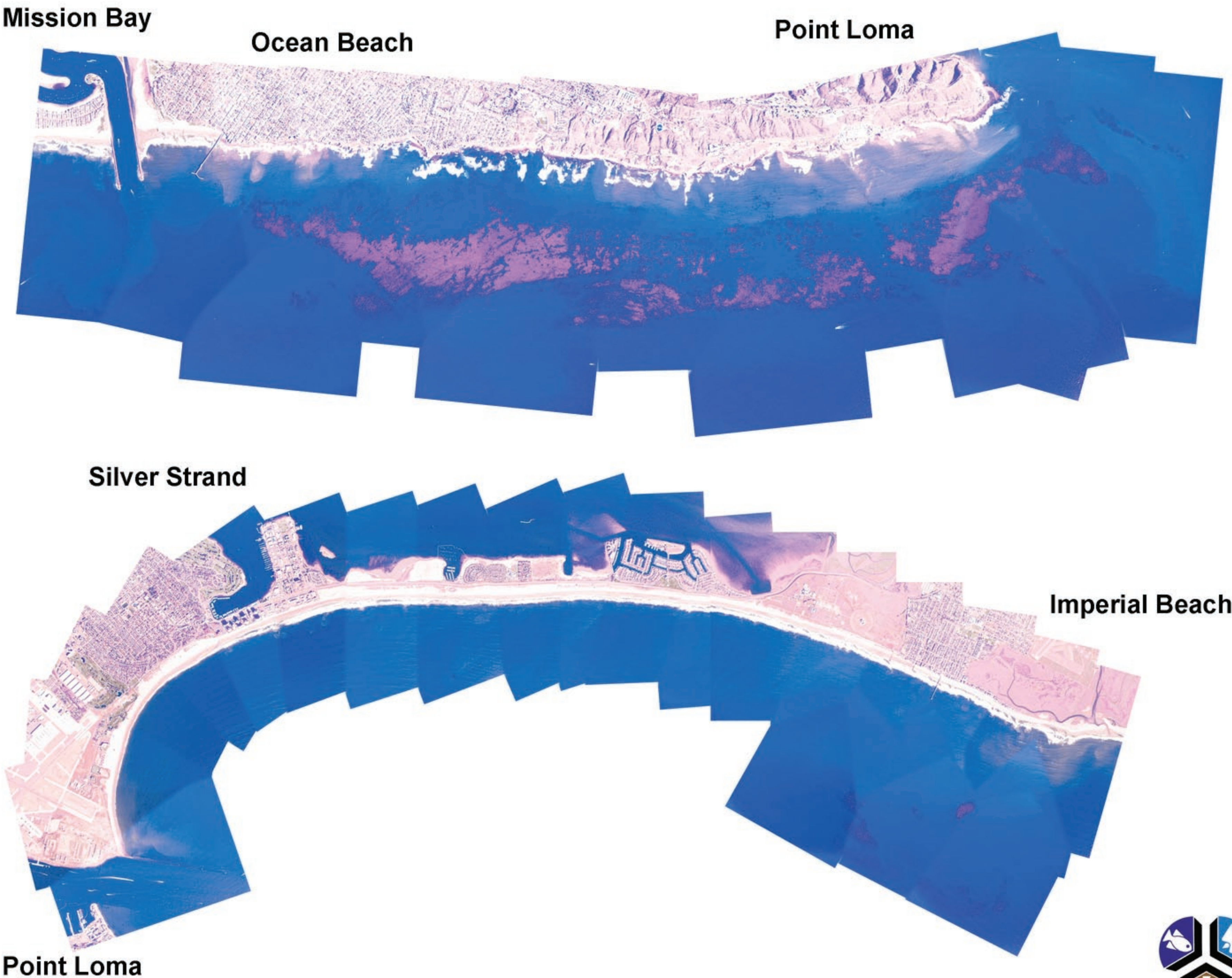
December 28, 2012



December 28, 2012



December 28, 2012



December 28, 2012