Status of the Kelp Beds 2011

San Diego and Orange Counties

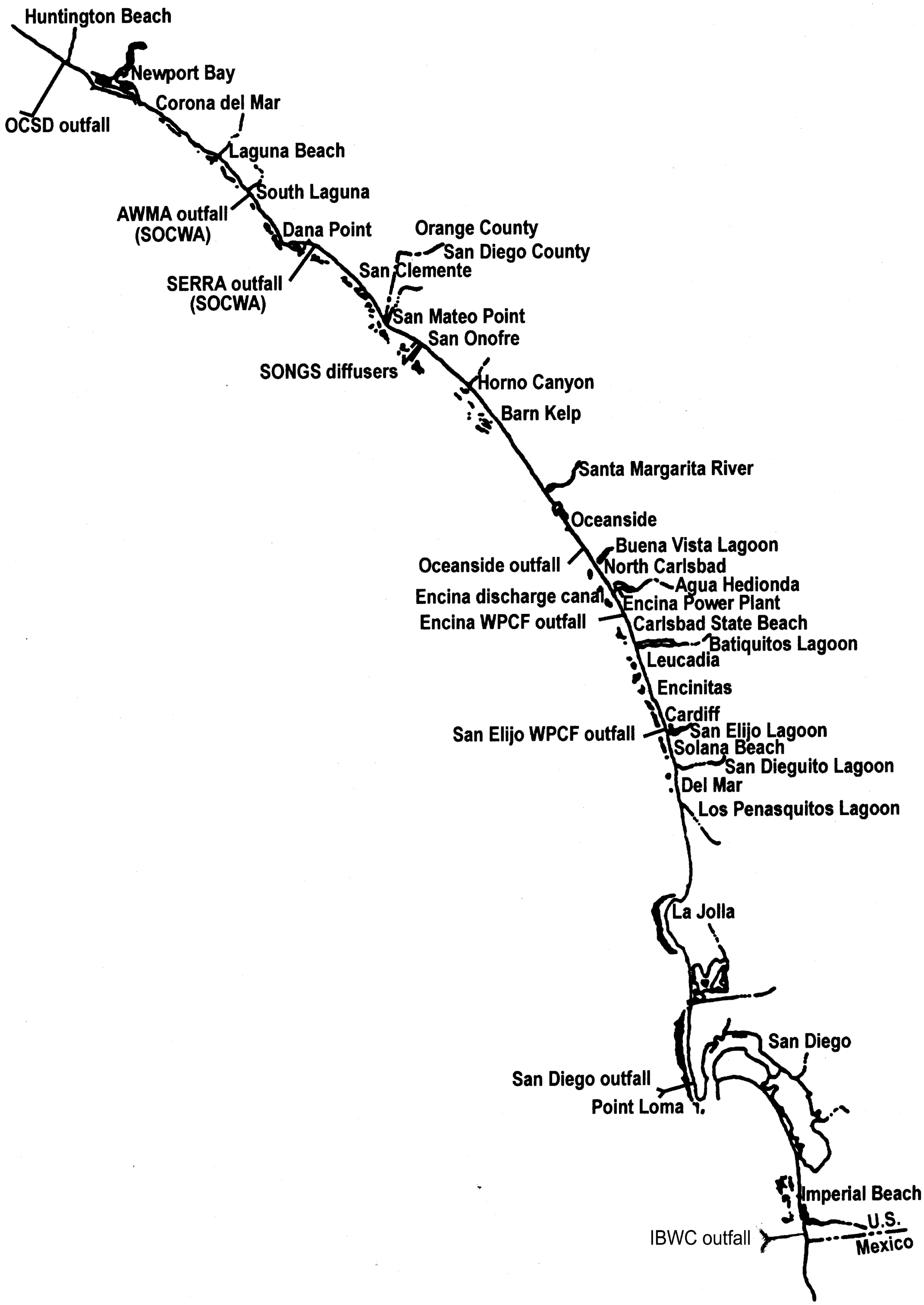
Region Nine Kelp Survey Consortium

June 2012

Prepared by:

MBC
Applied Environmental Sciences
Costa Mesa, California

MBC


Huntington Beach
Newport Bay
Corona del Mar
OCSD outfall
Laguna Beach
South Laguna
AWMA outfall
(SOCWA)
Dana Point
Orange County
San Diego County
San Clemente
SERRA outfall
(SOCWA)
San Mateo Point
San Onofre
SONGS diffusers
Horno Canyon
Barn Kelp
Santa Margarita River
Oceanside
Buena Vista Lagoon
Oceanside outfall
North Carlsbad
Agua Hedionda
Encina discharge canal
Encina Power Plant
Encina WPCF outfall
Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Encinitas
Cardiff
San Elijo WPCF outfall
San Elijo Lagoon
Solana Beach
San Dieguito Lagoon
Del Mar
Los Penasquitos Lagoon
La Jolla
San Diego
San Diego outfall
Point Loma
Imperial Beach
U.S.
IBWC outfall
Mexico

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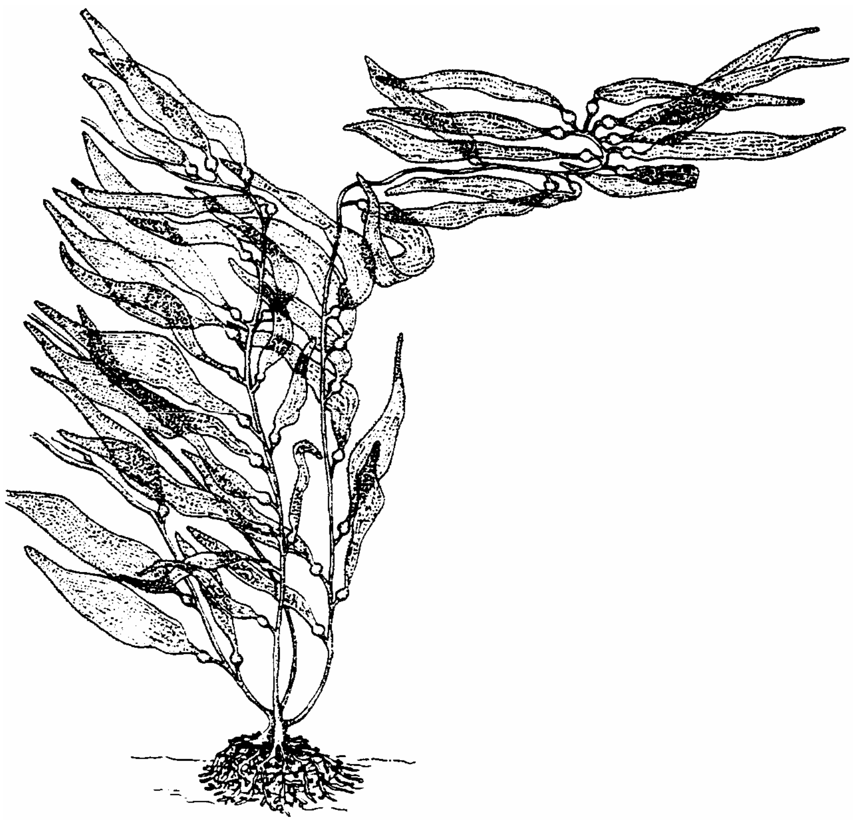

Region Nine Kelp Survey Consortium

June 2012

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Cover Photograph

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SAN DIEGO AND ORANGE COUNTIES

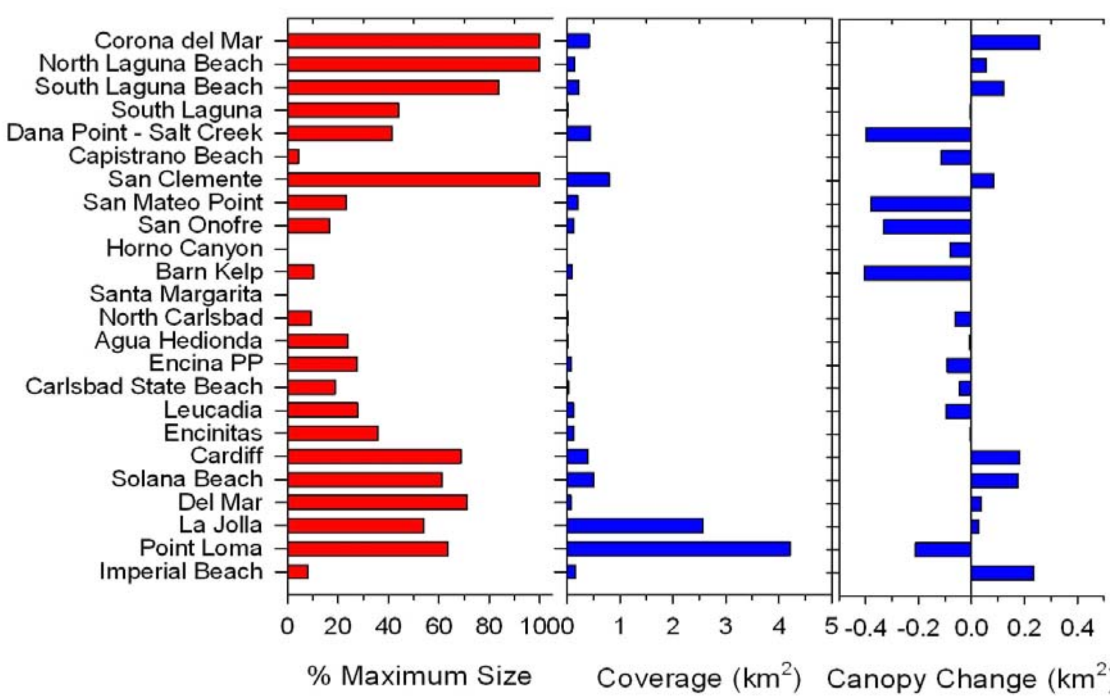
REGION NINE KELP CONSORTIUM
JUNE 2012

EXECUTIVE SUMMARY

Foreword. Giant kelp beds have been mapped annually in Orange and San Diego Counties for the Region Nine Kelp Survey Consortium since 1983, when it was formed as a result of regulations from the San Diego Regional Water Quality Control Board. When combined with a similar organization (Central Region Kelp Survey Consortium) formed as a result of requirements of the Los Angeles Regional Water Quality Control Board (LARWQCB), the continuous and synoptic coverage of coastal kelp beds is provided for approximately 220 of the 270 miles of the southern California mainland coast from the Ventura-Santa Barbara County line to the Mexican Border.

Aerial surveys of the giant kelp beds from Newport Harbor to the Mexican Border were conducted in 2011 by MBC *Applied Environmental Sciences* (MBC). The 2011 surveys were conducted on 16 April, 1 August, 28 October, and 21 December. One aerial surveys has also been completed for the 2012 survey year (on 6 April). Digital color infrared and color photos were taken of the entire coastline during each survey. These slides were then processed and the kelp depicted on each slide was transferred to base maps to facilitate intra-annual comparisons and for ease of analysis.

As far as the greatest extent of canopy coverage during the quarterly surveys, 2011 was typical in that the December survey depicted most of the beds at their greatest extent. Throughout the entire study area, kelp canopy coverage decreased slightly from a total of 11.706 square kilometers [km^2] in 2010 to 10.797 km^2 in 2011. As noted in the graph, many of the beds in the North and South were at a large percentage of their maximum size observed during the Region Nine monitoring history (Graph). It is also apparent that the La Jolla and Point Loma kelp beds dominate and account for a large percentage of the



Graph: Region Nine kelp canopy percent of maximum size during 29 year's monitoring, present coverage, and positive and negative canopy change.

region's canopy. Overall, kelp bed coverage in the region was larger than the 29-year average since 1983 of 7.144 km^2 since monitoring was initiated by the Region Nine Kelp Consortium.

Coverage increases and decreases were mixed across the Region Nine kelp beds, with most beds in the north recording large increases including beds from Corona del Mar to South Laguna Beach (all the result of extensive restoration programs) which had canopies as large as in the early 1990s (Graph). All the beds from South Laguna south to Encinitas (including Salt Creek-Dana Point, San Mateo, and San Onofre) were lower with the exception of the San Clemente bed (where the Wheeler J. North Kelp Reef is located and flourishing). From Cardiff and continuing south all beds (but La Jolla) were larger. Taken together La Jolla and Point Loma were slightly larger in 2011 than in 2010.

The giant kelp survey of 2011 continued to demonstrate that kelp bed dynamics in Region Nine are controlled by the large scale oceanographic environment. The mixed results are indicative of the varying oceanographic regimes in the Region Nine kelp beds. 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 six years from downturns of 2006 could be augmented in 2012 as nutrients appear to be replete in the region during the first few months of 2012, but El Niño neutral conditions are forecast for the remainder of the year which may continue the slight downward trend of the past three years observed in the long-term record.

STATUS OF THE KELP BEDS 2011
SAN DIEGO AND ORANGE COUNTIES

REGION NINE KELP CONSORTIUM
June 2012

INTRODUCTION

Giant kelp (*Macrocystis pyrifera*) beds have been mapped with aerial surveys quarterly in Orange and San Diego Counties for the Region Nine Kelp Survey Consortium since 1983, when it was formed as a result of regulations from the San Diego Regional Water Quality Control Board (SDRWQCB).It was agreed among the funding participants and the SDRWQCB that the design and implementation of a regional kelp bed monitoring program monitoring program would be methodologically based upon aerial kelp surveys that had been conducted by Dr. Wheeler J. North since 1967. The Region Nine Kelp Survey Consortium has been conducting aerial surveys (usually quarterly) of kelp canopy extent at 25 kelp beds along the San Diego and southern Orange County coast from Newport Beach to the Mexican Border (Appendix A and Figure 1). This program was reviewed by the Los Angeles Regional Water Quality Control Board (LARWQCB) and they formulated similar kelp monitoring regulations as the San Diego Board. From these regulations, dischargers in the Ventura, Los Angeles, and part of Orange Counties formed the Central Region Kelp Survey Consortium. This program then provides continuous and synoptic coverage of kelp beds along approximately 220 of the 270 miles of the southern California mainland coast from the Ventura-Santa Barbara County line to the Mexican Border.

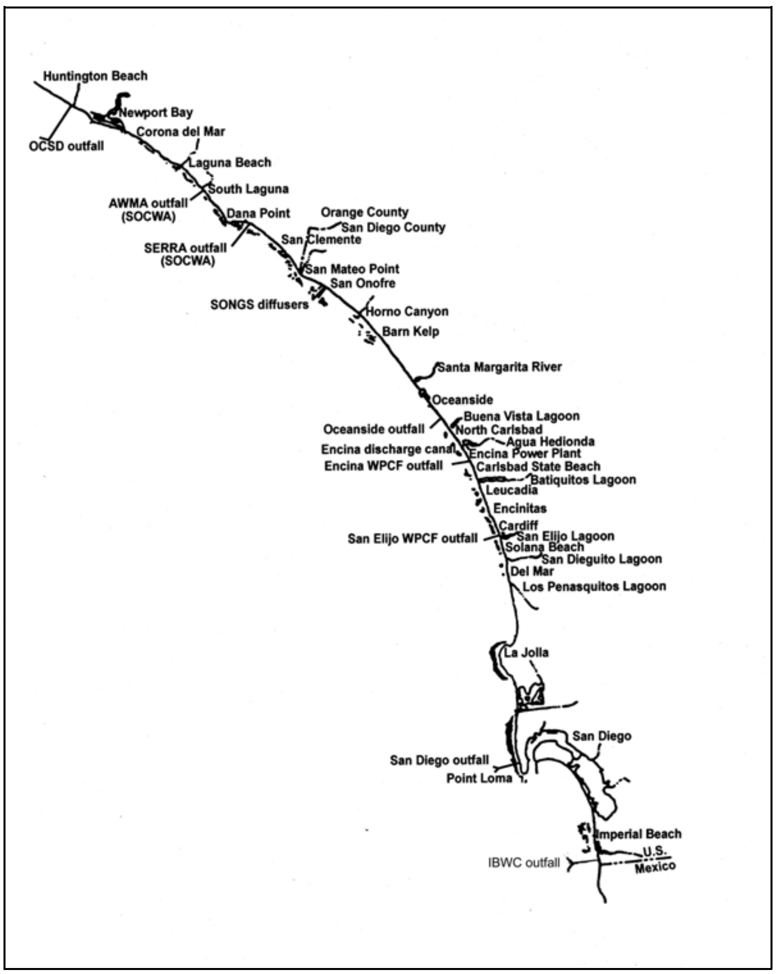


Figure 1. Ocean dischargers located within the Region Nine kelp survey area.

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). 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. Probably because of its imposing physical presence, it has attracted numerous researchers so that a sizable literature on *Macrocystis* biology and ecology began a century ago, with much effort spent 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 50 to 75 ft and can be found at depths of 90 ft. In conditions of unusually good water clarity (such as found at the Channel Islands), giant kelp may even thrive to depths of 150 ft.

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 also form in sandy bottom habitats (if sufficient attachment points such as large worm tubes are present) in regions protected from direct swells as is seen along portions of the Santa Barbara coastline. The brown alga giant kelp, like plants, requires light energy for photosynthesis and, therefore, light availability at depth is an important factor to kelp growth. Greater water clarity normally occurs at the offshore islands, and as a result, giant kelp is found growing in depths exceeding 100 ft. Along the mainland coast, high productivity, terrestrial inputs, and continental shelf mixing result in greater turbidity that attenuates light levels and precludes giant kelp from deeper depths. Consequently, kelp generally does not grow deeper than 60 ft along the coastal shelf, although exceptional conditions in San Diego produce impressively large beds that grow vigorously to a depth of 110 ft.

Giant kelp beds are susceptible to a host of challenges to survive and long-term studies have shown that the kelp beds tend to be cyclical in nature (SAI [Hodder and Mel] 1978, Neushul 1981, North 1983, North and Jones 1991, Jahn et al. 1998, Dayton et al. 1999, and North and MBC 2001). Giant kelp has a complex reproductive life cycle that requires favorable growth factors to be optimal for a span of many months to complete the life cycle. In order to reproduce giant kelp undergoes a heteromorphic alternation of generations, meaning the second generation offspring spores are microscopic and do not resemble the parent, whereas their progeny (the third generation) resemble the grandparents (adult giant kelp). The stage of giant kelp that is most familiar is the adult canopy-forming 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 very short distance from the parent sporophyte. Within three weeks, the zoospores mature into microscopic male and female gametophytes. These gametophytes release sperm and eggs into the water column where fertilization occurs. The life cycle is completed when a fertilized egg settles on suitable substrate and develops into a new sporophyte or juvenile giant kelp (Figure 2). However, as mentioned, successful completion of the life cycle relies on the persistence of favorable conditions throughout the process.

Giant kelp is known as a biological facilitator (Bruno and Bertness 2001), where its three-dimensional structure and the complexity of its holdfast provides substrate, refuge, reduction of physical stress, and a food source for many fish (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), which further acts to increase animal biomass in the vicinity. For these reasons, giant kelp is also of great importance to sport and commercial fisheries.

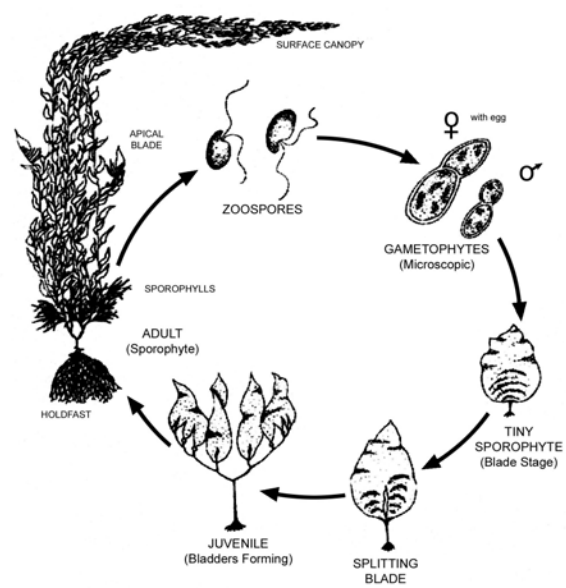


Figure 2. Kelp life cycle.

FACTORS AFFECTING KELP GROWTH

Giant kelp bed size and health is known to be highly variable but there has been a downward trend from the inception of surveying in 1911 and the end of the century. During this period kelp beds declined at most coastal and island sites in the SCB. A comprehensive historical review of kelp beds in the SCB (Neushul 1981) found that an approximately one-third loss of kelp bed cover had occurred since 1911 when compared to a 25-year mean. A statewide survey in 1989 (Ecoscan 1990) estimated Southern California kelp forests to total 103.6 km^2(10,360 ha) (Tarpley and Glantz 1992), a 25% reduction from that reported by Crandall (138 km^2) in 1911 (from Neushul 1981). Measurements Crandall took of the Region Nine kelp beds in 1911 indicated that total coverage was about 44 km^2, with Point Loma and La Jolla accounting for more than 24 km^2. The accuracy of Crandall's measurements have been questioned (Neushul 1981) because it was not an aerial survey and measurement errors may have resulted from using a rowboat to compute the perimeter, particularly on very large beds. Estimates of these potential errors have ranged from 10 to as much as 25%, however, the resultant total of the worst case (33 km^2) would still be impressively large (Table 1). In defense of Crandall's estimates, the total regional area was probably larger in aerial photos from 1934 than Crandall measured based on comparing the size of just the La Jolla bed measurement of 8.161 km^2 to the 6.060 km^2 that Crandall measured in 1911 (suggesting even larger losses have occurred overtime). Unfortunately, the survey did not include the remainder of the Region Nine so no definitive regional total was available. Another incomplete survey in 1941 still had La Jolla and Point Loma as very large beds totaling 16 km^2. The next complete survey of the region was not undertaken until 1955 which indicated the beds had decreased greatly from that recorded in1911 with La Jolla and Point Loma only covering 3.5 km^2. During 1963, kelp canopies were in very poor condition, the La Jolla and Point Loma beds totaled only about 0.9 km^2, but by three years later in 1967, Point Loma was at 2.7 km^2 while La Jolla had shrunk to one half that size. La Jolla stayed small until after 1975, and then became a consistently large kelp bed (over 1 km^2) through most of the next three decades. The beds were again impressively large after the impetus provided by the 1989 La Niña when the two beds totaled 10.5 km^2 and the entire region totaled almost 17 km^2 (Table 2). Very good conditions in Region Nine in 2008 culminated in a regional coverage of almost 19 km^2, but this was still far shy of the most conservative estimate (33 km^2) of Crandall's survey in 1911. As these measurements indicate, environmental factors such as the La Niña and El Niño have shaped the response of the kelp beds in Region Nine. It is almost certain that most of the beds remain smaller than those of a century ago, therefore we attempt herein to determine what environmental factors have changed in the intervening years to cause such large declines.

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. We also know that there are less obvious but potentially more far reaching effects in both time and scope such as the El Niño Southern Oscillation (ENSO) (referring to global climatic changes and effects), decadal regime shifts or climate shifts/variation (Miller et al. 1994, Breaker and Flora 2009), the Pacific Decadal Oscillation (PDO) which refers to events that are Pacific wide and decades long in nature, and the El Niño/La Niña events (which refer to more local effects 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 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 decrease in canopy coverage in 2005 that continued into 2006 as a result of a substantial, region-wide bloom. 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 holdfast. There were no major factors affecting light availability in 2011 and as

Table 1. Historical canopy coverages in km² 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. Known cold-water periods are depicted in Blue, warm-water periods in Red, and neutral periods in Green.

Kelp Bed	Canopy Area (km²)																					
	1911	1934	1941	1955*	1959*	1963*	1967	1970	1975	1980	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Corona del Mar	0.580	ND	ND	ND	ND	ND	0.086	0.180	0.160	0.150	0.031	0.006	-	-	-	0.007	0.010	0.001	0.0003	-	-	-
North Laguna Beach	Tr	ND	ND	0.680	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	ND	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	2.020	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	1.871	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	1.153	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	-
San Clemente	1.390	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	1.272	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	1.946	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
Horno Canyon	0.352	ND	ND	ND	ND	ND	-	-	-	-	-	-	-	-	-	0.006	0.033	0.010	0.018	0.040	-	-
Barn Kelp	3.171	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	0.710	ND	ND	ND	ND	ND	-	-	-	-	-	-	-	-	-	-	-	-	0.049	0.009	-	-
North Carlsbad	0.767	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	0.161	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	0.642	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	0.278	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
Leucadia	1.224	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	0.367	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	0.713	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	1.097	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	0.540	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	-	-	-	-	-
La Jolla	6.060	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	18.675	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	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	43.948*	19.626*	16.133*	16.990*	14.070*	2.380*	4.486	7.570	7.030	9.827	0.639	0.379	3.231	3.852	8.969	7.667	16.868	14.920	10.385	3.609	3.535	5.527

NOTE: p = part of above value; * = Incomplete data; ND - No Data; "-" = 0
Tr = Trace <100 m²

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

Table 2. Canopy coverages in km² of San Diego and Orange County kelp beds from 1995 to 2011 surveys. Values represent approximately the maximum coverages for each year. Areal estimates derived from charts based on infrared aerial photographs. Known cold-water periods are depicted in Blue, warm-water periods in Red, and neutral periods in Green.

Kelp Bed	Canopy Area (km²)																
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Newport Coast CDM	-	-	-	-	-	-	-	<0.001	0.002	0.002	0.0004	0.023	0.054	0.089	0.095	0.161	0.419
North Laguna Beach	-	0.001	-	-	-	-	-	-	0.0004	-	-	-	-	0.002	0.005	0.093	0.147
South Laguna Beach	-	-	-	-	-	-	-	0.005	0.0002	0.008	-	-	0.001	0.025	0.058	0.098	0.221
South Laguna	-	-	-	-	-	0.003	0.002	<0.001	0.004	0.009	0.003	-	0.004	0.023	0.017	0.023	0.018
Dana Point-Salt Creek	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
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
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
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
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
Horno Canyon	-	-	-	-	-	0.002	0.034	-	0.001	-	-	-	0.015	0.083	0.018	0.081	-
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
Santa Margarita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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
Agua Hedionda	0.008	0.009	-	-	-	-	-	<0.001	0.002	0.001	0.008	-	0.016	0.080	0.092	0.031	0.022
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
Carlsbad State Beach	0.025	0.013	-	-	-	0.003	0.023	0.047	0.002	0.0001	-	-	0.064	0.121	0.127	0.069	0.024
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
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
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
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
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
Torrey Pines	-	-	-	-	-	-	-	-	-	-	-	-	-	0.001	0.0004	0.003	0.031
La Jolla	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
Point Loma	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
Imperial Beach	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
TOTAL	3.032	2.341	3.385	0.547	3.540	5.676	11.542	10.710	10.573	4.137	4.233	2.371	10.644	18.795	13.571	11.706	10.798

NOTE: "-" = 0; Tr = Trace <100 m²

amounts of rainfall/runoff were not especially elevated and phytoplankton blooms were not persistent, there were no serious deleterious effects on the kelp beds within the region through 2011.

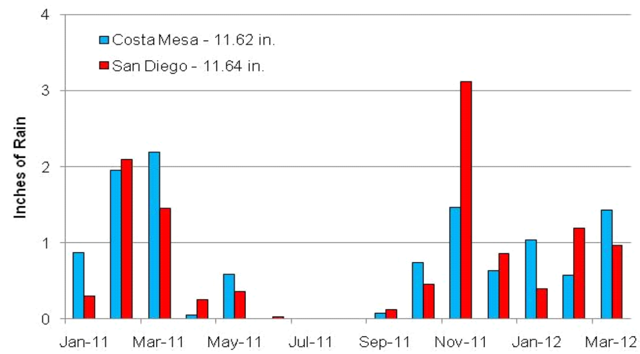


Figure 3. Rainfall at Costa Mesa and San Diego, 2011 through 12 March 2012. Long-term averages for Costa Mesa and San Diego are 9.50 inches and 10.33 inches, respectively.

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 landslides in the area such as the Portuguese Bend landslide (Kayen et al. 2002; Pondella 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 late-1970s extensive landscape modifications made in the Horno Canyon area that resulted in substantially accelerated erosion. Bence et al. (1989 MRC) reaffirmed the elevated 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 et al. 1989). While insufficient data exists to empirically test this theory, the timing of these events is striking and highly suggestive 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). 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 are typically devoid of nutrients. This is due to the abundance of phytoplankton in the surface waters which compete for nutrients in surface waters where light penetration is good. This presents a physiological challenge for giant kelp, which must compete for nutrients and light. In typical, low nutrient conditions generally encountered during the summer, giant kelp will persist only if it can adequately translocate nitrates from below the thermocline through its tissues (Jackson 1977). If the thermocline is depressed (along with nutrients) below the level where kelp is found for an extended period of time, extirpation of the kelp 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.

Coastal upwelling events are usually wind-driven phenomena in southern California (such as periods of Santa Ana Winds) where surface friction from 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 1 µmol/L as a generally minimal nutrient threshold concentration to support giant kelp growth. Kamykowski

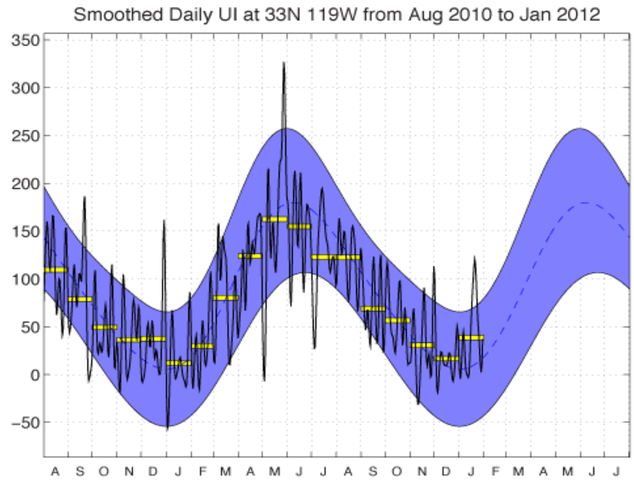


Figure 4. Upwelling Index 8-2010 to 1-2012.

and Zentara (1986) described a possibly stronger relationship between seawater density and nutrient concentration. Using this, Parnell et al. (2010) hindcasted the nutrient concentrations based on the seawater density and nutrient concentration relationship; however, this parameter is not typically available in the finer scales of a regional study. Studies demonstrating a correlation between the health of kelp beds and surface cooling events are numerous (e.g., Jackson 1977, Tegner et al. 1996, Dayton et al. 1999, etc.) and surface temperature data are readily available from many locations. 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). 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. Surface temperatures above 17°C (64°F) generally indicate waters with very low nutrient content (North and Jones 1991). With roughly each one degree centigrade temperature drop (1.9°F), the availability of nitrates essentially doubles. Therefore, at a temperature of 12°C (54°F), 14 times more nutrients are theoretically available than at 16-17°C (62-64°F).

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). These 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* sp. and *Lytechinus pictus*) overgrazing by populations results in urchin barrens. The sustainability of urchin barrens requires immigration as urchins sampled from barrens are nearly devoid of gonad material while those sampled from kelp forests have much larger gonads (Tegner and Dayton (1991). Urchin barrens are documented in both time and space. 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 area 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 algae biomass (typically as a result of adverse nutrient deficient periods) and elevated sea urchin recruitment. When drift algae 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 and 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. As these accumulate, there is an increasing drag force on each neighbor causing them to be ripped free of their attachment to the bottom. Once dislodged individuals often entangle with other nearby giant kelp, increasing the surface area susceptible to wave energy which can dislodge additional individuals. 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 that wash ashore or become a floating kelp paddy offshore (Dayton et al. 1984).

Of particular concern are storms that produce swell heights that exceed 4 m 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 the Orange and San Diego Counties' coastline. This energy likely 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, probably as the result of 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).

ENSOs. Physical 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 on a scale of 2-7 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 coincide 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 lead 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 responses ranging from minor to catastrophic to giant kelp. 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 has been compiled that uses these variables to parse cold water and warm water periods since the early 1870s (Figures 5 and 6). As depicted, it is clear that most of 2009 was a warm water period; however, as Tsonis et al. (2005) and Bjorkstedt (2010) suggested this may not necessarily cause local

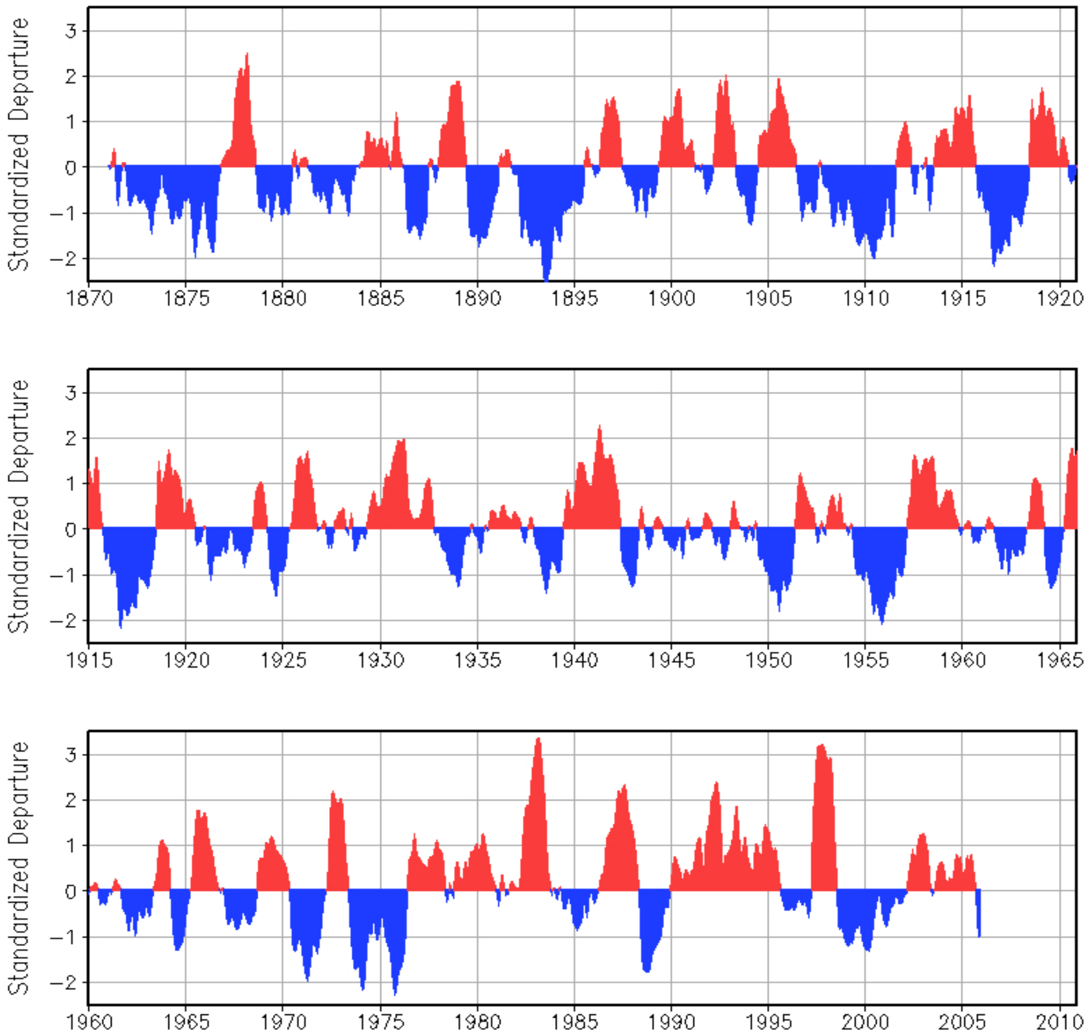


Figure 5. Multivariate ENSO Index from 1870 through 2006.

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 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.

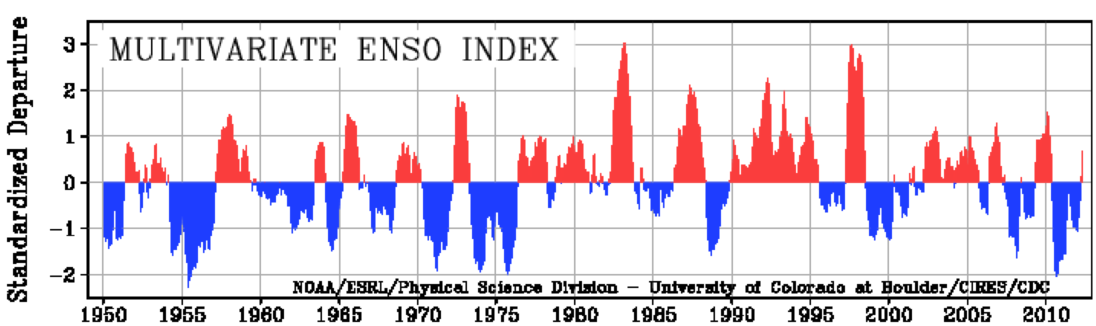


Figure 6. Multivariate ENSO Index from 1950 through 2011.

As ENSOs have been recurring events presumably 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 which tracks periods of SSTs at the equator above the mean (warm water events) and below the mean (cold water events) indicates that between 1977 and 2007 the area was 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, it can be seen that cold water events lasted longer during the period preceding Crandall's survey probably very favorable to the kelp beds of the time. The last five years have been characterized by two long La Niñas interspersed by one shorter El Niño.

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 late1950s through much of the 1970s) and Point Loma (in the mid-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 (North 2001; City of San Diego 1992a,b; Tegner et al. 1995.). Other factors have included unchecked runoff of construction of the Interstate 5 in the late-1960s (loss of Barn Kelp for several years); construction of homes at Salt Creek in the late-1970s which 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 the construction of Anaheim Bay, Alamitos Bay, and the Long Beach breakwaters increasing turbidity in the area.

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 take sometimes 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 (which 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 in about 1977 during a period in which we assumed was just a strong El Niño (Parnell et al. 2010). Upon review of water density data collected since the 1950s by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) and from Scripps Institution of Oceanography pier data, 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 observed on kelp beds during El Niño and La Niña events in the latter part of the 20th century appeared much subdued prior to the regime shift during the period of replete conditions which preceded this period of depleted nutrients (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 (Peterson and Schwing 2003), but this has yet manifested as altered conditions in the Southern California Bight 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. in press). 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 of which did not result in a corresponding giant kelp canopy area that would be predicted by a direct PDO: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 Southern California Bight 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 has limited the relevance of common climate indices derived from environmental data gathered across the Northeast Pacific Basin such as the Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), Multivariate ENSO Index (MEI), etc. The PDO's minimal applicability to the Southern California Bight was best detailed by Di Lorenzo et al. (2008) and their conclusion that the PDO correlated with SST south of the 38°N while the NPGO correlated with several productivity measures (Cavanaugh et al. 2011) . Cavanaugh et al. 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 ENSO events and ENSO events of long duration do impact the region’s kelp beds as can be elicited 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 the locations of these historically established kelp beds at Sunset Beach, 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 2010, 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 REGION NINE KELP BEDS

In the Region Nine kelp survey area extending from Newport Harbor (Orange County) to the north and the Mexican Border to the south, MBC has identified 25 persistent kelp beds, two other beds that have shown up ephemerally (Santa Margarita and Torrey Pines), and four other areas of interest (marinas and small boat harbors). In this same region, California Department of Fish and Game recognizes just 10 administrative kelp bed lease areas (Figure 7). 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 25 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.

Administrative kelp bed areas in California waters are numbered, defined by compass bearings from known landmarks, and have applicable commercial regulations (see CCR, Title 14, §165 and 165.5). The entire California coastline, including the Channel Islands, is divided up into number administrative kelp beds, although not all areas contain kelp beds. 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, open beds may be harvested by anyone with a kelp harvesting license. In the Region Nine study area, there are 10 administrative kelp beds: five are open, four are leasable, and one (Bed No. 10, located between Abalone Point and the Newport Bay south jetty) is closed (Figure 7).

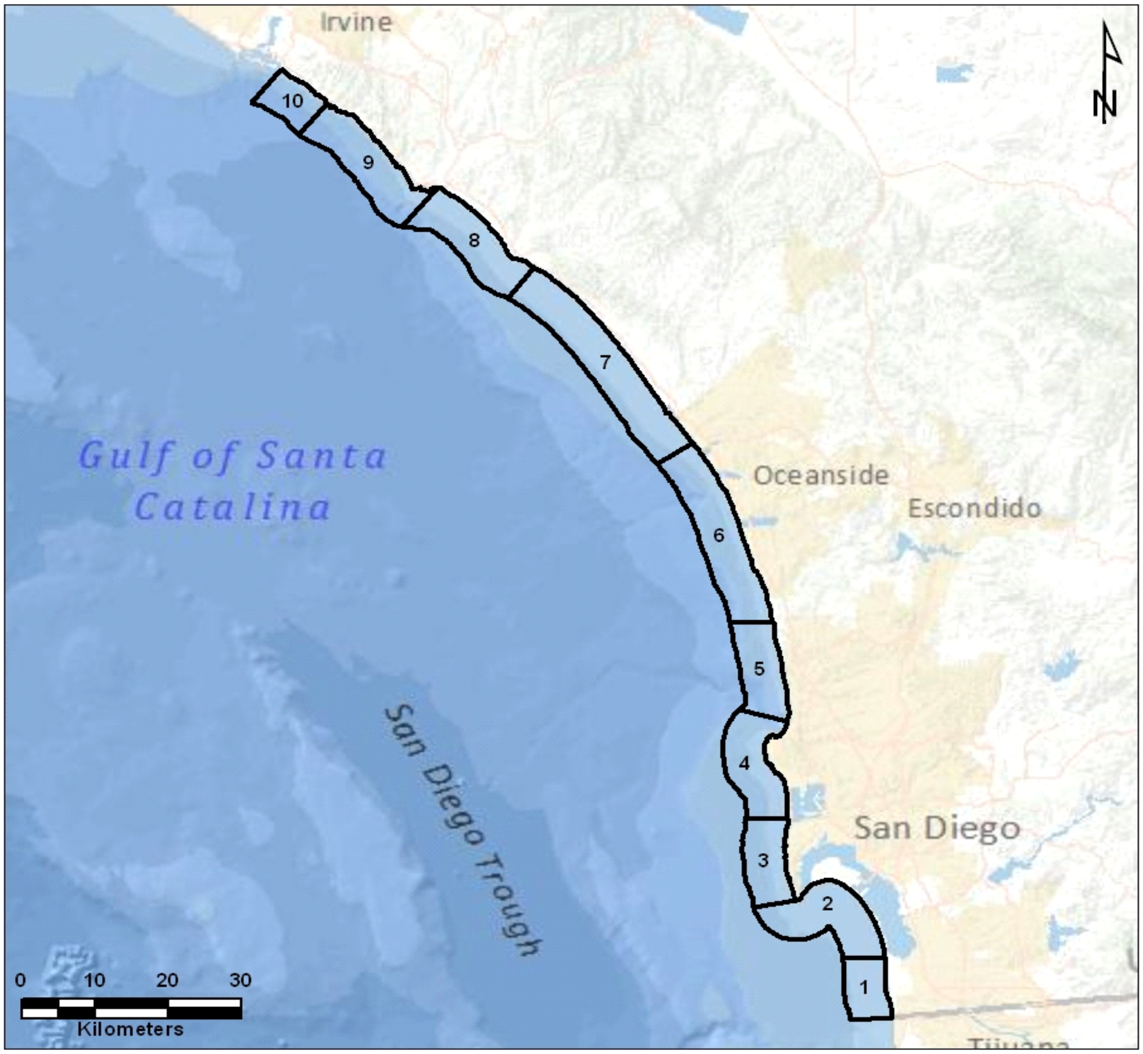


Figure 7. Administrative kelp bed lease areas in the Region Nine study area.

Giant kelp was first harvested along the California coast during the early 1900s. Since 1917, kelp harvesting has been managed by the CDFG under regulations adopted by the California Fish and Game 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 which can be leased for up to 20 years; however, no more than 25 mi^2 or 50% of the total kelp bed area (whichever is greater) can be exclusively leased by any one harvester.

HABITAT DESCRIPTIONS

The descriptions of the CDFG administrative kelp lease areas below are ordered from upcoast to downcoast (Figure 7).

Fish and Game Kelp Bed Number 10 covers the kelp beds beginning at Newport Harbor and moving south past Crystal Cove State Park to Abalone Point. The north Orange County coastline was the most severely affected by the El Niños of 1982-1984 and 1997-1998 resulting in the complete extirpation of giant kelp from the region. In past El Niños, typically some giant kelp will survive below the thermocline until conditions become more favorable for growth. In most of the north Orange County kelp beds (with the exception of Dana Point), available rocky substrate ends at depths shallower than 40 ft, and historically, the beds have never been large. With the exception of one bed outside of Newport Harbor, Crandall did not report any other beds along this section of the coastline in his 1911 survey. The thermocline during the 1982-1984 and the 1997-1998 El Niños was depressed below the depth critical to the survival of the giant kelp, resulting in the total extirpation of kelp from the southern part of the region. There was no surviving giant kelp below the thermocline when conditions returned to a more favorable regime. The prevailing longshore currents in the area are to the south; therefore, a source of kelp spores would most likely be to the north. Any potential donor beds were too distant to provide enough spores to colonize rocky substrate at locations more than about 100 m from the primary bed. Based on numerous dive surveys, there were urchin barrens on many of the rocky reefs, or there was little available substrate that was not already occupied by multi-storied, encrusting invertebrate and algal coverage. The urchins and this coverage would have precluded settlement by spores on appropriate substrate. No natural kelp beds were close enough to supply kelp spores to initiate a recovery of the giant kelp in this region. Subsequently, no kelp was noted in any aerial surveys of the north Orange County coast nor found during numerous dive surveys and therefore, giant kelp remained absent from this area after the 1982-1984 El Niño.

Restoration attempts in the late-1980s resulted in short-lived success, but the beds were subsequently wiped out by El Niños in the early-1990s. Further restoration attempts in the region beginning in 2000 continued until there were ultimately measurable kelp bed canopies by 2007 which have continued to increase through 2011 to historic levels.

Fish and Game Kelp Bed Number 9 stretches from Abalone Point through Laguna Beach. Available hard-bottom subtidal habitat is intermittent with sandy substrate predominating in much of the area. The hard substrate, where found, does not extend much beyond depths of 40 ft throughout this region. This area too was devoid of kelp from about 1993 until restoration efforts began in 2002. Two groups (Orange County Coast Keepers and MBC Applied Environmental Sciences) began kelp restoration in several locations in both north and south Laguna Beach, with varying degrees of success through 2007, before environmental conditions ultimately favored the efforts resulting in fair size canopies that appeared in 2008 which have become progressively larger through 2011. Beginning at South Laguna and at the Salt Creek-Dana Point kelp beds, rocky bottom extends further offshore reaching depths of 60 ft offshore of Salt Creek-Dana Point and supports large stands of kelp during favorable years. South of Dana Point, rocky bottom is restricted to depths of 50 ft or less and again intermittent rock, cobble, and sand substrate is found in the nearshore environment to San Clemente.

Fish and Game Kelp Bed Number 8, consists of the San Clemente, San Mateo, and San Onofre kelp beds, and they are located on cobble bottoms with intermittent sand patches to depths of 50 ft. Although historically several large beds existed in this region (Crandall 1912), most of the substrate turns from cobble to predominantly sand about one mile downcoast of San Onofre with little or no hard substrate available for several miles until reaching Barn Kelp, suggesting that reefs that presumably existed here in Crandall's survey of 1911 have been inundated by sand.

Fish and Game Kelp Bed Number 7 includes Horno Canyon and Barn Kelp to just north of Oceanside. Barn Kelp is a layered shelf reef community extending out to depths of 50 ft. Beyond Barn Kelp to the south, large expanses of sand characterize the bottom with small areas of hard substrate that occasionally support kelp off Santa Margarita, although Crandall reported a very large kelp bed offshore of Santa Margarita in 1911. 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 Game Kelp Bed Number 6 encompasses the beds offshore of Carlsbad, Agua Hedionda, Encina Power Plant, and Carlsbad State Beach. Rocky substrate is found out to depths of 60 ft offshore of most of this area, supporting good canopy coverage with intermittent sand patches between the beds.

Fish and Game Kelp Bed Number 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. 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 Game Kelp Bed Number 4 is the La Jolla Kelp Bed as 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 90 ft 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. Downcoast of Mission Bay, rocky substrate again begins to dominate and hard substrate and giant kelp is found out to 100 ft and deeper during favorable conditions.

Fish and Game Kelp Bed Number 3 is a very extensive bed and is a part of Point Loma Kelp Bed that runs the length of the peninsula for several miles.

Fish and Game Kelp Bed Number 2 is a significant 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 Game Bed 2. Sand predominates just south of the San Diego Bay entrance to just upcoast from the Imperial Beach Pier, no kelp is typically observed in the southern portion of Bed Number 2.

Fish and Game Kelp Bed Number 1 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 20 to 25 ft and extending out to depths of about 55 ft. This area supported a bed that was over 1.0 km^2 in 1911, it covered 0.727 km^2 in 1987, but was never again as large as Crandall reported in 1912 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, the next recorded survey of the area was in 1967 and no kelp was reported in the area. No kelp is currently found offshore of the International Boundary and Water Commission's outfall.

HISTORICAL KELP SURVEYS (1911-1982)

In 1911, a mapping expedition of canopy-forming kelps for 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 (Crandall 1912). Using this methodology, most of the kelp beds in the CRKSC area were mapped (Appendix B). The ability to accurately map kelp beds such as the Point Loma kelp bed would require numerous triangulations using a sextant, compass, and the need to row a boat to enough locations to have some confidence in the quality of the data. It is likely that relatively few points were taken in order to depict the kelp bed. Most of the discussion on the quality of the data appears to focus on the ability to measure the size of the kelp beds printed on the maps, but not whether the maps were accurate depictions of the kelp beds. The latter is a valid point and the answer is unlikely to be elicited readily. Given this ambiguity, the Crandall estimates should be viewed qualitatively rather than as quantitative estimates comparable to aerial survey data taken since the 1920s. However, the data is a very good approximation to use as our baseline as anecdotal reports from area stakeholders reported by Cameron (1915) indicate kelp beds in 1912 were in fairly poor condition at the time of his survey from that seen in previous years. Although the historical ENSO index suggests that the previous five years had been favorable to the kelp (Figures 5 and 6), the PDO (another environmental metric that has historical data extending back to that period) is in agreement with Cameron’s statement. While 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 (Di Lorenzo et al. 2008). 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 2.53 square nautical miles (Nm^2 [8.68 kilometers^2]) Crandall reported (all of his measurements were in square nautical miles) to be very similar to his measurement of 2.42 Nm^2. The map used by North likely did not include much of Malaga Cove. Due to the large sizes reported by Crandall, Neushul (1981) assumed there was a scaling error and re-measured the maps which 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 found the area (2.57 Nm^2) to be slightly greater but very similar to that reported by Crandall (2.53 Nm^2). Therefore, the actual size of the beds that Crandall reported was probably relatively accurate since the areal survey extent and configuration reported had been confirmed from contemporary charts (Hodder and Mel 1978, Neushul 1981). Some of these beds have since grown to the sizes similar to or larger than those noted in Crandall (1912), confirming that the physical dimensions of the beds he reported were probable. This suggests that the ability to accurately measure the beds on the charts in 1911 were similar to that available to North in 1964 and Neushul in 1981.

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 was measured to be larger than about 0.727 km^2 (occurring in 1987) (Table 1). However, at the end of 2007, Imperial Beach kelp bed measured 1.493 km^2, almost 50% greater than what Crandall measured, lending further credence to Cameron’s (1915) statement that beds were in poor condition compared to earlier years (Table 2). It therefore follows that the Palos Verdes and other kelp beds of the Southern California Bight prior to 1911 were likely much larger than they are today. Because the error we derive between Crandall's estimate of the physical dimensions of the beds and ours is only about 1.5%, we incorporate Crandall's original measurements in our table (Table 1). Although we believe that Crandall's physical dimensions are relatively accurate, we take exception to the actual canopy sizes he records as all of his beds depict the encompassed areas as solid kelp, whereas all of the kelp beds we have been monitoring for the past 40 years have many interstitial voids. This factor probably reduces the overall canopy estimate by at least 10% and possibly more. However, there is no uncertainty that between 1911 and the mid-1970s, kelp beds declined at most coastal and island sites in southern California. Current measurements indicate most of the beds remain smaller than those of a century ago (Tables 1 and 2).

CONSORTIUM KELP SURVEYS (1983-2011)

The Consortium's monitoring began in the midst of the El Niño of 1982-1984 with only 11 of the 25 monitored sites displaying canopy in 1983; a high was reached in 1991 with all 25 beds (two in Laguna Beach and the three beds for Leucadia) displaying canopy (due to its ephemeral existence, Torrey Pines is not one of the regularly monitored beds) and a low in 1998 during the 1997-1998 El Niño with only eight kelp beds displaying canopy at some point during the year. The southern California kelp beds have been subjected to repeated warm water events and powerful storms during the last two decades that have adversely affected the kelp beds of the region. Storms have been very severe with wave heights during El Niños exceeding 4 m on more than 40 occasions since 1980 (NOAA 1999).

These oceanographic events and regime shifts have resulted in changes that appear to be magnitudes greater to the regional kelp bed resources than the effects that can be determined from all but the most egregious cases of anthropogenic effects. However, there have been several cases where turbidity from either sanitation discharges or construction activities have been implicated in the disappearance of kelp beds. As described previously, the loss of beds at White Point (Palos Verdes), Salt Creek, and Point Loma probably resulted from man's activities (North and Jones 1991, North 2001).

Large-scale oceanographic events, however, are likely responsible for the loss of kelp from Newport Beach to South Laguna during most of the decade of the 1990s with warm water prevalent during these years. The shallower beds of the Newport-Irvine coast failed to reappear after the El Niño of 1982-84 and the deeper beds offshore of Laguna disappeared after the 1992 El Niño. The beds of San Diego County typically extend into deeper waters and, although seriously depleted, were able to survive the El Niño of 1982-84. Typically, the basal portions of kelp will survive beneath the thermocline and be able to regenerate canopy fairly quickly following the return of nutrient rich waters, as evidenced by the remarkable recovery of Point Loma and La Jolla kelp beds in 1985.

The decade of the 1990s followed a very large La Niña. The favorable conditions of that La Niña, combined with the impetus provided by the great storm of 1988, resulted in increasing kelp canopy coverage to levels not seen since the 1970s. However, most of the following decade was characterized by a string of almost continuous El Niños. These culminated in the 1997-1998 El Niño that was as great (or greater depending on the parameters measured) in its negative impact on the kelp beds than that of the large 1982-84 El Niño. The adverse effects of this El Niño seriously damaged the remaining kelp beds, resulting in only eight of the 25 kelp beds monitored having kelp canopies in 1998 (Table 2). Of these eight, only Point Loma displayed any canopy by the end of 1998.

The positive effect on the kelp canopies of the La Niña of 1999-2000 was encouraging and it had an appreciable positive impact on the kelp beds in southern California (CDF&G 1999 in Veisze et al. 2004). The effect, however, did not proceed at the rapid pace noted during the 1989 La Niña (after the 1988 Great Storm), probably because of the lack of the combination of the other serendipitous factors mentioned earlier. The difference between these two apparently similar events was that the La Niña of 1989 started with 23 canopies totaling 7.7 km^2 of kelp along the coast, whereas at the beginning of the 1999-2000 La Niña (April 16, 1998 survey) only 3 canopies (Dana Point, La Jolla, and Point Loma), together, with less than 0.5 km^2 of kelp canopy, were present (Table 2).

With the advent and impetus provided by the large La Niña of 1999-2000, favorable conditions returned and generally remained through 2002. The La Niña had a very positive effect on the kelp beds and nutrients remained high in early- and late-2002. Despite the formation of a small El Niño on the equator, at the end of 2003 about one-half of the kelp beds increased and the remainder decreased, resulting in small net loss of kelp in the region overall from that noted in 2002.

As 2004 began, temperatures were near normal in both the north and south when compared to their respective long-term means. However, temperatures at Newport and La Jolla suggested that nutrients were lacking in much of the region for most of 2004, resulting in about a 60% loss of canopy (to about 4.1 km^2) from the more than 10 km^2 recorded in 2002 and 2003. Although conditions did not improve greatly in 2005, the canopy coverage noted in 2004 was maintained through the end of the year (although there was a reduction in the number of beds to 15) with some losses, probably as a result of persistent phytoplankton blooms and severe storm surge. By the 20 April 2006 survey, deterioration in all of the kelp canopies was noted, especially in the area from Salt Creek/Dana Point to and including La Jolla. Water temperatures were warmer than average from March through December indicating a severe lack of nutrients in the entire region (Table 3). By the June and September overflights, most of the canopies were missing or just a trace of kelp was noted. Overall, conditions in 2006 were poor for kelp with total area of kelp coverage declining from 2005 by more than 40% to about 2.4 km^2 (Table 2). Only 11 of the 25 beds displayed canopy at some time during the 2006 survey year.

The maximum measured kelp canopy in Region Nine increased greatly from the 2.391 km^2 recorded in 2006 to 10.644 km^2 in 2007. NOAA indicated that relatively average temperatures were observed in early 2007, followed by a long warm summer, and finally a decrease in temperatures in November and December as recorded by the NOAA Climate Diagnostic Center (www.cdc.noaa.gov). The observed increase in kelp growth during the 2007 year suggests that nutrients were available below the thermocline as the recovery from a very poor October aerial survey was significant. Another factor in the increases noted was probably the absence of unusually high turbidity caused by runoff or phytoplankton blooms, and the absence of effects from large swells and breaking waves, which have contributed to losses in the past (and especially in 2006). In 2008, the increases in kelp canopies noted in December 2007 maintained their size, and by June a few beds from Leucadia to Imperial Beach were slightly larger than noted during the past December survey. By the 24 September overflight, many of the canopies in the northern portion were missing (only 4 of 12 beds between Newport Harbor and North Carlsbad showed canopy, whereas 12 of the 13 beds from Agua Hedionda to Imperial Beach were present). However, data from numerous boat trips and diver surveys confirmed that in spite of the loss of most of the beds surface canopy, kelp was surviving below the thermocline. The seemingly poorer nutrient conditions in the middle-to-late part of the year in both the north and south resulted in serious deterioration of many of the kelp canopies, but temperatures became cooler (presumably with nutrients) by year's end and resulted in a remarkable recovery that surpassed expectations (Table 3). Overall, kelp in 2008 capitalized on the relatively good conditions of 2007, which promoted favorable kelp growth, with total area of kelp coverage increasing to 18.795 km^2, more than that recorded in almost the 70 years since 1941. The three years since has recorded canopies that (while still robust and much larger than average during the 29 years of Region Nine monitoring) have been mainly declining with a few notable exceptions.

Table 3. The table below indicates the kelp nutritional index of each month based on weighting values given to Sea Surface Temperature (SST) data compiled monthly and derived from Scripps Institute of Oceanography (SIO) pier data, Newport Pier (NP), San Clemente Pier (SCP), and Point Loma South (PLS), and historic data from 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). The season begins 1 July and ends 31 June. Years in Red denote warm-water years, Blue cold-water years, based on NOAA Multivariate ENSO Index (MEI), June 2012.

	Number of months falling into indicated temperature range					SIO	NP	PLS	KML	SCP
Weighting Factor	*14*	*8*	*4*	*2*	*1*	Season	Season	Season	Season	Season
Season	12.01-13.0°C	13.01-14.0°C	14.01-15.0°C	15.01-16.0°C	16.01-17.0°C	NQ	NQ	NQ	NQ	NQ
	NP (SIO)	NP (SIO)	NP (SIO)	NP (SIO)	NP (SIO)					
2011-2012	1(-)	-(1)	4(4)	1(2)	2(-)	30	34	21	NA	23
2010-2011	-(-)	2(3)	3(1)	3(1)	1(3)	33	35	19	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
1968-1969	-	1	4	-	2	ND	29	NA	26	NA
1967-1968	-	-	3	2	2	ND	24	NA	18	NA
ND = no data					Average Since 1967	15.8	28.3	16.5	20.1	17.7
- = 0					Since 1977	15.8	34.4	16.5	16.6	17.7
					1967-1976	NA	35.6	NA	30.3	NA

MATERIALS AND METHODS

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. MBC has conducted the surveying for Region Nine since its inception 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 to facilitate aerial photography. MBC conducted quarterly overflights of the coastline for the Consortium from the Newport Harbor entrance to the U.S./Baja California 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 (Table 4). 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 five feet and tide less than +1.0' MLLW, and
- Sun angle greater than 30 degrees nadir.

Vessel Surveys. The vessel survey in 2011 was conducted on 28 and 29 December 2011. 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 which includes:

- extent and density of the bed
- tissue color
- frond length on the surface
- presence absence of growing tips -apical blades
- extent of encrustations of hydroids or bryozoans
- sedimentation on blades
- any evidence of disease -holes-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 will be to investigate apparent causes of a beds 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 Barn Kelp, and Imperial Kelp beds.

KELP DATA ANALYSIS

All photographs were reviewed after each overflight and the canopy surface area of each kelp bed was ranked in size by comparison to historical bed size, excluding El Niños and La Niñas. 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 Consortium) was calculated.

All slides were individually digitized, and the slides from one of the four surveys that showed the greatest areal coverage were digitally assembled into a composite photo-mosaic that provides a regional view of whole kelp bed areas. The assembly was done using Adobe Photoshop CS2 to combine photos for the photomosaic. The Photoshop mosaics were then transferred to GIS (ArcGIS 9.2) to geo-reference them to place into the specific Fish and Game shape file. Each mosaic was geo-referenced to at least three prominent features on the map and converted to UTM or other acceptable coordinate system and ultimately converted to a geo-referenced TIFF file. Surface canopy areas was calculated using the Hawth's Analysis Tools (Version 3.27), 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.

Table 4. Synopsis* of status of planned aerial flights 2011.

Target Date	**Mid-March**	**Status**	**Results**
Planned Flight	16-Mar-11	Cancel	Overcast Entire Range
	19-Mar-11	Cancel	Overcast Entire Rnge
	29-Mar-11	Cancel	Partly Cloudy Entire Range
	14-Apr-11	Cancel	Overcast Partial Range
	15-Apr-11	Cancel	Overcast Entire range
	16-Apr-11	Flown	Generally Good Visibility Entire Range
Target Date	**Mid-June**	**Status**	**Results**
	15-Jun-11	Cancel	Overcast Entire range
	29-Jun-11	Cancel	Partly Cloudy Entire Range
	3-Jul-11	Cancel	Overcast Entire range
	14-Jul-11	Cancel	Overcast Partial range
	16-Jul-11	Cancel	Overcast Entire range
	1-Aug-11	Flown	Generally Good Visibility Entire Range
Target Date	**Mid-September**	**Status**	**Results**
New	**Mid-October**	split remaining month	
	23-Oct-11	Cancel	Partly Cloudy Entire Range
	25-Oct-11	Cancel	Partly Cloudy Entire Range
	28-Oct-11	Flown	Generally Good Visibility Entire Range
Target Date	**Mid-December**	**Status**	**Results**
	19-Dec-11	Cancel	Partly Cloudy Entire Range
	21-Dec-11	Flown	Generally Good Visibility Entire Range

* See Appendix C for Entire Flight Status Report

ENVIRONMENTAL DATA

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

1. Water temperature data from automated stations at Scripps Pier (La Jolla), San Clemente Pier, and Newport Pier. At all three locations, automated samplers measure conductivity, temperature, and fluorometry every one to four minutes. These data are made available in real time via the Southern California Coastal Ocean Observation System (SCCOOS) website (www.sccoos.org).
2. Water temperature data from the Coastal Data Information Program (CDIP) Point Loma South data buoy, which records water temperature, wave height, period, and direction every 30 minutes.
3. Sea and swell height data from CDIP data buoys located at San Pedro, Dana Point, and Torrey Pines. Wave direction, height, and period are available in real time via the CDIP website (cdip.ucsd.edu).

RESULTS

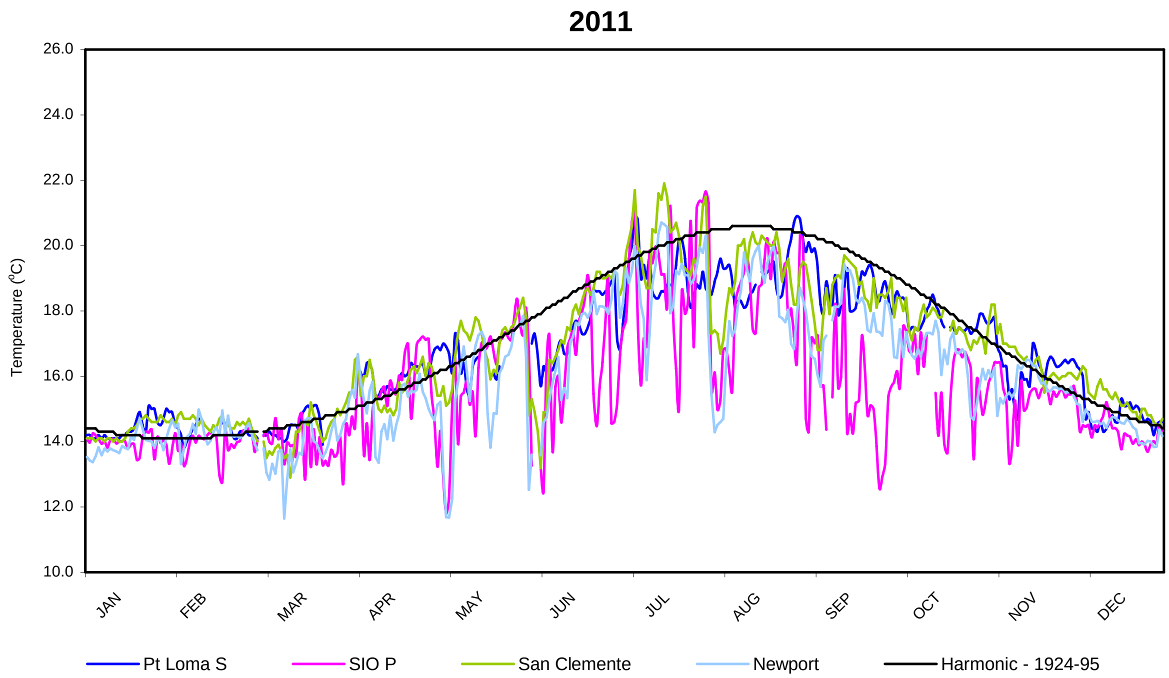
WATER TEMPERATURES AND NUTRIENTS

As previously discussed, temperatures at the sea surface (SST) are a useful surrogate for nutrient availability; while there appears to be convincing evidence that seawater density can also be used as a surrogate, and in some cases predict nutrient availability possibly better than temperature, long-term measurements on smaller scales than the Southern California Bight are not readily available. Temperature measurements in the marine environment, however, have been ongoing for decades in many areas along the coast resulting in a readily available resource that can predict nutrient availability. A temperature/nutrient index covering several decades is presented in Table 3.

Sea surface temperatures from the Newport, San Clemente, and Scripps Piers, and the Point Loma South CDIP buoy and were used to determine the theoretical availability of nutrients in the region. Comparing these long-term means, the variability of SST in 2011 tracked closely between Scripps on the south and Newport in the north where both data sets indicated cool SSTs with numerous upwelling events Figure 8). The middle of the range was tracked by the SSTs at San Clemente Pier, while the extreme southern portion of Region Nine was tracked by the Point Loma south buoy, both of these stations indicated temperatures were near the average with only occasional nutrient upwelling spikes (Figures 8-12). This relationship between temperature and nutrients appeared very favorable beginning about mid-April 2011 at Scripps Pier and late-February at Newport Pier based on the monthly Nutrient Quotient Index (NQ) (described in "Status of the Kelp Beds of San Diego and Orange Counties for the Years 1990-2000" [North and MBC 2001]). The average early morning sea surface temperature (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 (12 monthly values) for the indexed year (July 1 to June 30) (Table 3). 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 during any given year, making it possible to pinpoint those years when nutrients were replete or when depleted to establish possible temporal trends.

At Scripps Pier, (NQs not starting until 1984) the NQ value has averaged 15.8, at Point Loma south, the average has been 16.5, and at San Clemente Pier it has averaged only 17.7 (three years only at these two sites) indicating that the beds in these three regions have had below average nutrient availability. These low NQs and the 35.6 NQ average at Newport Pier over the past 44 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 which kelp beds had reached their maximum extents in several decades) had nutrient quotient values of 27, 36, and 39, respectively (Table 3).

The NQ index was 30 at Scripps Pier and 34 at Newport Pier for the 2011-2012 season through May 17 (ends on June 30). However, the lack of nutrients (based on warmer SSTs) at San Clemente (NQ=23) and at Point Loma South buoy (NQ=21) may have contributed to the poor canopy totals at Salt Creek-Dana Point and Capistrano and (Point Loma South) at lower Point Loma and Imperial Beach Kelp beds (Table 2). The above average kelp canopy coverage in 2008 was the result of a very good impetus in late-2007, nurtured early in 2008, a relatively mild summer, and good nutrient availability in the fall in 2008 season. The very low NQs for the 2009-2010 year (9 at Scripps and 19 at Newport Pier) resulted in good but reduced canopies through June and then a serious reduction in canopies by the end of 2009. NQs indicated good nutrient availability in 2010 with an NQ of 33 at Scripps Pier and 35 at Newport Pier. Kelp beds in the region had mixed results, but overall canopies in the Region Nine were still very robust by the ends of 2010 and 2011 benefitting from a continuing favorable temperature regime with an ongoing La Niña throughout most of Region Nine.



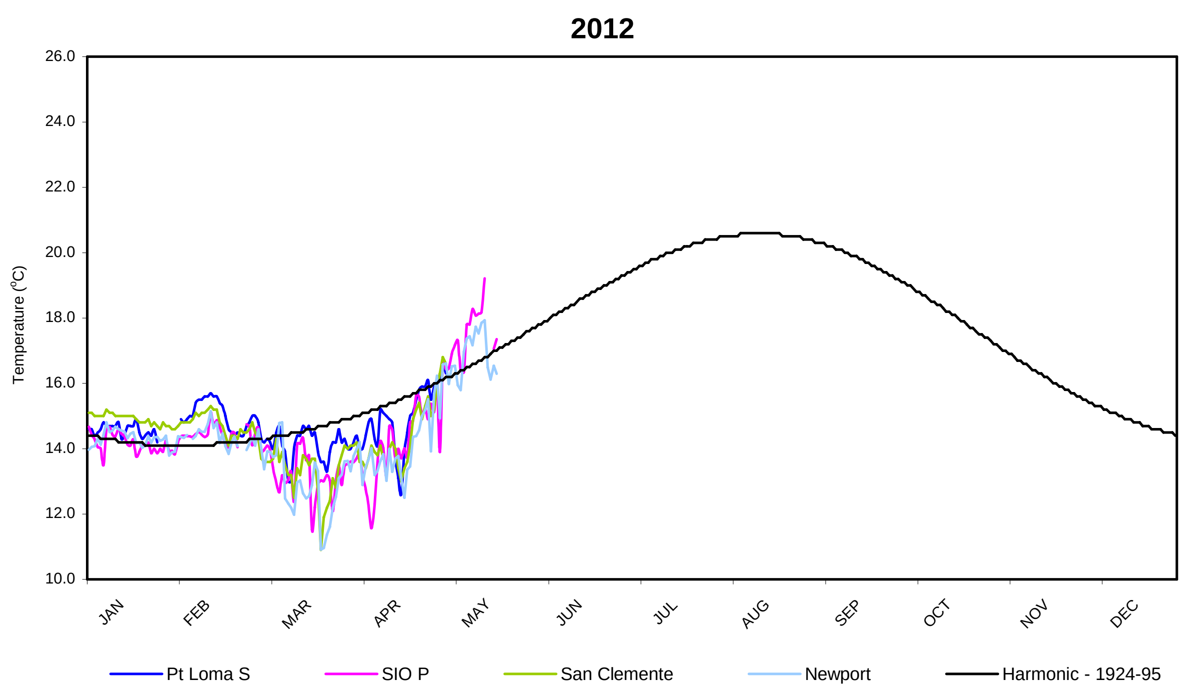
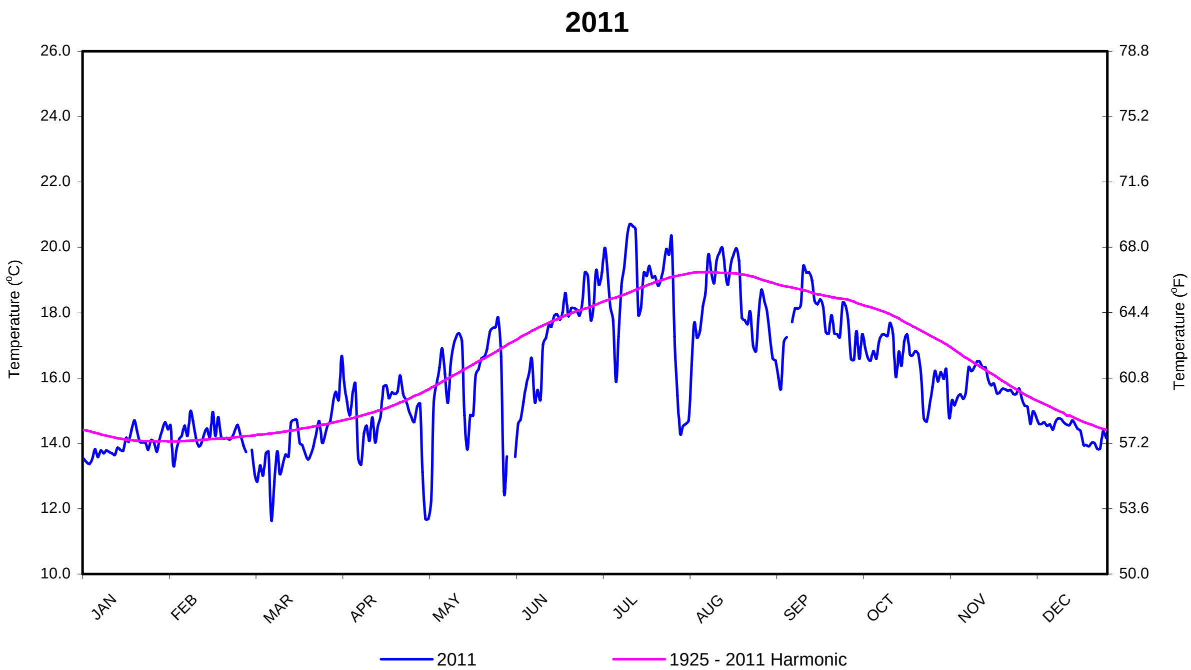


Figure 8. Daily SSTs from four locations within Region Nine superimposed on the long-term harmonic equation from Scripps Pier, 2011 through 15 May 2012.



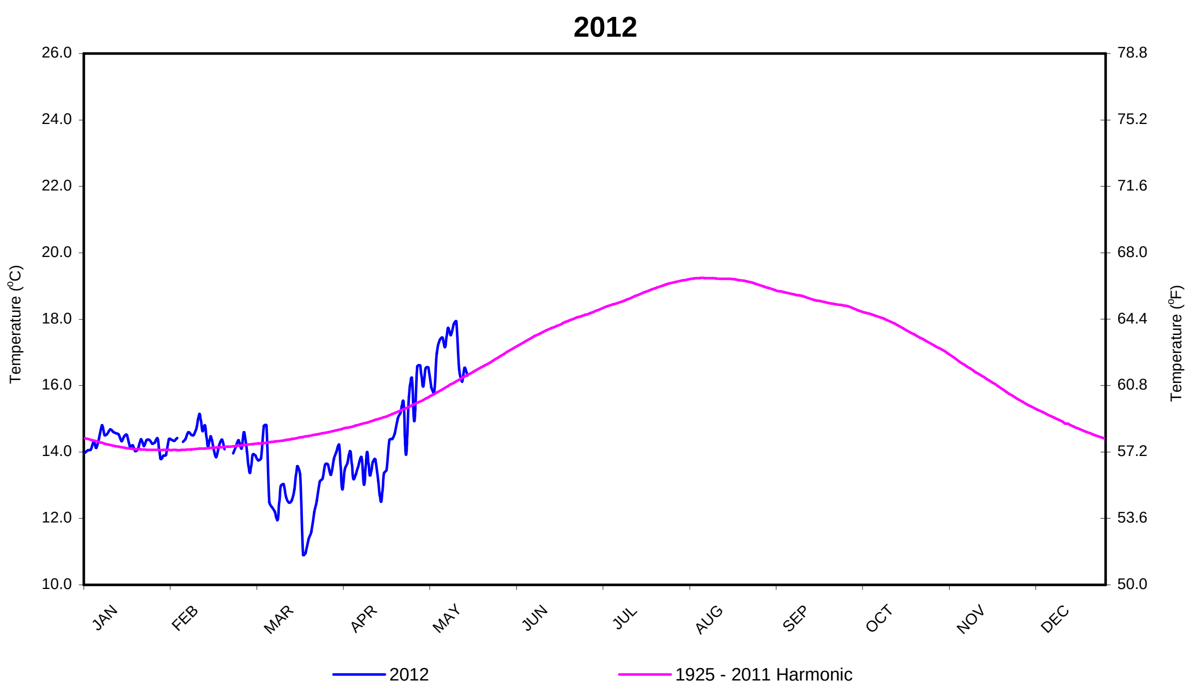
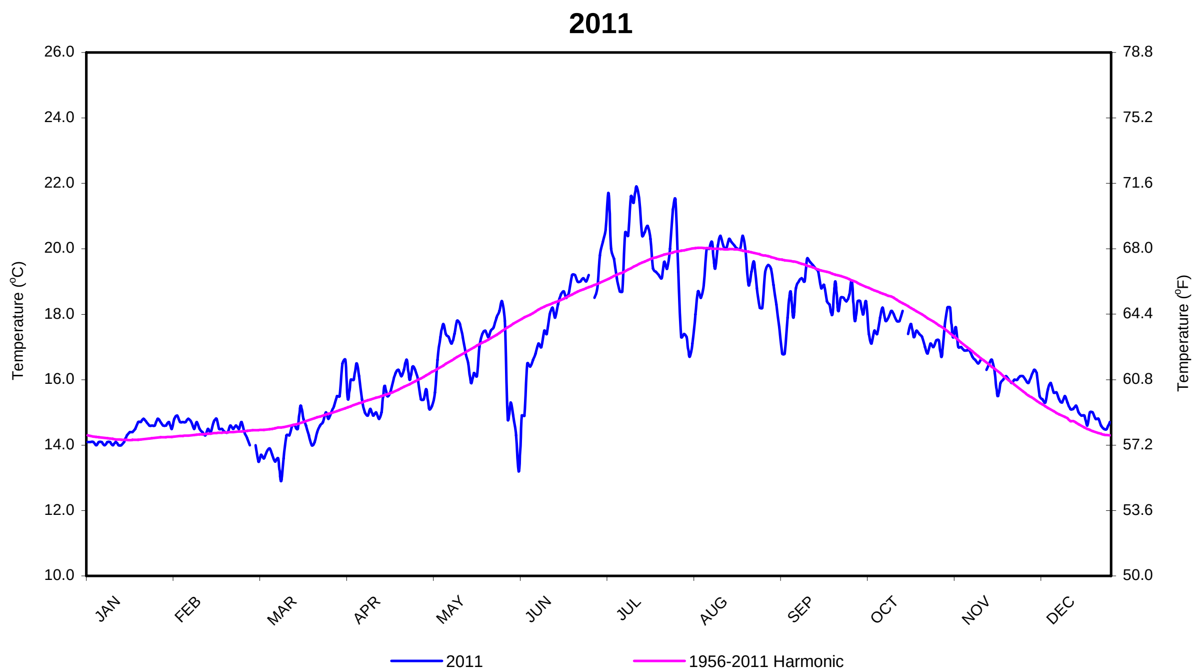


Figure 9. Daily SSTs from Newport Pier, 2011 through 15 May 2012.



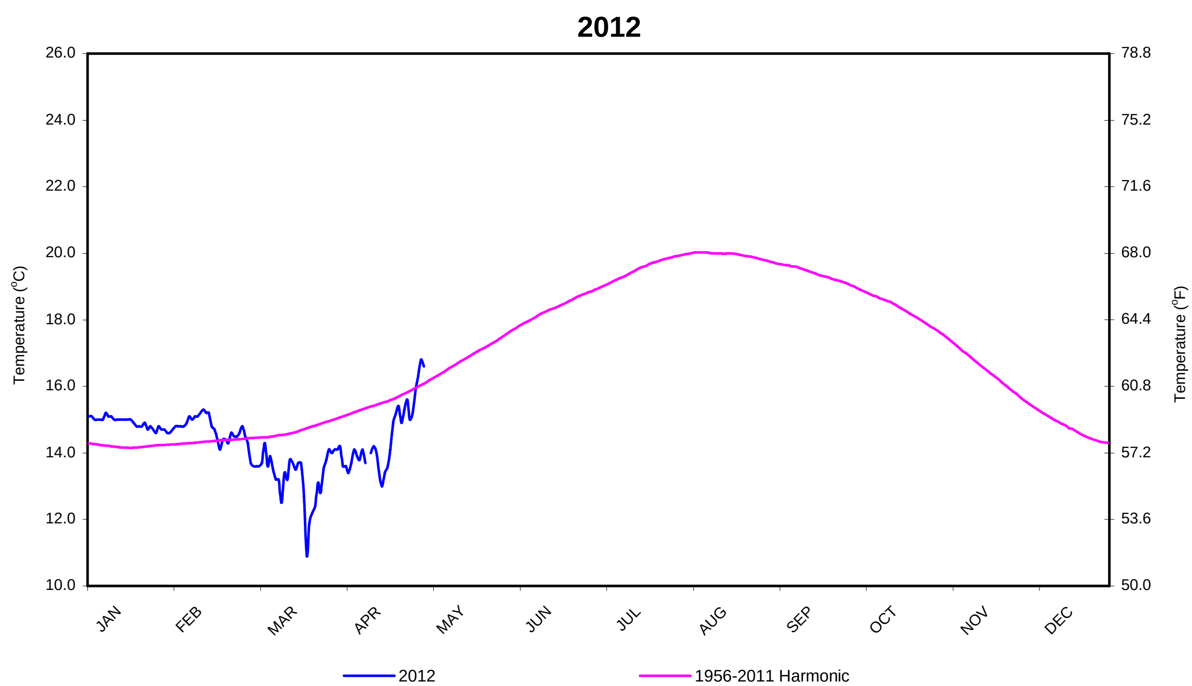
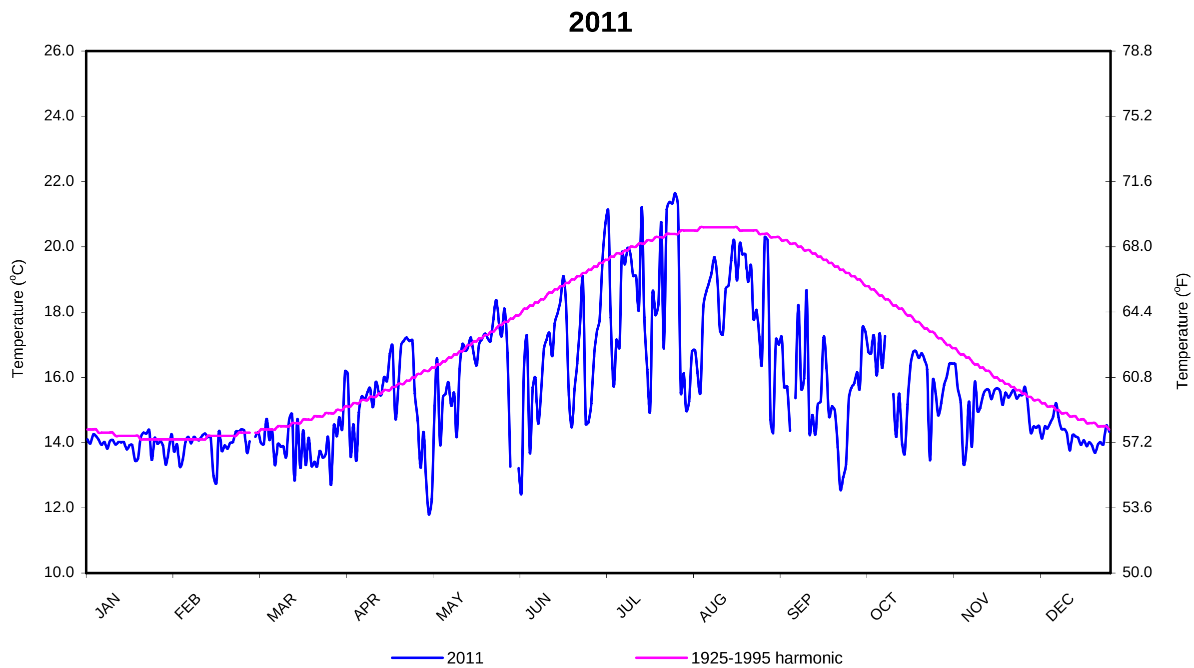


Figure 10. Daily SSTs at San Clemente for 2011 through April 2012.



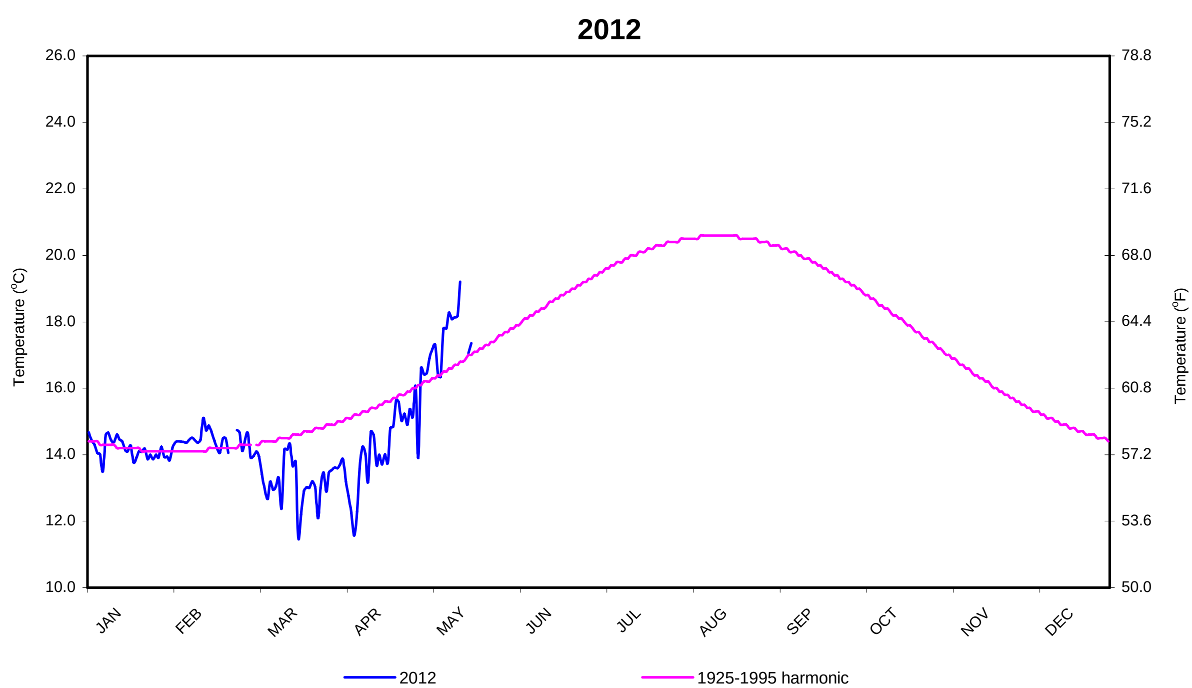


Figure 11. Daily SSTs from Scripps Pier, 2011 through 15 May 2012.

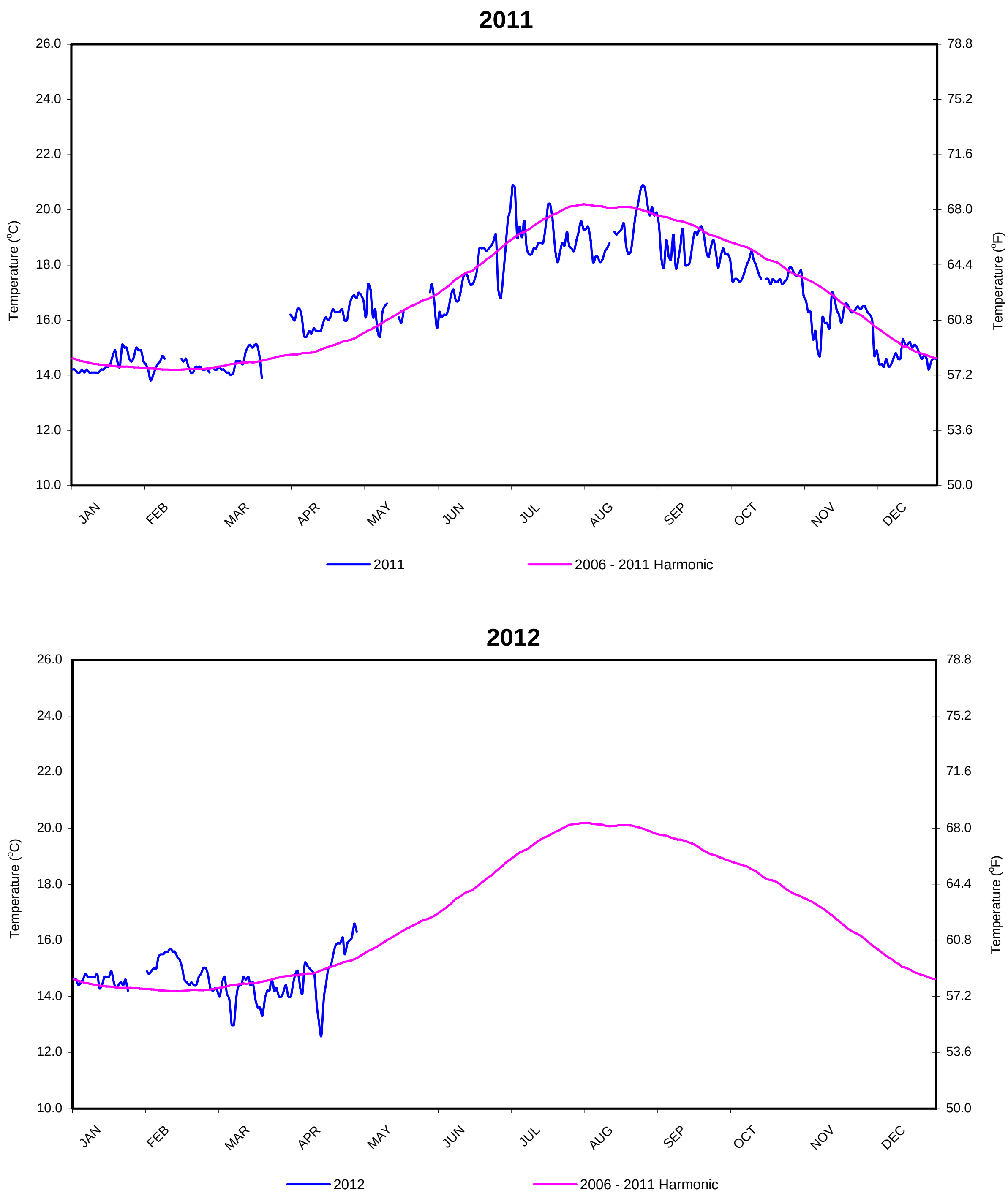


Figure 12. Daily SSTs from Point Loma South Buoy, 2011 through mid-April 2012.

WAVE HEIGHTS

Typical swell sizes and directions were observed through most of 2011, with swells generally approaching the region from the south most of the time (about 60% of the time at San Pedro) and westerly the remainder of the time (Figure 13). 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 late-February and early-March again in late-November into December when wave energy height and density at the San Pedro, Dana Point, Oceanside, and Point Loma South CDIP Buoys indicated high amplitude waves near or over 3.5 m (with some over 3.75 m). For most of the spring and summer, swells were either low energy (except mid-April to mid-May with swells to 2.5 m at San Pedro and, less so, at Dana Point). 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 swells recorded during 2011, they were not persistent and there was no evidence of any substantial impacts on the kelp beds in Region Nine.

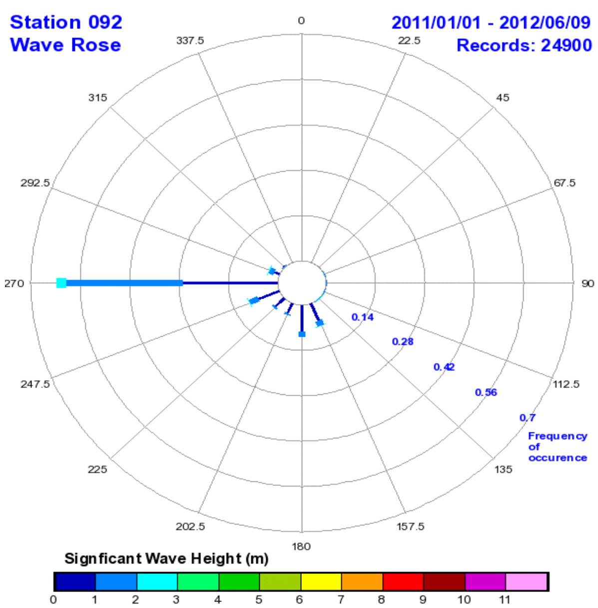


Figure 13. Wave Rose significant wave direction San Pedro, CA from 2011 through June 2012.

At a wave sensing buoy (Scripps Coastal Data Information Program [CDIP] Station 092), offshore of San Pedro, the wave and swell station recorded wave heights approaching 3 m or more on four separate occasions from late-February (3.0 m high), early-March (2.9 m high), mid-April (2.7 m high), and late-May (3.1 m high), a relatively mild winter and spring (Figure 14). At a buoy offshore of Dana Point (CDIP Station 096) waves over 3 m in height were present in mid-February 2011 (3.0) and late-March (3.3 m high), but seas were relatively calm after that with one wave set reaching about 2.5 m high in late-May (Figure 15). At Oceanside (CDIP Station 045), the wave and swell station recorded wave heights of over 3 m on two separate occasions from mid-

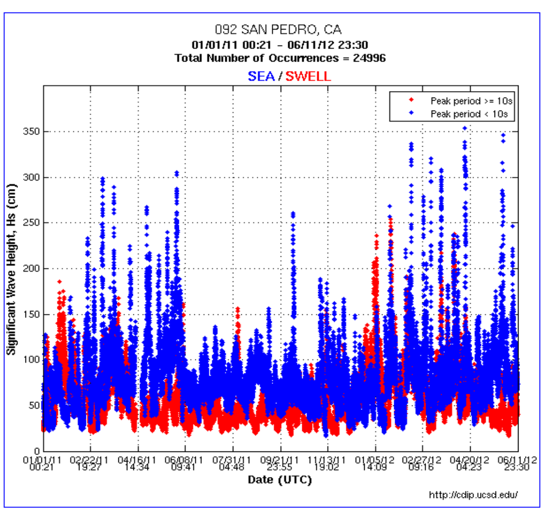


Figure 14. Significant wave heights offshore San Pedro, 2011 through 11 June 2012.

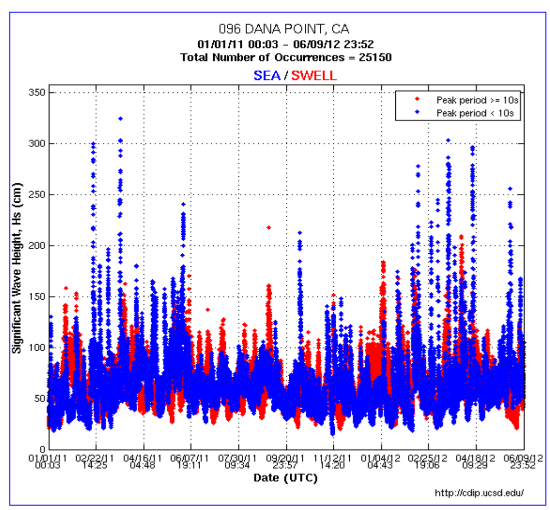


Figure 15. Significant wave heights offshore Dana Point, 2011 through 9 June 2012.

February (3.8 m high) and late-March (3.3 m high); again in late-May swells to 2.4 m high were recorded; this was followed by a relatively calm period until early to mid November when relatively large waves again occurred on two occasions with peaks of 2.8 and 2.4 m height occurring (Figure 16). Point Loma South is another monitoring buoy (CDIP Station 191). At this station, the same large swells that impacted the remainder of the Region Nine coastline were recorded in mid-February (3.1 m high) and late-March (3.7 m high), with minor swells in mid-April (2.4 m high) and early-November at 2.8 m high. Several of the wave events could have caused considerable damage to the kelp bed resources as several events approached the 4 m height, the bench mark where the force or magnitude of the waves could have caused considerable damage to the kelp beds. Very little apparent damage to the kelp beds that could be attributed to the wave regime was recorded from San Pedro to Point Loma (Figures 17 and 18).

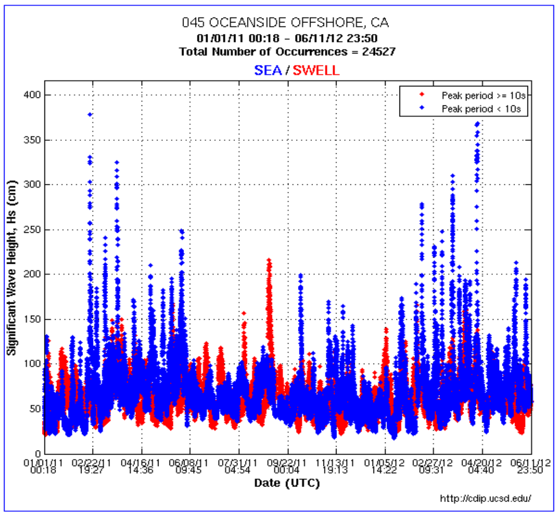


Figure 16. Significant wave heights offshore Oceanside, 2011 through 11 June 2012.

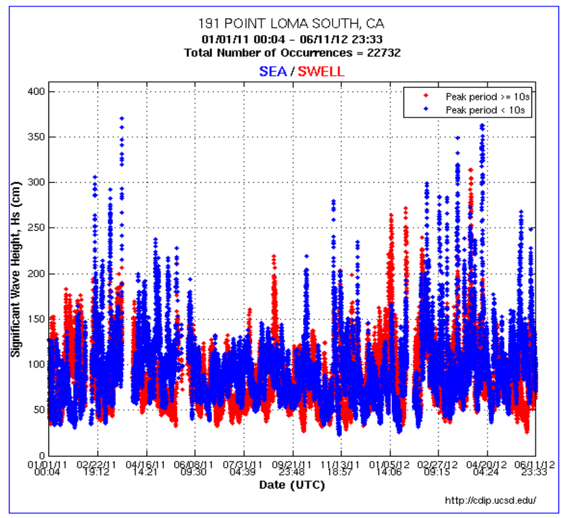


Figure 17. Significant wave heights offshore Point Loma, 2011 through 11 June 2012.

RAINFALL AND WATER CLARITY

Water clarity was relatively good in 2011. Runoff in 2011 was not significant heavy with about one inch of rain in January in the northern portion of the range, and about two inches in the region in February (Figure 3). There was essentially no significant rainfall again until November when over 3 inches fell in San Diego (www.wunderground.com). There were periods of algal blooms in the region, but they did not persist for sustained periods during 2011. The concentrations of diatoms and dinoflagellates that were present throughout the region in 2006 were much reduced in 2011 (SCCOOS 2012). Concentrations at over 3.5 X 10^5 cells per liter (Shipe 2006, pers. comm.) can effectively exclude light from all but the shallowest depths, which prohibits 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).

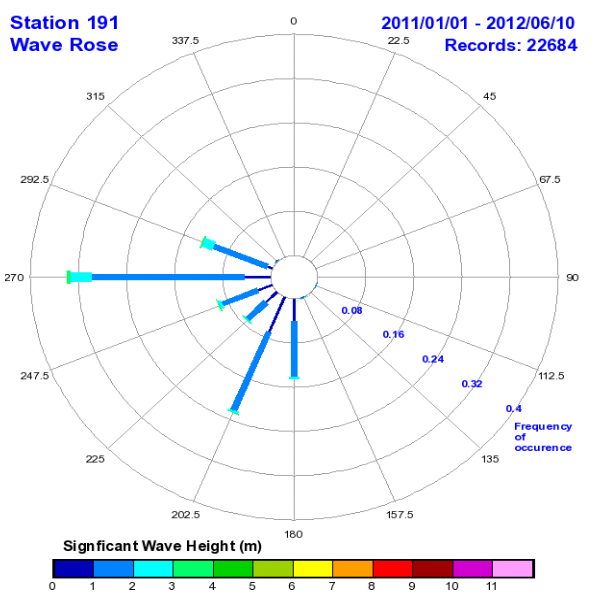


Figure 18. Wave Rose significant wave direction Point Loma South, CA from 2011 through June 2012.

2011 QUARTERLY OVERFLIGHT SUMMARY

The aerial surveys for 2011 were conducted on 16 April, 1 August, 28 October, and 21 December 2011. One aerial survey (6 April 2012) has been completed for the 2012 survey year (Appendix C).

Flight conditions were generally good during all surveys with some clouds present during the late-December 2011 survey over Imperial Beach. Reasonable attempts were made to conduct one aerial overflight within each of the four quarters in the year. However, inclement weather conditions resulted in the postponement of the first quarterly survey to just into the spring quarter. The mid-June survey was postponed for 1.5 months, due to persistent clouds and fog as a result of very cold water and warm inland air colliding. The mid-September survey was rescheduled for mid-October (as a result of conversations with the Region Nine Kelp Consortium), but could not be flown for two weeks due to fog along the coast. The mid-December survey was flown as scheduled. Based on the results of the four surveys, maximum canopy coverage throughout most of the region was seen during the December survey, although impressively large canopies were also observed in August and October at various kelp beds (Appendix A, Table 5).

Table 5. Rankings assigned to the 2011 aerial photograph surveys of the San Diego and Orange County kelp beds, and rankings assigned to an April 2012 aerial survey. 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.

	2011 Surveys				2012 Survey
Kelp Bed	April 16	August 01	October 28	December 21	April 06
Newport Harbor*	3.0	2.5	3.5	3.5	3.5
Corona del Mar	3.5	3.0	3.0	3.0	3.5
No. Laguna Beach	3.5	3.5	3.5	4.0	3.5
So. Laguna Beach	2.5	3.5	3.0	4.0	3.5
South Laguna	2.5	3.5	3.5	4.0	1.0
Salt Creek-Dana Point	3.5	3.0	4.0	3.5	2.5
Dana Marina *	3.5	3.0	4.0	3.5	3.5
Capistrano Beach	2.5	3.5	3.5	3.0	1.5
San Clemente	3.0	3.5	4.0	4.0	4.0
San Mateo Point	3.0	3.0	2.5	3.0	2.5
San Onofre	2.5	3.0	2.0	2.5	2.0
Pendleton Reefs*	-	-	-	-	-
Horno Canyon	-	-	-	-	-
Barn Kelp	2.0	1.5	1.5	2.0	1.0
Santa Margarita	-	-	-	-	-
Oceanside Harbor*	1.0	0.5	0.5	1.0	0.5
North Carlsbad	1.5	-	1.0	1.5	1.0
Agua Hedionda	2.0	2.5	1.0	3.0	1.0
Encina Power Plant	2.5	2.0	2.5	3.0	2.0
Carlsbad State Beach	2.0	2.0	2.0	2.5	2.0
North Leucadia	1.5	1.5	2.0	2.5	1.0
Central Leucadia	2.0	2.5	2.5	2.5+	2.5
South Leucadia	2.5	2.5	2.5	2.5+	2.5
Encinitas	2.0	2.5	2.5	2.5+	2.5
Cardiff	2.0	2.5	2.5	3.0	2.0
Solana Beach	2.0	2.5	2.5	3.0	2.5
Del Mar	-	0.5	1.5	2.0	1.5
Torrey Pines Park*	-	-	-	2.5	2.0
La Jolla Upper	1.0	1.5	2.0	3.0	2.0
La Jolla Lower	1.0	2.0	2.0	4.0	3.5
Point Loma Upper	1.0	1.5	2.0	4.0	4.0
Point Loma Lower	1.0	2.5	2.5	3.0	3.0
Imperial Beach	-	-	1.5	1.0	-

Notes:
Ranking values: 0.5 = vert small amt of kelp present, 1 = well below average , 2 = below average, 3 = above average, and 4 = well above average, + slightly greater, - = no canopy present; NA = Not Available ; * not part of the monitored beds

In some years, a few kelp beds will appear equally large in another survey, but in the interest of using synoptic data whenever possible, one flight will be chosen to represent those areas. In 2011, there were several canopies measured that could have been just as easily taken from either the August or October surveys, therefore the largest extent was chosen from usually the December survey and in a few cases from the October survey). Overall, the recovery by December 2011 was not as marked as seen the previous year (Table 5).

2011 VESSEL SURVEY SUMMARY

Boat surveys were conducted during most of the year from Newport Beach to Barn Kelp and in late-December in the southern portion to document the kelp canopies and verify anomalies suggested by the earlier data. By the December 28 boat survey, very few kelp canopies appeared to have maintained their size from that seen in late-2010. The Newport Coast to Laguna Beach beds were considerably larger, and the beds from Cardiff to Point Loma were also larger, but most of the beds from South Laguna to Encinitas were smaller, with the exception of San Clemente Kelp which had grown a little larger. The reduced upwelling near San Clemente and Point Loma may have been responsible for reductions in some of the nearby beds; however, beds such as San Mateo (and by extension Wheeler North Kelp at San Clemente), La Jjolla, and Point Loma benefit from local upwelling which is not always captured by our SST stations. Relatively good nutrient conditions during the spring allowed the beds to maintain canopies and actually increase during the summer months. By the 1 August overflight many of the canopies in the upper and lower portion of Region Nine were beginning to improve, while beds from San Onofre through Leucadia were showing reduced canopy coverage. Data from the boat survey and diver surveys at Barn Kelp and Imperial Beach Kelp beds confirmed that in spite of the loss of most of these beds surface canopy, kelp was surviving below the thermocline. Water temperatures stayed favorable through October indicating nutrients were available in the entire region during this period, but becoming slightly unfavorable by year's end (Table 3). The recovery from a relatively poor April aerial survey showing was very good with what appeared to be a favorable nutrient regime through at least October 2011. Overall, kelp in 2011 had mixed responses to nutrient pulses available, with some capitalizing on the relatively good conditions of 2010 and increasing, while some of the very large beds lost considerable canopy coverage, with total area of kelp coverage by the December survey very good, but below that documented in 2010 (and well below the 2008 total which was the best since 1941 in our records).

2011 KELP CANOPY SUMMARY

Utilizing the 2011 aerial surveys, 23 of the 25 beds monitored were present (Figure19), and the following changes were documented:

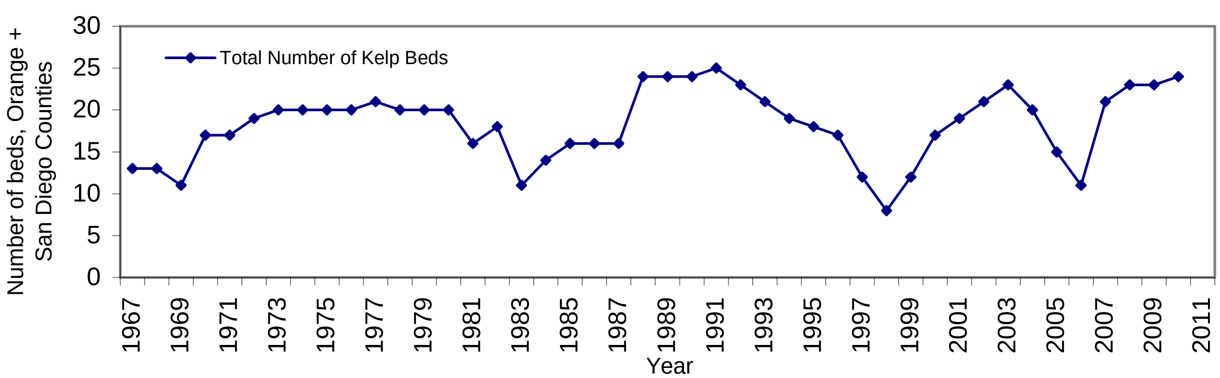


Figure 19. Historical changes in the total number of kelp beds in Orange and San Diego Counties determined by presence or absence of canopies assessed by aerial photography.

10 kelp beds increased
14 kelp beds decreased
1 kelp bed was unchanged (not present)

Of the two small beds at Torrey Pines and Santa Margarita that appear only occasionally in the region, only Torrey Pines was present in 2011, whereas Santa Margarita has not been observed since 1992.

Results of the 2011 Region Nine survey indicated that the maximum measured kelp canopy decreased from 11.706 km^2 in 2010 to 10.797 km^2 in 2011 (Figure 20, Table 2). NOAA ENSO data indicated that cooler-than-average temperatures were observed in early 2011, which has followed a cooler-than-average 2010 (La Niña conditions), and finally an increase in temperatures in November and December as recorded by the NOAA Climate Diagnostic Center (www.cdc.noaa.gov). The extremely large increase in kelp growth during 2008 year suggests that the kelp growth was nurtured by nutrients below the thermocline to a degree far in excess of that suggested by the NQs or SSTs recorded in the region.

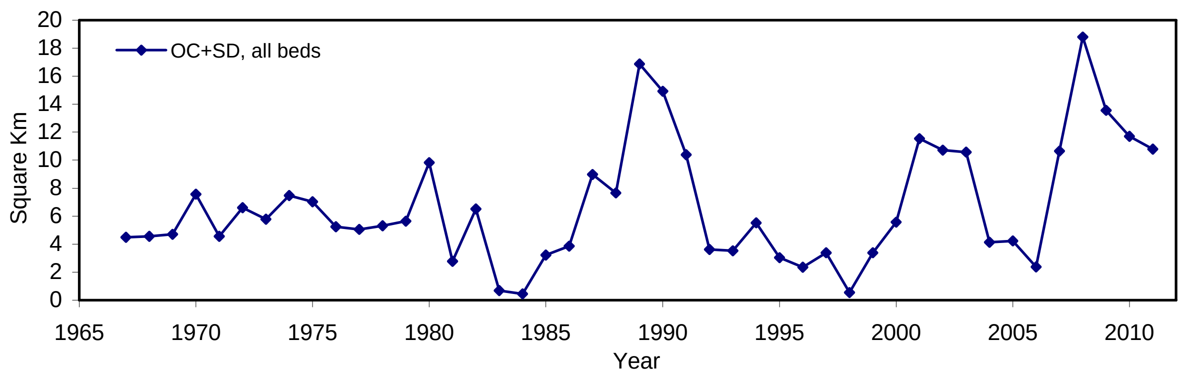


Figure 20. Combined canopy coverages of all kelp beds in Orange and San Diego Counties.

STATUS OF THE 25 KELP BEDS IN 2011

The following is a brief synopsis of the status of each individual bed during the survey year of 2011, as observed by aerial photography and supplemented by boat cruises and direct diver observations, where available.

Each kelp bed description below is a portion of what Fish and Game refers to as a kelp bed lease area which can contain more than one giant kelp bed. The Region Nine program identifies these as 25 individual 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, we compare not only the area of each individual bed, but how that bed compares to the average for the beds in both Orange and San Diego County, excluding the very large beds of La Jolla (LJ) and Point Loma (PL) as they tend to skew the data. We also compare total area of the beds in Orange County, the beds in San Diego (with the exception of LJ and PL), and the LJ and PL beds to determine whether any distinct differences are elicited in the overall coverage in a region over time (Figure 21). 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.

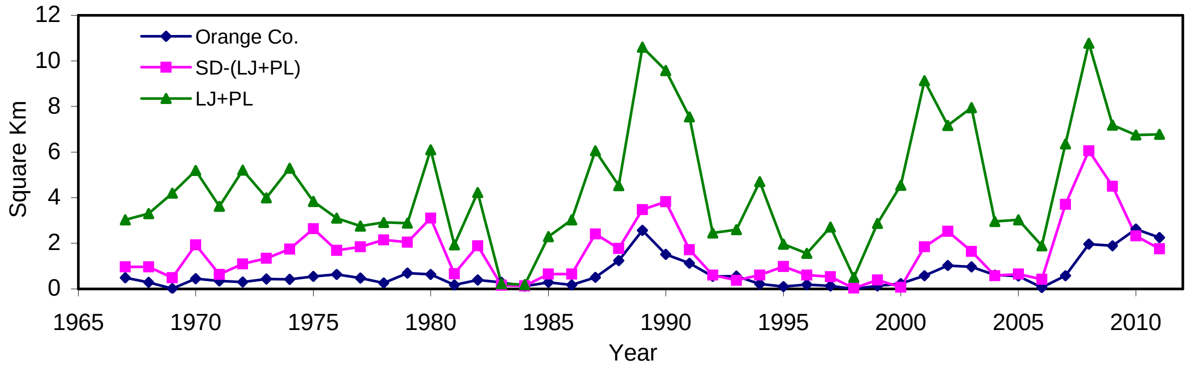


Figure 21. Diagram showings components of the Total Area graph partitioned into the kelp beds of: Orange County; San Diego County less La Jolla and Point Loma ((SD-(LJ+PL)); La Jolla plus Point Loma (LJ+PL).

Huntington Flats to Newport Harbor 2011. 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 30 ft of water and situated between Bolsa Chica State Beach and 23rd Street in Huntington Beach (North and Jones 1991). No information is available on its size and it was not observed during aerial surveys by Fish and Game in the 1950s. The construction of the Port of Long Beach, Alamitos Harbor, and Anaheim Bay likely changed or interrupted sediment transport sufficiently to increase sedimentation in the area, thereby reducing the likelihood of a kelp bed being sustained. No kelp has been observed historically or in any Region Nine survey along the shoreline past the Huntington Beach Generating Station, the Orange County Sanitation District outfalls, or along the remainder of the coastline to Newport Harbor. Kelp continues to grow on the inside west jetty of the Newport Harbor entrance and on the outside of the east jetty. These narrow bands of kelp were observed in the 2011 quarterly surveys.

Newport Coast - Corona del Mar to Crystal Cove 2011. Giant kelp in this region consisted of a number of small beds (collectively called the Corona del Mar kelp bed) covering 0.580 km^2 of the nearshore coastline during Crandall's survey of 1911, but down to 0.180 km^2 by 1970. Kelp beds persisted in the region until the El Niño of 1982-1984, when they disappeared from this section of the coastline. Due to kelp reforestation efforts in the late-1980s they reappeared as very small beds until disappearing again in the early 1990s as a result of 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, and expanded to the southeast to Scotchman's Cove (now Crystal Cove). Two other sites, Wheeler's Reef and the bed southeast of Rocky Point at Scotchman's Cove, displayed canopy during the early portion of 2003. A dive survey was conducted at the restored Corona del Mar bed in 2003 and purple urchins were prevalent in the area, but kelp recruitment was so successful that drift algae was apparently sufficient to keep the urchins from overwhelming the kelp recruits. Neither of these two beds had canopy during any of the aerial surveys of 2005, but the Newport Coast kelp bed was the largest bed in Orange County in 2006 (0.023 km^2). 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 Coast kelp bed was (0.089 km^2), which increased to 0.095 km^2, (approximately 65% of the bed size recorded in 1980) in June 2009 (Table 2). In the March, November, and December aerial surveys of 2010, the various small beds comprising the Corona del Mar kelp bed were very robust. A relatively large kelp bed measuring 200 by 100 m was observed off of Whistler's Reef and a dive survey on 2 November 2010 indicated that the bed was growing on large rocky reefs and tissue colors were indicative of sufficient nutrients. The fronds of the giant kelp appeared to be about 50% mature and about 30% very young suggesting that the bed was healthy and growing. Offshore of

Scotchman's Cove, another large canopy was visible having grown from a small bed observed in May 2009 to a bed about 300 m long by 100 m wide and growing in water as deep as 60 ft (Curtis 2010, pers. obs.). The measurement of the Newport Coast kelp bed in December 2010 calculated coverage of 0.161 km^2, which is slightly larger but almost equal to the 1975 and 1977 totals for the region. This indicates that as a result of kelp restoration efforts from 1986 through 2009 (and the added impetus of the 2010 La Niña). The 2011 aerial surveys indicated that the beds continued to expand as a result of a sustained La Niña and by the December 2011 survey, the north and south Laguna Beach kelp beds totaled 0.368 km^2 which was larger than the previous maximum in the past 45 years of 0.319 km^2 in the very good kelp year of 1989.This indicates that as a result of kelp restoration efforts from 1986 through 2009, the beds of this region have finally recovered from their total extirpation in the early 1980s. The average bed area per year (ABAPY) was graphed showing that this bed followed the other beds of the region until giant kelp was extirpated from the coastline 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 (Figure 22).

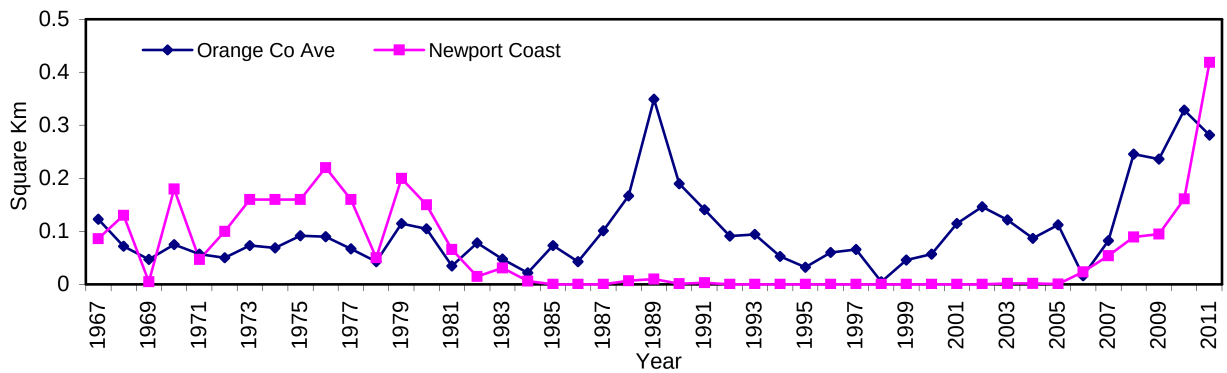


Figure 22. Comparisons between the average Orange County ABAPY and the canopy coverages of the kelp bed off Newport Coast (Corona del Mar/Crystal Cove) for the years shown.

North Laguna Beach/South Laguna Beach 2011. Kelp at this location appears prominently in a map from 1890 produced by T.C. Mendenhall for the U.S. 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. 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 1). 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 and 1993 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 25 to 45 ft, 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 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 and again as the result of 1000s of hours of restoration efforts over an eight-year period (MBC 2010b). The results of the 2011 survey indicate that the Laguna Beach kelp beds were larger in 2011 (0.419 km^2) than at any time in the continuous 45 year record, but not as large as the canopy coverage in 1955 of 0.680 km^2 (Table 1). 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, remaining at zero in our measurements until about 2006 when the beds again reappeared as a result of restoration efforts (Figure 23).

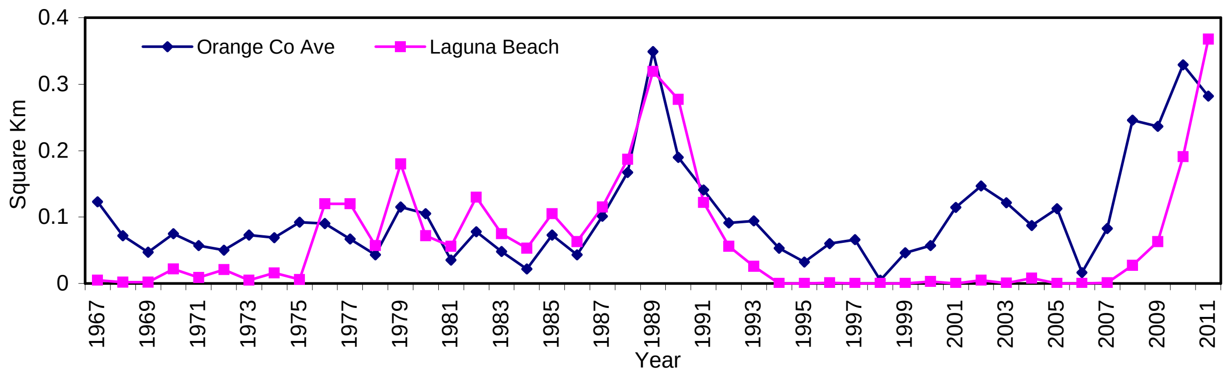


Figure 23. Comparisons between the average Orange County ABAPY with the history of Laguna Beach kelp (i.e., the sums of canopy coverages for North Laguna Beach plus South Laguna Beach kelp) for the years shown.

South Laguna 2011. 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 in the Salt Creek-Dana Point and spilling into the South Laguna region (twice what has been recorded in the region since). Based on that assessment, it was likely the bed was near 0.10 km^2 (twice what has been recorded for this bed). By 1959, the two beds were recorded as being only 0.18 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 the 2006 survey year. 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 40 to 50 ft depths extending from Salt Creek north about 0.5 kilometers, 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 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 and one pink abalone was observed at a depth of about 32 ft. The reduction in size of the canopy was not distinguishable from that of the previous year in spite of a reduction from 0.023 to 0.017 km^2. The ABAPY for this bed indicated that the bed responded to relatively large stimuli such as the 1989-1990 La Niña and has continued to respond to the increase in the Orange County average noted since 2007 (Figure 24).

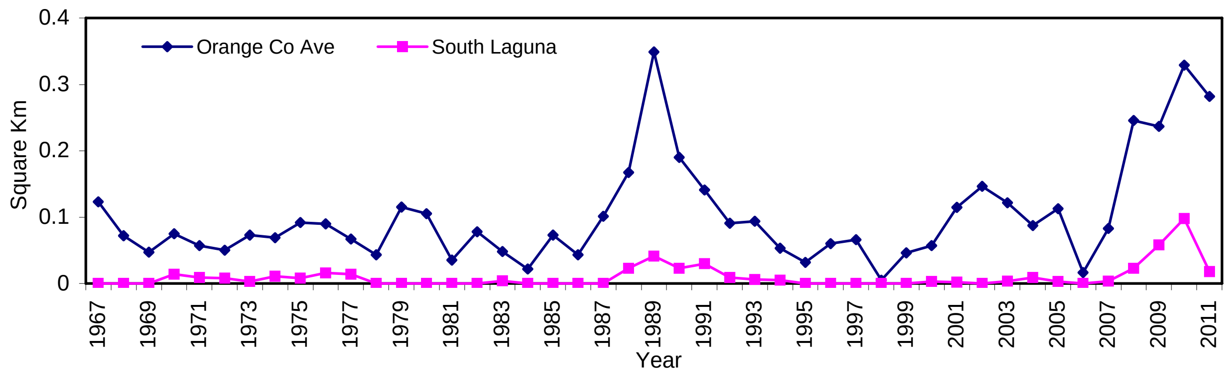


Figure 24. Comparisons between the average Orange County ABAPY and the canopy coverages of the kelp bed off South Laguna for the years shown.

Salt Creek-Dana Point 2011. Kelp beds in the Salt Creek-Dana Point area were large in Crandall's 1911 survey, totaling 1.871 km^2 (Table 1). 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 0.4 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, which continued through 2002. Kelp canopy was extensive and on the surface from depths of 35 ft extending out to 64 ft by the end of 2002, covering an area of 0.432 km^2, and again becoming smaller and disappearing 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 quarterly 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 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 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 increased to a significant percentage (94%) of that seen in 2009 and canopy coverage totaled 0.839 km^2. 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 which had weakened many holdfasts. 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 25).

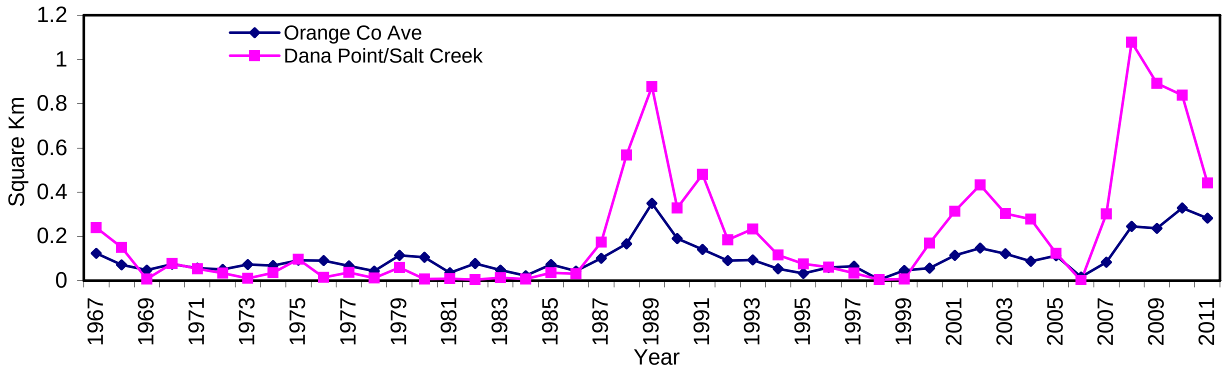


Figure 25. Comparisons between the average Orange County ABAPY and the canopy coverages at the Dana Point/Salt Creek kelp bed for the years shown.

Capistrano Beach 2011. The baseline for this stretch of the coastline is Crandall's map of 1911 showing canopy coverage of 1.153 km^2. The beds at Capistrano Beach were small in 1967, covering only 0.08 km^2, and stayed small or 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 responded to stimuli to reach 0.118 km^2. The beds shrunk once again and have stayed small since. Kelp was also missing in most of 2004, but re-emerged by the December 2004 aerial survey. A trace of kelp was seen in early 2005, but kelp was again missing through the remainder of 2005. The kelp beds offshore of Capistrano Beach in 2006 were reduced to just a trace in April and December. A small recovery was recorded in 2008, but only to the level noted in early 2006. In 2009, however, kelp was recorded as very good and increased greatly by June 2009 from that seen in 2008 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 from that found in 2009 to 0.124 km^2. Canopies were scattered over a large area during the December boat survey and several canopies were found offshore of the breakwater at Doheny Beach. By the December 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. 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 26).

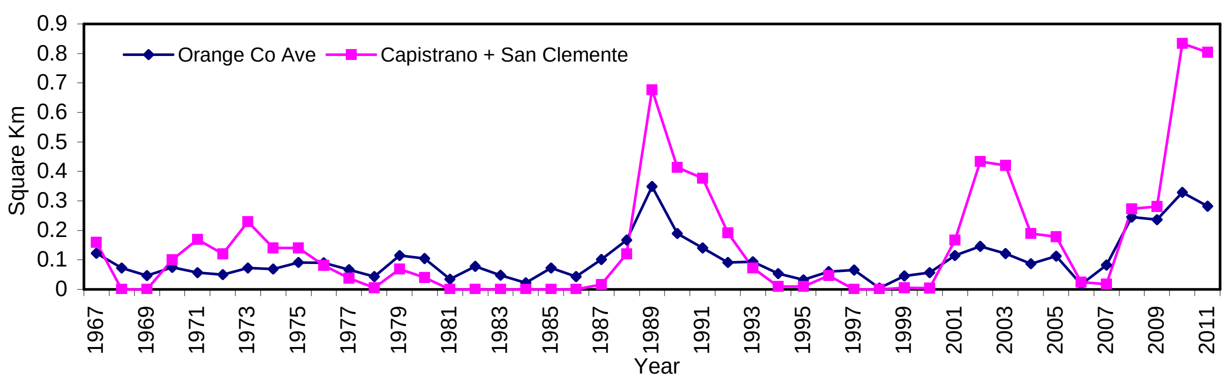


Figure 26. Comparisons between the average Orange County ABAPY and the canopy coverages at the Capistrano Beach plus San Clemente kelp beds for the years shown.

San Clemente 2011. In 1911, Crandall recorded the beds as covering an area of 1.390 km^2. The beds at San Clemente were small in 1967, covering only 0.08 km^2, and stayed small or missing until 1988, when the bed increased in canopy size to 0.124 km^2 and the next year to 0.444 km^2. After a major decline in 1994, kelp bed canopy coverage at San Clemente stabilized in 1995 and increased through 1996. With the advent of the 1997-98 El Niño, kelp disappeared for two years, 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 approximately 50 small artificial reefs measuring 40 by 40 m each that were placed offshore of San Clemente on barren sand at depths of about 40 to 50 ft. 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, 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 and kelp was reported as recruiting to the new reefs in late 2008. Kelp stayed fairly robust through both the March and June 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 of kelp canopy which was the highest recorded for this bed since at least 1959. The aerial survey 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 adequate nutrients available. This bed probably benefits from its proximity to San Mateo Point and localized upwelling associated with the point. 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 26).

San Mateo Point 2011. San Mateo kelp beds were large in 1911 when Crandall reported them as covering 1.272 km^2. Based on a total for several beds in the region, it was likely the beds remained fairly large during surveys of 1955 and 1959, but they were only about 0.057 km^2 by 1970. The beds again became fairly large by 1980 (0.360 km^2) and a large fraction of their 1911 size in 1989, when they covered 0.870 km^2. After that period they began a slow decline, becoming precipitous by 1994. After a major decrease in 1995, San Mateo kelp beds 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 beds decreased greatly in 2004 to one-half of their 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 beds were still small in March 2007 and a large hole was observed in the middle of the kelp (this area had previously been a 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 beds to double in size totaling 0.487 km^2 by the December 2008 survey, larger than they 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 in 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. There is a perennial hole in the San Mateo kelp bed that we note from year to year. As questions had been raised about the nature of this hole (sand bottom, urchin barrens, etc.), a dive survey was conducted in January 2010 to make observations. As North noted (North and Jones 1990), the bathymetry below the hole is a rocky cobble and boulder reef area that is elevated above the surrounding reef area. North thought that the area preferentially recruits sea urchin larvae to this hillock. Diver observations indicated that it is a large sea urchin barrens and both red and purple urchins were massed in a front along the kelp bed one to two meters 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 ABAPY for the San Mateo kelp beds showed that these beds respond typically to stimuli such as the El Niño and La Niña by following the Orange County average relatively close although responding slightly more negatively in 2011 than the average of the Orange County beds (Figure 27).

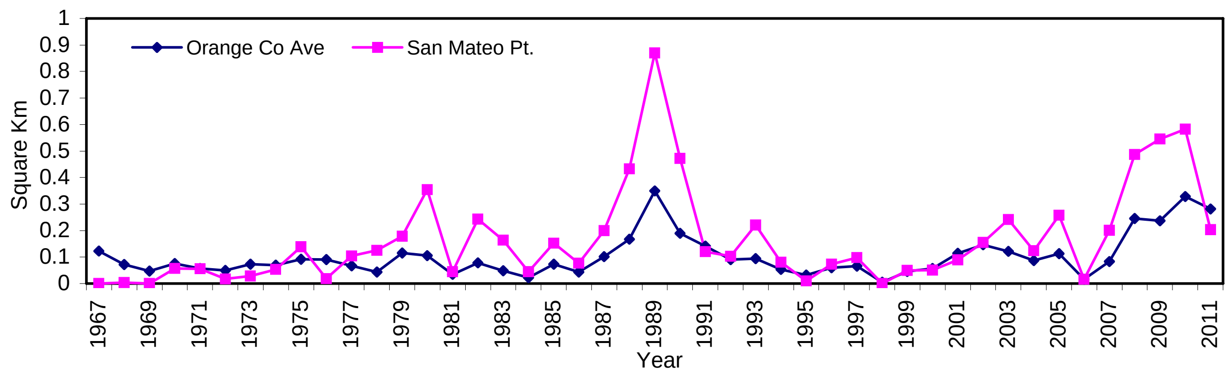


Figure 27. Comparisons between the average Orange County ABAPY and the canopy coverages of the San Mateo Point kelp bed for the years shown.

San Onofre 2011. The kelp beds at San Onofre were large in 1911 when Crandall reported them as covering 1.946 km^2. Based on a total for several beds in the region, 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 0.20 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 0.10 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 2007and 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, waning in the summer, and recovering well in the fall and winter, resulting in the canopy increasing in size to 0.476 km^2, the best it in almost two decades (1990). As 2009 began, the kelps 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 subsequent two 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 that was larger than in 2009, but slightly smaller than the 2008 total. 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. Although the bed covers a similar area, it was much thinner in 2011 than observed in 2010. It decreased (0.127t km^2) to about one fourth of its 2010 size. It is of interest to demonstrate that the San Onofre and San Mateo beds react very similar to stimuli as depicted in Figure 28. 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 29).

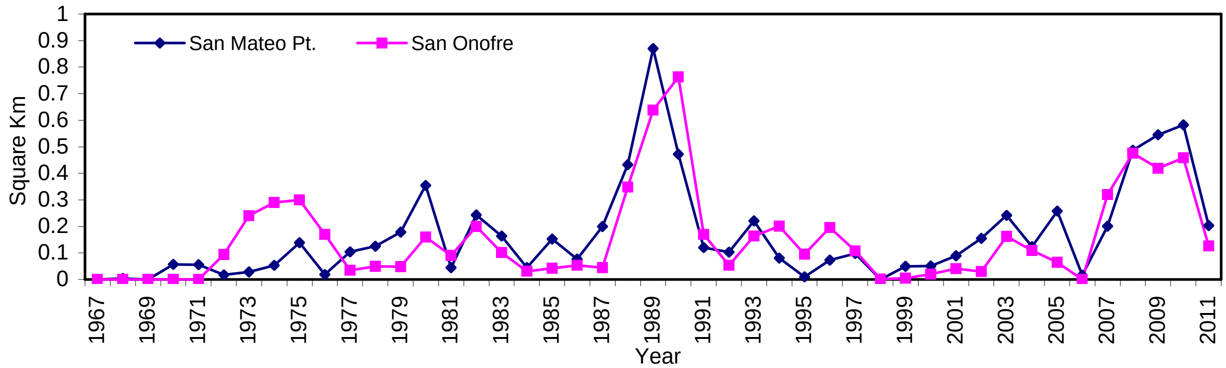


Figure 28. Comparison of histories of canopy coverages for the kelp beds off San Mateo Point and San Onofre. Operations at Unit 2 of the San Onofre Generating Station (SONGS) commenced in 1983. SONGS Unit 3 became operational in 1984.

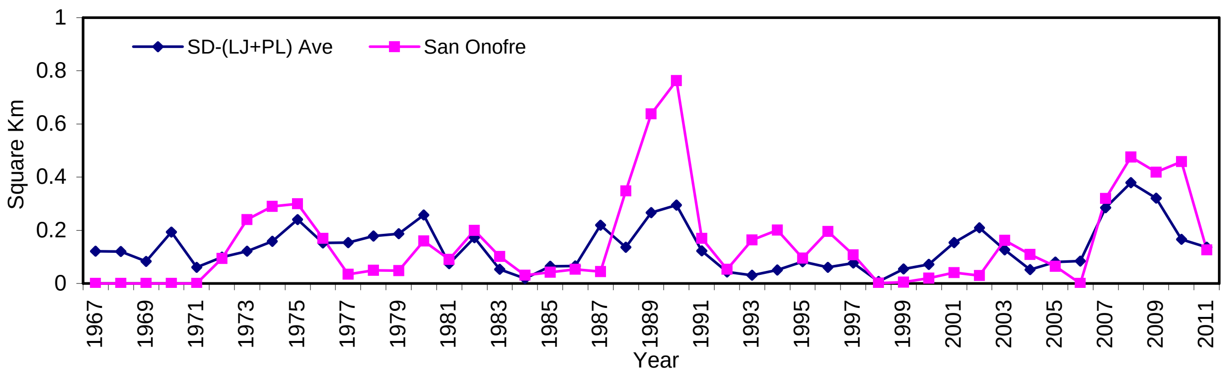


Figure 29. Comparisons between the average SD-(LJ+PL) ABAPY and the canopy coverages of the San Onofre kelp bed for the years shown.

Horno Canyon 2011. Kelp in this region appeared substantial in Crandall's maps of the 1911 survey, recording a canopy coverage of 0.352 km^2. Kelp was not recorded here again until it reappeared at Horno Canyon in 1988 as a very small bed of 0.006 km^2 and 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 at Horno Canyon or at nearby Pendleton Artificial Reef in 2005 as evidenced by boat surveys and the aerial surveys. Conditions began to deteriorate at nearby Barn kelp, indicating that nutrients were lacking in the area. 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 Pendleton Reef (just upcoast of the Horno Canyon area) during a boat survey of the area 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 Pendleton Reefs, a diving survey was conducted in January 2010. Large numbers of sea fans and urchins, but only two ragged and grazed kelp recruits growing on isolated rocks in the area were found. Small kelp beds comprising the Horno Canyon kelp bed appeared numerous by the December 2010 survey and resulted in a total canopy coverge of 0.081 km^2, much larger than 2009 and very near the total in 2008. No kelp was observed on the surface at Pendleton Reef 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. In 2011, the 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 2010-2011 (Figure 30).

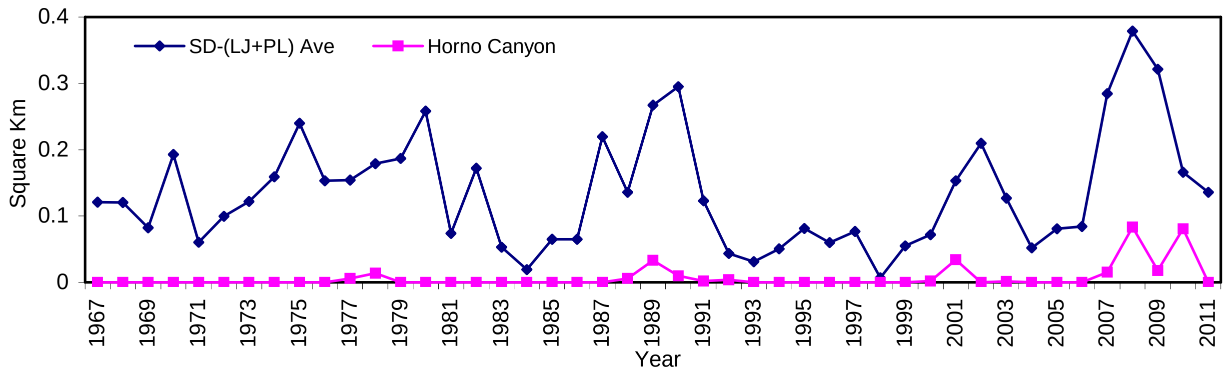


Figure 30. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Horno Canyon kelp bed for the years shown.

Barn Kelp 2011. Barn kelp bed was very large during Crandall's survey of 1911, covering an area of 3.171 km^2. It was next recorded in 1967 as very small 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 0 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 1911. 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 1911 survey), presumably reacting to cooler waters and adequate nutrients. Kelp in 2009 continued to respond to favorable conditions at the end of 2008 and increased to 0.926 km^2 by the March 2009 survey, but decreased thereafter. The bed again began increasing 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 than the 2009 total area coverage, but none-the-less it was still a substantial kelp bed of 0.5 km^2. Extensive kelp canopy was observed during the vessel survey, 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 that there were considerable numbers of new recruits indicating that the bed could make a resurgence. The aerial survey of December 2011recorded a canopy which covered only a small fraction (about 20% = 0.095 km^2) of that observed in 2010. 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 (Figure 31). However, it decreased greater than the other kelp beds in the region in 2011.

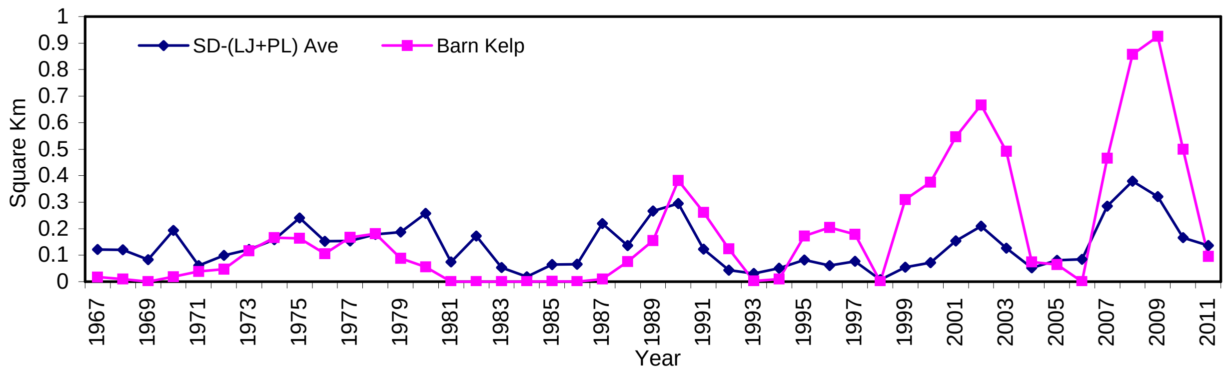


Figure 31. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of Barn Kelp for the years shown.

Santa Margarita 2011. In 1911, Santa Margarita was the site of a substantial kelp bed covering 0.710 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 disappeared and has not been seen since despite searching the area of the last known kelp beds. No kelp was observed at this location in 2011 despite careful viewing of the photos and efforts to find kelp during a 28 December 2011 boat survey.

North Carlsbad 2011. The small kelp beds that comprised North Carlsbad kelp bed were observed to be substantial covering 0.787 km^2 during Crandall's 1911 survey. The bed was next recorded in 1967 as a very small bed covering only 0.009 km^2, but increasing to 0.120 km^2 by 1980, and becoming larger with a canopy size of 0.165 km^2 by 1990. The interim period 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 in the region. 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 in the area, but an increase was observed with a canopy in the region totaling 0.078 km^2 during the late December survey. This bed has disappeared by the August aerial survey, but reappeared in both the October and December surveys as a small bed (0.017 km^2) about one-fifth that observed in 2010. In 2011, 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 (Figure 32).

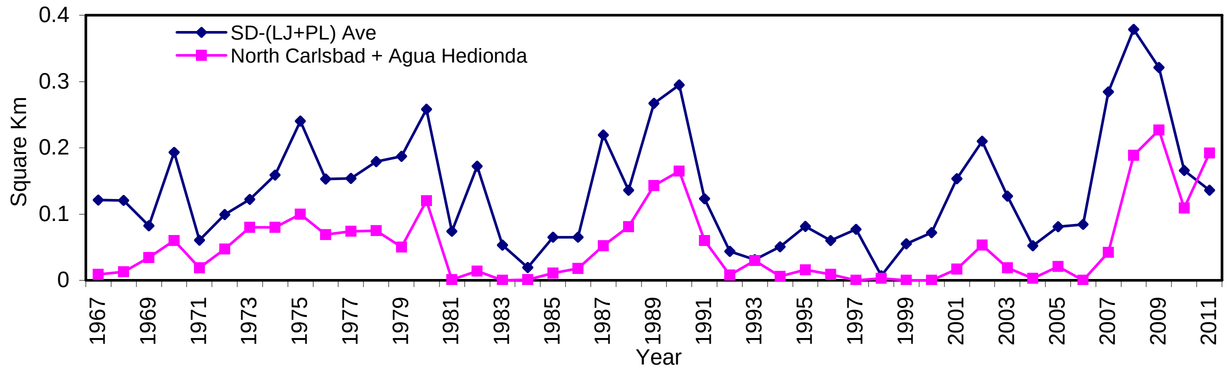


Figure 32. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the North Carlsbad plus Agua Hedionda kelp beds for the years shown.

Agua Hedionda 2011. The kelp beds comprising Agua Hedionda kelp totaled 0.161 km^2 in Crandall's 1911 survey. No bed was recorded here from surveys between 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. Subsequent surveys indicated that the increase in size of the kelp bed noted in late1996 was arrested and the El Niño of 1997-1998 devastated the bed. No kelp was observed at this site after the El Niño of 1997-1998 until a trace of kelp was 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 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 survey in late 2006 in the vicinity of the last known bed indicating that the area was poised to recover pending adequate nutrients and favorable environmental conditions during the remainder of the year. 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 than seen in December 2007, 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 and began to increase again, but the canopy only measured 0.031 km^2 by the December 2010 aerial survey. The increase in kelp coverage and density at Agua Hedionda did not occur until the December 2011 survey when it was measured to cover 0.022 km^2, a decrease of about one-third from 2010. Kelp at this site was scattered, but there were two distinct patches of canopy observed during the aerial survey on 21 December and the vessel survey on 29 December 2012. Observations indicated that there was very little new kelp on the surface and growing tips were missing from most of the fronds indicating the bed was stressed. The ABAPY in 2011 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 32).

Encina Power Plant 2011. The Encina Power Plant kelp canopy covered an estimated area of 0.642 km^2 during Crandall's survey of 1911. Kelp was not observed in the area during surveys from 1967 to 1969, but reappeared in 1990 as a small bed covering 0.025 km^2; by1975 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 following favorable environmental conditions, but 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 the aerial survey of 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, larger than it was estimated to be in 1911. By the March 2009 survey, the kelp canopies had diminished by a third dropping 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 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 0.084 km^2) by about one-half from that observed in 2010. It was fairly large in April 2011, but had decreased considerably by the August survey and began increasing during both the October and December surveys. In 2011, 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 (Figure 33).

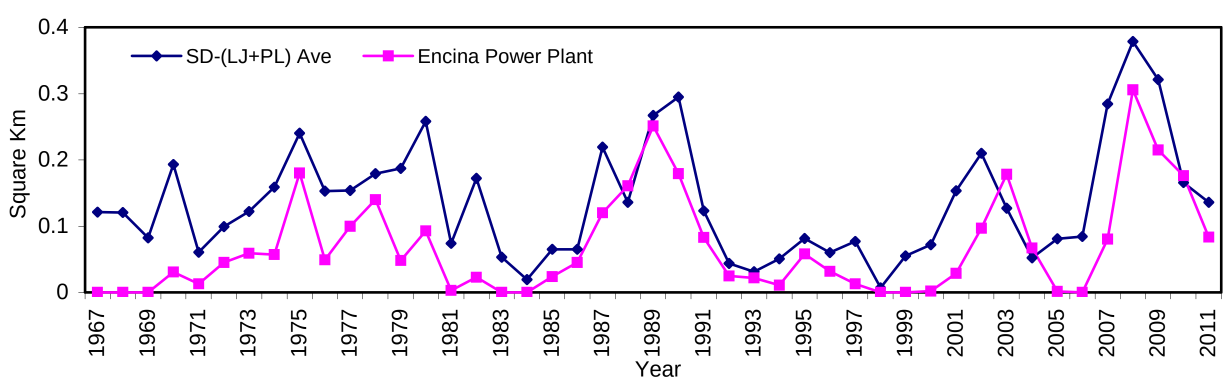


Figure 33. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Encina Power Plant kelp bed for the years shown.

Carlsbad State Beach 2011. This bed was estimated to be composed of many mid-size canopies during Crandall's survey of 1911, covering a total area of 0.278 km^2. 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 less than one half that size 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, which 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. Again, only a trace of kelp was noted at this location during 2004. The kelp bed was not observed in any of the aerial surveys of 2005, nor in any of the other aerial surveys of 2006. It reappeared as small (0.064 km^2) canopies 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 survey and became further reduced by the early November survey, but rebounded by the late December 2010 survey to cover an area of 0.069 km^2 with canopy. 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. In 2011, 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 1980, but generally became a smaller bed thereafter, not reacting favorably to the 1998-1999 La Niña (Figure 34).

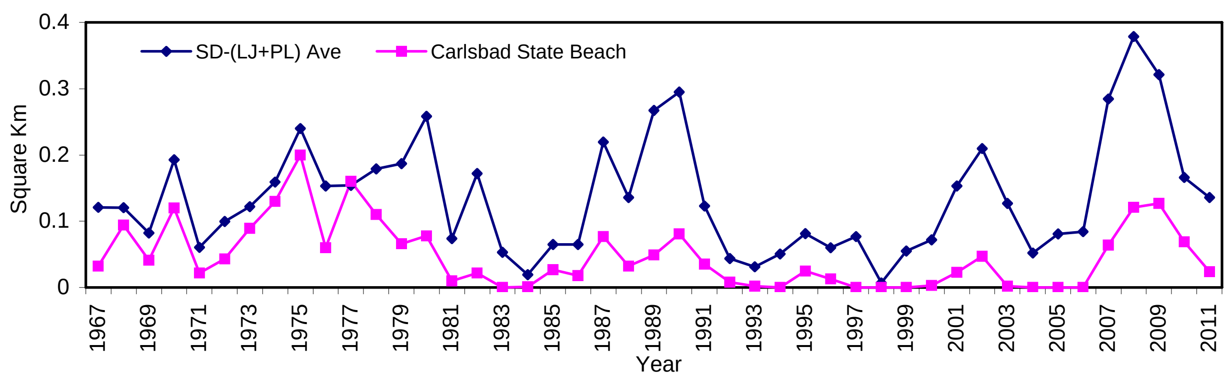


Figure 34. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Carlsbad State Beach kelp bed for the years shown.

Leucadia 2011. The Leucadia kelp beds (sometimes referred to as the North, Central, and South Leucadia kelp beds) covered an estimated area of 1.224 km^2 during Crandall's survey of 1911. 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 to about one-fourth their 2003 size (0.185 km^2) 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, yellowish brown 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 2009 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, but ultimately were the largest during the December 2010 survey with a canopy total of 0.215 km^2, almost exactly one-half what it was in 2009. The northern portion of the Leucadia kelp bed was very poor during the first two aerial surveys not increasing 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. 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 Kelp all decreased by the end of 2011 measuring only 0.119 km^2, about one-half that observed in 2010. In 2011, the ABAPY for the Leucadia kelp beds indicated that these beds mirrored the other beds in the San Diego region from about 1983 to the present, although they did not reach the magnitude of the changes recorded from 1967 to 1980 in the other beds (Figure 35).

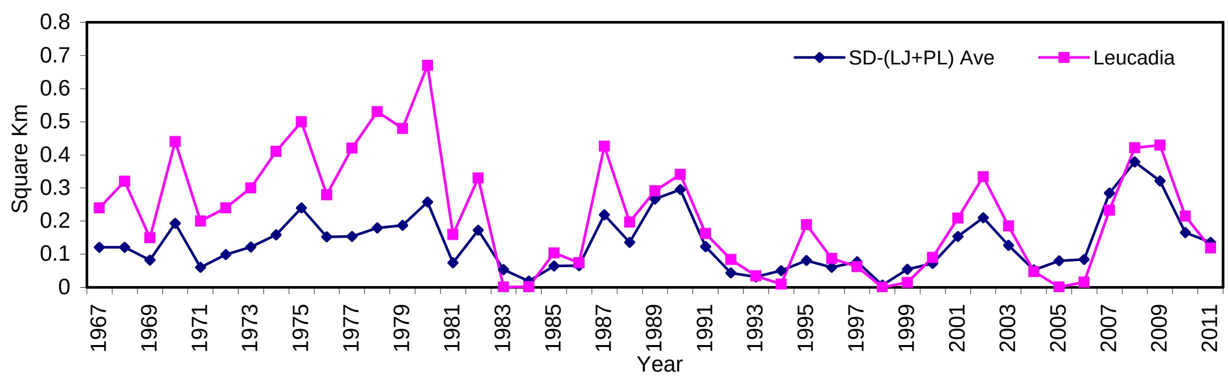


Figure 35. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Leucadia kelp bed for the years shown.

Encinitas 2011. Encinitas kelp bed was estimated to cover about 0.367 km^2 during Crandall's 1911 surveys. This bed was not recorded 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 two-thirds in 2003 and continued a downward trend, as by 2004 the bed was only about one-third the size noted in 2003. 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 June 2008 overflight, but was not substantially larger than that observed in December 2007, but by the December 2008 overflight, the canopies had increased to 0.346 km^2, a size not recorded since the 1911 survey. 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 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, slightly larger than one half its size in 2009. The Encinitas bed covered a very large area in 2011, and unlike the other nearby beds to the north, it did not decrease greatly measuring (0.124 km^2), almost the same as it did in 2010. The vessel survey noted that the kelp color was a medium yellow which typically indicates that nutrients were limiting in the area. In 2011, the ABAPY for the Encinitas kelp bed indicated that this bed almost exactly mirrored the other beds in the San Diego region (Figure 36).

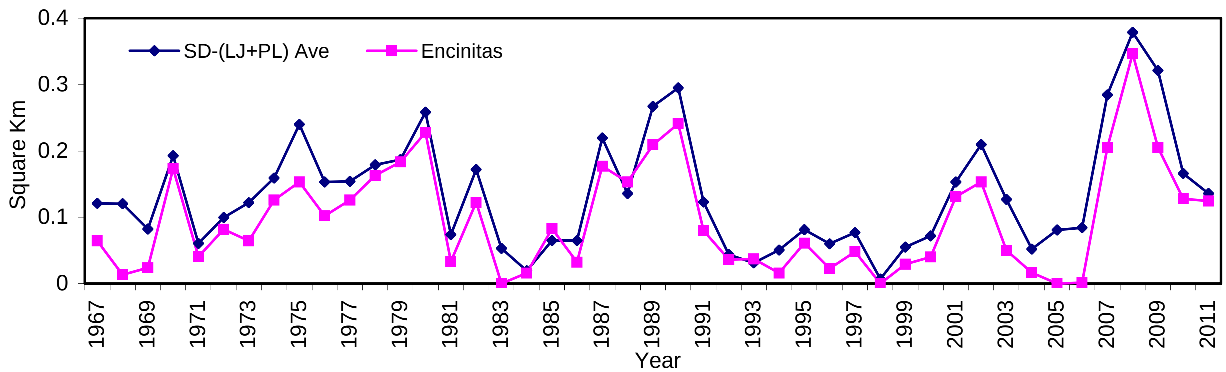


Figure 36. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Encinitas kelp bed for the years shown.

Cardiff and Solana Beach 2011. From Crandall's maps, the kelp bed at Cardiff was estimated to be 0.713 km^2 and the Solana Beach bed was estimated to cover 1.097 km^2. 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 again 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 two kelp beds' 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 ramped up 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 by more than 75% from their size in 2003. 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 2005 year's end, the Cardiff bed had no canopy, while the Solana Beach bed increased. 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, ranging in size from 14 to 18 cm in length, were observed in about a 15-minute survey. Apparently, kelp remained below the thermocline and survived unfavorable environmental conditions (swells, turbidity, and low nutrients) which 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 (a substantial portion of what Crandall reported in 1911 and its largest size since then). 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, almost to 2009 levels. Canopies were noted as very large during the vessel survey, underwater visibility was good, and kelp tissues were dark yellow indicating probably adequate nutrients in the recent past In 2011, the ABAPY for the Cardiff and Solana Beach kelp beds indicated that these beds mirrored the other beds in the San Diego region from about 1983 to the present, although the magnitude of the changes was greater because of the relatively large size of these two beds compared to the remainder of the beds in the region (Figure 37).

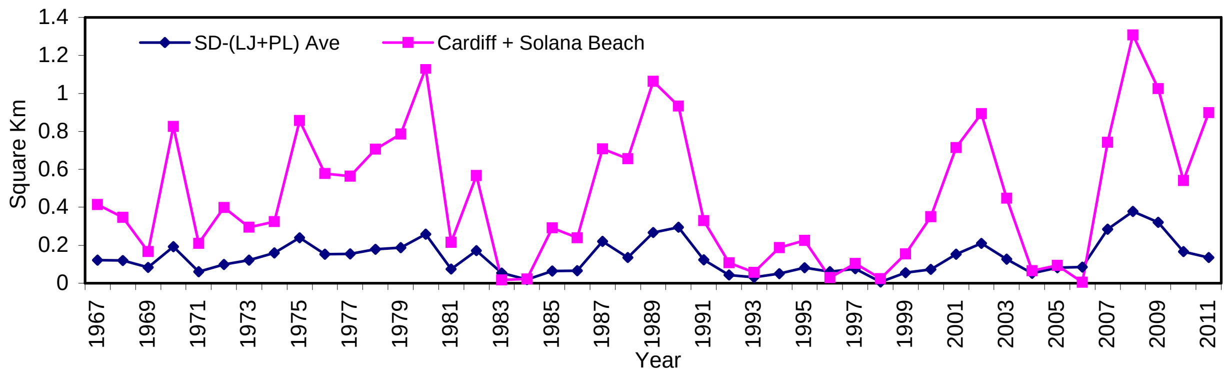


Figure 37. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Cardiff and Solana Beach kelp beds for the years shown.

Del Mar 2011. Del Mar kelp bed was estimated at 0.540 km^2 during Crandall's survey of 1911. Although, the 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 La Niña, and then again was small to very 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 2011to 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 area was available with favorable conditions to potentially grow to the size observed in 1989. In 2011, the ABAPY for the Del Mar kelp bed indicated that this bed which typically had mirrored the other beds in the San Diego region until about 1995, was in lockstep with its nearest neighbors and increased. Generally, from about 1983 to last year it had stayed very small in spite of large stimuli that occurred and affected the other beds in the region (Figure 38).

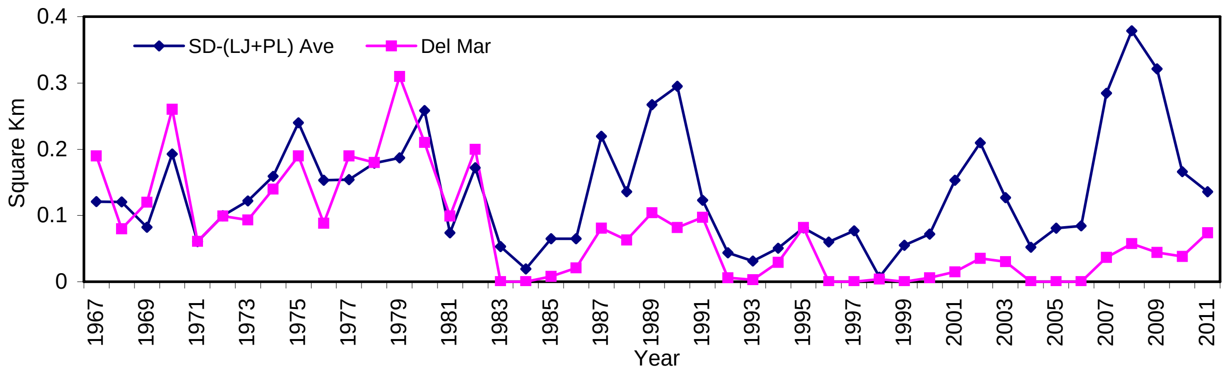


Figure 38. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Del Mar kelp bed for the years shown.

La Jolla 2011. La Jolla kelp bed was composed of two main canopies and were large when Crandall measured them in 1911, covering an area totaling 6.060 km^2. The canopy coverage was larger still in 1934 (8.161 km^2) 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 larger than 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 later 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 (78%) of the size seen in 1911. By 1990, they were 98% 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. They 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 80-ft depth contour on the north edge of the bed and out to 95 ft 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 1/30th - 0.117 km^2- of their 2003 size). 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 (80 ft) 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 and kelp appeared stressed during the first three aerial surveys of 2007, but the beds increased by the December 2007 survey by more than 25-fold (to 2.750 km^2) over their size noted in 2006. 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 June 2009 and stayed smaller 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 16 survey, both the upper and lower section of the La Jolla Kelp bed were not showing much canopy; they slowly increased by the August and October surveys, but they were still below average. By the 21 December 2012 survey, the bed had responded very favorably to nutrient pulses noted in Scripps Pier SST data and increased to 2.565 km^2, a substantial fraction of the amount noted in 2010. The vessel survey about one week later confirmed that nutrients had been present recently as all of the surface fronds were a dark yellow indicative of an ample supply of nutrients. In 2011, 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, suggesting that they are affected by the same oceanographic regime (Figure 39).

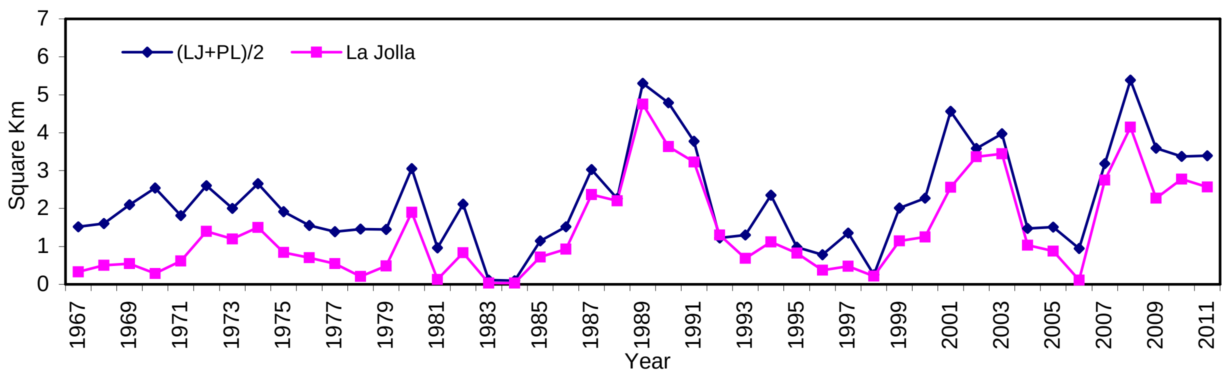


Figure 39. Comparisons between the (LJ+PL)/2 ABAPY and canopy coverages of the La Jolla kelp bed for the years shown.

Point Loma 2011. The Point Loma kelp bed is composed of many usually contiguous kelp canopies ranging from depths of 15 ft to over 100 ft 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 18.675 km^2 (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 suffered a reversal during some portion of the next 14 years, as by 1955 they 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 covered 2.700 km^2, growing larger with a canopy coverage of 4.990 km^2 by 1970. Over the next 10 years to 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 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 areas began to dissipate and were noticeably less during all of the 2002 surveys, retreating from deeper depths, but still covering much of the same area. It was, however, noticeably more diffuse and scattered holes were noted along the entire length of the bed. After experiencing a loss of 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 again began to decrease and was less than one half its 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), but was still less than one half that noted in 2003. In 2006, the bed remained substantial, but a somewhat smaller bed than noted 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 (an area of 1.767 km^2) was only about 40% of its size recorded in 2003. It appeared to be much reduced during the first three aerial surveys of 2007, but responded well to apparent increases in nutrients and increased to 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 2008, decreased somewhat during the summer, and by December 2008 rebounded to the largest (a total canopy coverage of 6.631 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, increased slightly to 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 alarmingly throughout the remainder of 2010. The April 16 survey indicated both the upper and lower portions of Point Loma were in very poor condition; however, by the August survey small improvements were noted in the canopies (better 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, larger than it had been in 2010. In 2011, 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 oceanographic regime (Figure 40).

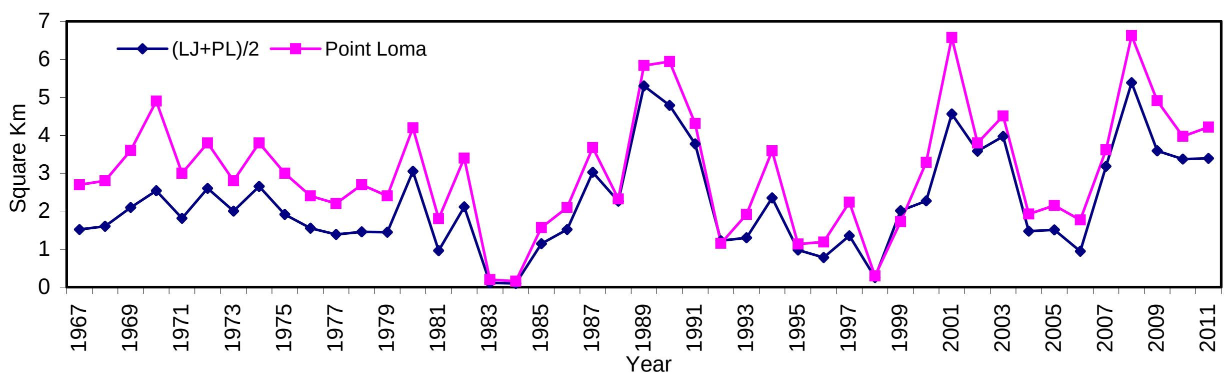


Figure 40. Comparisons between the (LJ+PL)/2 ABAPY and canopy coverages of the Point Loma kelp bed for the years shown.

Imperial Beach 2011. The Imperial Beach kelp bed canopies were recorded as covering 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 further 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 survey 2006, 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 further 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 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 which 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. Examining the swell record from the CDIP Point Loma South station which is offshore of Imperial Beach, it appears swells may have been the cause or at least contributed to the loss. Wave heights in late December and January reached 3 to 4 m on several occasions. This included a one week period in January with sustained swells exceeding 3 m. It is very likely that these sustained swells had a serious deleterious effect on the kelp found on the cobble bottom of this region. The bed was represented only by 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, small (0.152 km^2) but considerably larger than noted in 2010. By the December survey, the beds had begun to decrease again. Interestingly, the vessel survey determined that one small canopy noted was actually comprised of elkhorn kelp *(Pelagophycus porra*). In 2011, the ABAPY for the Imperial Beach kelp beds indicated that this bed followed the San Diego region kelp bed ABAPY by increasing, but more sharply than those of the other beds (Figure 41).

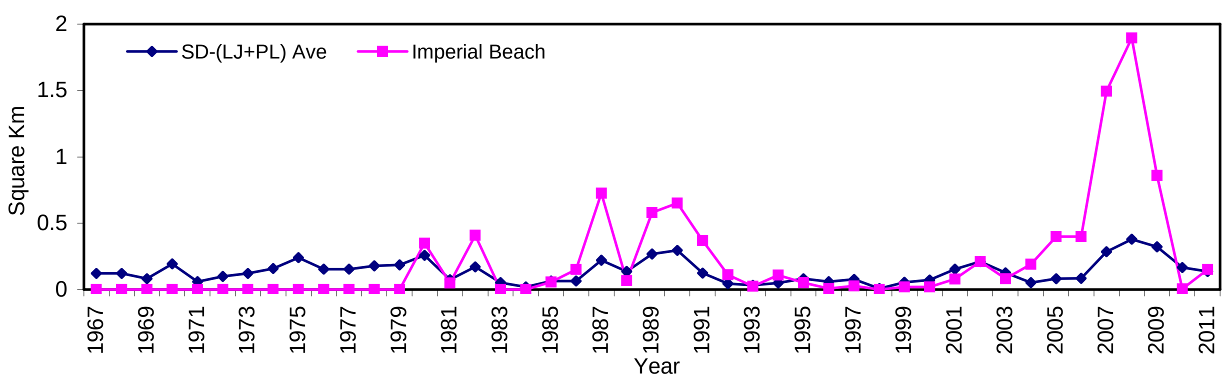


Figure 41. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages of the Imperial Beach kelp bed for the years shown.

2012 UPDATE TO THE PRESENT

One aerial survey for 2012 has been conducted and been critically evaluated. This survey was conducted on 6 April 2012. The daily pattern in temperature change tracked closely between the northern and southern automated sampling stations through May 2012 (the latest data available); however, SSTs at Scripps Pier were slightly warmer than at Newport Pier (Figures 9 and 11). Temperatures oscillated above and below the long-term mean during this same period in both the southern and northern portions of the range. At this early stage, it is unclear how the Region Nine kelp beds will fare in 2012; however, based on boat surveys in the northern portion of the range, kelp beds are continuing to expand from what was observed in December 2011. Most recently, the models being used to forecast El Niño suggest neutral conditions developing and possibly reentering a El Niño phase. The year end result may enhance or reverse the April survey status of the beds in Region Nine.

DISCUSSION

Based on the analysis of the oceanographic data and the aerial overflight surveys in 2011, kelp growth within the 25 kelp beds monitored as part of the Region Nine program was reduced in the early portion of the year, and then responded to nutrient pulses from mid-February until the end of October, but staying cool through the remainder of the year. Most of the kelp beds saw their largest canopies in December as is typical; however, many beds were equally large in the August and October surveys which typically is a very poor period for growth. Sea surface temperatures in 2011 were generally well below average during most of the year in the north and slightly below average in the middle portion of the range, but again well below average at Scripps Pier in the south. For the 2011-2012 season, the NQ for the waters off Scripps Pier was 30, while off Imperial Beach the NQ was 21, indicating nutrients were marginal during this period in that region. This would explain why the kelp beds in the extreme southern region (lower Point Loma, and Imperial Beach) were heavily impacted during the latter part of 2011.The surface waters of Newport Beach (in the 2011-2012 season) had an NQ of 34, suggesting more than adequate availability of nutrients explaining the growth in the northern section. However, the nutrient availability at San Clemente Pier with an NQ of 23 appeared to be marginal. Therefore kelp beds in the San Clemente to Del Mar area had mixed reactions based on the availability of nutrients. By the final survey of 2011, the strong response of the kelp beds across the region suggested that nutrients were available in the region that were not necessarily being detected by SSTs. These stealth nutrient pulses were apparently due to local upwelling which gave an impetus to the kelp canopies in the region beyond what was recorded in the SSTs resulting in canopies along the Region Nine coastline reconstituting to sizes that were a large percentage of that recorded in early 2010. Overall, most of the kelp beds persisted into 2012 fairly healthy. Canopy coverage appears to have responded favorably in the region by maintaining the robust canopies observed in December 2010. A La Niña persisted through much of 2011 and contributed to a recovery of many of the kelp beds to significant fractions of what was observed during late-2008. The ongoing discussion at the El Niño watch forum suggests the region has transitioned to neutral conditions by May 2012. In light of recent studies suggesting that all of southern California, since 1977, has been subjected to a marine environment relatively depleted in nutrients, the recent La Niña has been welcome.

CONCLUSION

Kelp canopy coverage was very good in 2011 and would have been considered phenomenally good if not for the size of the canopies that were measured at the end of 2008 (and in 2009). The differing responses of the Region Nine kelp beds are indicative that during marginal nutrient conditions their viabilities are determined by differing localized factors, which reflect the variability in flow regimes and oceanographic conditions, from locally and regionally determined sources.

Based on the results of the 2011 surveys, there were two kelp beds (Barn Kelp and Imperial Beach kelp bed) that appeared to be responding atypically to environmental inputs when compared to neighboring beds in the region. The almost entire loss of these two beds was not consistent with temperature regimes in the adjoining areas. An examination of the swell record could potentially implicate large swells in the reduction of the Imperial Beach Kelp bed which was very sudden; as the kelp grows on cobble bottom in this area, it is especially susceptible to storm damage. The loss of Barn Kelp is likely due to urchins based on the diver surveys which recorded numerous floating holdfasts infested with urchins and many extant kelp under attack from purple urchins. Although the data would suggest very good growth in 2011, most of the canopies seen in 2011 were smaller than observed in 2010. It appears that good nutrient conditions mitigated some of the damage noted by the April 2011 survey and certainly contributed to a fairly large resurgence of kelp canopy in Region Nine by the end of 2011. Without the continued pulses of nutrients recorded all summer long, it is very likely that there would have been a very large reduction from the 11.706 km^2 of canopy coverage in 2010 to far less than the 10.797 km^2 of kelp coverage still in the region in December 2011. Individual beds reacted differently to what on the surface appeared to be identical stimuli. This illustrates that conditions throughout Region Nine are determined by differing localized factors, which reflect the variability in flow regimes and oceanographic conditions, locally and regionally determined sources of turbidity, the angle of the coastline, and exposure to swells. If the influence is region wide, it may indicate an overarching influence to varying degrees by larger scale meteorological cycles such as Pacific Decadal Oscillation, Inter-decadal Pacific Oscillation, and the El Niño Southern Oscillation (Power et al. 1999, Verdon et al. 2004, Verdon and Franks 2006).

The 2011 kelp study again demonstrated that oceanographic environmental factors controlled the fate of the Region Nine kelp beds. There was no evidence to suggest any perceptible influence of the various dischargers on the persistence of the regions giant kelp beds.

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PERSONAL COMMUNICATIONS

Curtis, M. 2010, 2011. Michael Curtis is a kelp biologist with MBC Applied Environmental Sciences working with kelp ecosytems in the Southern California Bight.

Elwany, H. 2007. Dr. Hani Elwany 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.

Pondella,II, D. 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 has investigated the distribution of phytoplankton species within Santa Monica Bay and their relationship to coastal processes.

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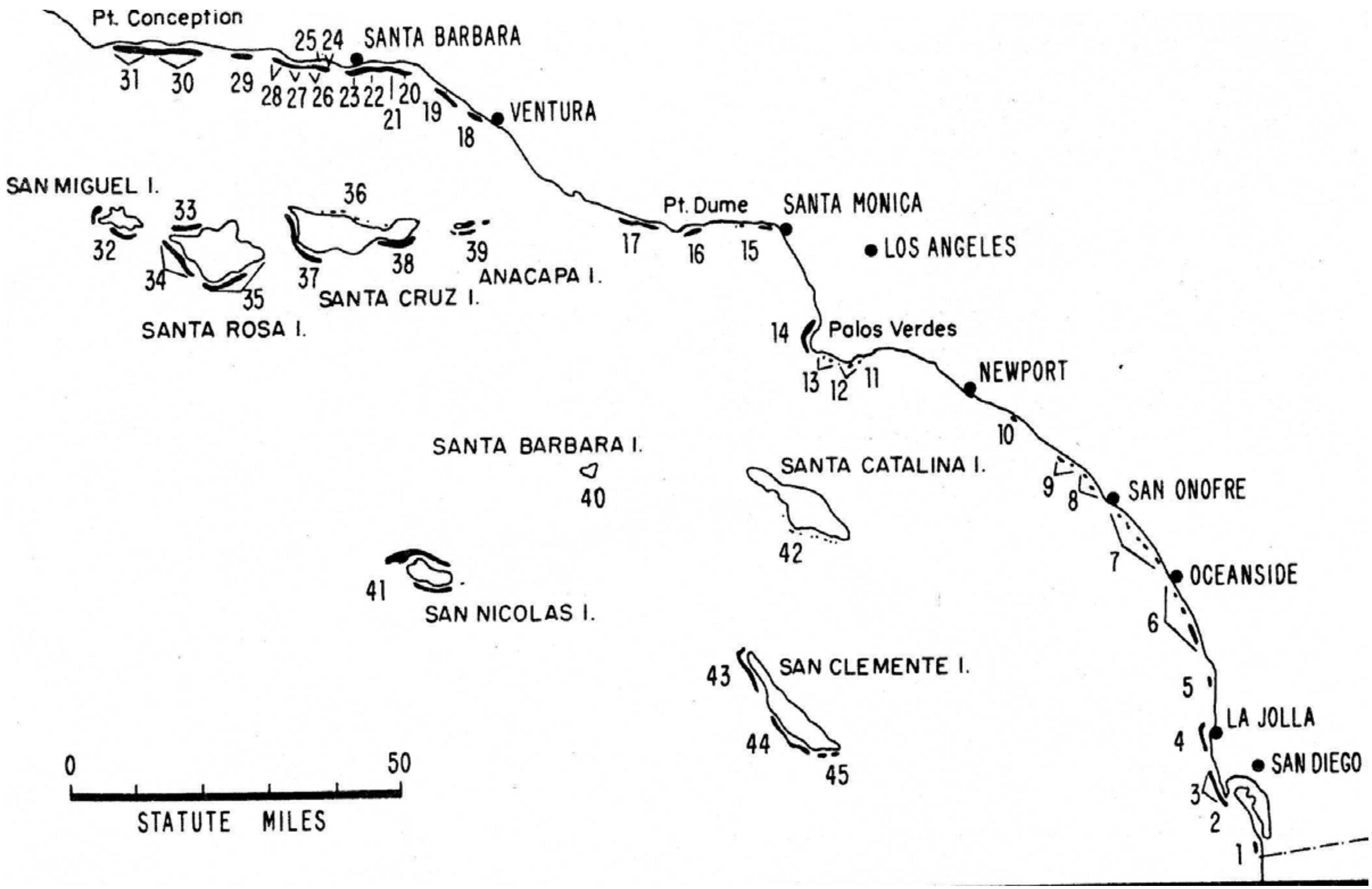
APPENDIX A

Kelp Canopy Maps

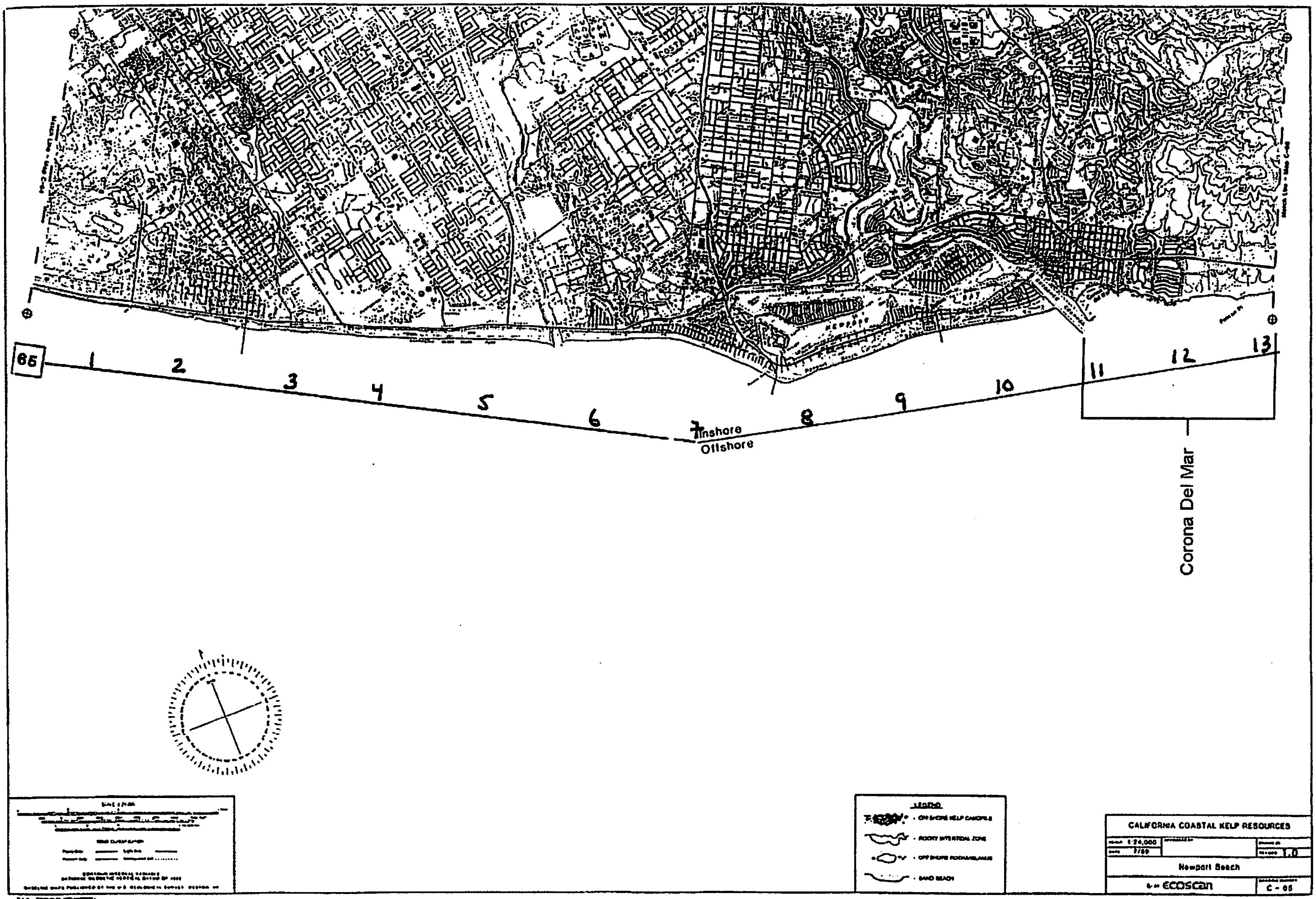


Appendix A. Fish and Game designated kelp bed numbers in the Southern California Bight.

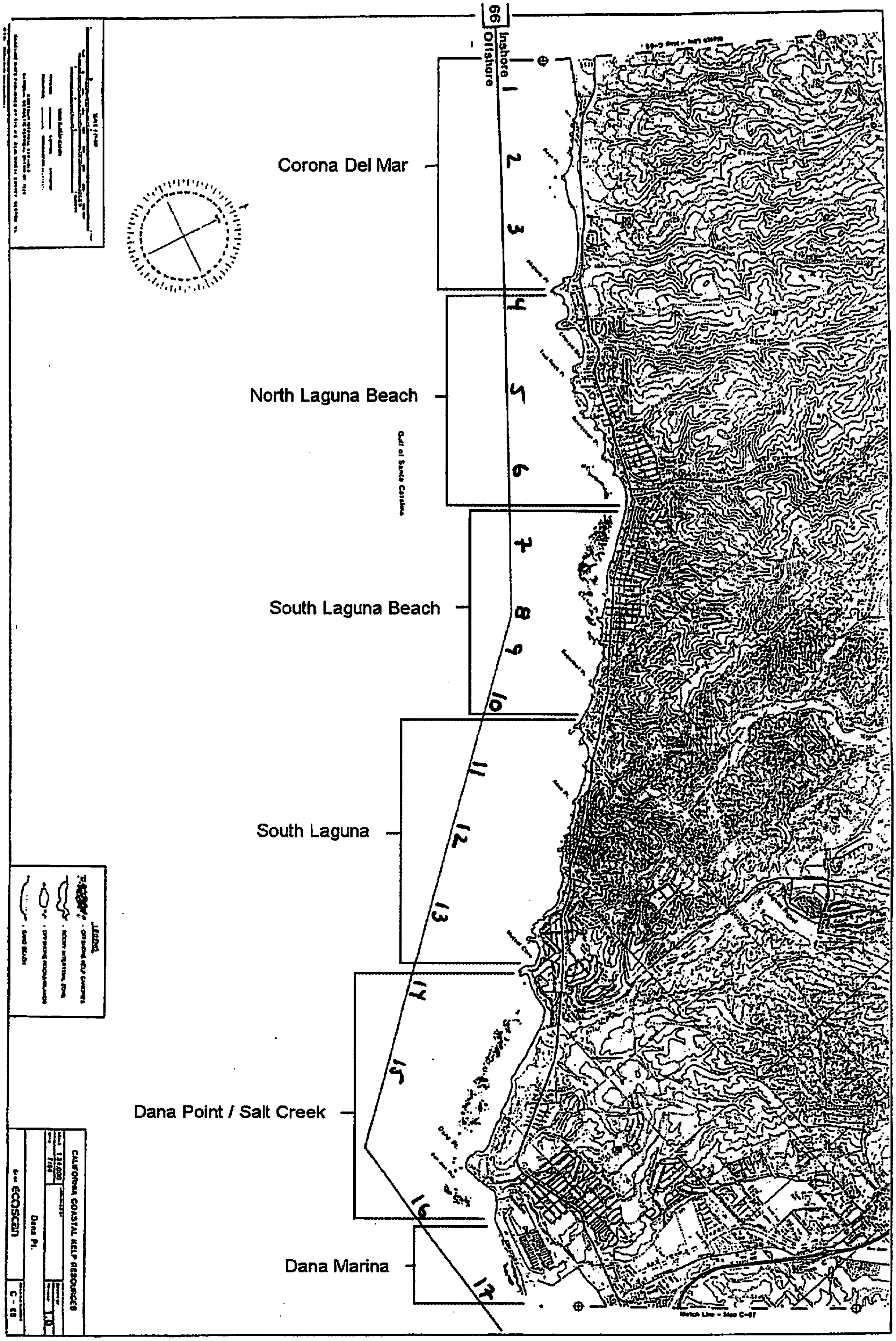
Kelp Slide Atlas

Region Nine

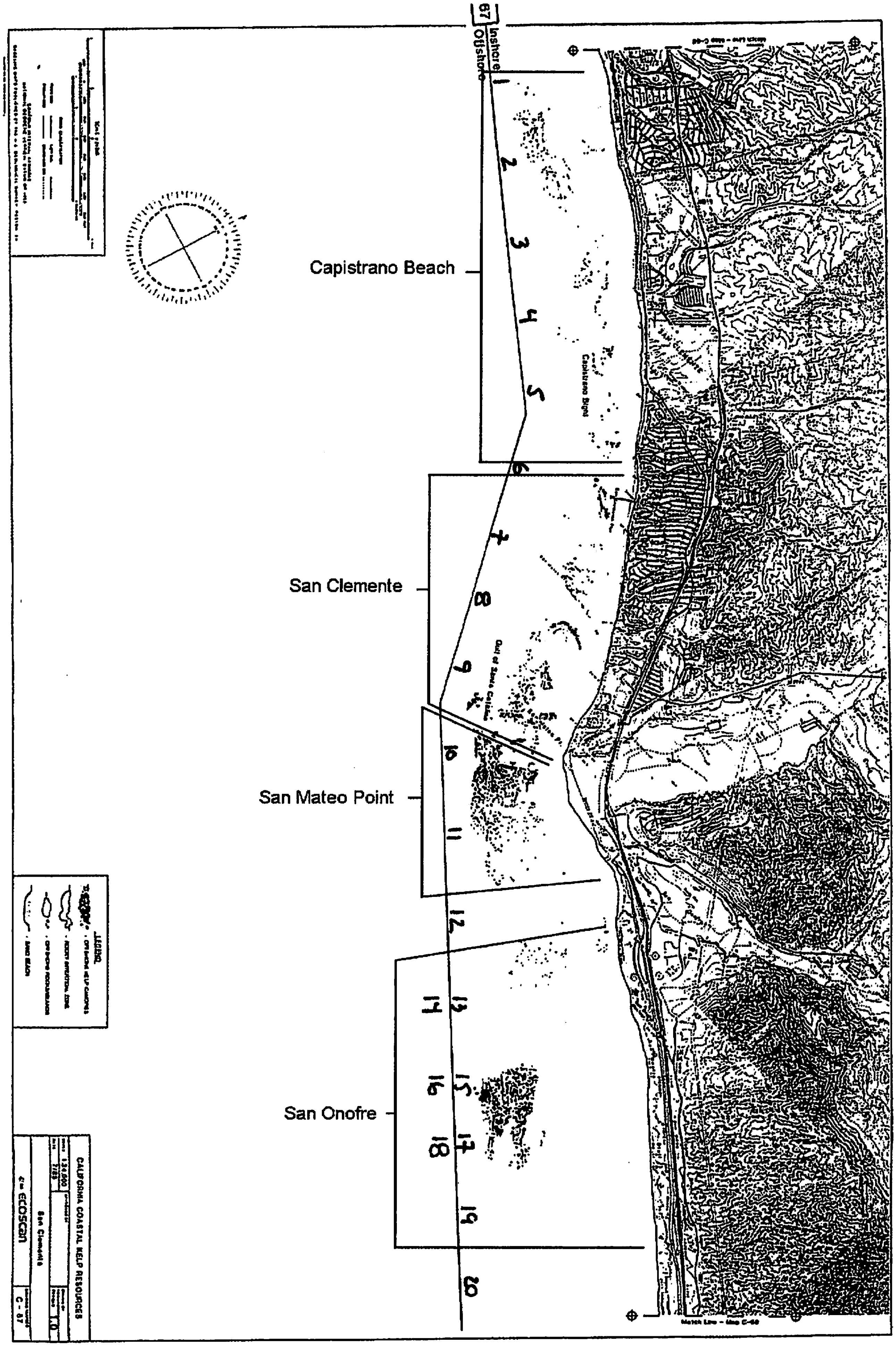
Kelp Bed	Map	Shot Nos
Newport Harbor*	65	15-18
Corona del Mar	65, 66	17--20, 1--3
No. Laguna Beach	66	4--6
So. Laguna Beach	66	7--10
South Laguna	66	11--13
Salt Creek-Dana Point	66	13--16
Dana Marina *	66	17
Capistrano Beach	67	1--6
San Clemente	67	6--9
San Mateo Point	67	10--12
San Onofre	67	13--19
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

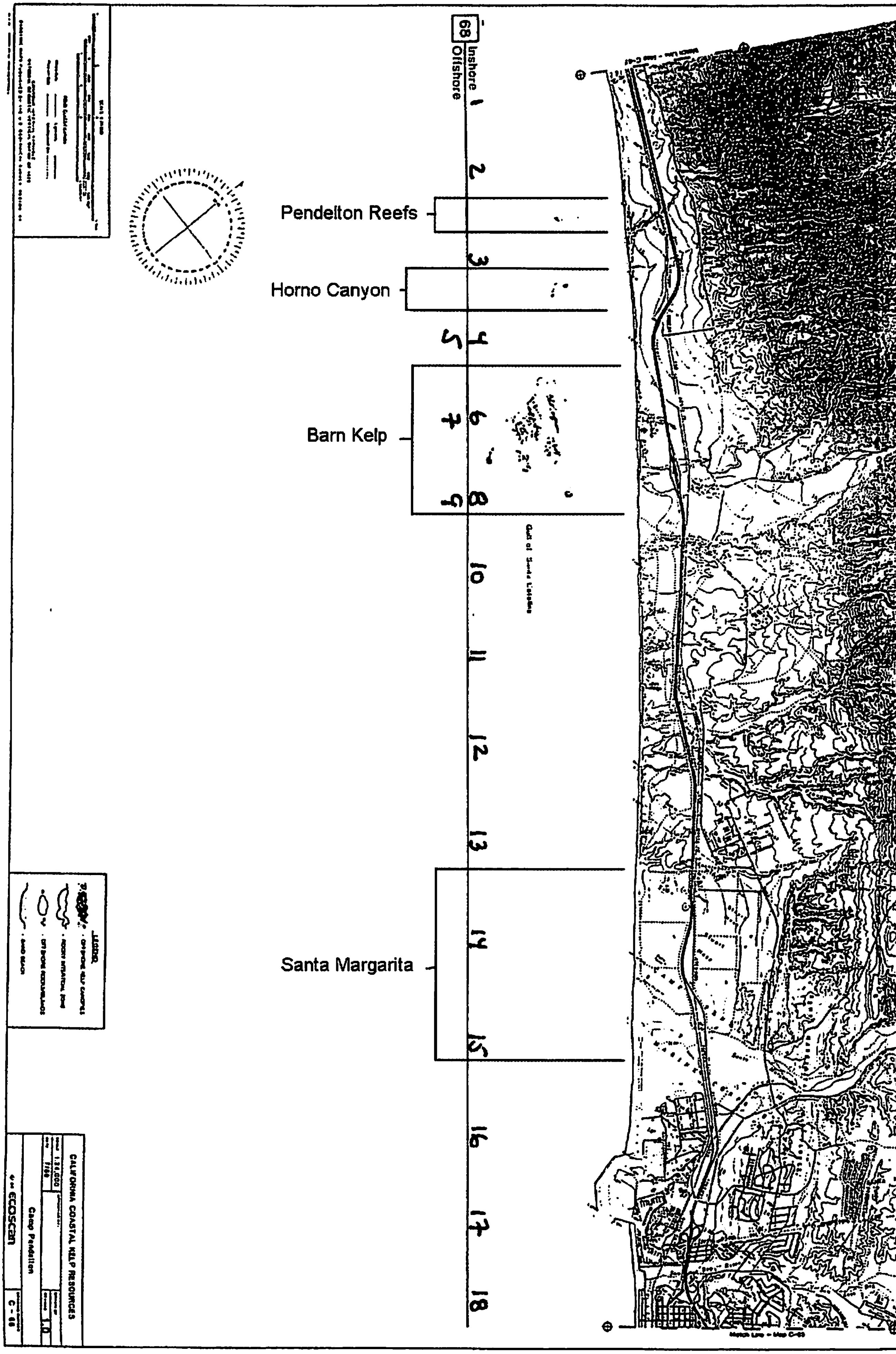


65
1
2
3
4
5
6
7
8
9
10
11
12
13
Inshore
Offshore
Corona Del Mar
LEGEND
ROCKY INTERTIDAL ZONE
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
1.0
Newport Beach
ECOSCAN
C - 65

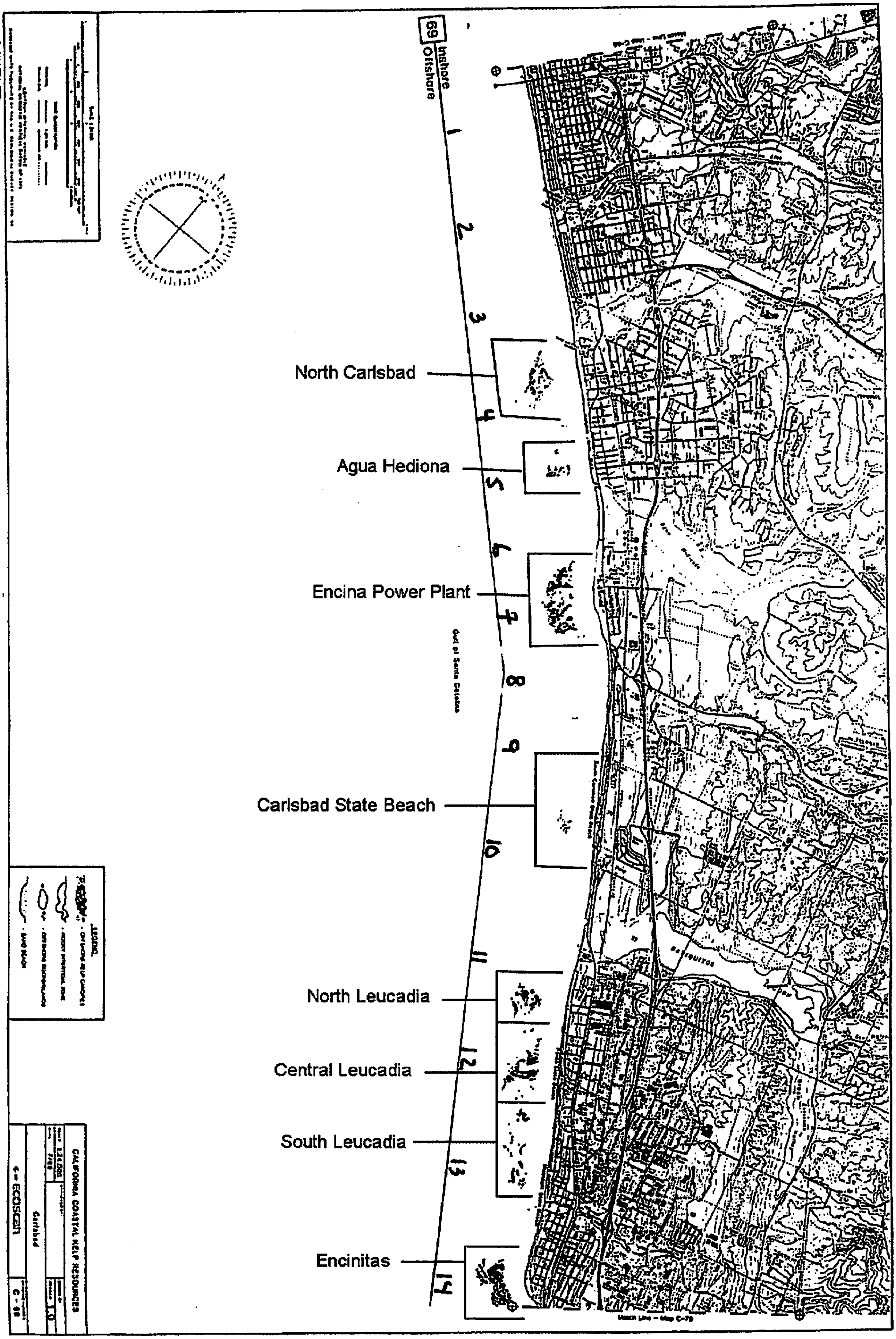


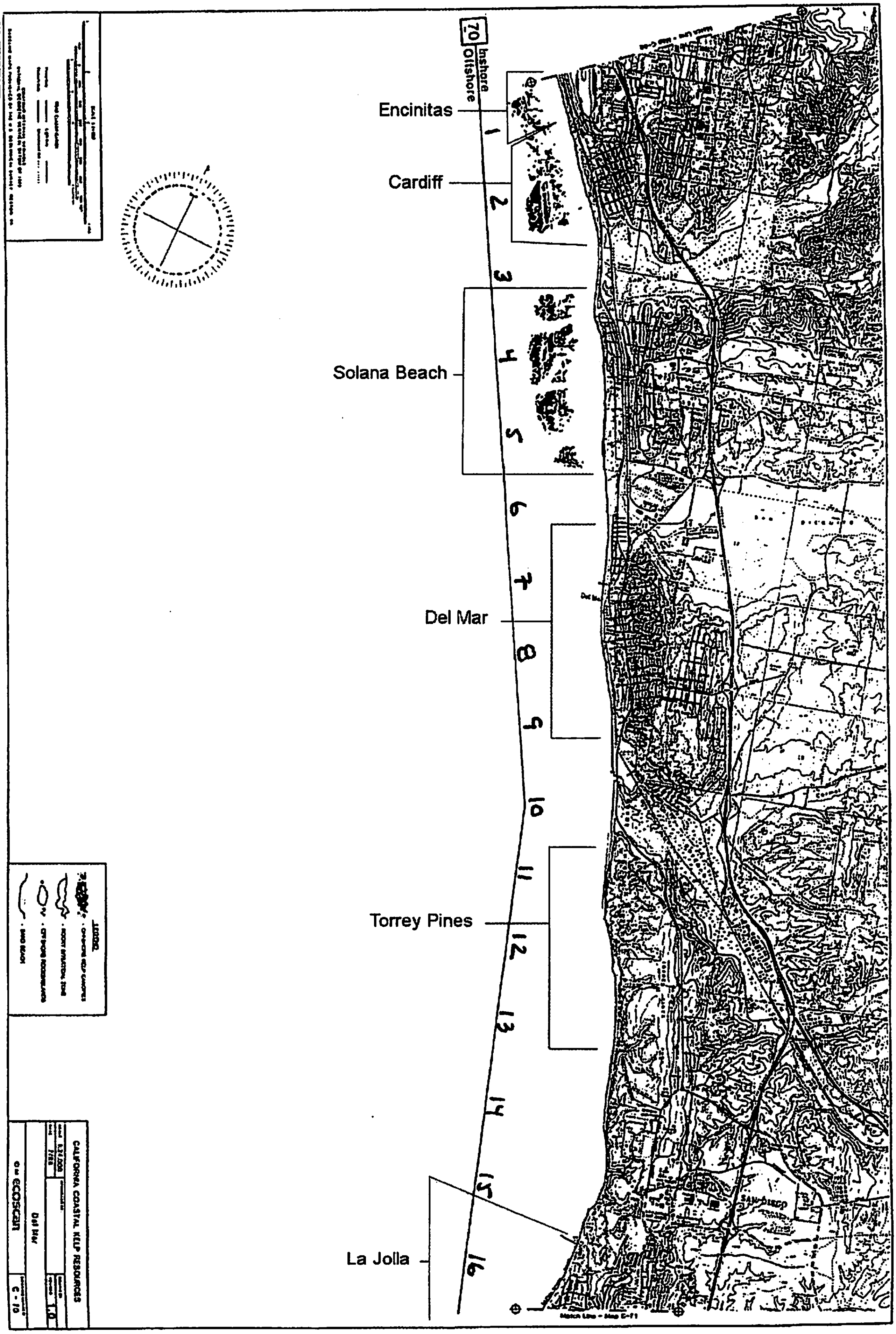
99
Inshore
Offshore
Corona Del Mar
North Laguna Beach
South Laguna Beach
South Laguna
Dana Point / Salt Creek
Dana Marina
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
CALIFORNIA COASTAL KELP RESOURCES
Dana Pt.


Capistrano Beach
San Clemente
San Mateo Point
San Onofre

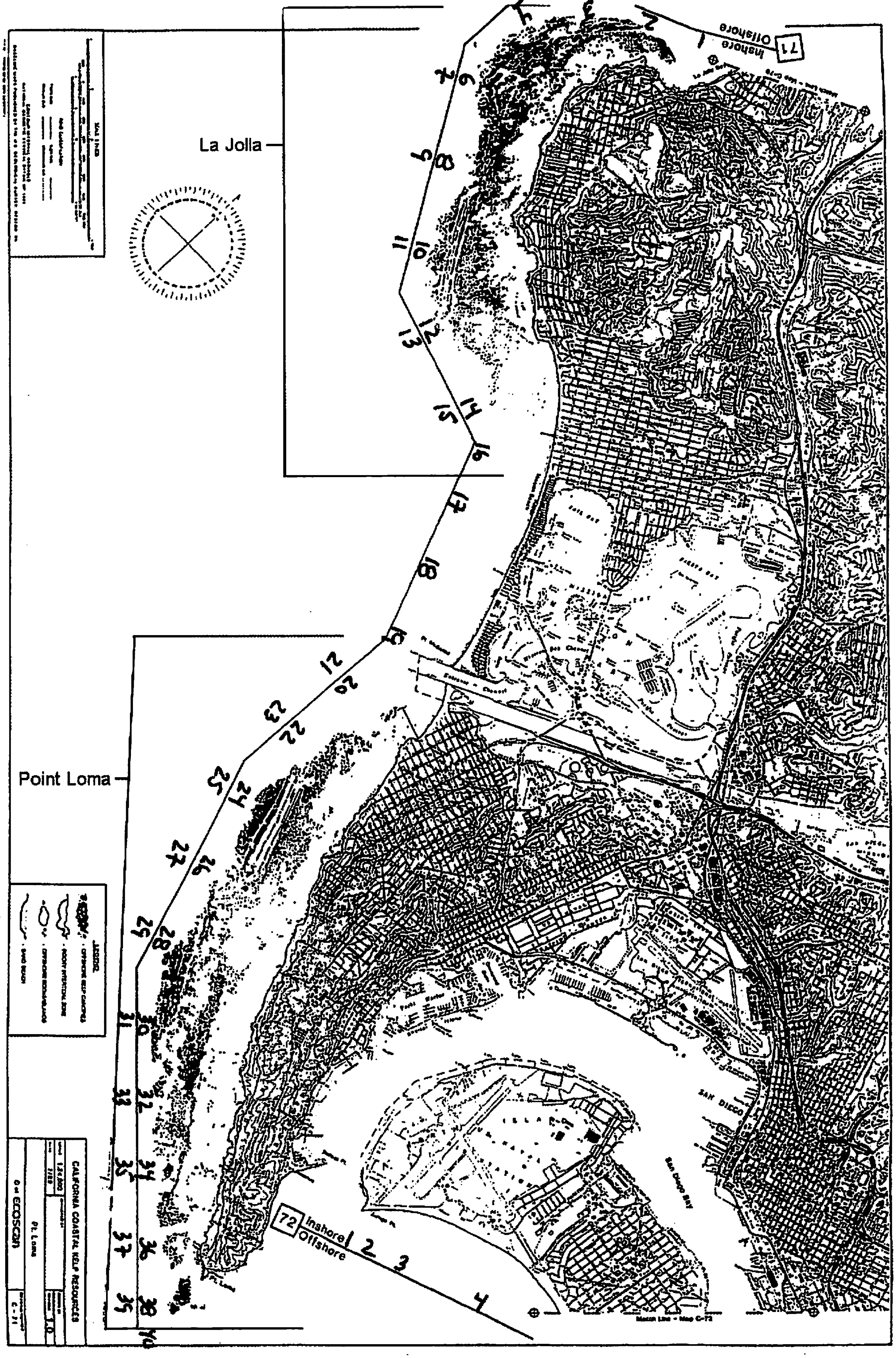


68 Inshore
Offshore
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Pendelton Reefs
Horno Canyon
Barn Kelp
Santa Margarita
CALIFORNIA COASTAL KELP RESOURCES
Camp Pendelton
ecoscan
C-68

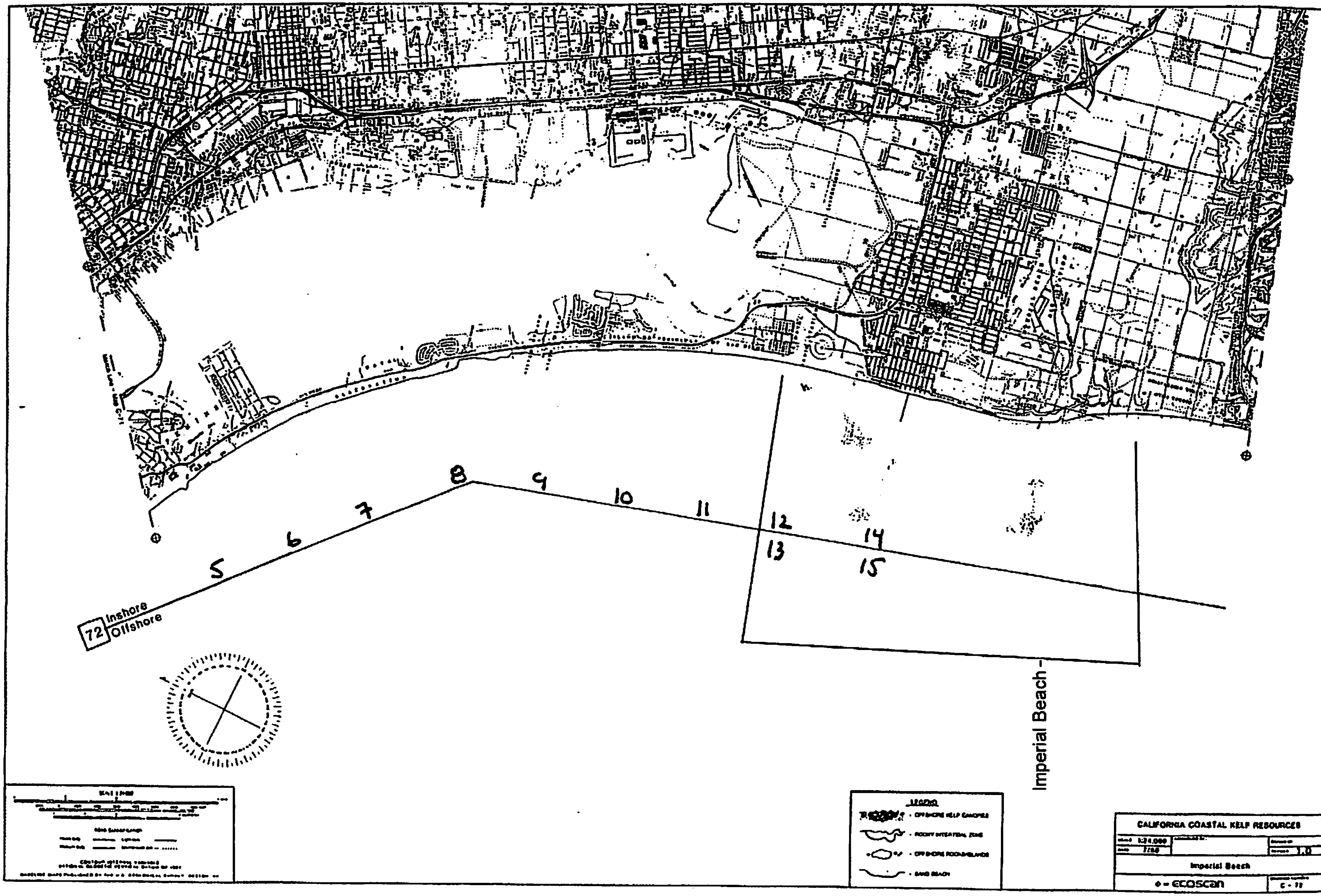

North Carlsbad
Agua Hediona
Encina Power Plant
Carlsbad State Beach
North Leucadia
Central Leucadia
South Leucadia
Encinitas



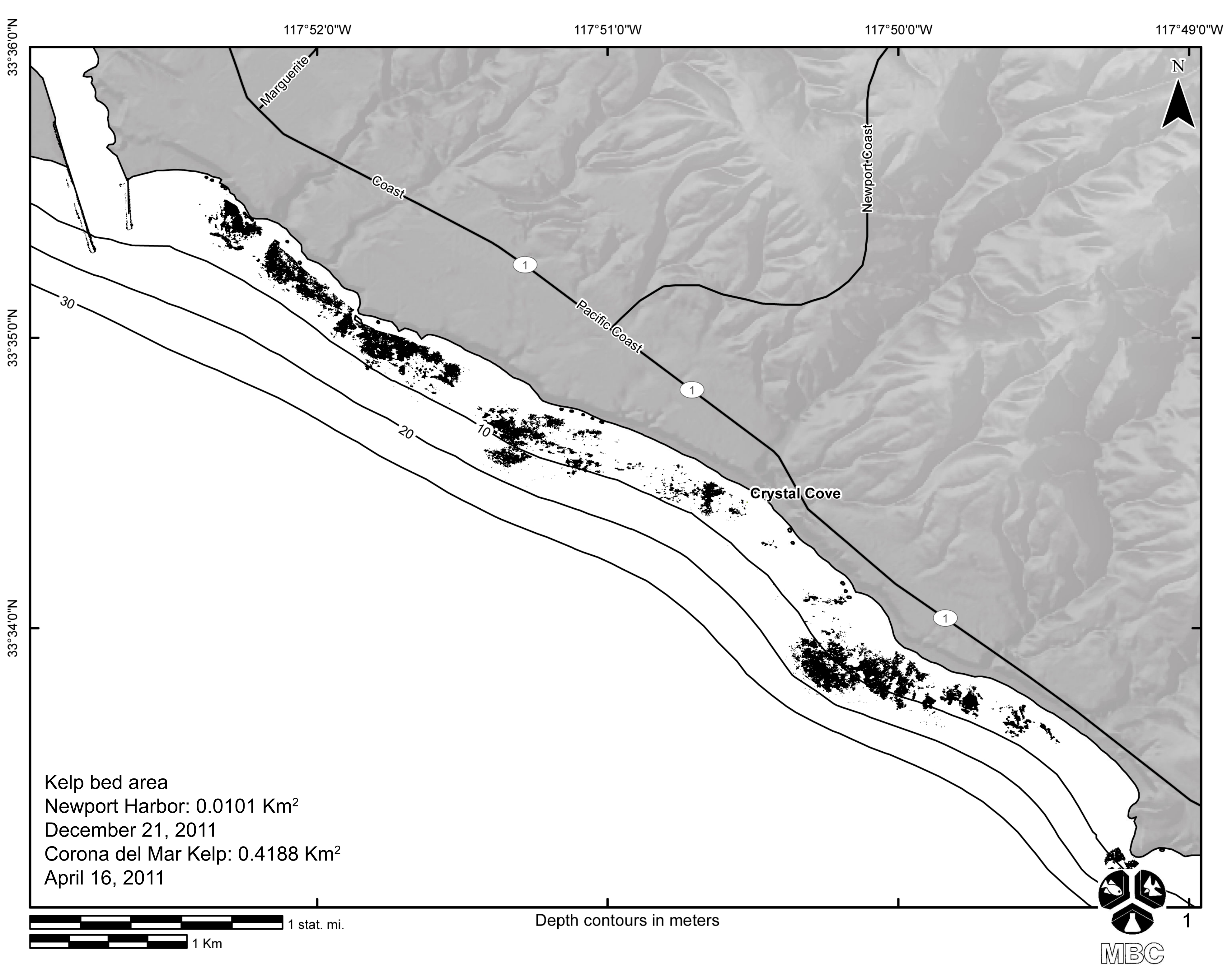
70
Inshore
Offshore
Encinitas
Cardiff
Solana Beach
Del Mar
Torrey Pines
La Jolla
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
CALIFORNIA COASTAL KELP RESOURCES
Del Mar
ecoscan
C - 10

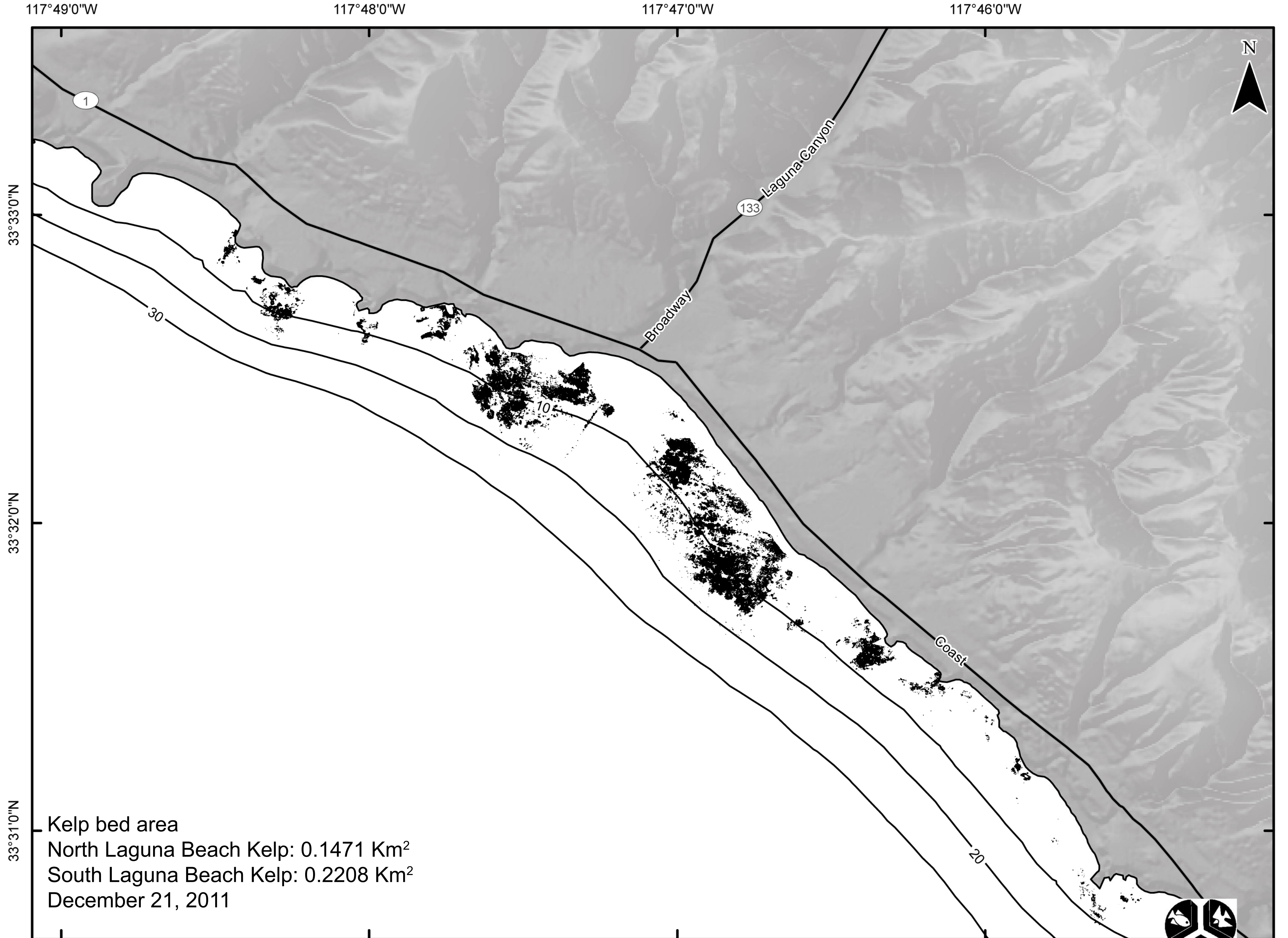


La Jolla
Point Loma
71
Inshore
Offshore
72
Inshore
Offshore
CALIFORNIA COASTAL KELP RESOURCES
Pt. Loma
SAN DIEGO
San Diego Bay

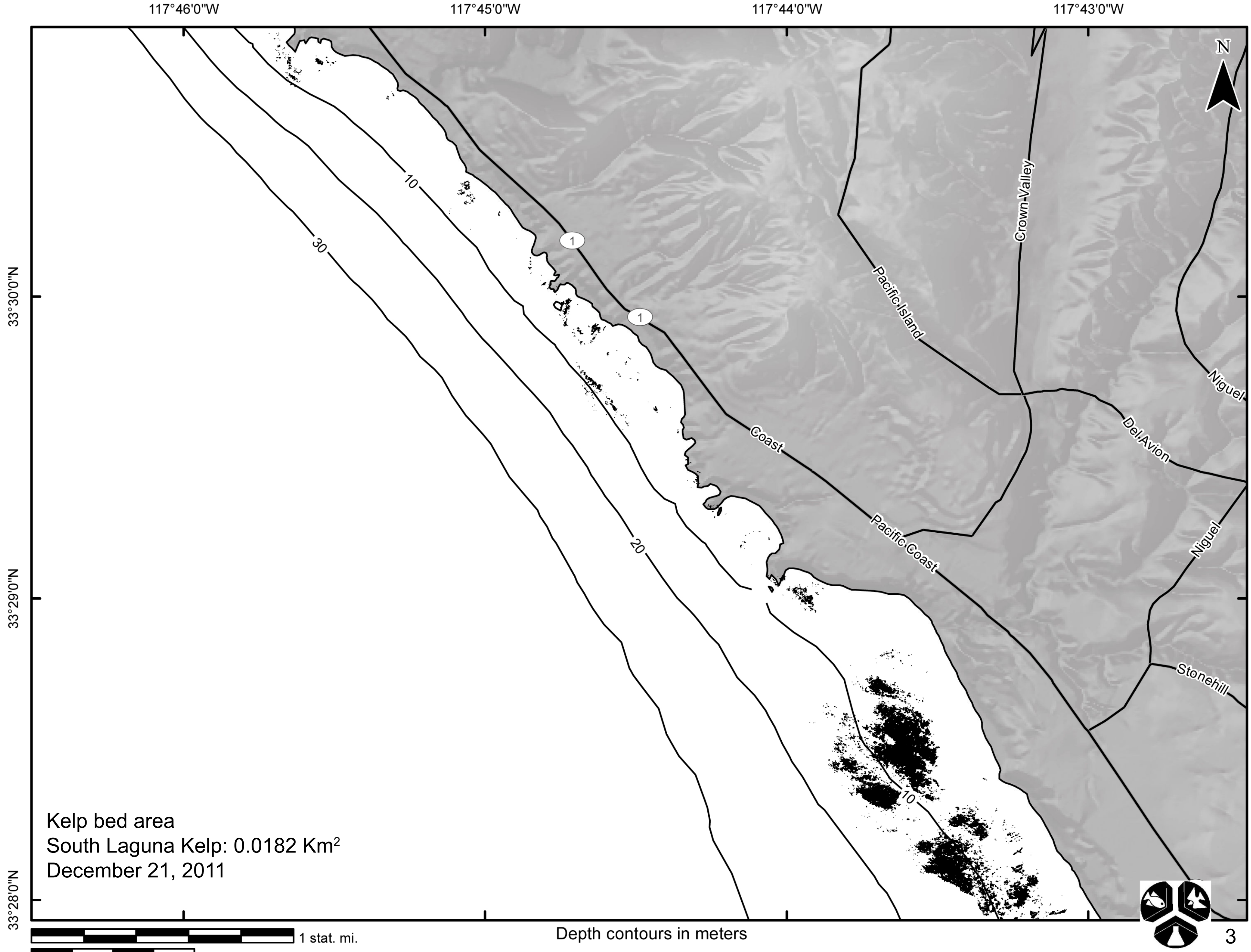


72 Inshore
Offshore
5
6
7
8
9
10
11
12
13
14
15
Imperial Beach
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Imperial Beach
ECOSCAN

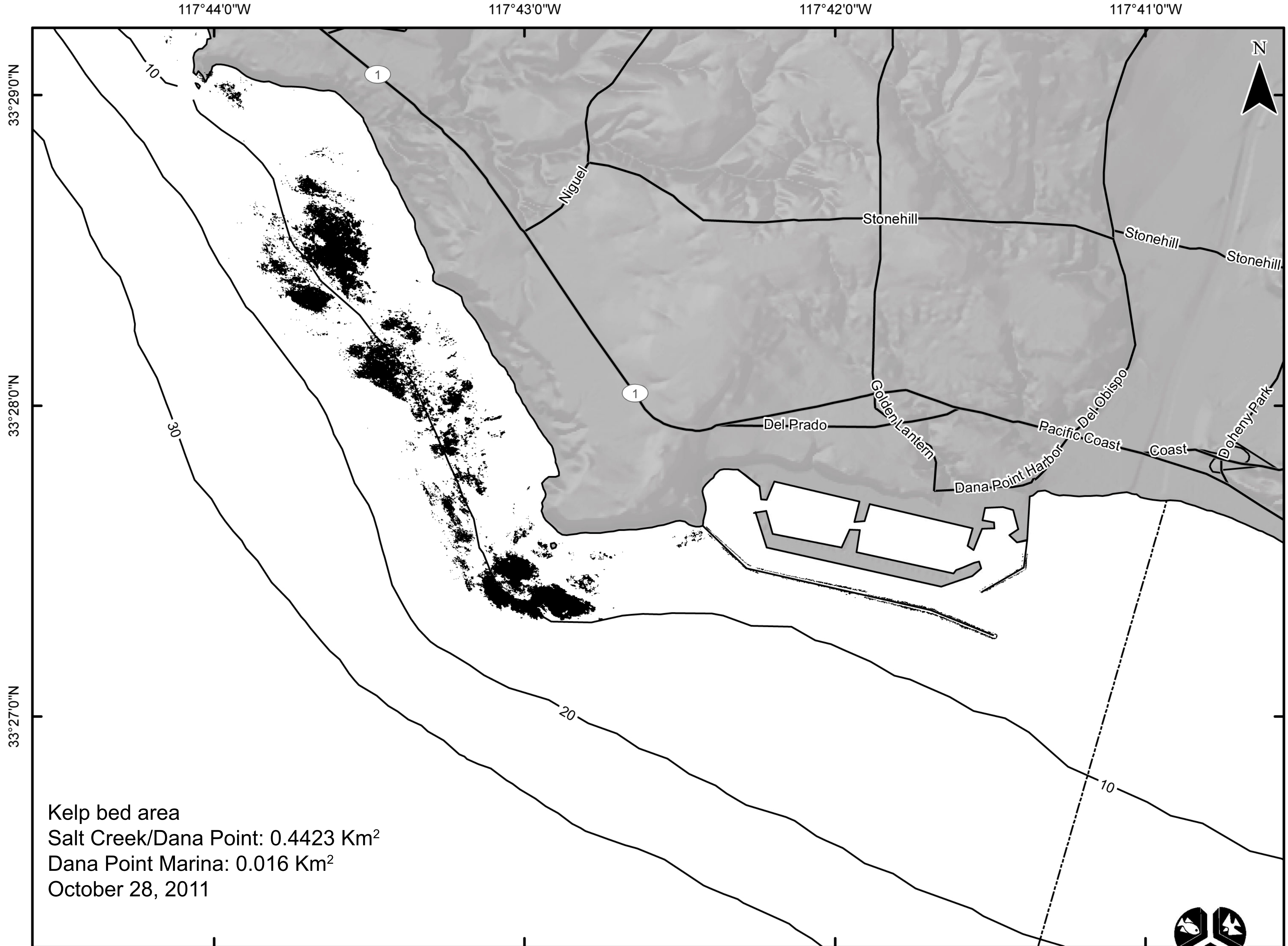

117°52'0"W
117°51'0"W
117°50'0"W
117°49'0"W
33°36'0"N
33°35'0"N
33°34'0"N
N
Marguerite
Coast
Newport Coast
1
Pacific Coast
Crystal Cove
30
20
10
Kelp bed area
Newport Harbor: 0.0101 Km²
December 21, 2011
Corona del Mar Kelp: 0.4188 Km²
April 16, 2011
1 stat. mi.
1 Km
Depth contours in meters
1
MBC



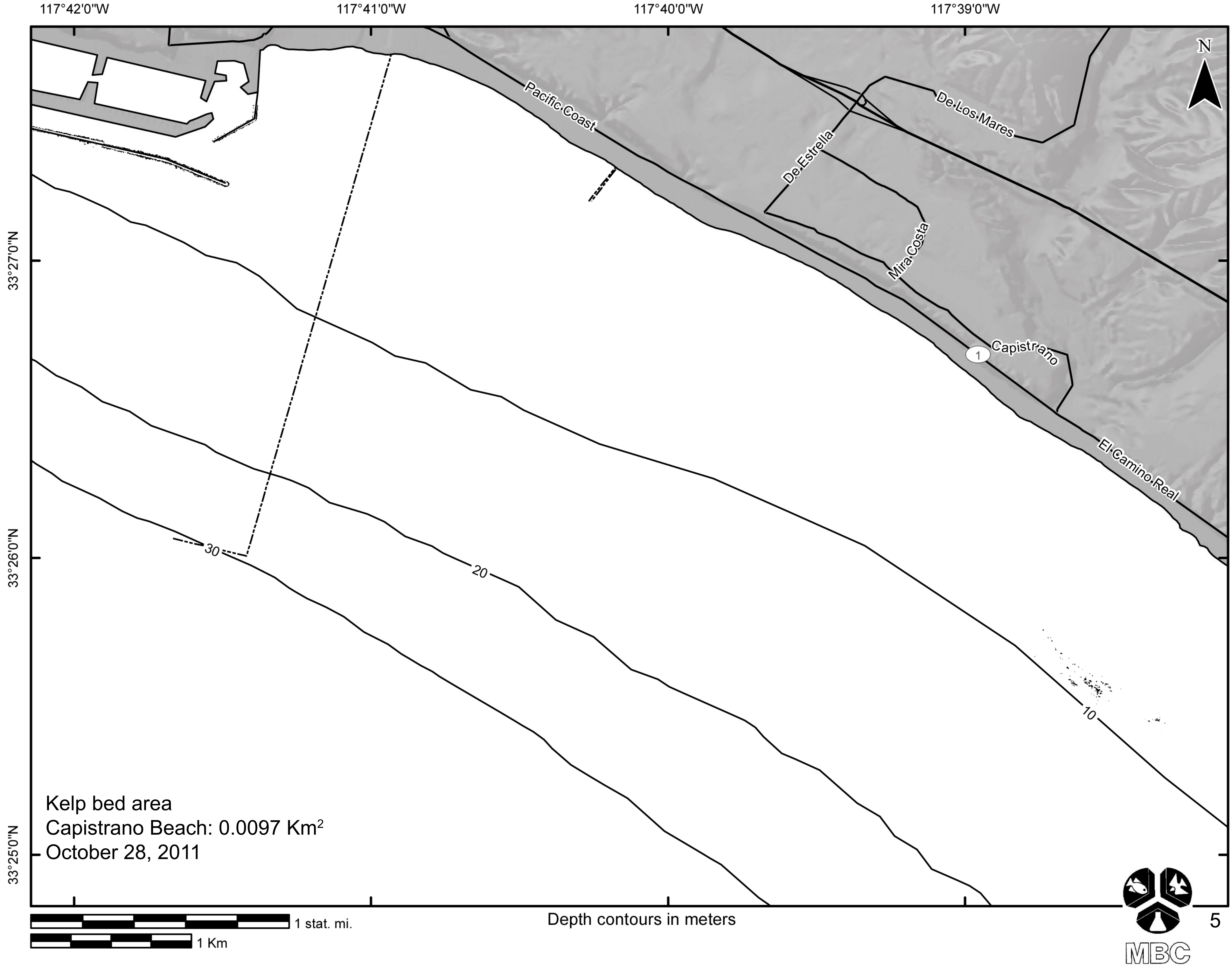
117°49'0"W
117°48'0"W
117°47'0"W
117°46'0"W
33°33'0"N
33°32'0"N
33°31'0"N
N
1
133
Laguna Canyon
Broadway
Coast
30
20
10
Kelp bed area
North Laguna Beach Kelp: 0.1471 Km2
South Laguna Beach Kelp: 0.2208 Km2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC



117°46'0"W
117°45'0"W
117°44'0"W
117°43'0"W
33°30'0"N
33°29'0"N
33°28'0"N
N
10
20
30
1
Crown Valley
Pacific Island
Coast
Pacific Coast
Niguel
Del Avion
Stonehill
Kelp bed area
South Laguna Kelp: 0.0182 Km^2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC



Depth contours in meters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117°41'0"W
117°40'0"W
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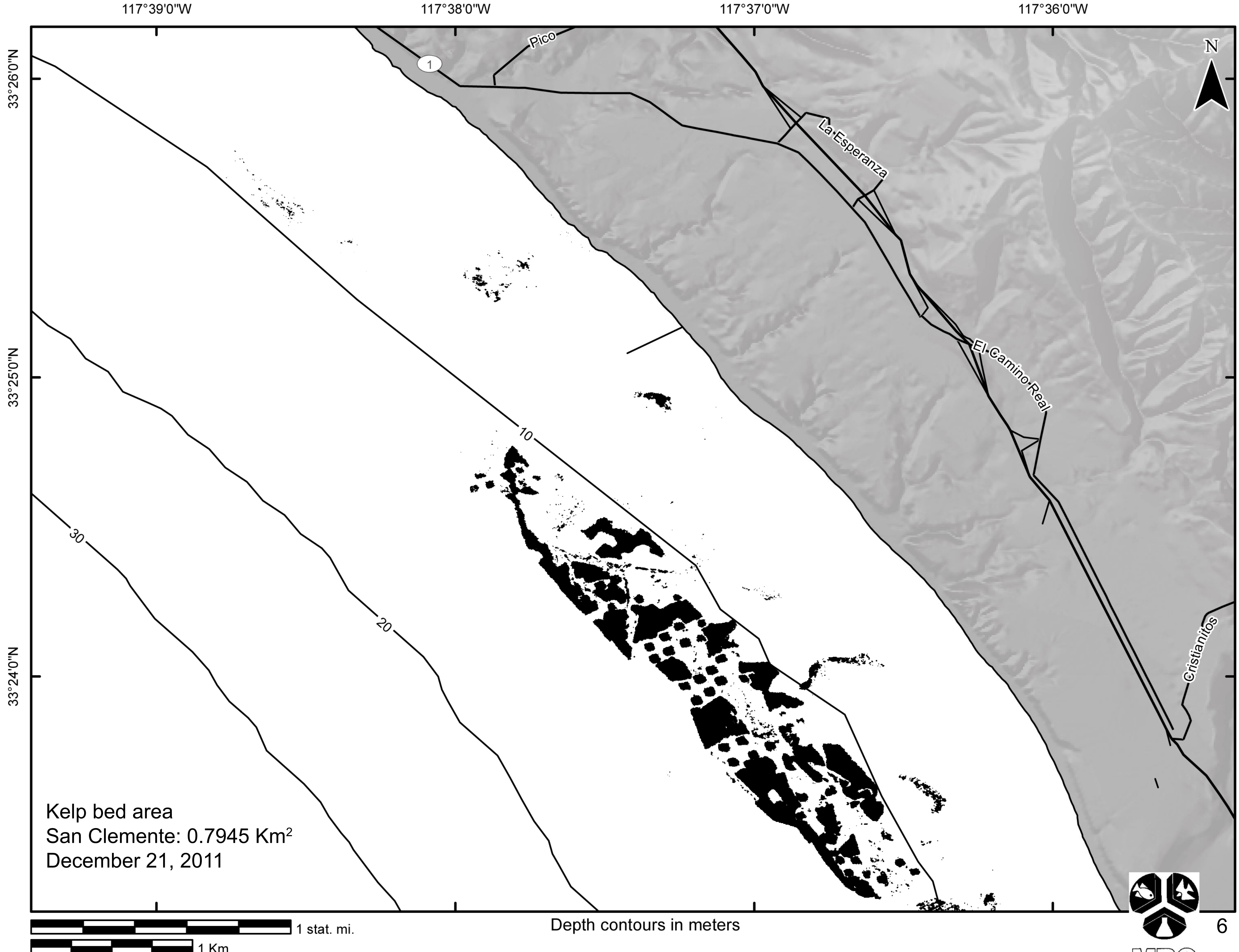
33°27'0"N
33°26'0"N
33°25'0"N
N
Pacific Coast
De Los Mares
De Estrella
Mira Costa
Capistrano
1
El Camino Real
30
20
10
Kelp bed area
Capistrano Beach: 0.0097 Km2
October 28, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC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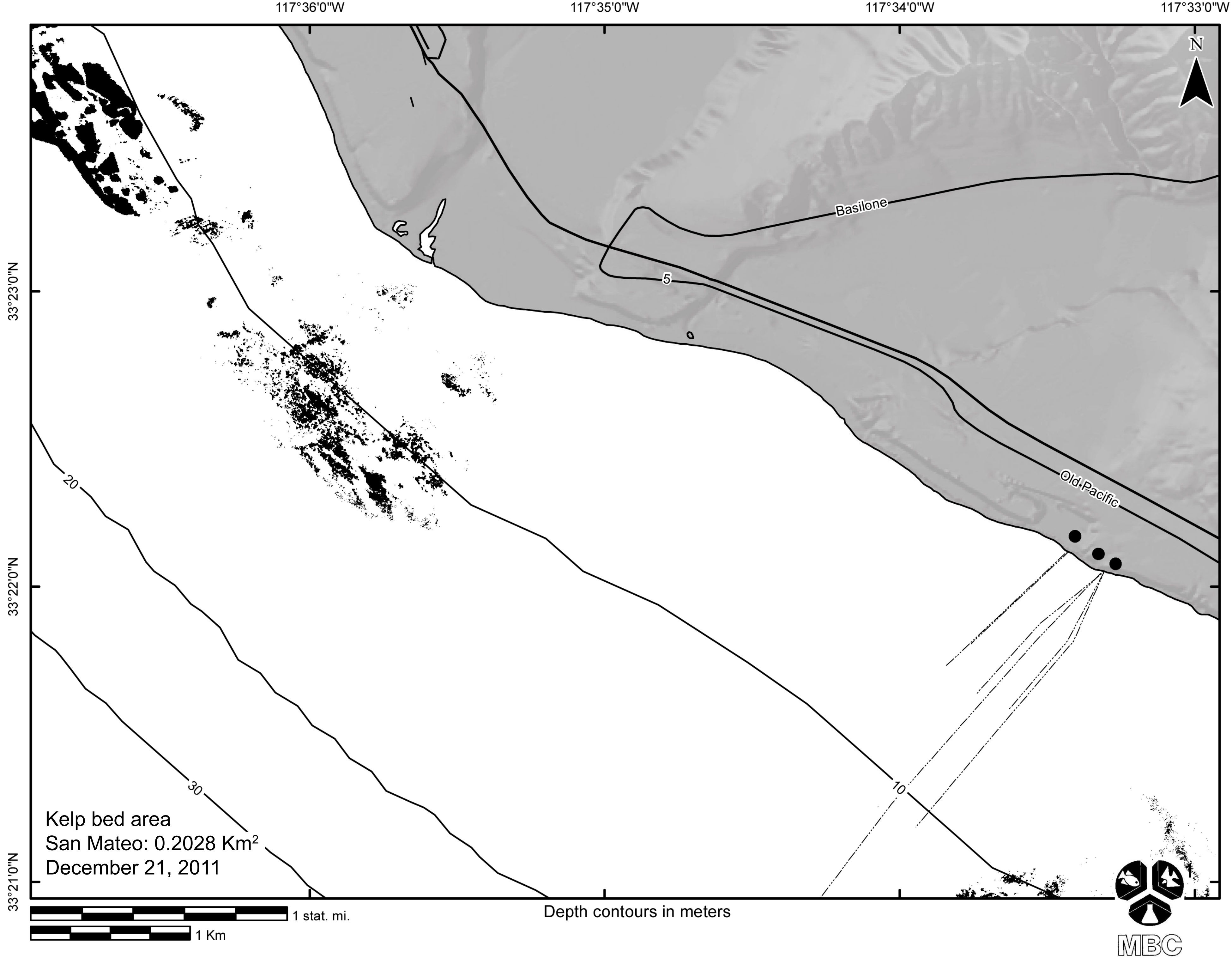
117°37'0"W
117°36'0"W
33°26'0"N
33°25'0"N
33°24'0"N
N
Pico
1
La Esperanza
El Camino Real
Cristianitos
10
20
30
Kelp bed area
San Clemente: 0.7945 Km²
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters

MBC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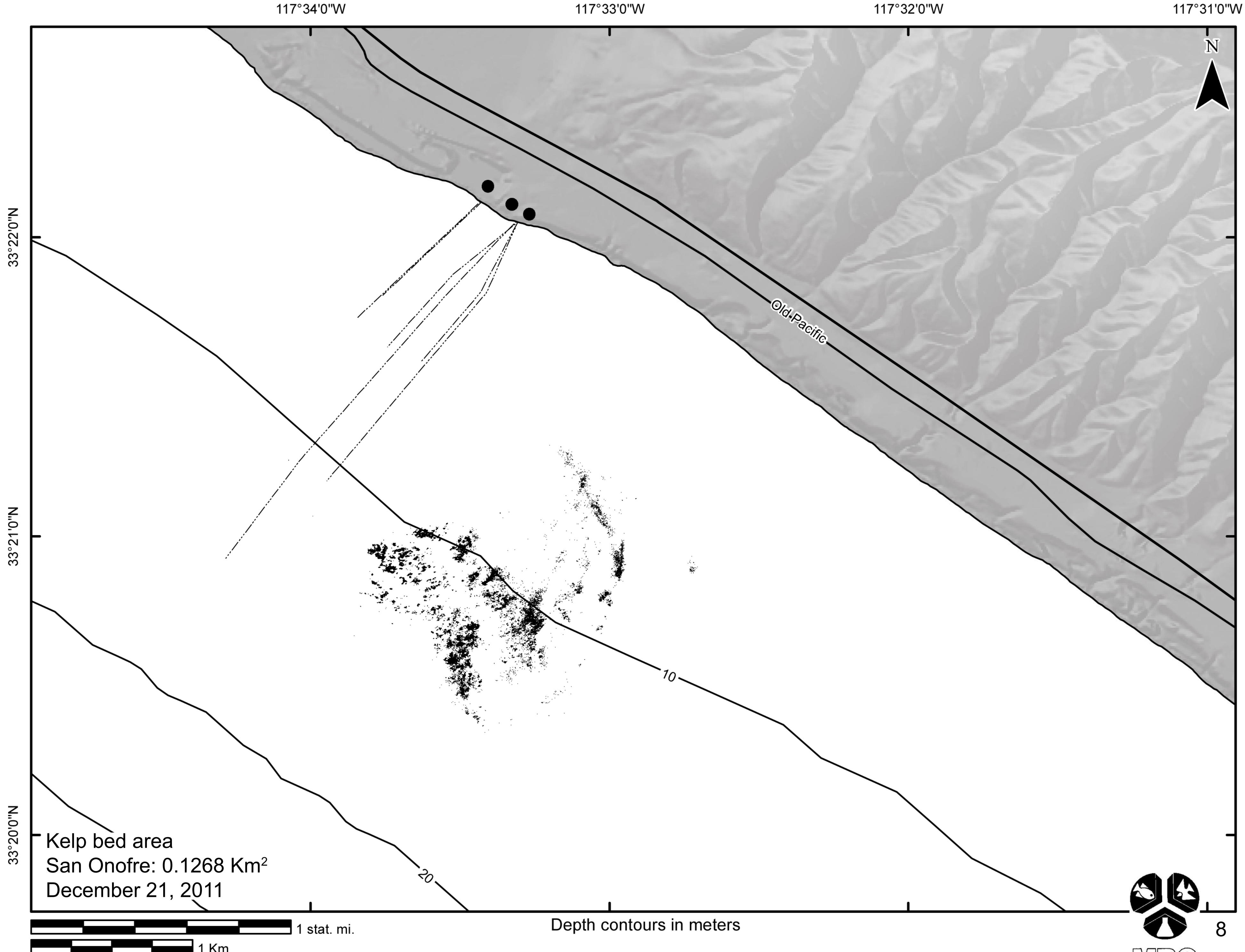
33°23'0"N
33°22'0"N
33°21'0"N
N
Basilone
Old Pacific
5
10
20
30
Kelp bed area
San Mateo: 0.2028 Km²
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC



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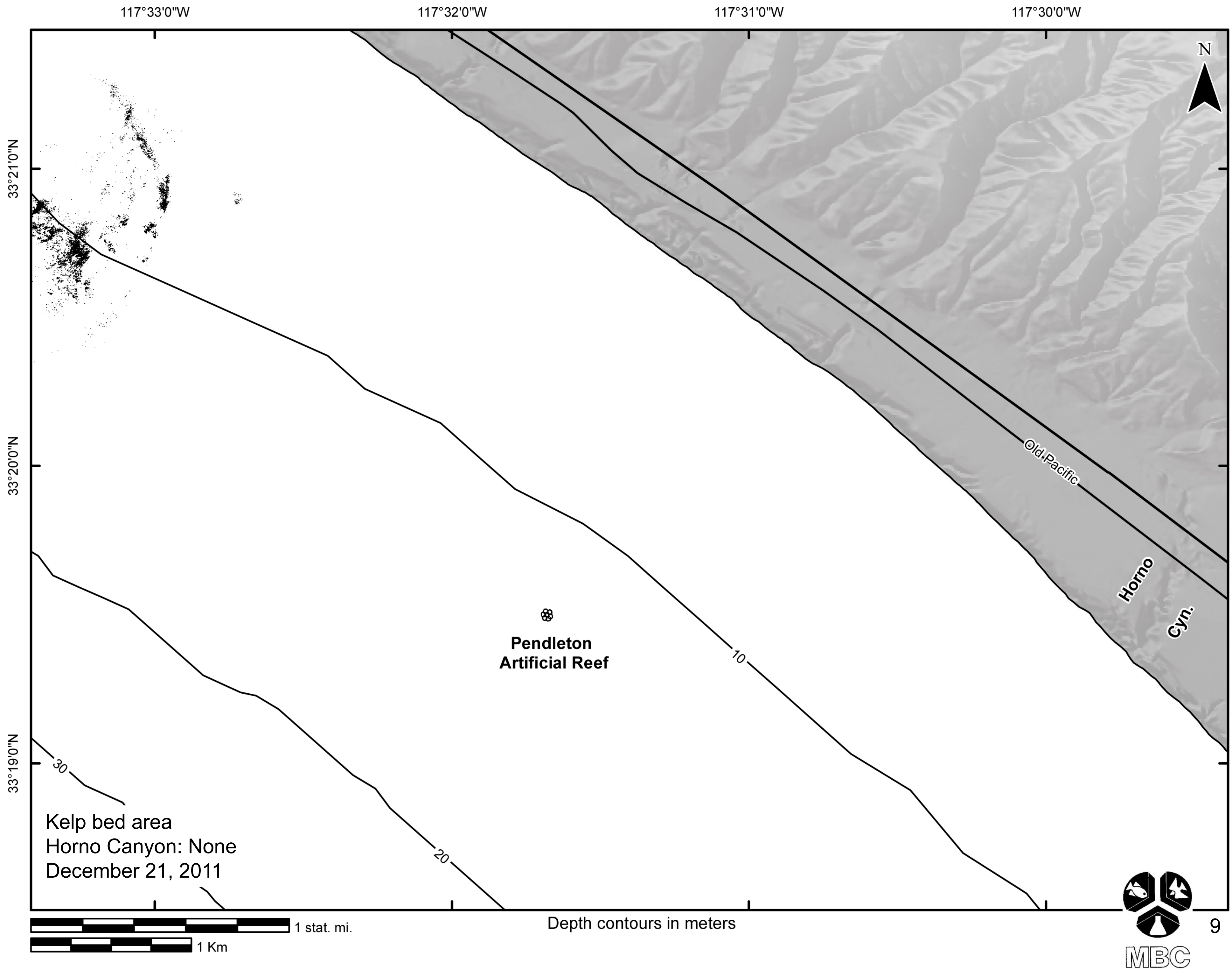
117°33'0"W
117°32'0"W
117°31'0"W
33°22'0"N
33°21'0"N
33°20'0"N
N
Old Pacific
10
20
Kelp bed area
San Onofre: 0.1268 Km²
December 21, 2011
Depth contours in meters
1 stat. mi.
1 Km
MBC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117°31'0"W
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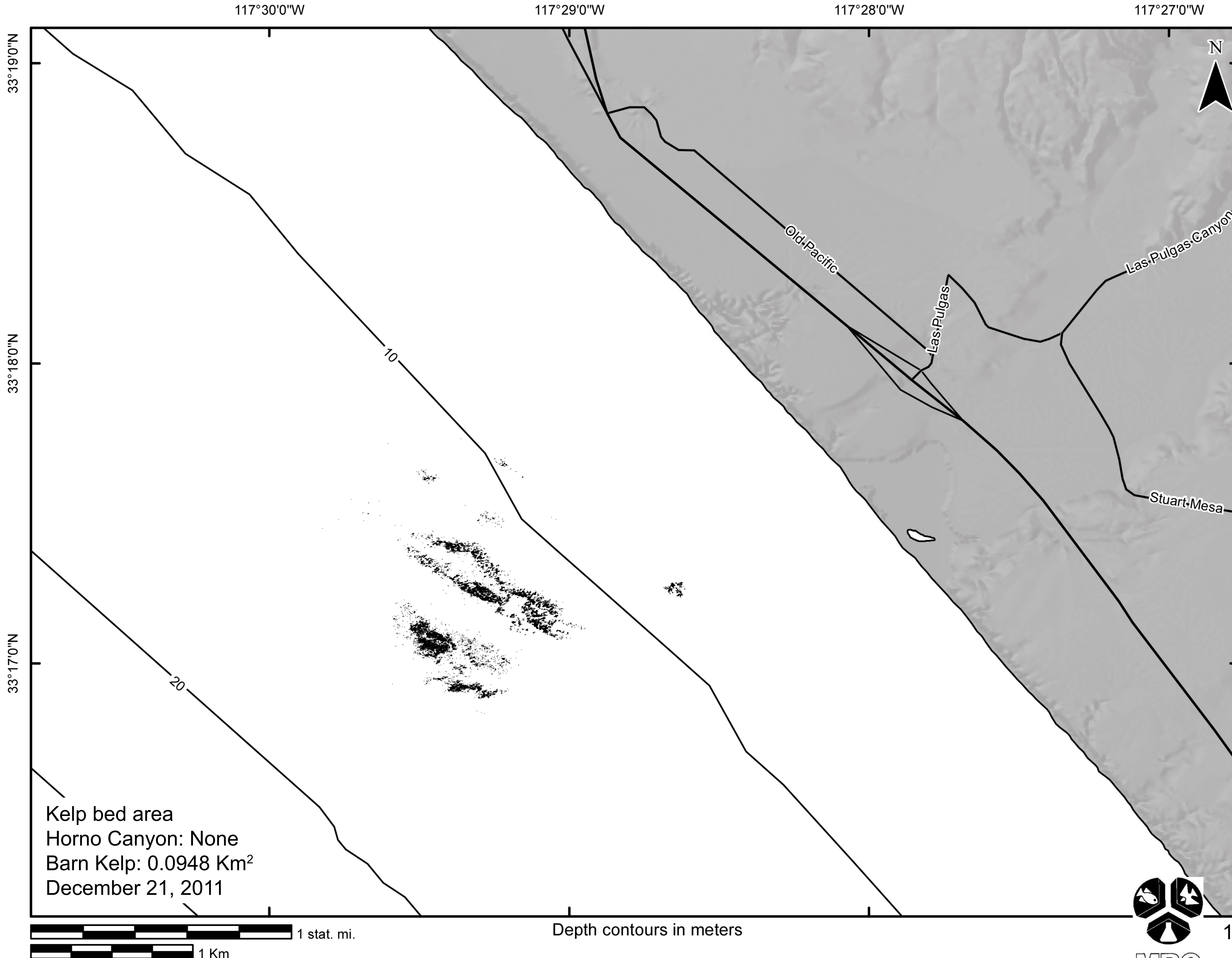
33°21'0"N
33°20'0"N
33°19'0"N
N
Old Pacific
Horno
Cyn.
Pendleton
Artificial Reef
10
20
30
Kelp bed area
Horno Canyon: None
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC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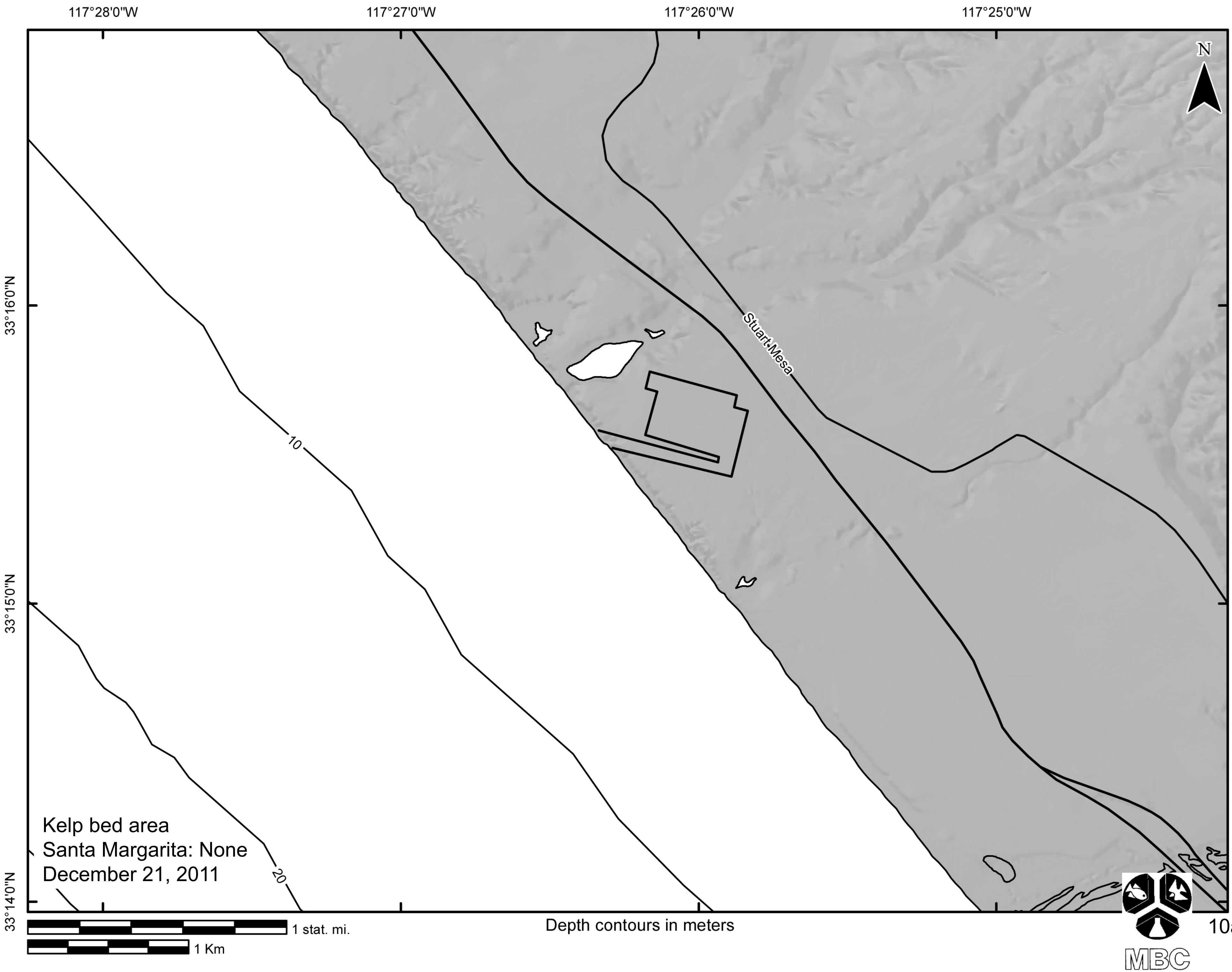
117°28'0"W
117°27'0"W
33°19'0"N
33°18'0"N
33°17'0"N
N
Old Pacific
Las Pulgas
Las Pulgas Canyon
Stuart Mesa
10
20
Kelp bed area
Horno Canyon: None
Barn Kelp: 0.0948 Km2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC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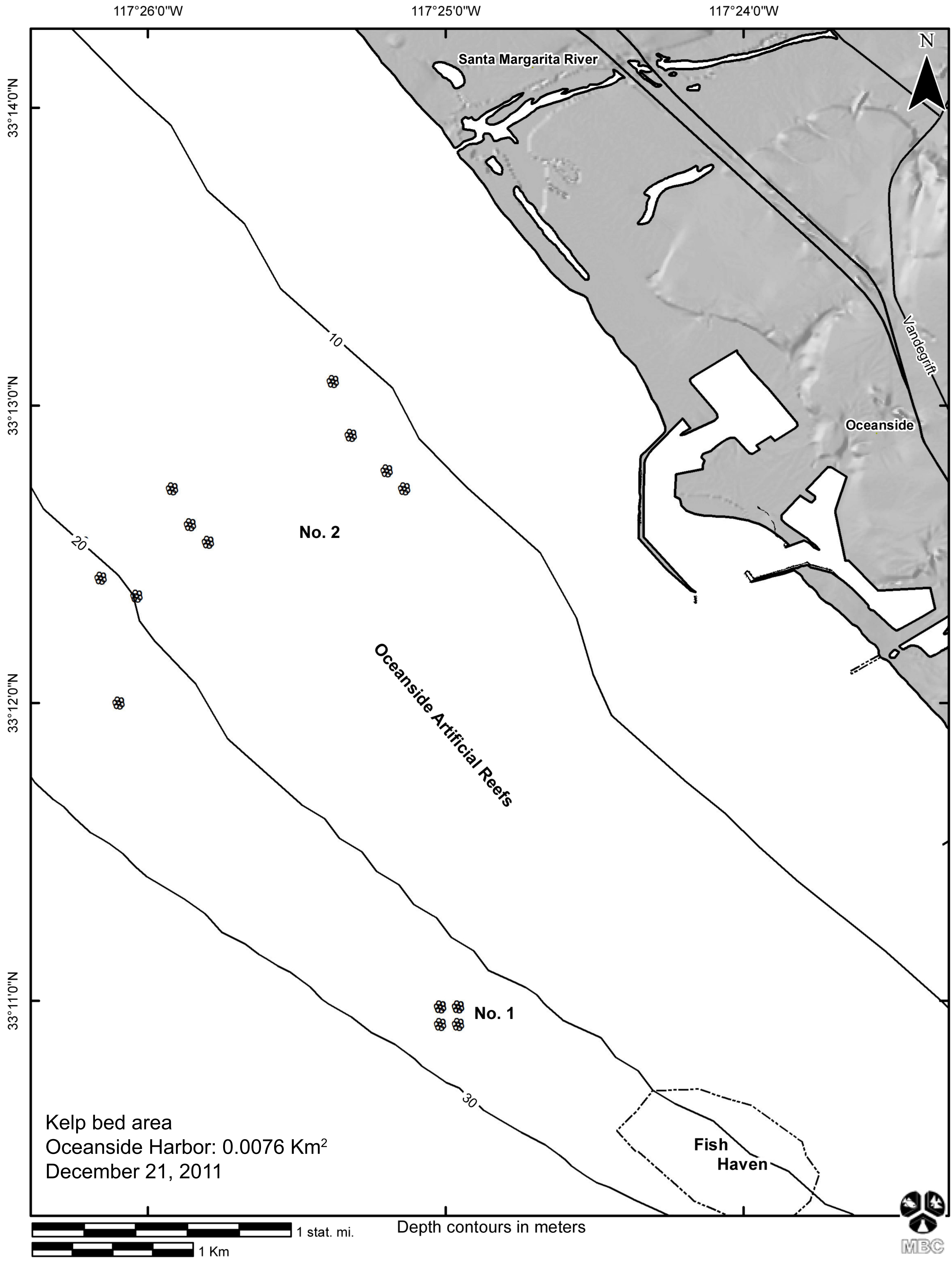
117°27'0"W
117°26'0"W
117°25'0"W
33°16'0"N
33°15'0"N
33°14'0"N
N
Stuart Mesa
10
20
Kelp bed area
Santa Margarita: None
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

10a



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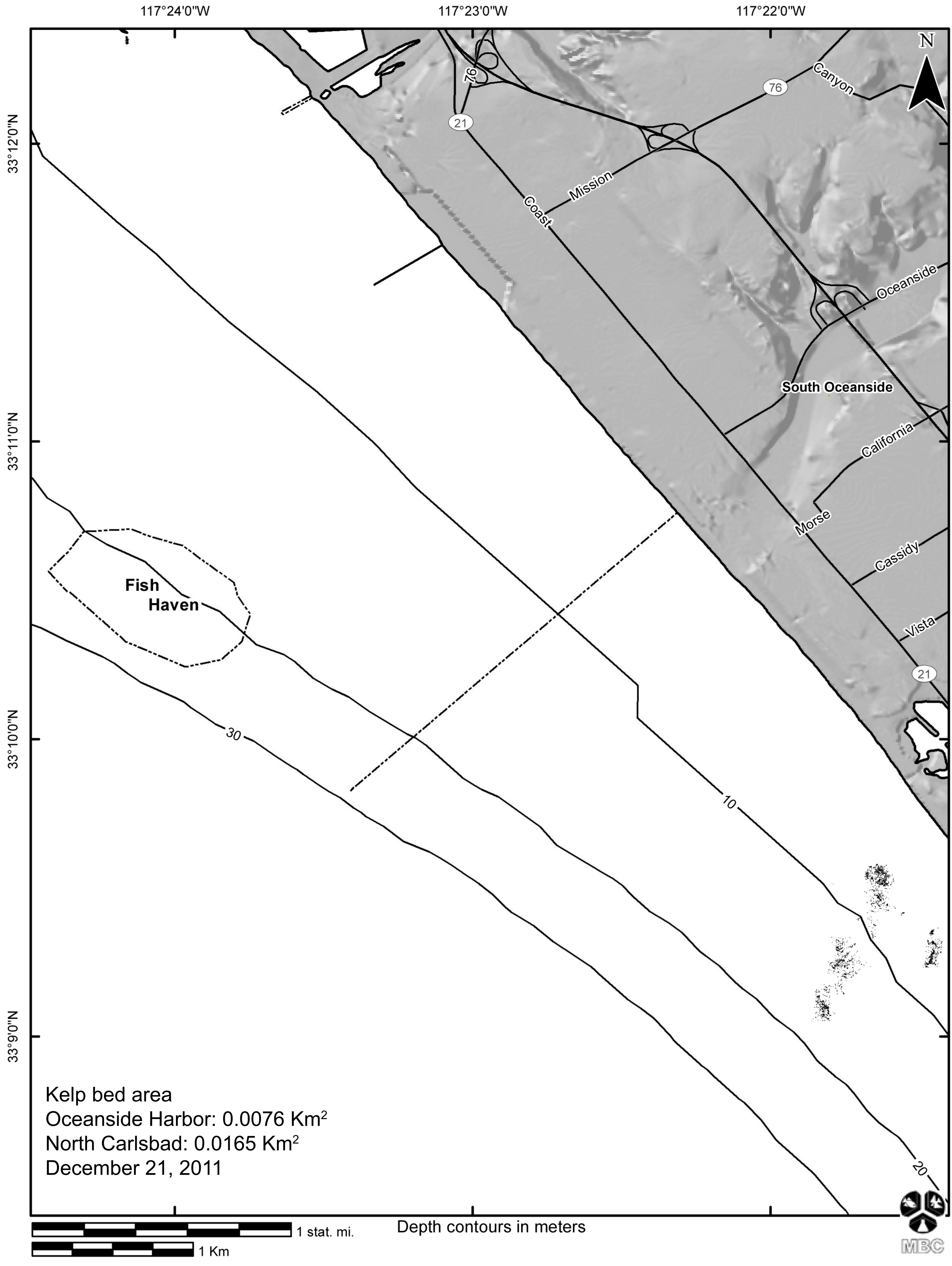
117°25'0"W
117°24'0"W
33°14'0"N
33°13'0"N
33°12'0"N
33°11'0"N
N
Santa Margarita River
Vandegrift
Oceanside
10
20
30
No. 2
No. 1
Oceanside Artificial Reefs
Fish Haven
Kelp bed area
Oceanside Harbor: 0.0076 Km²
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

10b



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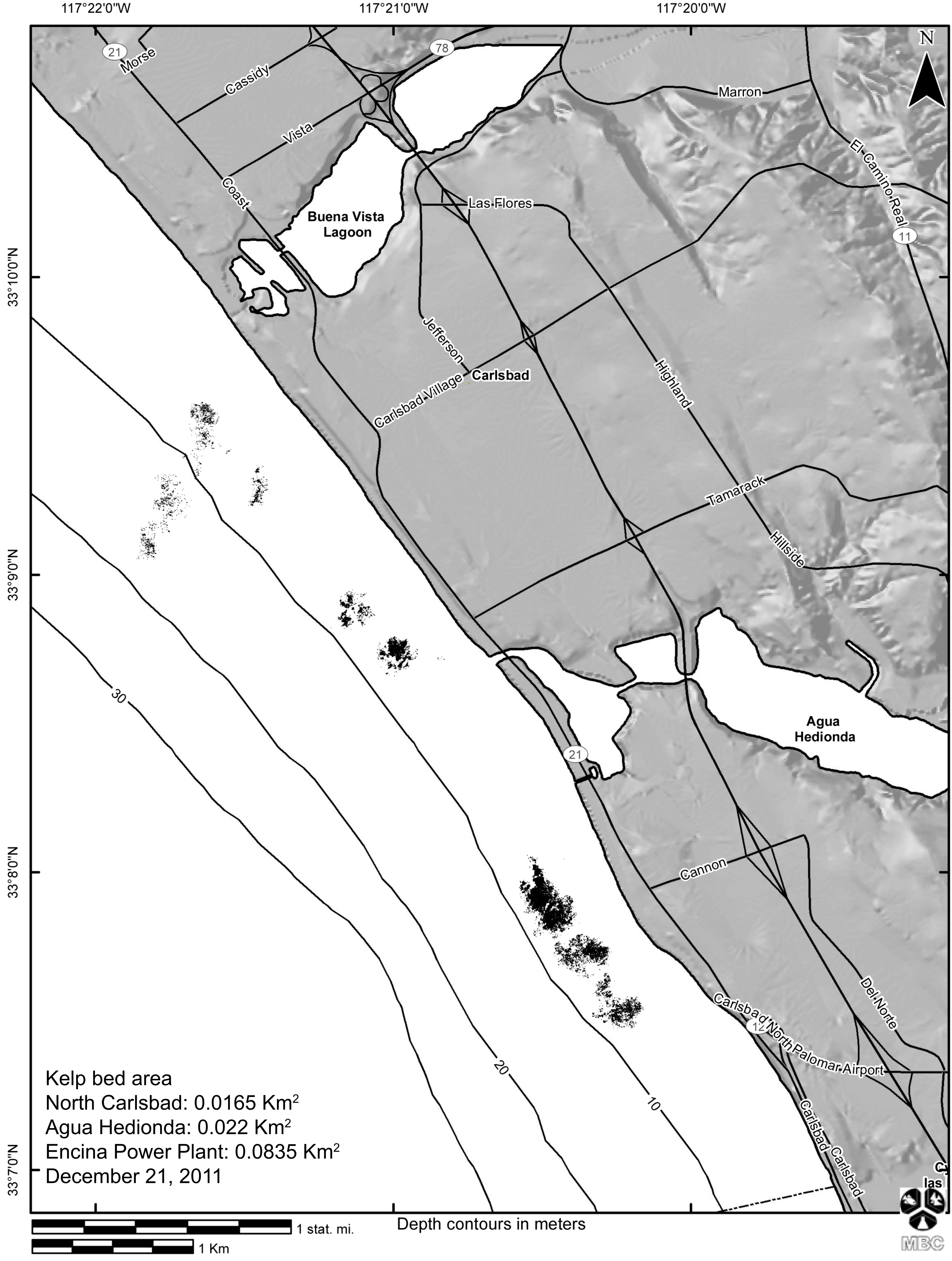
117°23'0"W
117°22'0"W
33°12'0"N
33°11'0"N
33°10'0"N
33°9'0"N
N
76
Canyon
76
21
Mission
Coast
Oceanside
South Oceanside
California
Morse
Cassidy
Vista
21
Fish
Haven
30
10
20
Kelp bed area
Oceanside Harbor: 0.0076 Km²
North Carlsbad: 0.0165 Km²
December 21, 2011
1 stat. mi.
Depth contours in meters
1 Km
MBC

10c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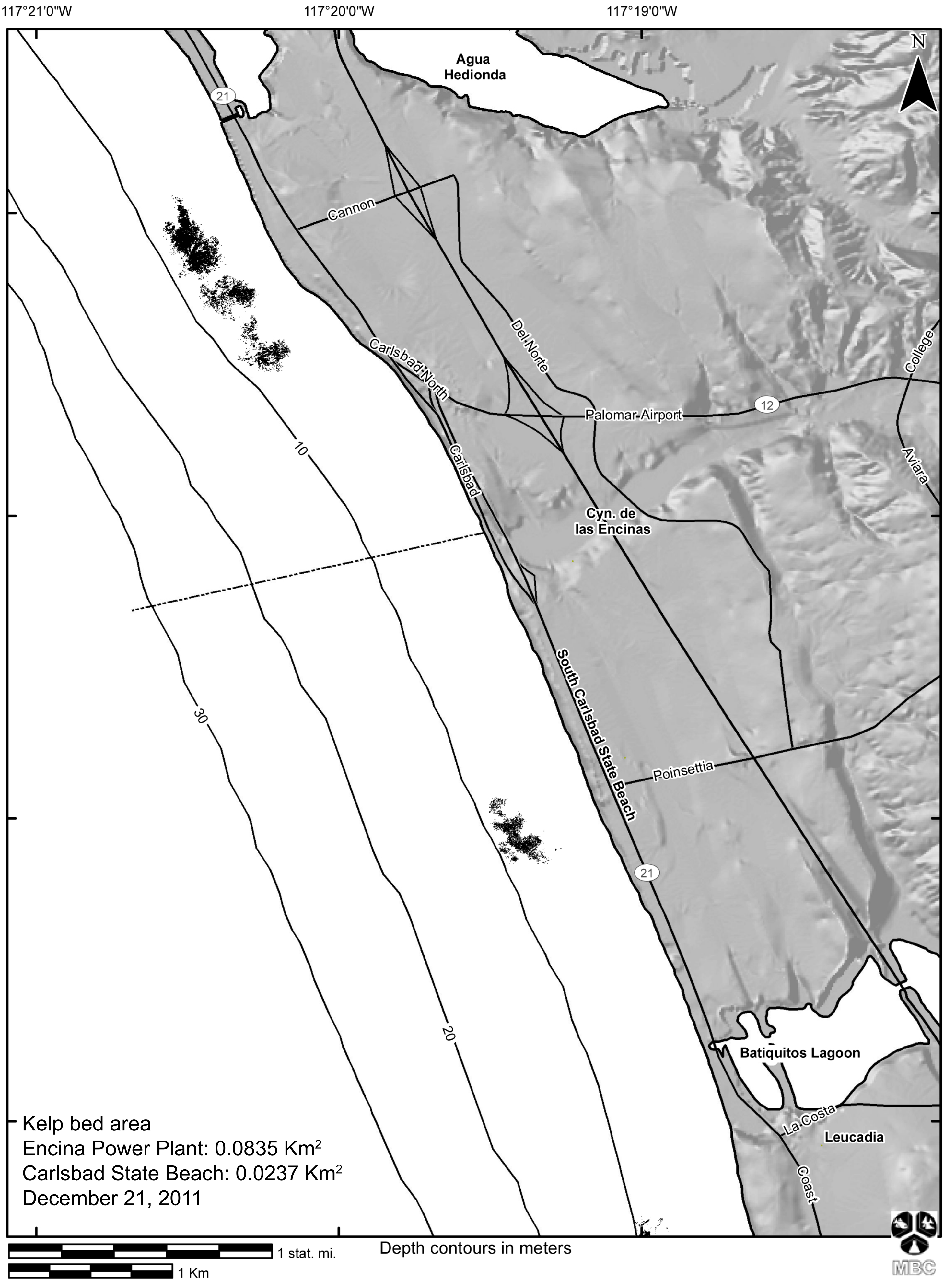
117°21'0"W
117°20'0"W
33°10'0"N
33°9'0"N
33°8'0"N
33°7'0"N
N
21
Morse
Cassidy
Vista
78
Marron
El Camino Real
11
Coast
Las Flores
Buena Vista Lagoon
Jefferson
Carlsbad Village
Carlsbad
Highland
Tamarack
Hillside
Agua Hedionda
21
Cannon
30
20
10
Del Norte
Carlsbad
12
North Palomar Airport
Carlsbad
Carlsbad
Kelp bed area
North Carlsbad: 0.0165 Km2
Agua Hedionda: 0.022 Km2
Encina Power Plant: 0.0835 Km2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC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117°20'0"W
117°19'0"W
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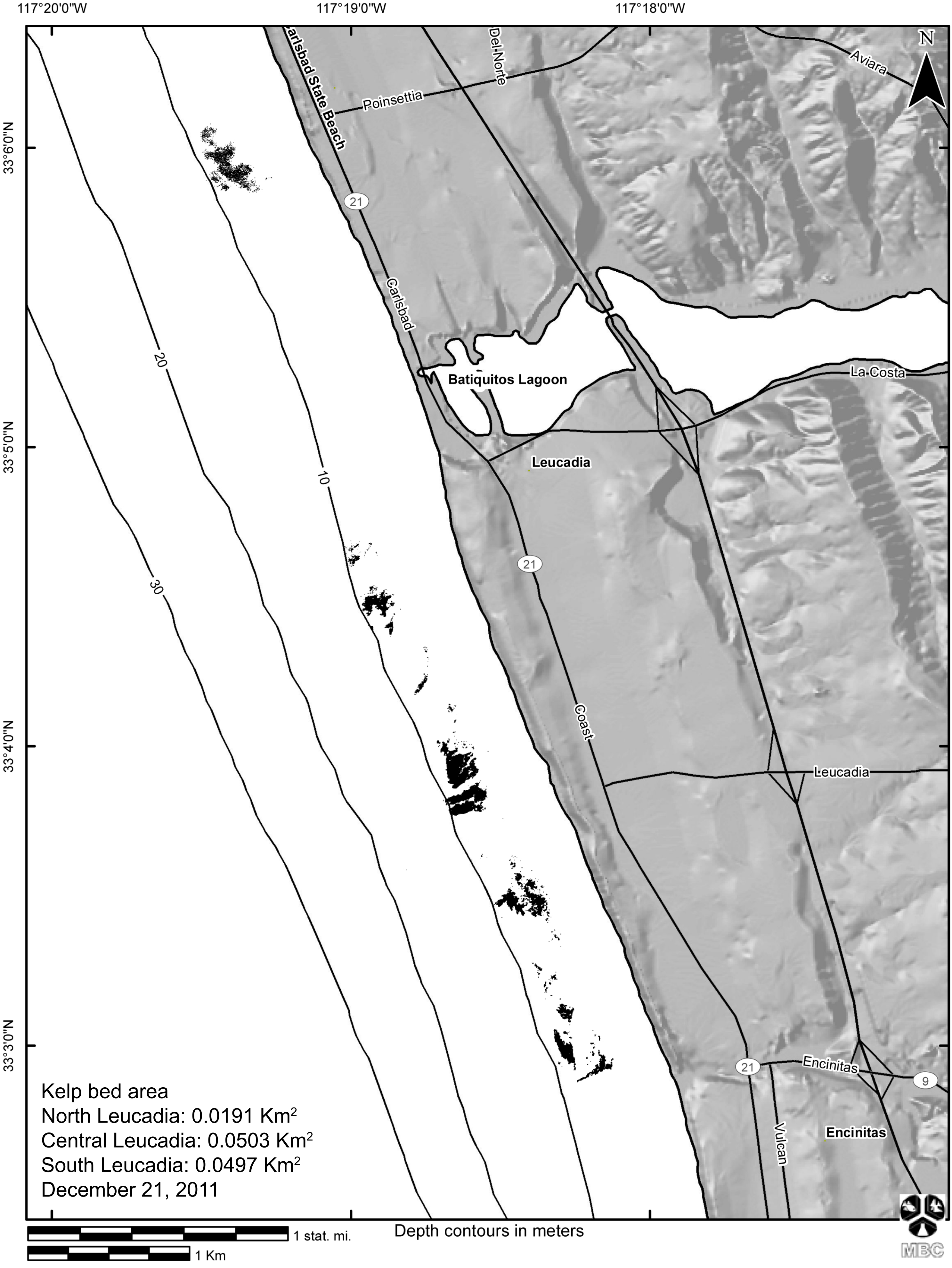
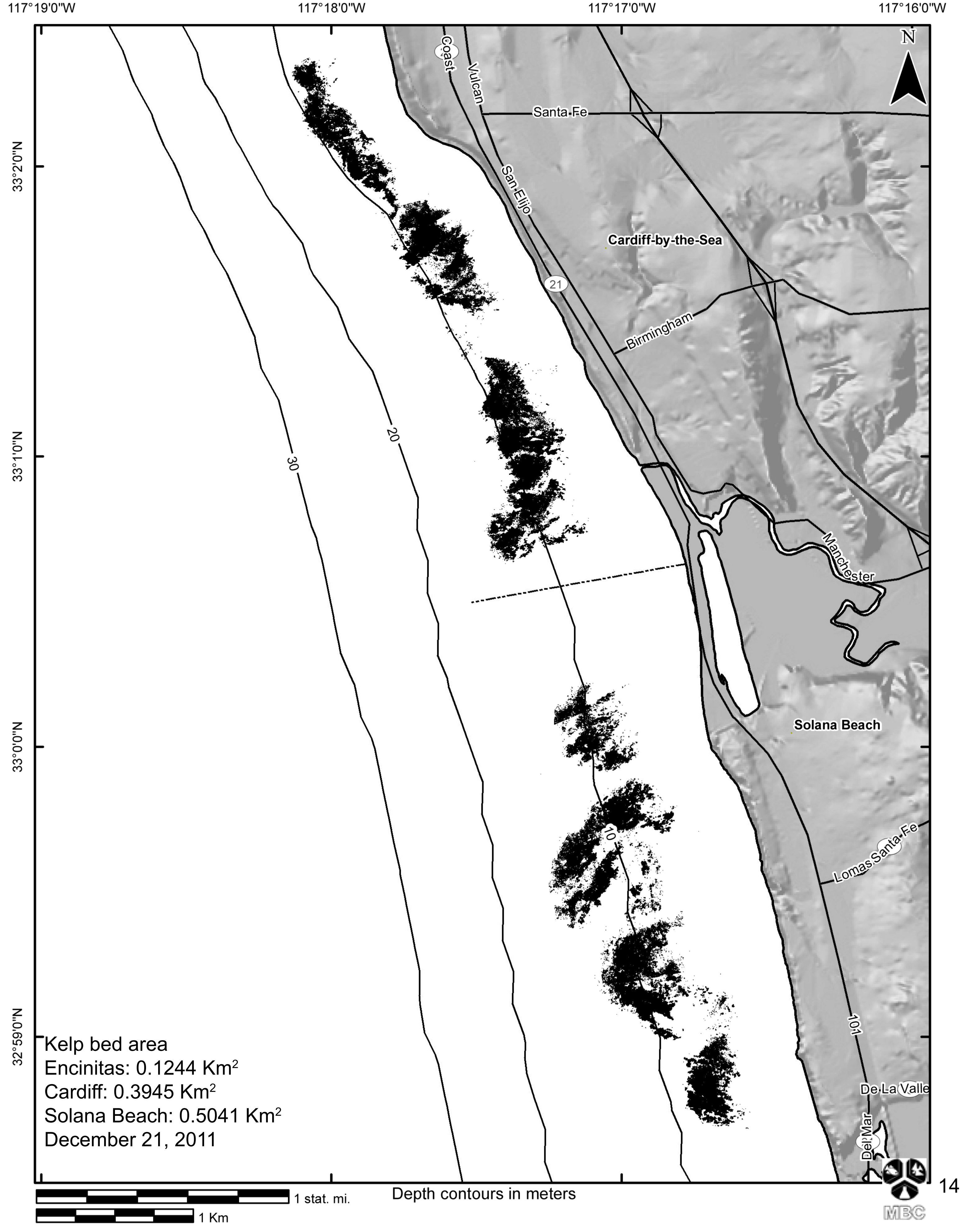
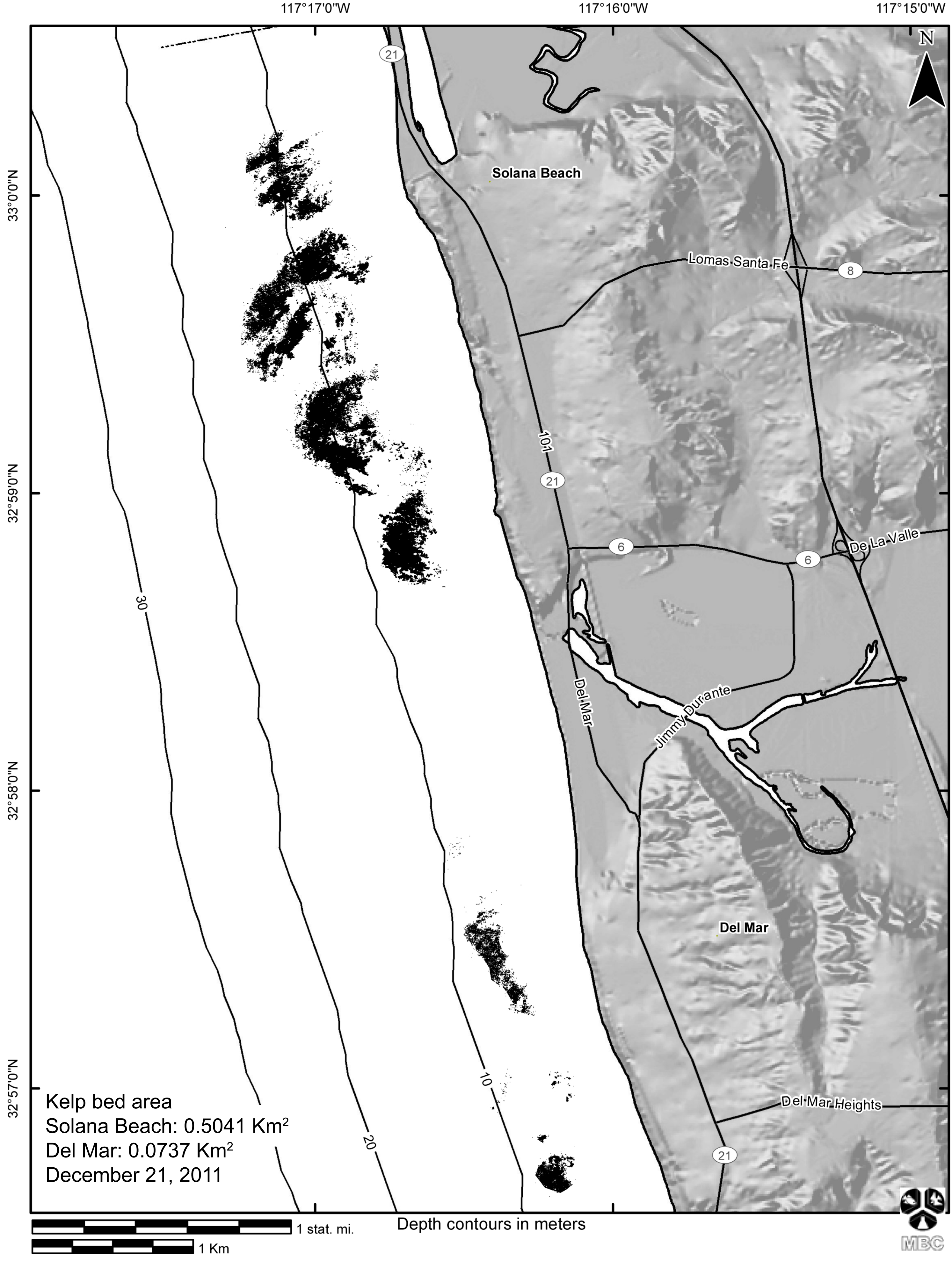
33°7'0"N
33°6'0"N
33°5'0"N
N
Agua Hedionda
21
Cannon
Del Norte
Carlsbad North
College
12
Palomar Airport
Carlsbad
Aviara
10
Cyn. de las Encinas
South Carlsbad State Beach
30
Poinsettia
21
20
Batiquitos Lagoon
La Costa
Leucadia
Coast
Kelp bed area
Encina Power Plant: 0.0835 Km²
Carlsbad State Beach: 0.0237 Km²
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

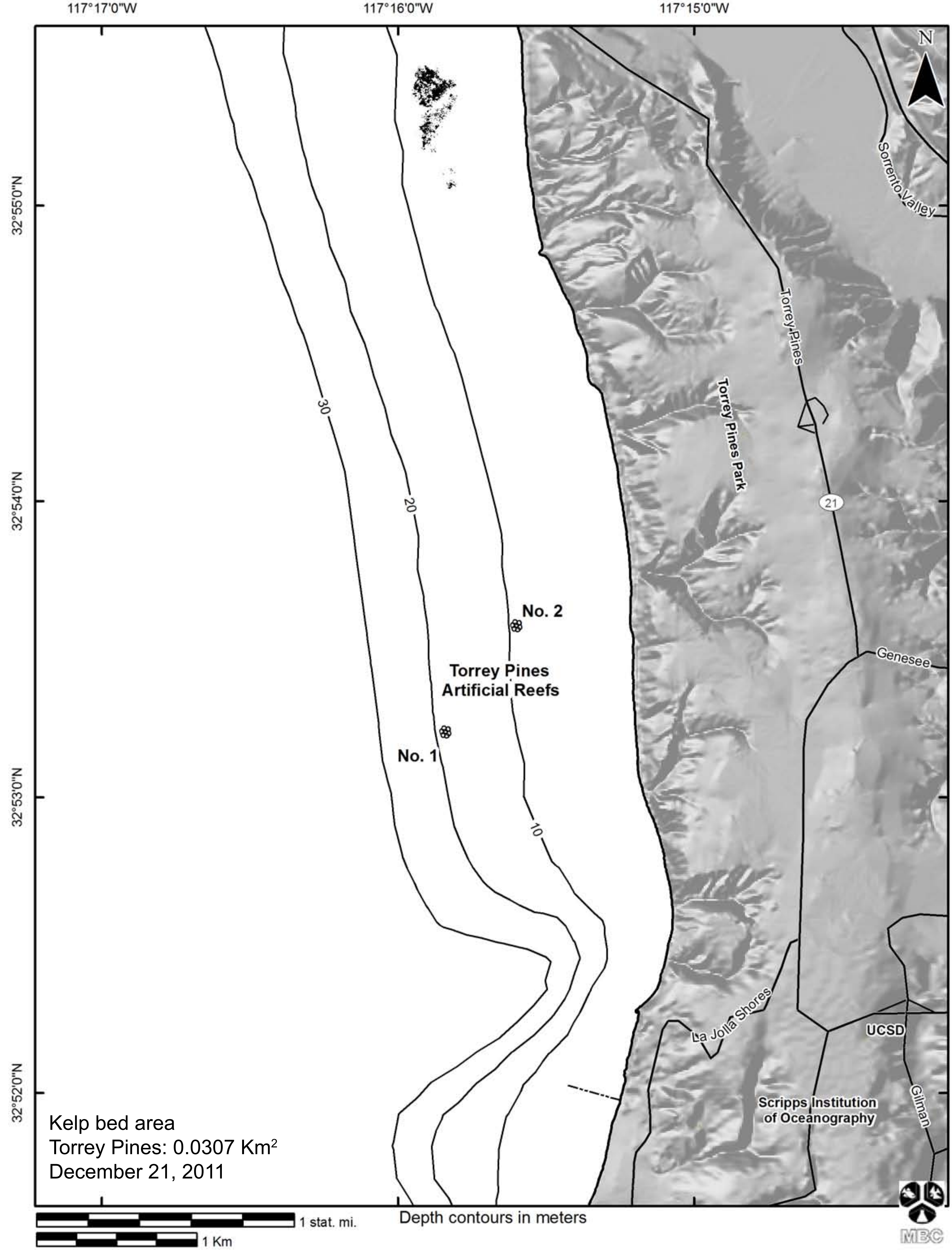


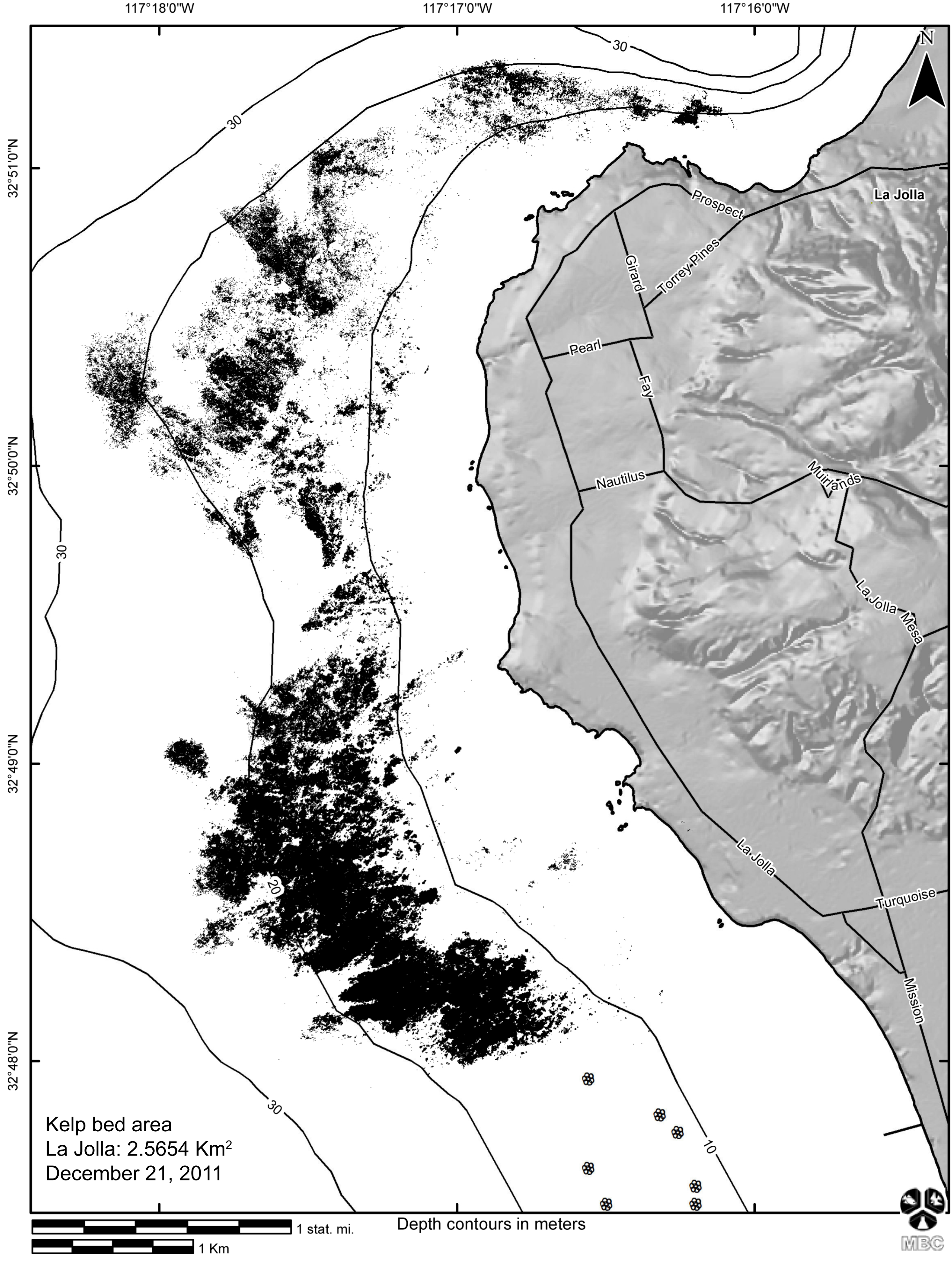
117°20'0"W
117°19'0"W
117°18'0"W
33°6'0"N
33°5'0"N
33°4'0"N
33°3'0"N
N
Carlsbad State Beach
Del Norte
Poinsettia
Aviara
21
Carlsbad
Batiquitos Lagoon
La Costa
Leucadia
20
10
30
Coast
Leucadia
21
Encinitas
9
Vulcan
Encinitas
Kelp bed area
North Leucadia: 0.0191 Km^2
Central Leucadia: 0.0503 Km^2
South Leucadia: 0.0497 Km^2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

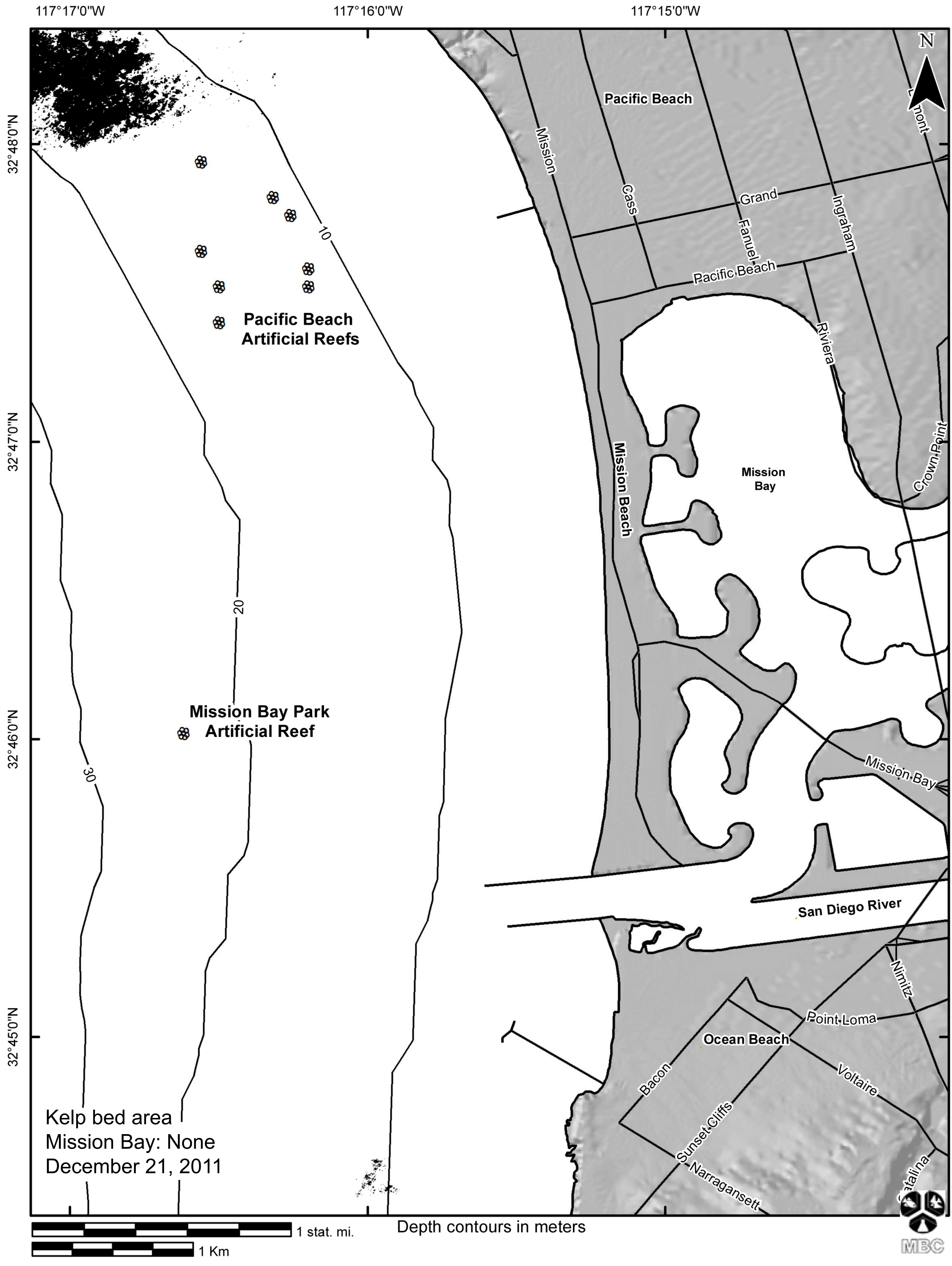


117°19'0"W
117°18'0"W
117°17'0"W
117°16'0"W
33°2'0"N
33°1'0"N
33°0'0"N
32°59'0"N
N
Coast
Vulcan
Santa Fe
San Elijo
Cardiff-by-the-Sea
21
Birmingham
Manchester
Solana Beach
Lomas Santa Fe
101
De La Valle
Del Mar
30
20
10
Kelp bed area
Encinitas: 0.1244 Km²
Cardiff: 0.3945 Km²
Solana Beach: 0.5041 Km²
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

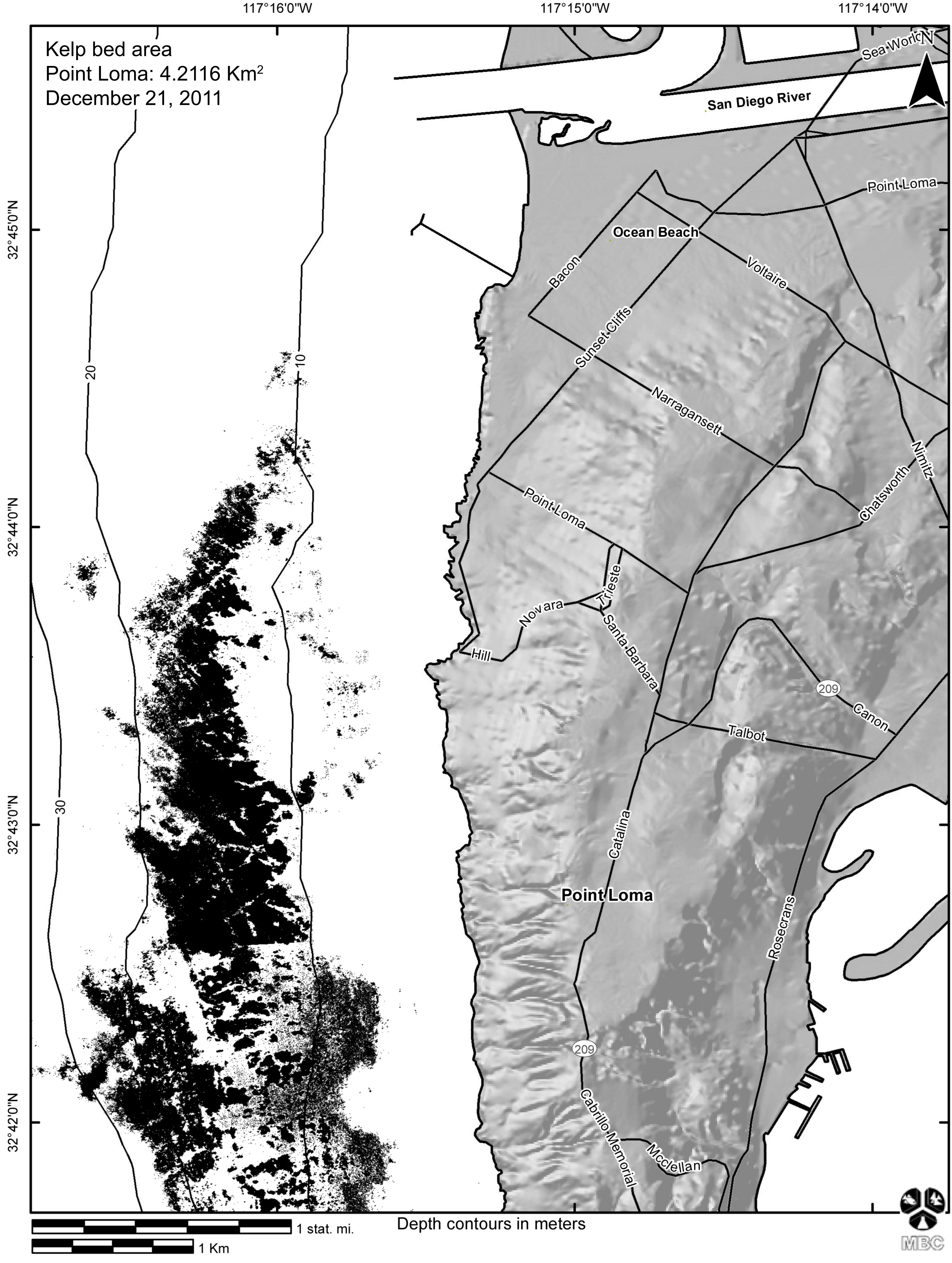

117°17'0"W
117°16'0"W
117°15'0"W
33°0'0"N
32°59'0"N
32°58'0"N
32°57'0"N
N
21
Solana Beach
Lomas Santa Fe
8
101
21
6
6
De La Valle
Del Mar
Jimmy Durante
Del Mar
Del Mar Heights
21
30
20
10
Kelp bed area
Solana Beach: 0.5041 Km2
Del Mar: 0.0737 Km2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
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
32°52'0"N
N
Sorrento Valley
Torrey Pines
Torrey Pines Park
21
30
20
10
No. 2
No. 1
Torrey Pines Artificial Reefs
Genesee
La Jolla Shores
UCSD
Scripps Institution of Oceanography
Gilman
Kelp bed area
Torrey Pines: 0.0307 Km^2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

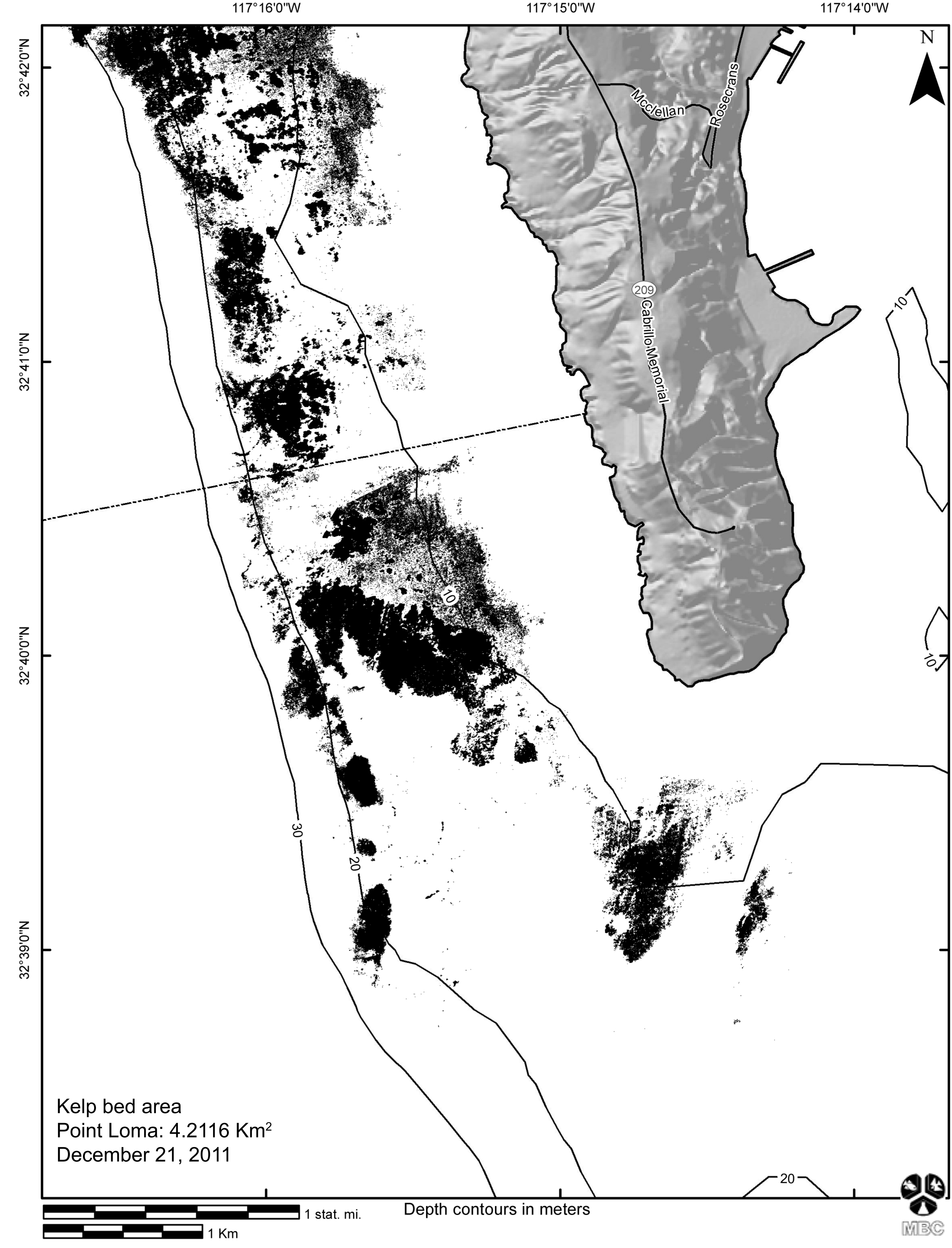

117°18'0"W
117°17'0"W
117°16'0"W
32°51'0"N
32°50'0"N
32°49'0"N
32°48'0"N
N
30
30
30
30
20
10
La Jolla
Prospect
Torrey Pines
Girard
Pearl
Fay
Nautilus
Muirlands
La Jolla Mesa
La Jolla
Turquoise
Mission
Kelp bed area
La Jolla: 2.5654 Km²
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC


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
Mission
Cass
Grand
Fanuel
Ingraham
Pacific Beach
Riviera
10
Pacific Beach
Artificial Reefs
Mission Beach
Mission
Bay
Crown Point
20
Mission Bay Park
Artificial Reef
30
Mission Bay
San Diego River
Nimitz
Point Loma
Ocean Beach
Bacon
Voltaire
Sunset Cliffs
Narragansett
Catalina
Kelp bed area
Mission Bay: None
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

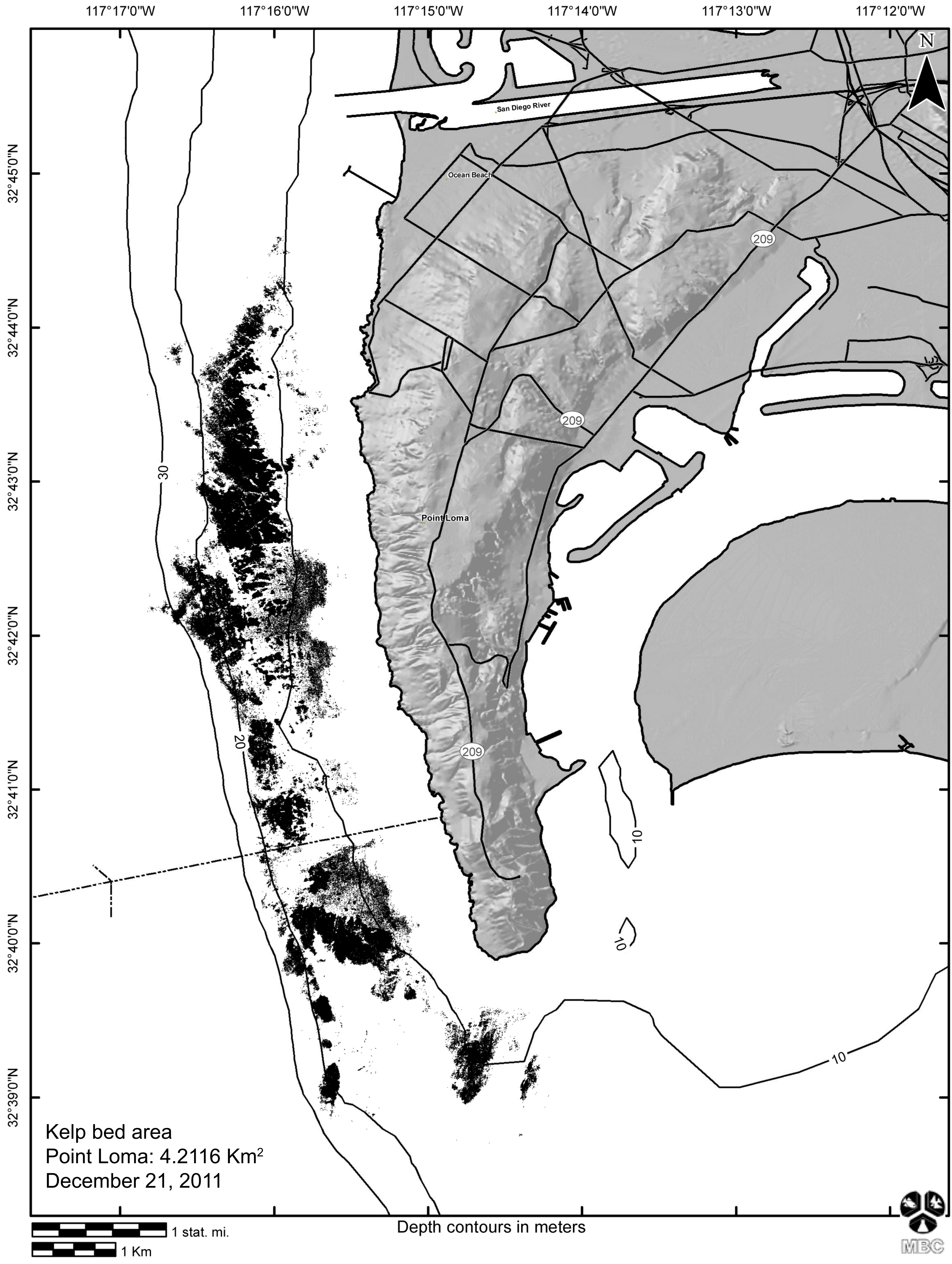
16a



Kelp bed area
Point Loma: 4.2116 Km²
December 21, 2011
117°16'0"W
117°15'0"W
117°14'0"W
32°45'0"N
32°44'0"N
32°43'0"N
32°42'0"N
20
10
30
N
Sea World
San Diego River
Point Loma
Ocean Beach
Bacon
Voltaire
Sunset Cliffs
Narragansett
Nimitz
Chatsworth
Point Loma
Trieste
Novara
Hill
Santa Barbara
209
Canon
Talbot
Catalina
Point Loma
Rosecrans
209
Cabrillo Memorial
Mcclellan
1 stat. mi.
1 Km
Depth contours in meters
MBC

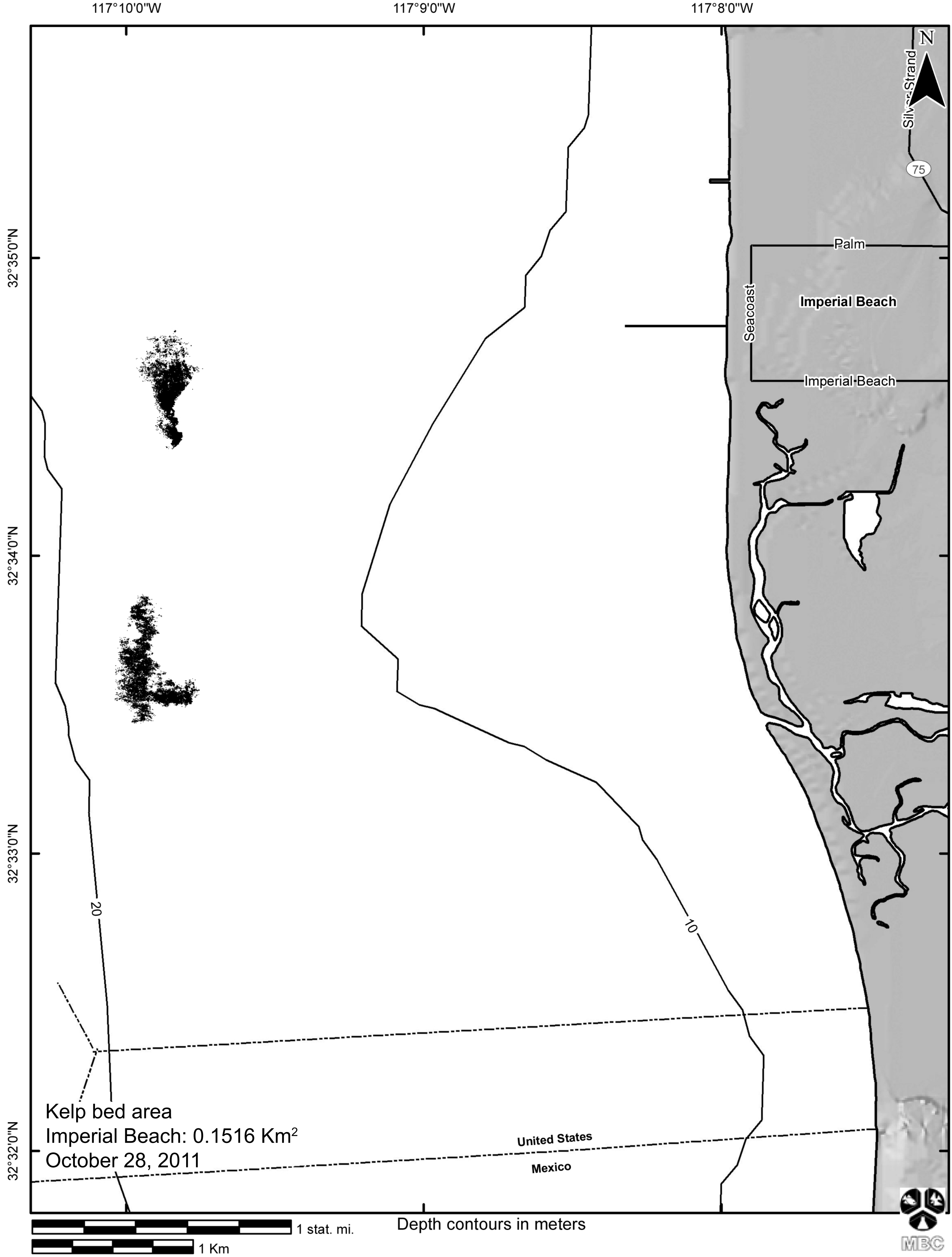


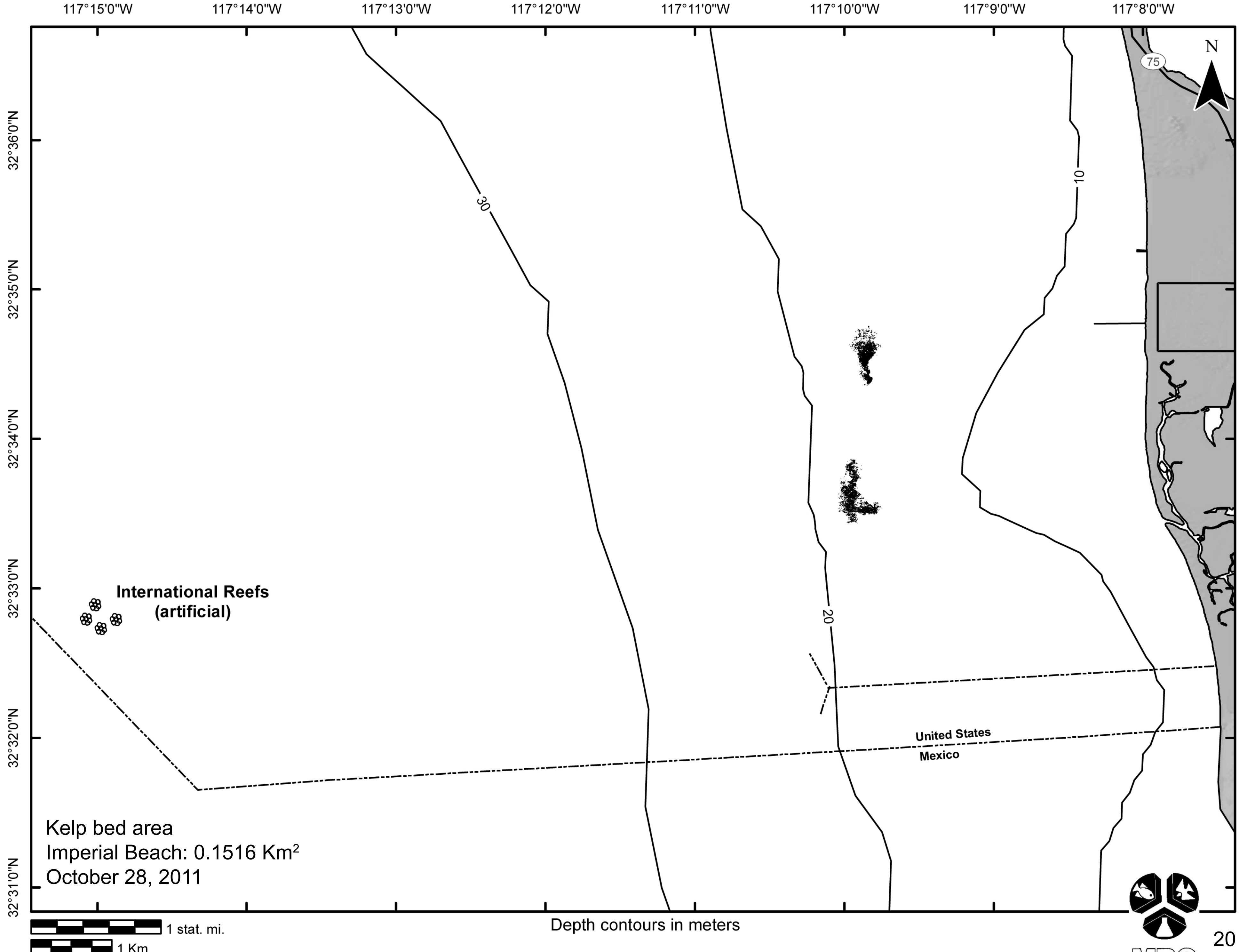
Kelp bed area
Point Loma: 4.2116 Km^2
December 21, 2011



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
San Diego River
Ocean Beach
Point Loma
209
30
20
10
Kelp bed area
Point Loma: 4.2116 Km^2
December 21, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC

18a

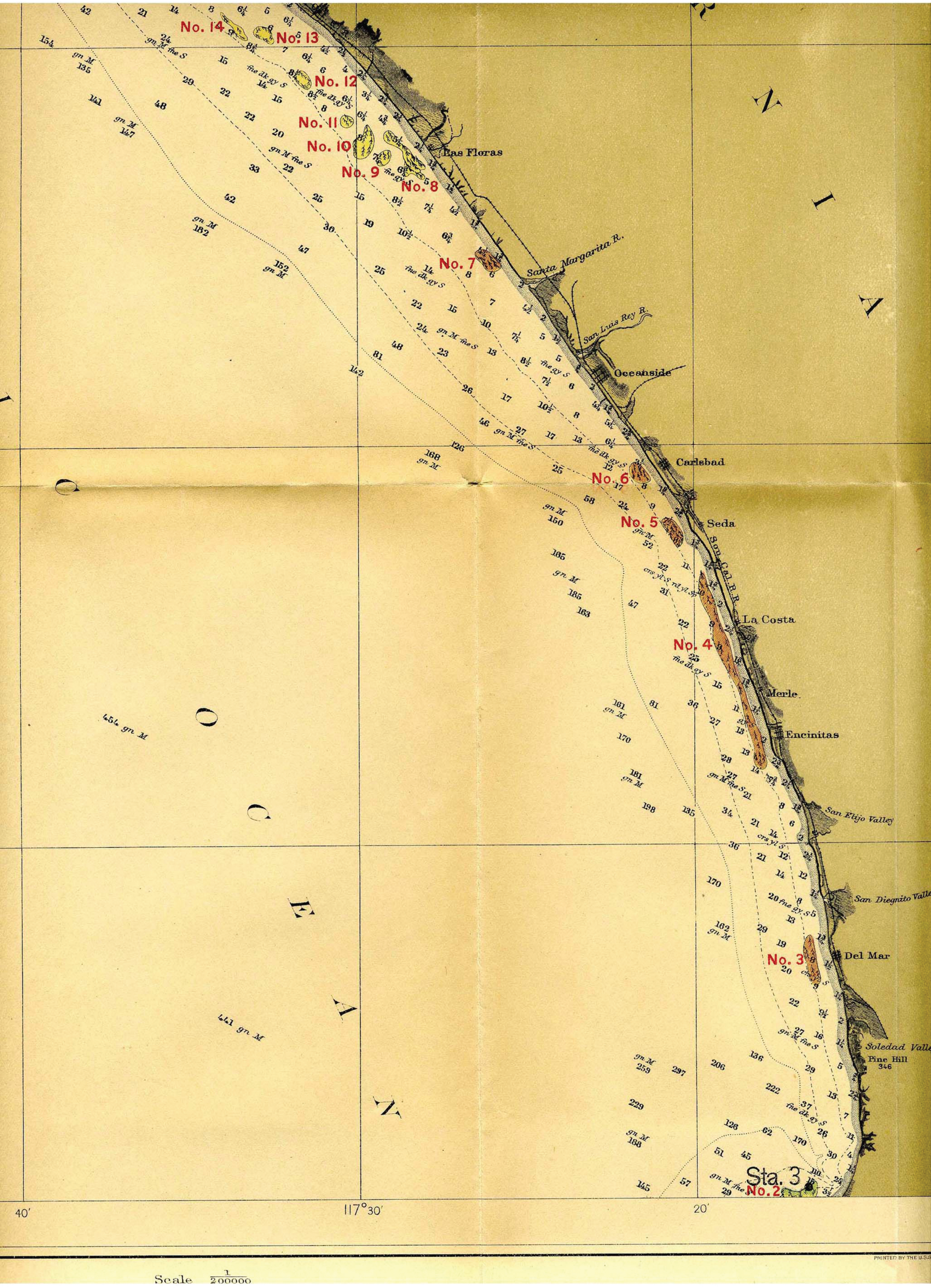

117°10'0"W
117°9'0"W
117°8'0"W
32°35'0"N
32°34'0"N
32°33'0"N
32°32'0"N
N
Silver Strand
75
Palm
Seacoast
Imperial Beach
Imperial Beach
20
10
United States
Mexico
Kelp bed area
Imperial Beach: 0.1516 Km²
October 28, 2011
1 stat. mi.
1 Km
Depth contours in meters
MBC


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
32°31'0"N
N
75
30
20
10
International Reefs
(artificial)
United States
Mexico
Kelp bed area
Imperial Beach: 0.1516 Km^2
October 28, 2011
1 stat. mi.
1 Km
Depth contours in meters

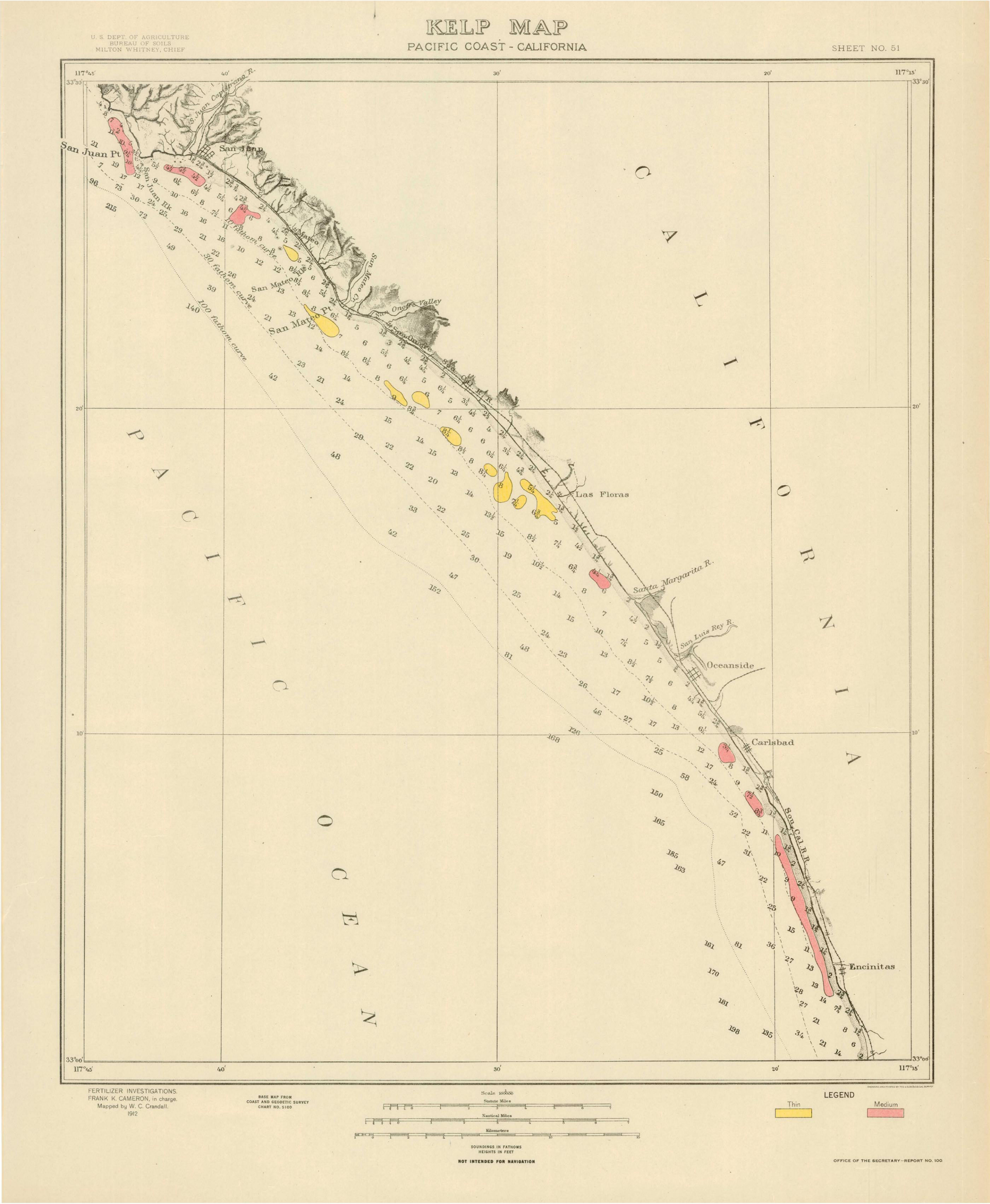
APPENDIX B

Historic Coverage Area of Kelp Canopies

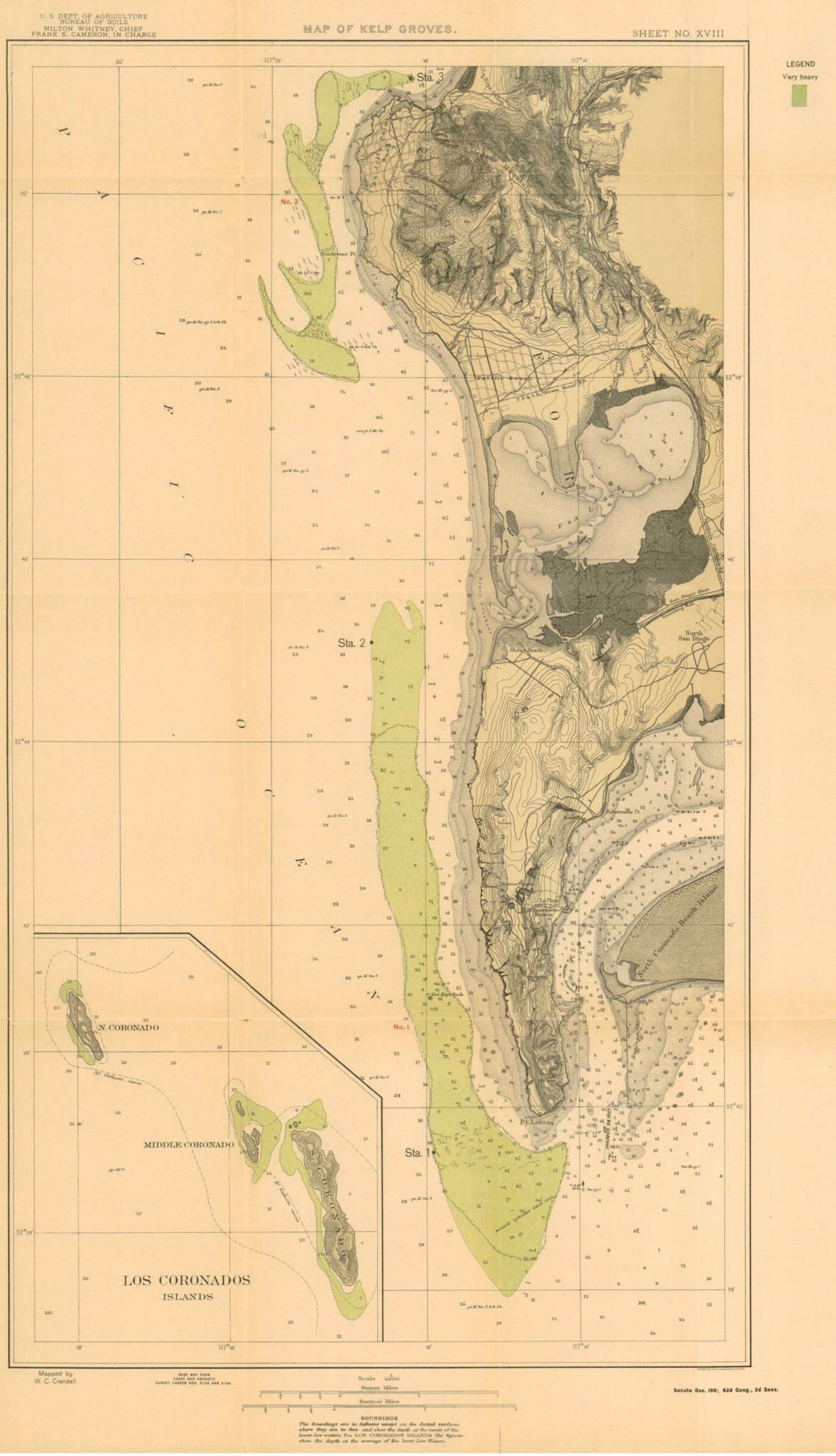
1911 Crandall kelp bed survey, Newport to San Onofre



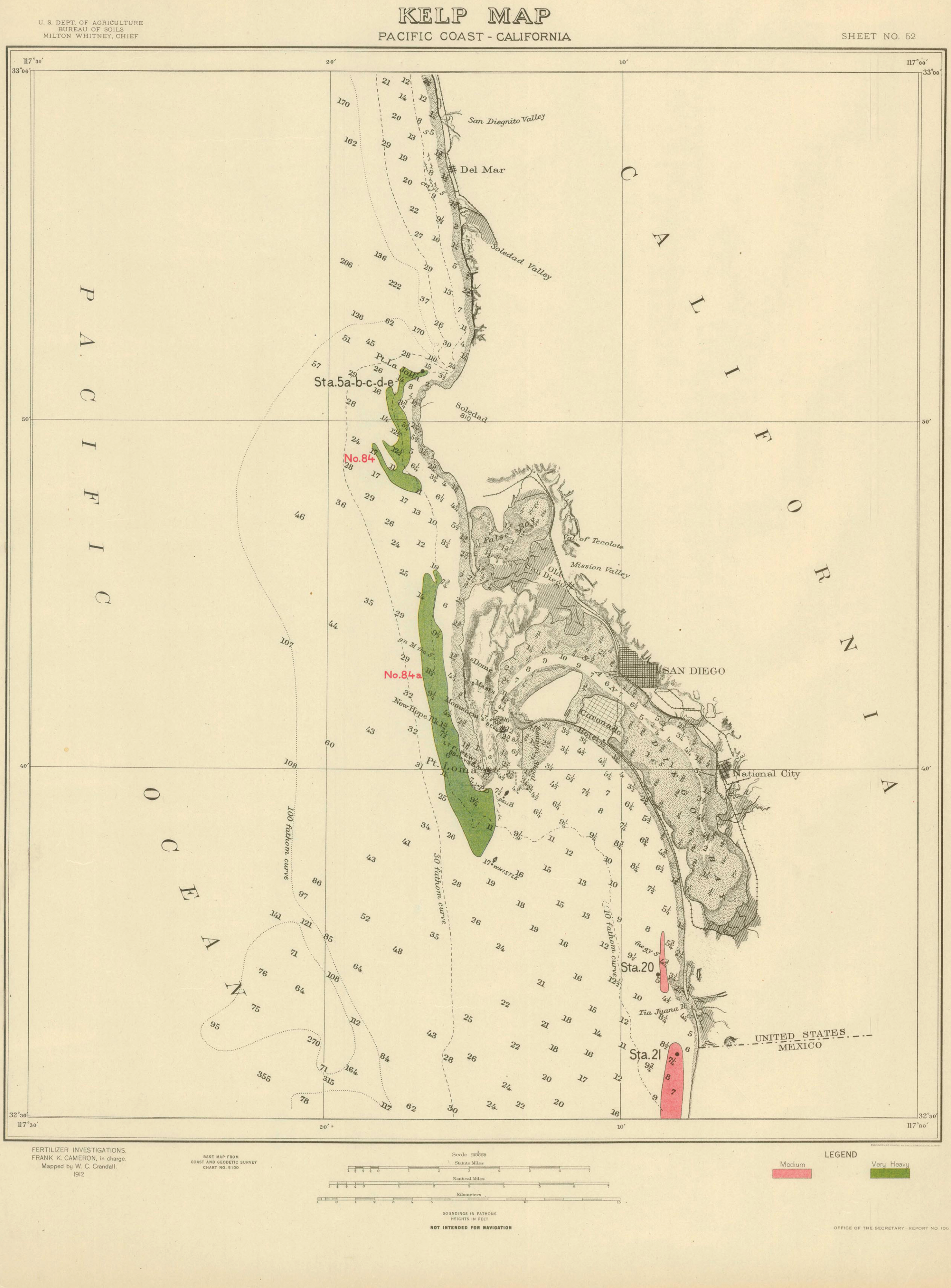
1911 Crandall kelp bed survey, San Onofre to Del Mar



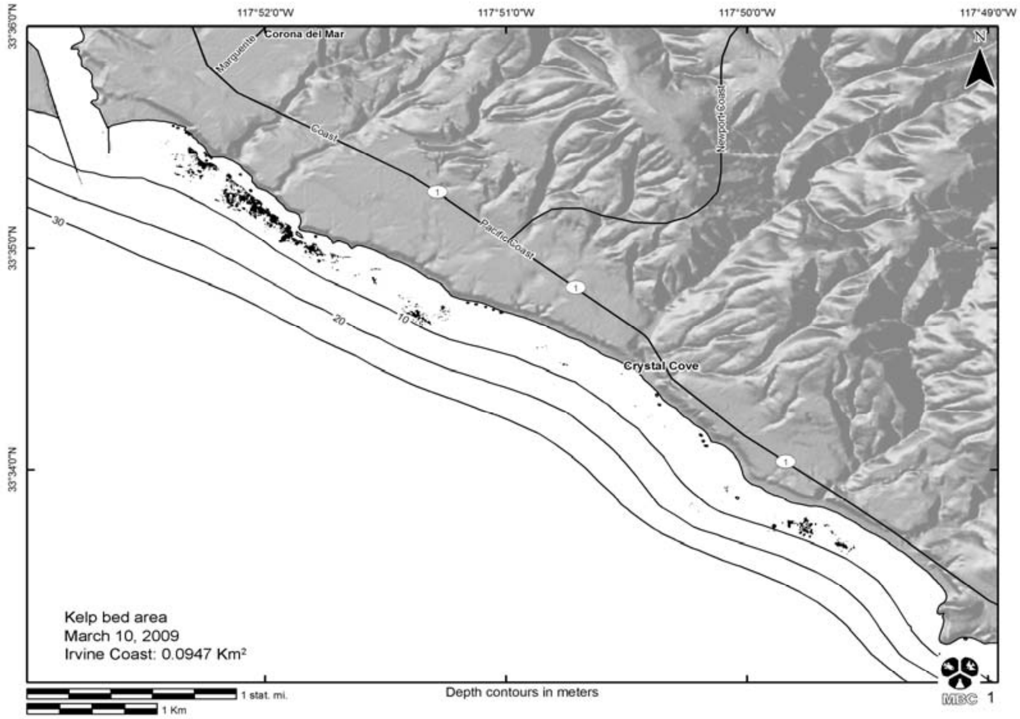
1911 Crandall kelp bed survey, San Juan to Encinitas

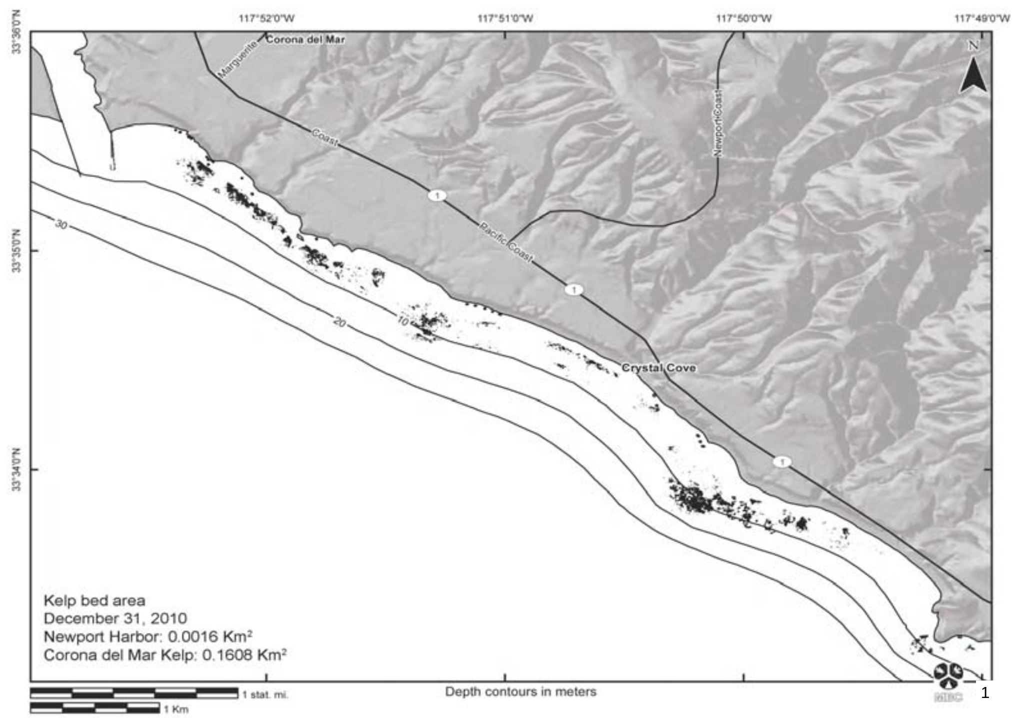


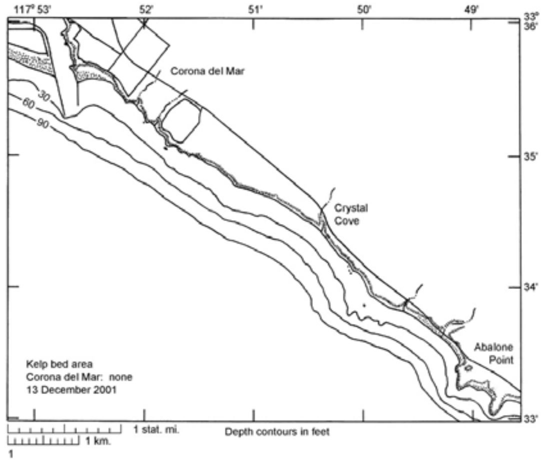
1911 Crandall kelp bed survey, La Jolla to Point Loma

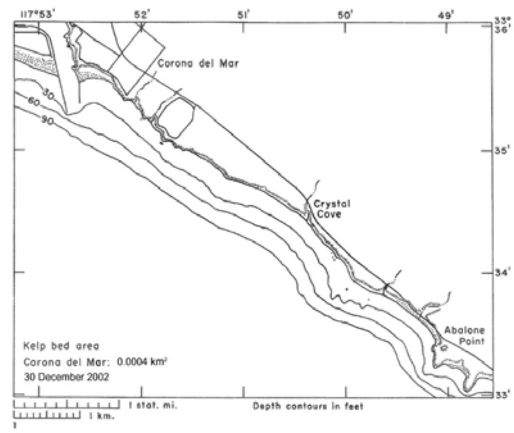


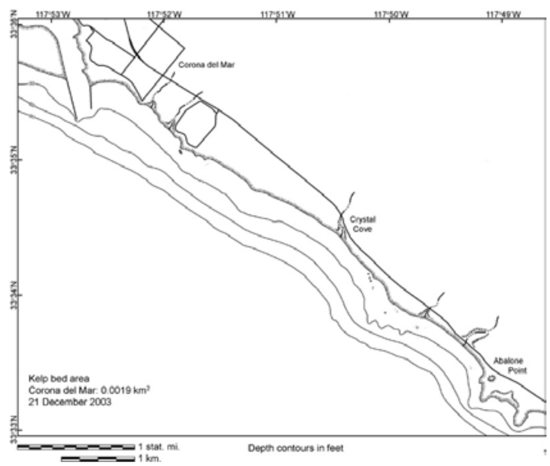
1911 Crandall kelp bed survey, La Jolla to Imperial Beach

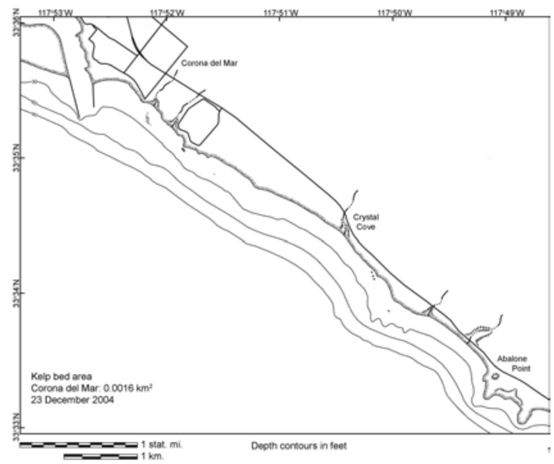

117°52'0"W
117°51'0"W
117°50'0"W
117°49'0"W
33°36'0"N
33°35'0"N
33°34'0"N
Corona del Mar
Marguerite
Coast
Pacific Coast
Newport Coast
Crystal Cove
10
20
30
N
Kelp bed area
March 10, 2009
Irvine Coast: 0.0947 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC 1

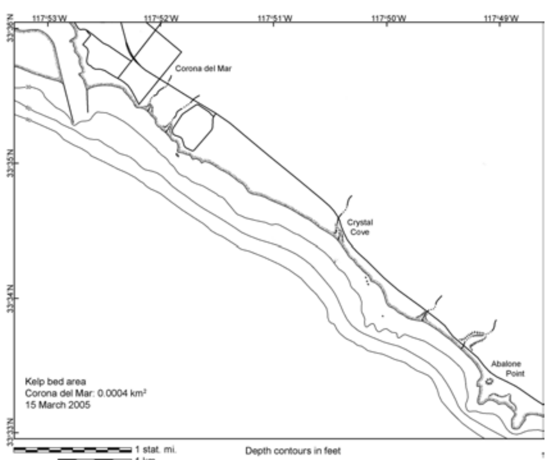

117°52'0"W
117°51'0"W
117°50'0"W
117°49'0"W
33°36'0"N
33°35'0"N
33°34'0"N
Corona del Mar
Marguerite
Coast
Pacific Coast
Newport Coast
Crystal Cove
10
20
30
N
Kelp bed area
December 31, 2010
Newport Harbor: 0.0016 Km²
Corona del Mar Kelp: 0.1608 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC 1

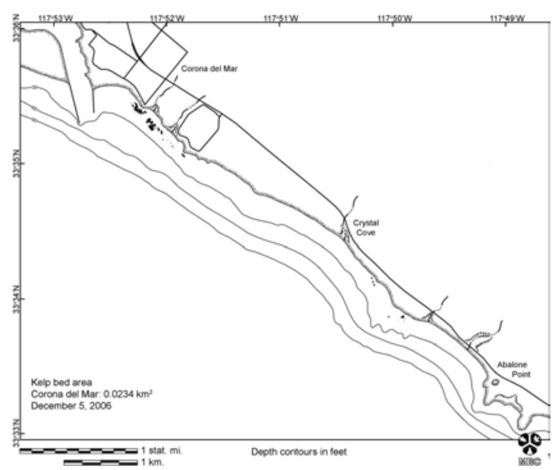

117° 53'
52'
51'
50'
49'
33° 36'
35'
34'
33'
Corona del Mar
Crystal Cove
Abalone Point
30
60
90
Kelp bed area
Corona del Mar: none
13 December 2001
1 stat. mi.
1 km.
Depth contours in feet

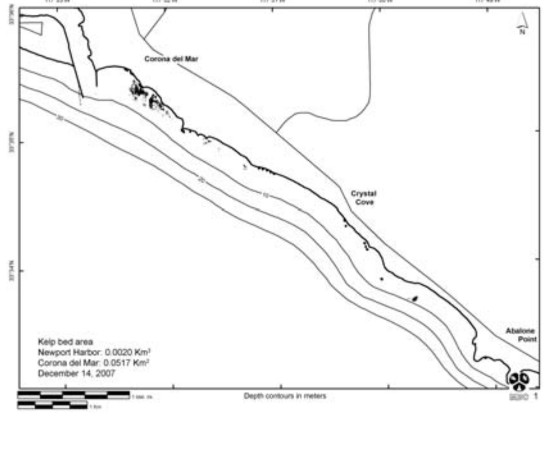

117°53'
52'
51'
50'
49'
33° 36'
35'
34'
33'
Corona del Mar
Crystal Cove
Abalone Point
30
60
90
Kelp bed area
Corona del Mar: 0.0004 km²
30 December 2002
1 stat. mi.
1 km.
Depth contours in feet

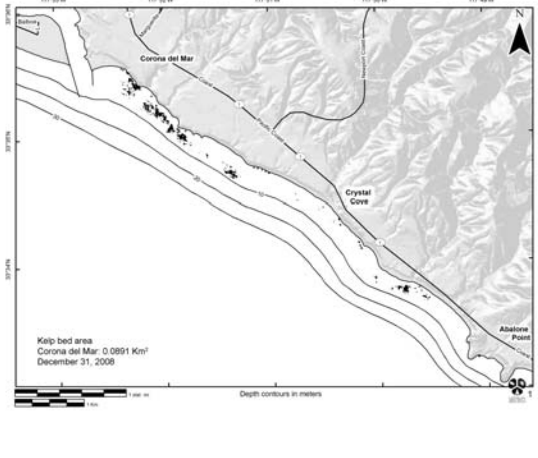

117°53'W
117°52'W
117°51'W
117°50'W
117°49'W
Corona del Mar
Crystal Cove
Abalone Point
Kelp bed area
Corona del Mar: 0.0019 km²
21 December 2003
1 stat. mi.
1 km.
Depth contours in feet

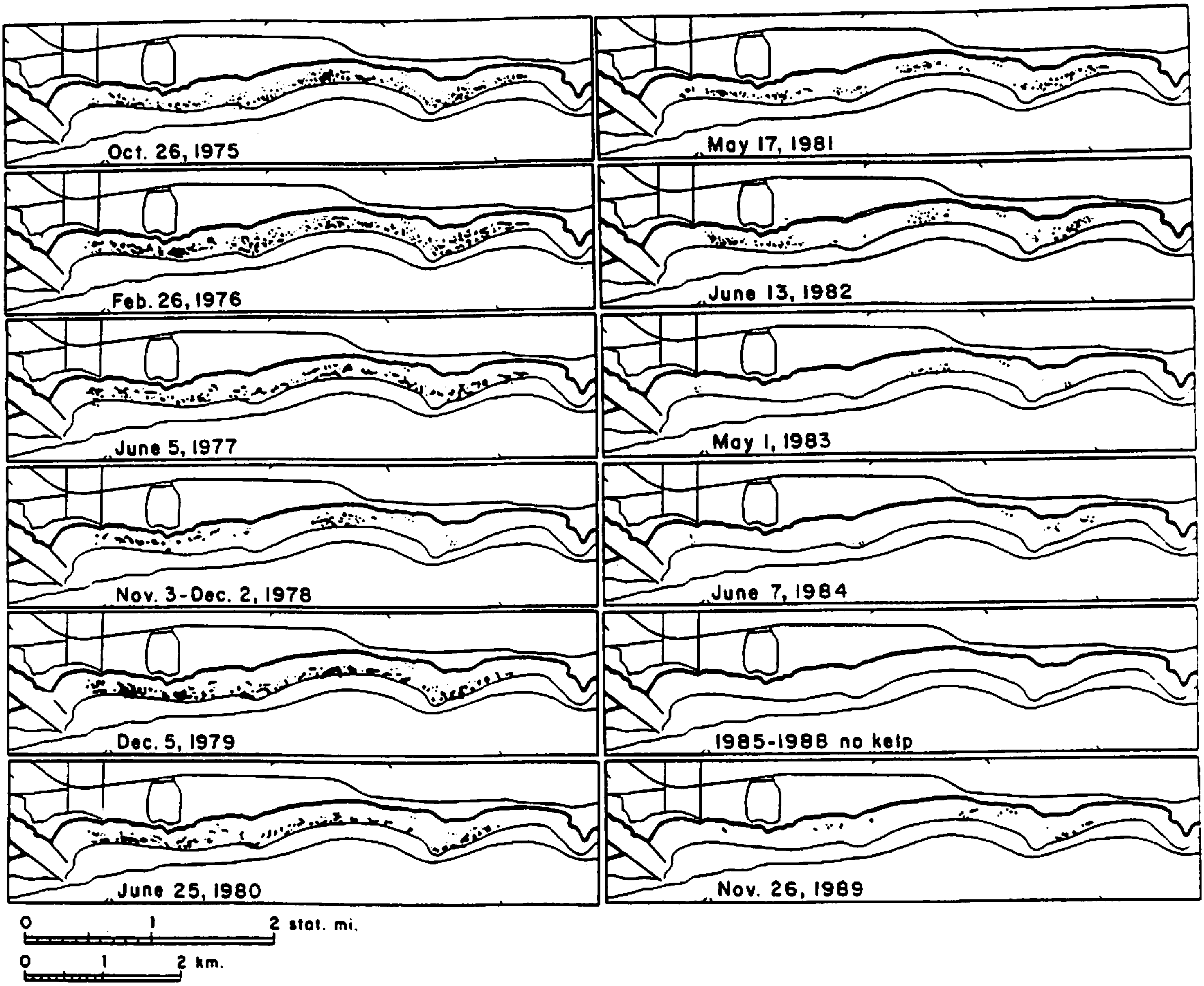

117°53'W
117°52'W
117°51'W
117°50'W
117°49'W
Corona del Mar
Crystal Cove
Abalone Point
Kelp bed area
Corona del Mar: 0.0016 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet


117°53'W
117°52'W
117°51'W
117°50'W
117°49'W
Corona del Mar
Crystal Cove
Abalone Point
Kelp bed area
Corona del Mar: 0.0004 km²
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet

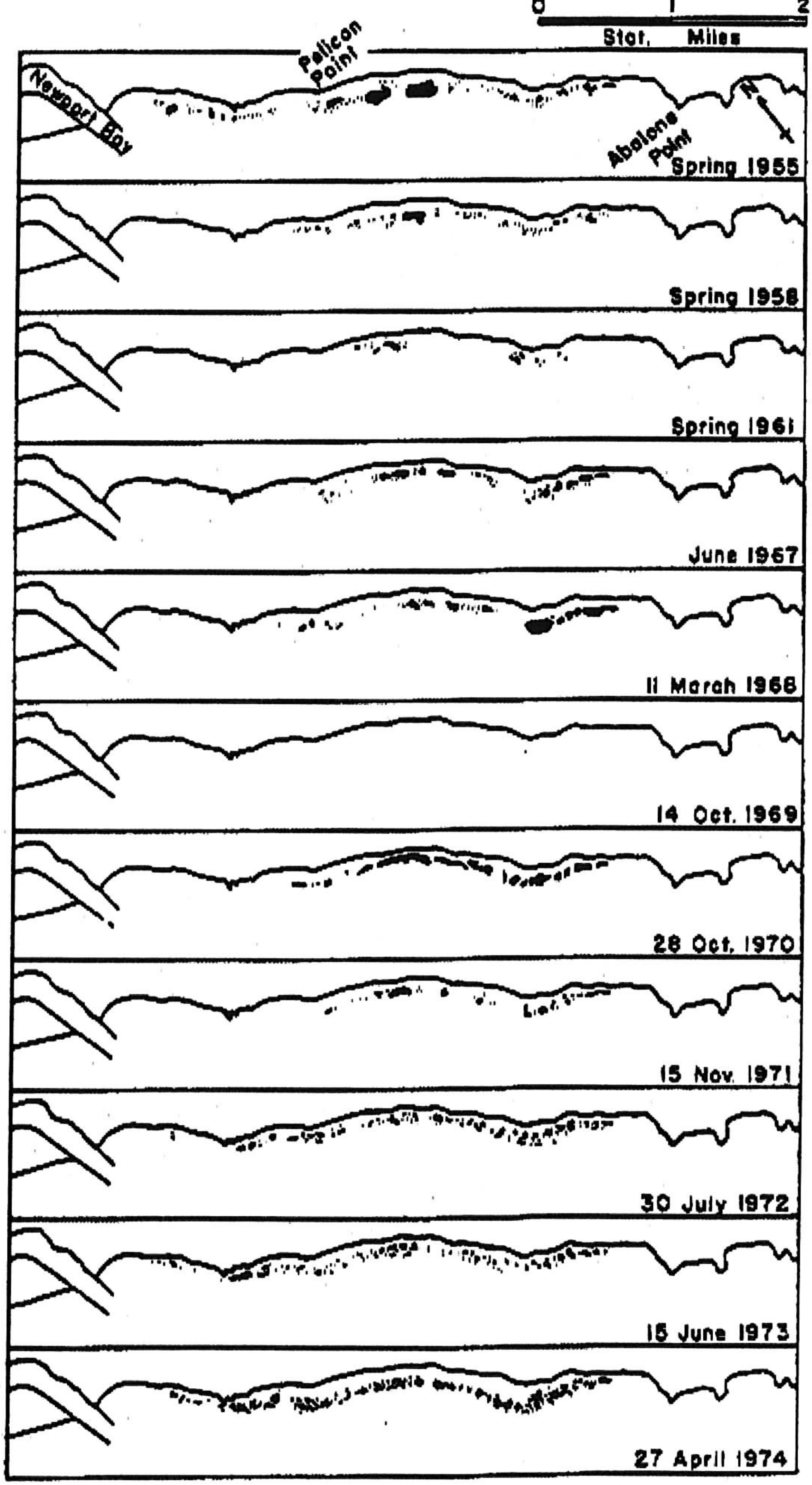

117°53'W
117°52'W
117°51'W
117°50'W
117°49'W
Corona del Mar
Crystal Cove
Abalone Point
Kelp bed area
Corona del Mar: 0.0234 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet


Corona del Mar
Crystal Cove
Abalone Point
Kelp bed area
Newport Harbor: 0.0020 Km²
Corona del Mar: 0.0517 Km²
December 14, 2007
Depth contours in meters

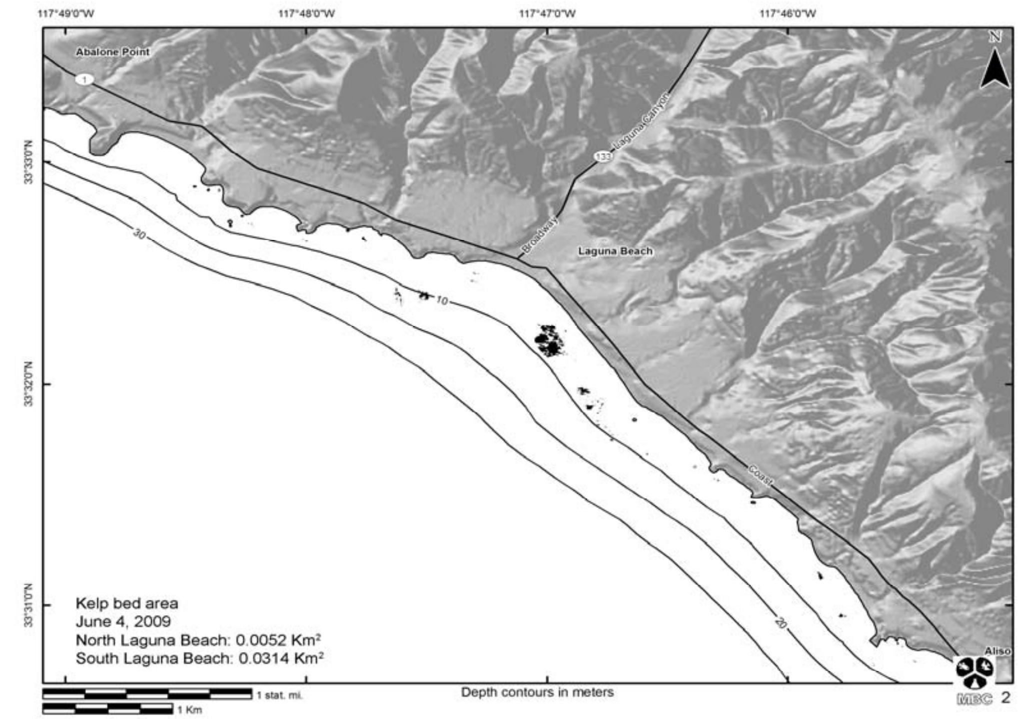

N
Corona del Mar
Crystal Cove
Abalone Point
Kelp bed area
Corona del Mar: 0.0891 Km²
December 31, 2008
Depth contours in meters

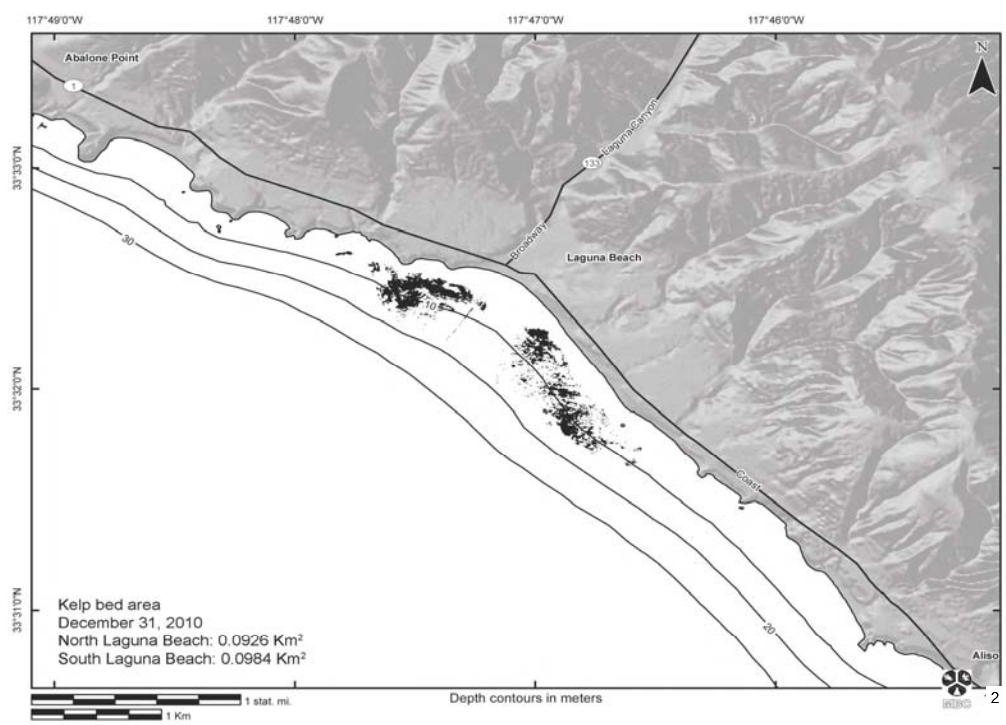


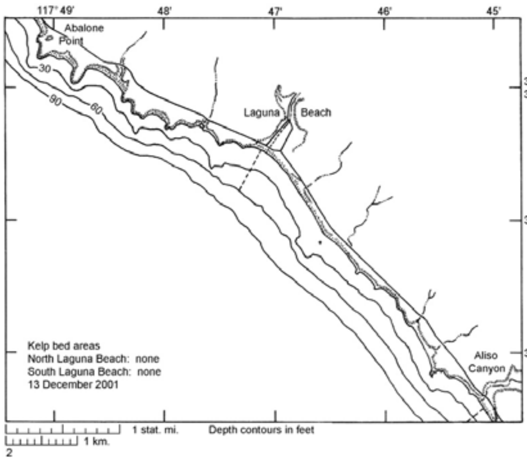
Historical charts of Corona del Mar kelp from 1975 to 1989.

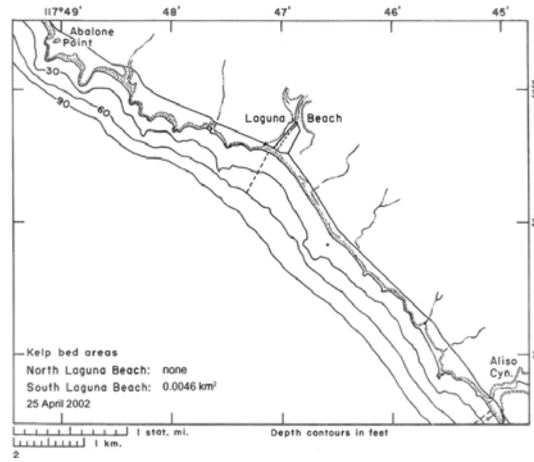


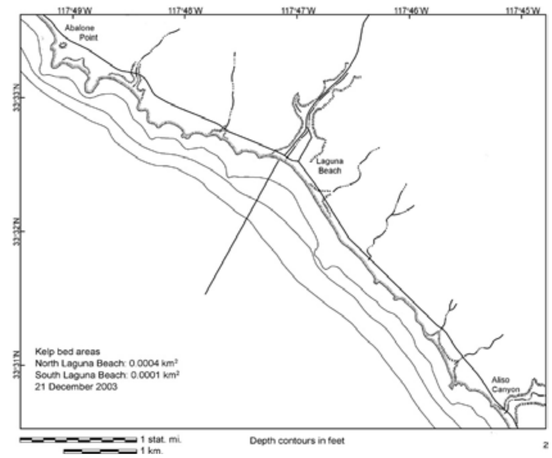
Historical charts of Corona del Mar kelp from 1955 to 1974.

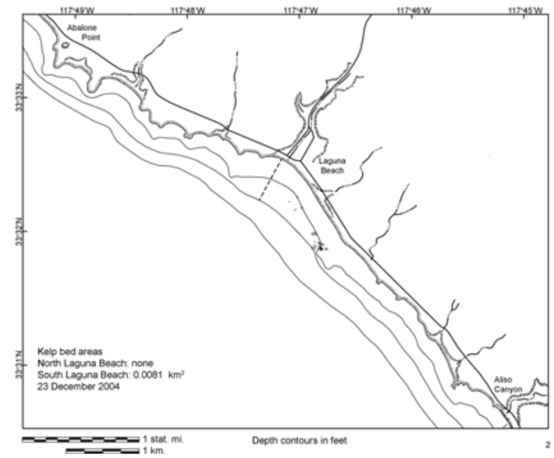

117°49'0"W
117°48'0"W
117°47'0"W
117°46'0"W
33°33'0"N
33°32'0"N
33°31'0"N
Abalone Point
Laguna Canyon
133
Broadway
Laguna Beach
Coast
Aliso
30
10
20
N
Kelp bed area
June 4, 2009
North Laguna Beach: 0.0052 Km²
South Laguna Beach: 0.0314 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
2

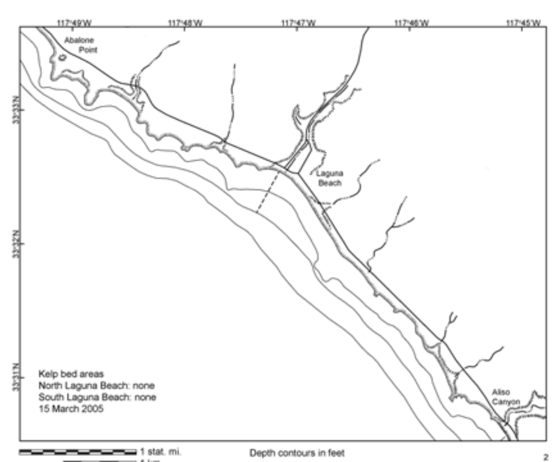

117°49'0"W
117°48'0"W
117°47'0"W
117°46'0"W
33°33'0"N
33°32'0"N
33°31'0"N
Abalone Point
Laguna Canyon
133
Broadway
Laguna Beach
Coast
Aliso
30
10
20
N
Kelp bed area
December 31, 2010
North Laguna Beach: 0.0926 Km²
South Laguna Beach: 0.0984 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
2

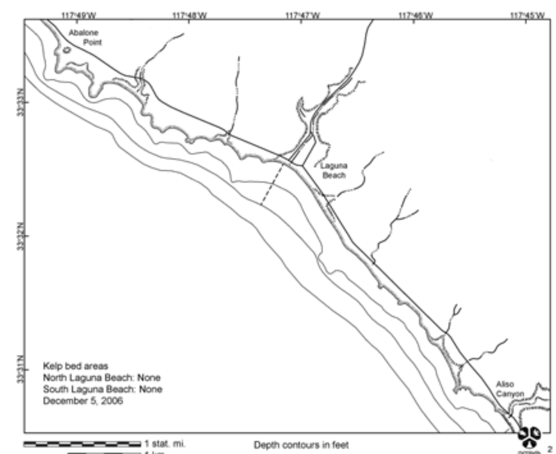

117° 49'
48'
47'
46'
45'
33°
33'
32'
31'
Abalone Point
30
60
90
Laguna Beach
Aliso Canyon
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: none
13 December 2001
1 stat. mi.
1 km.
Depth contours in feet
2

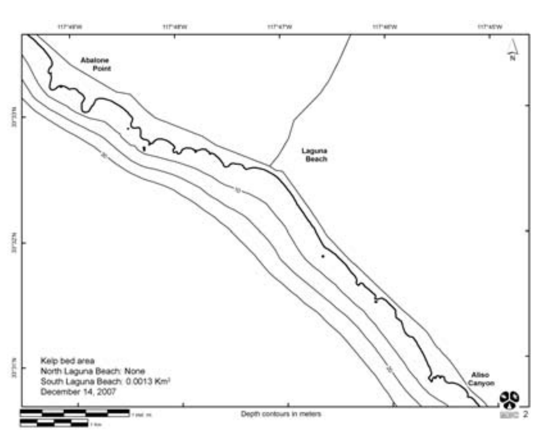

117°49'
48'
47'
46'
45'
33°
33'
32'
31'
Abalone Point
30
60
90
Laguna Beach
Aliso Cyn.
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: 0.0046 km²
25 April 2002
1 stat. mi.
1 km.
Depth contours in feet
2

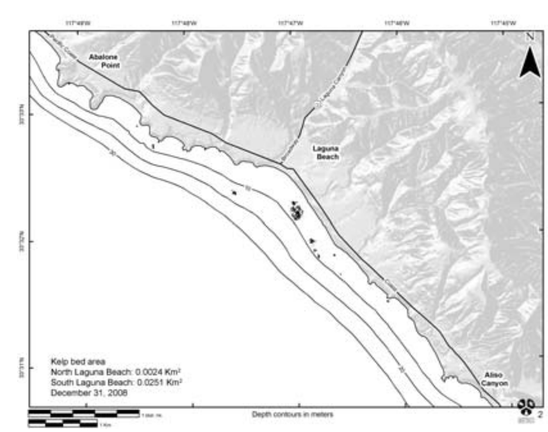

117°49'W
117°48'W
117°47'W
117°46'W
117°45'W
33°33'N
33°32'N
33°31'N
Abalone Point
Laguna Beach
Aliso Canyon
Kelp bed areas
North Laguna Beach: 0.0004 km²
South Laguna Beach: 0.0001 km²
21 December 2003
1 stat. mi.
1 km.
Depth contours in feet
2

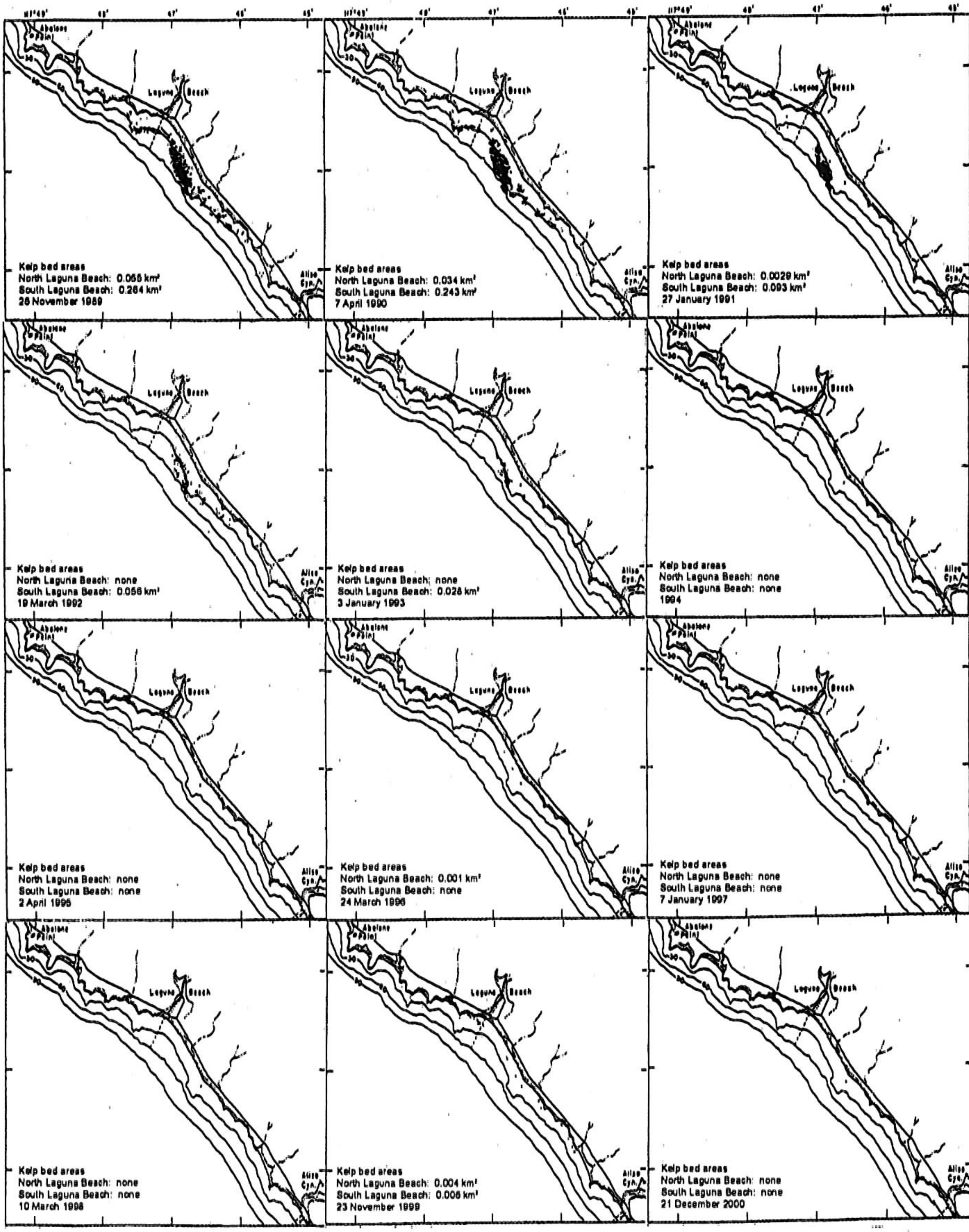

117°49'W
117°48'W
117°47'W
117°46'W
117°45'W
33°33'N
33°32'N
33°31'N
Abalone Point
Laguna Beach
Aliso Canyon
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: 0.0081 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
2

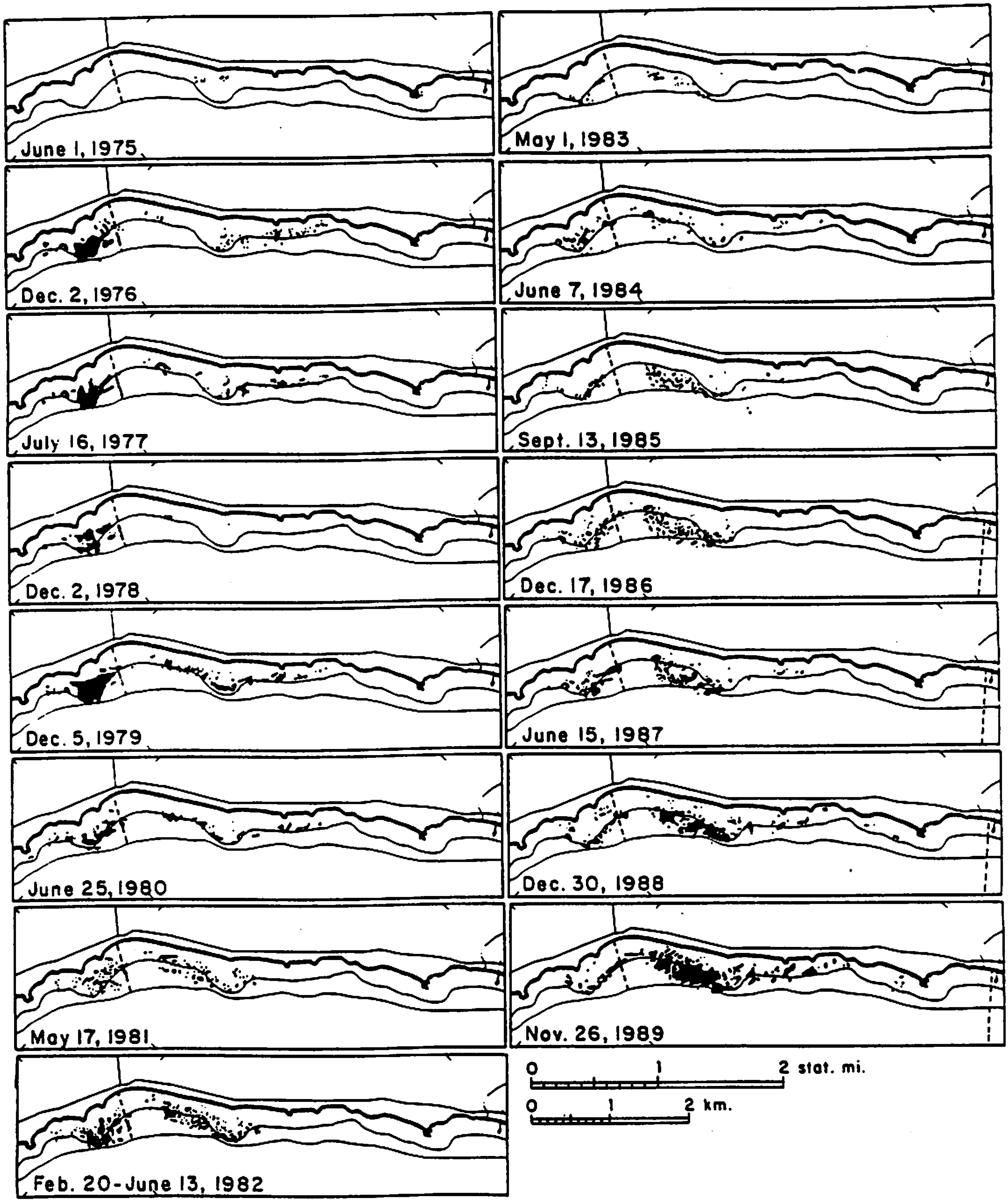

117°49'W
117°48'W
117°47'W
117°46'W
117°45'W
33°33'N
33°32'N
33°31'N
Abalone Point
Laguna Beach
Aliso Canyon
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: none
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
2


117°49'W
117°48'W
117°47'W
117°46'W
117°45'W
33°33'N
33°32'N
33°31'N
Abalone Point
Laguna Beach
Aliso Canyon
Kelp bed areas
North Laguna Beach: None
South Laguna Beach: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
2

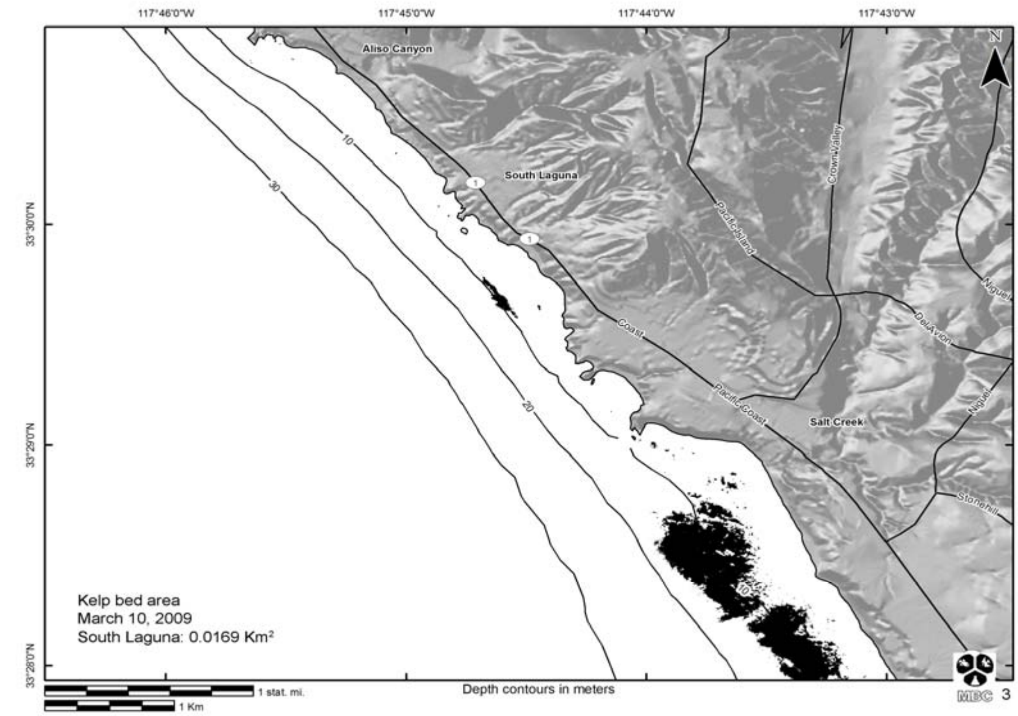

Abalone Point
Laguna Beach
Aliso Canyon
Kelp bed area
North Laguna Beach: None
South Laguna Beach: 0.0013 Km²
December 14, 2007
Depth contours in meters
2


N
Abalone Point
Laguna Beach
Aliso Canyon
Kelp bed area
North Laguna Beach: 0.0024 Km²
South Laguna Beach: 0.0251 Km²
December 31, 2008
Depth contours in meters
2


Abalone Point
Laguna Beach
Aliso Cyn.
Kelp bed areas
North Laguna Beach: 0.055 km²
South Laguna Beach: 0.264 km²
28 November 1989
Kelp bed areas
North Laguna Beach: 0.034 km²
South Laguna Beach: 0.243 km²
7 April 1990
Kelp bed areas
North Laguna Beach: 0.0029 km²
South Laguna Beach: 0.093 km²
27 January 1991
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: 0.056 km²
19 March 1992
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: 0.028 km²
3 January 1993
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: none
1994
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: none
2 April 1995
Kelp bed areas
North Laguna Beach: 0.001 km²
South Laguna Beach: none
24 March 1996
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: none
7 January 1997
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: none
10 March 1998
Kelp bed areas
North Laguna Beach: 0.004 km²
South Laguna Beach: 0.006 km²
23 November 1999
Kelp bed areas
North Laguna Beach: none
South Laguna Beach: none
21 December 2000



Historical charts of Laguna Beach kelp from 1975 to 1989.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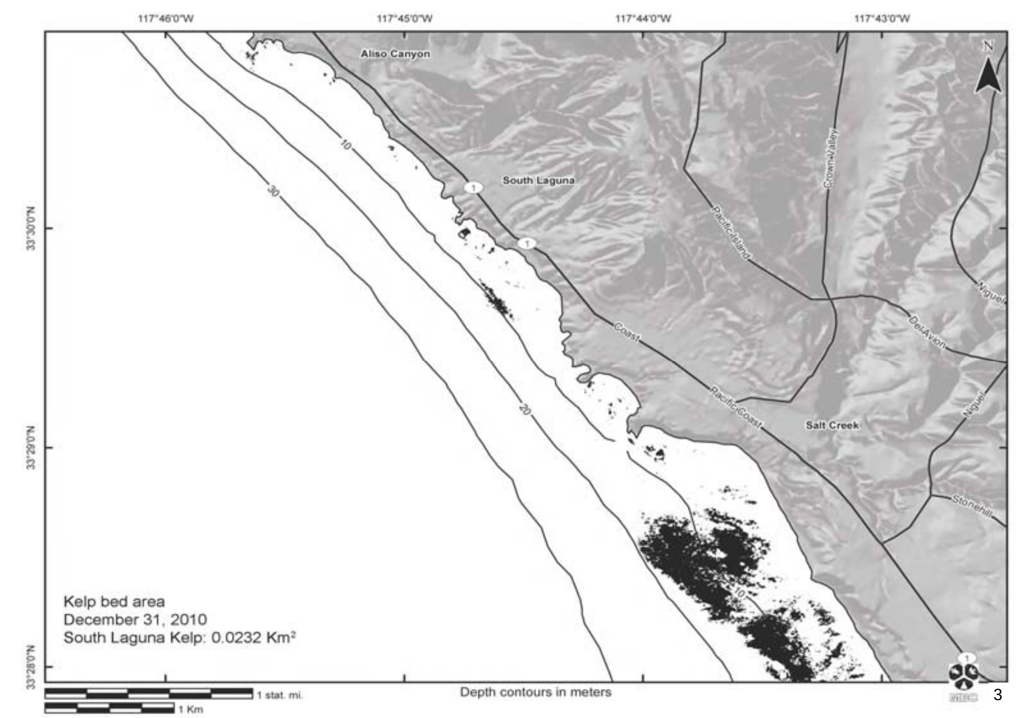
117°45'0"W
117°44'0"W
117°43'0"W
33°30'0"N
33°29'0"N
33°28'0"N
Aliso Canyon
South Laguna
Salt Creek
Crown Valley
Pacific Island
Niguel
Del Avion
Stonehill
Coast
Pacific Coast
10
20
30
Kelp bed area
March 10, 2009
South Laguna: 0.0169 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC 3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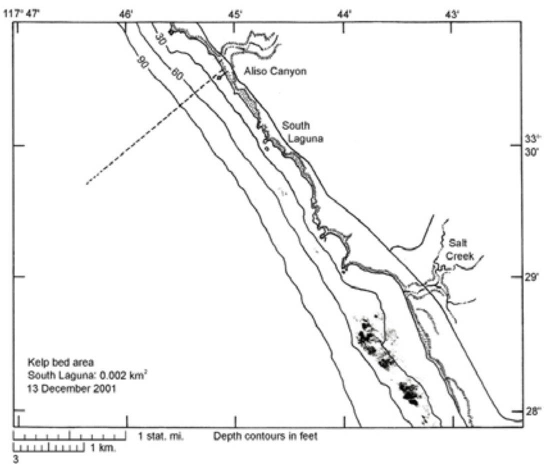
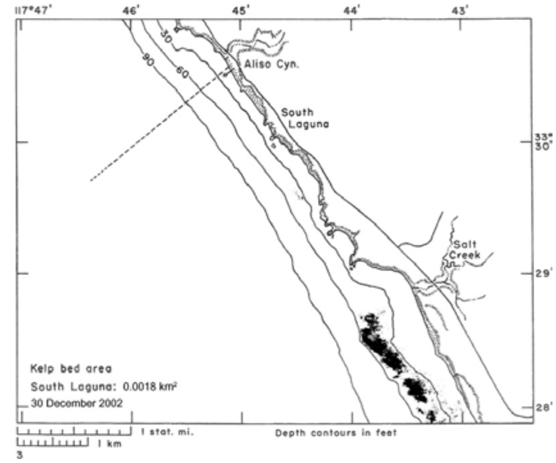
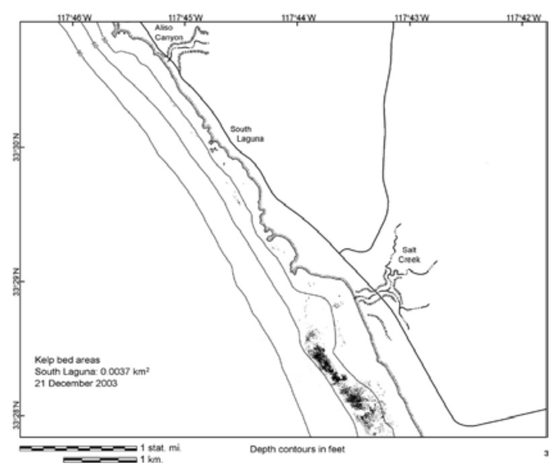
117°45'0"W
117°44'0"W
117°43'0"W
33°30'0"N
33°29'0"N
33°28'0"N
Aliso Canyon
South Laguna
Salt Creek
Crown Valley
Pacific Island
Niguel
Del Avion
Stonehill
Coast
Pacific Coast
10
20
30
Kelp bed area
December 31, 2010
South Laguna Kelp: 0.0232 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC 3


117° 47'
46'
45'
44'
43'
33°
30'
29'
28'
30
60
90
Aliso Canyon
South
Laguna
Salt
Creek
Kelp bed area
South Laguna: 0.002 km²
13 December 2001
1 stat. mi.
1 km.
Depth contours in feet
3


117°47'
46'
45'
44'
43'
33°
30'
29'
28'
30
60
90
Aliso Cyn.
South
Laguna
Salt
Creek
Kelp bed area
South Laguna: 0.0018 km²
30 December 2002
1 stat. mi.
1 km
Depth contours in feet
3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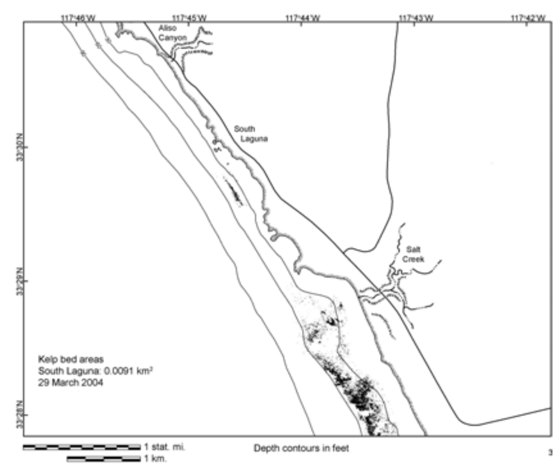
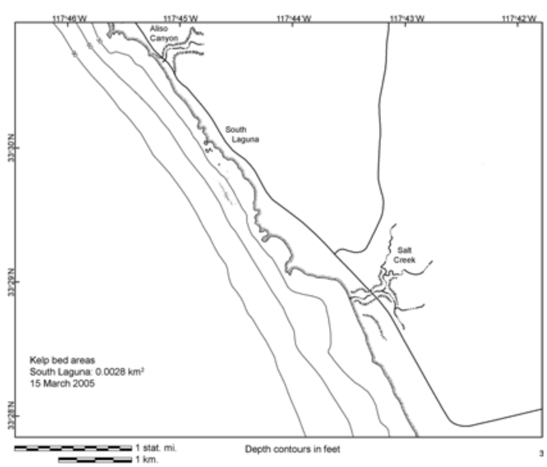
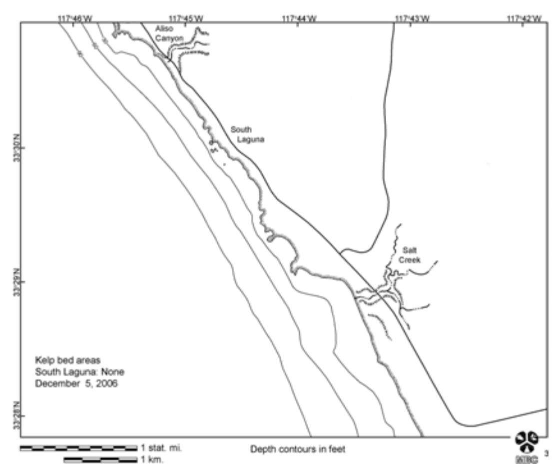
117°45'W
117°44'W
117°43'W
117°42'W
33°30'N
33°29'N
33°28'N
Aliso
Canyon
South
Laguna
Salt
Creek
Kelp bed areas
South Laguna: 0.0037 km²
21 December 2003
1 stat. mi.
1 km.
Depth contours in feet
3


117°46'W
117°45'W
117°44'W
117°43'W
117°42'W
33°30'N
33°29'N
33°28'N
Aliso
Canyon
South
Laguna
Salt
Creek
Kelp bed areas
South Laguna: 0.0091 km²
29 March 2004
1 stat. mi.
1 km.
Depth contours in feet
3


117°46'W
117°45'W
117°44'W
117°43'W
117°42'W
33°30'N
33°29'N
33°28'N
Aliso
Canyon
South
Laguna
Salt
Creek
Kelp bed areas
South Laguna: 0.0028 km²
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
3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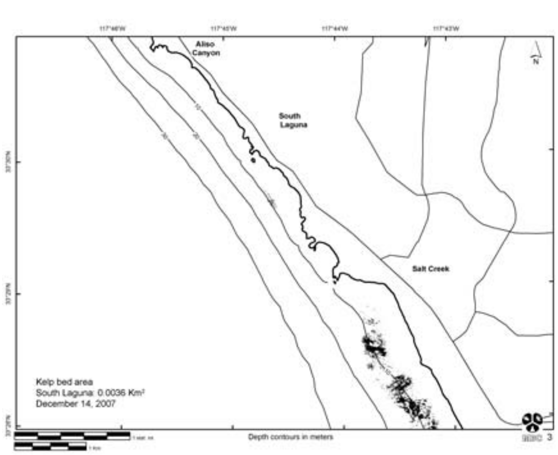
117°45'W
117°44'W
117°43'W
117°42'W
33°30'N
33°29'N
33°28'N
Aliso
Canyon
South
Laguna
Salt
Creek
Kelp bed areas
South Laguna: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
3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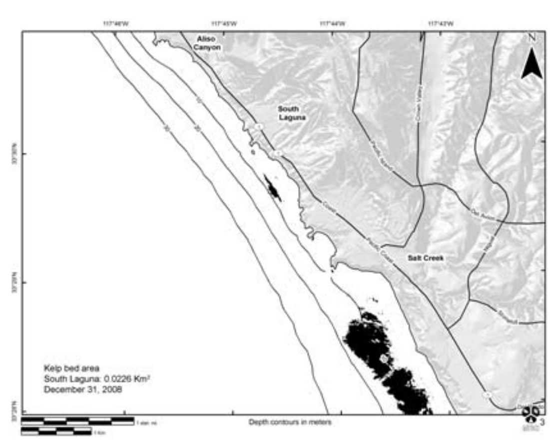
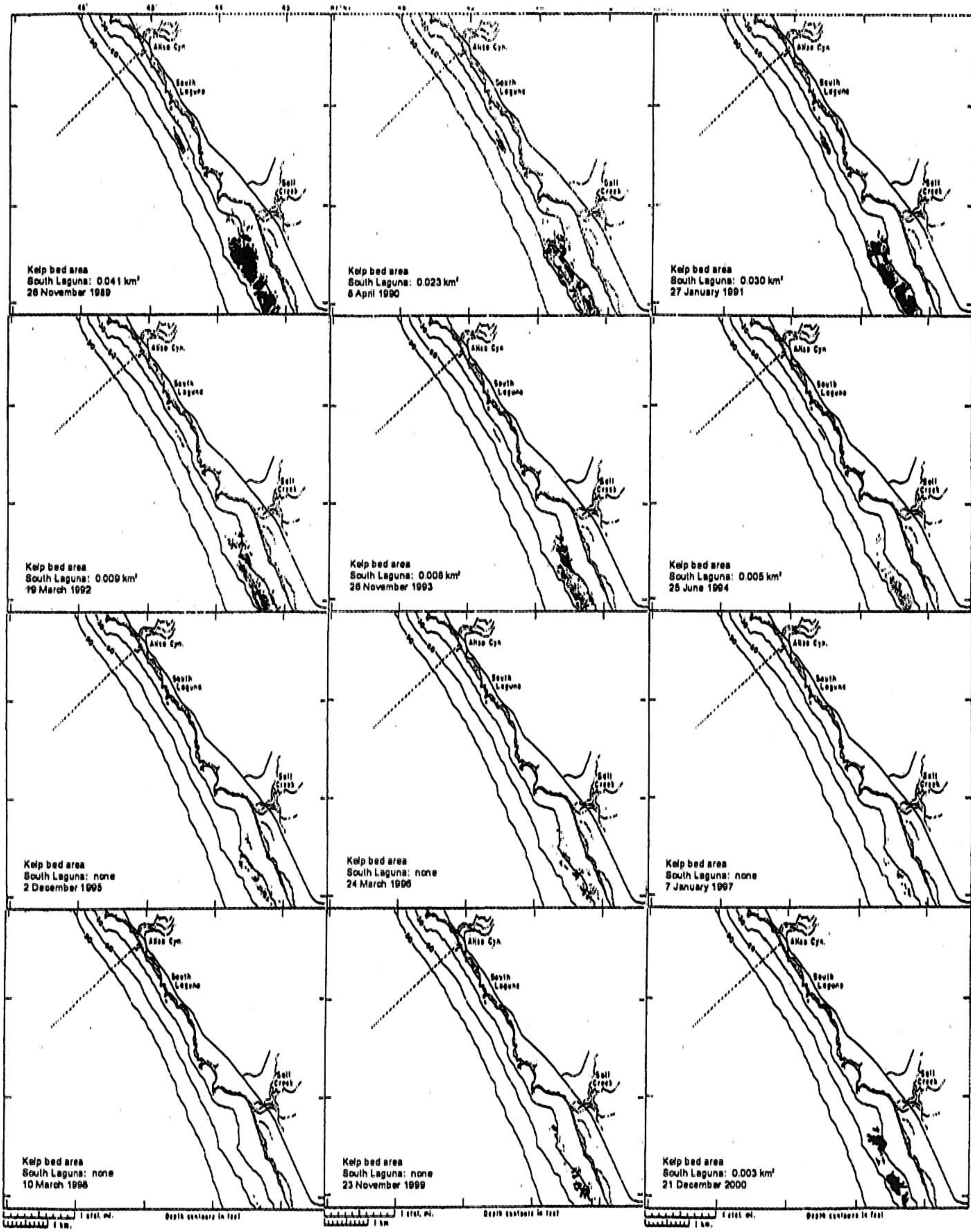
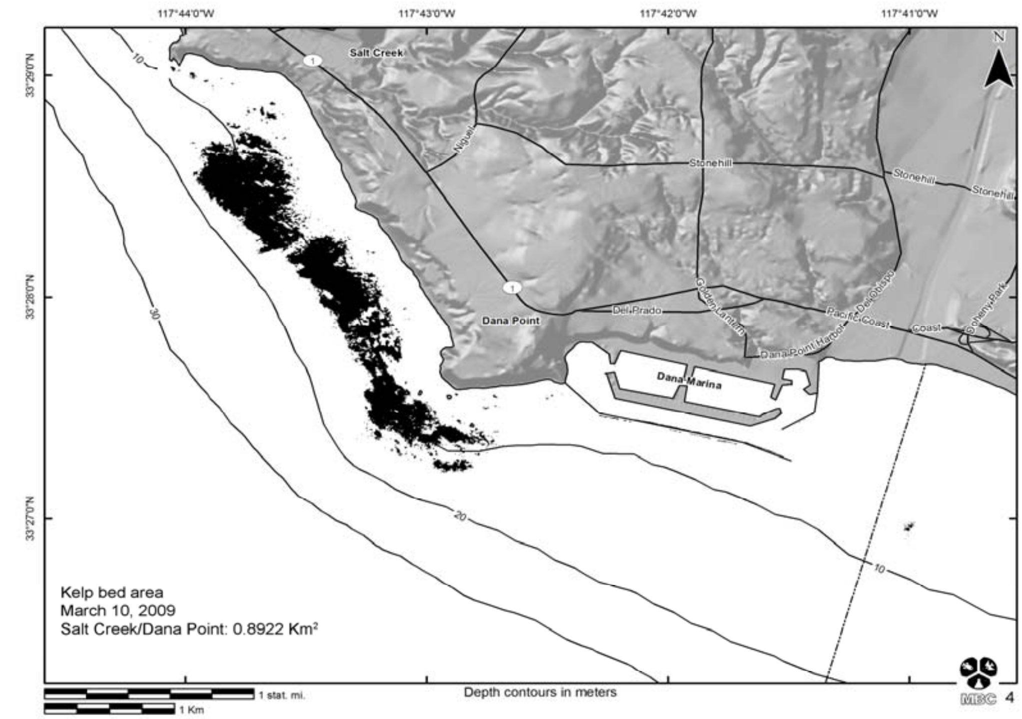
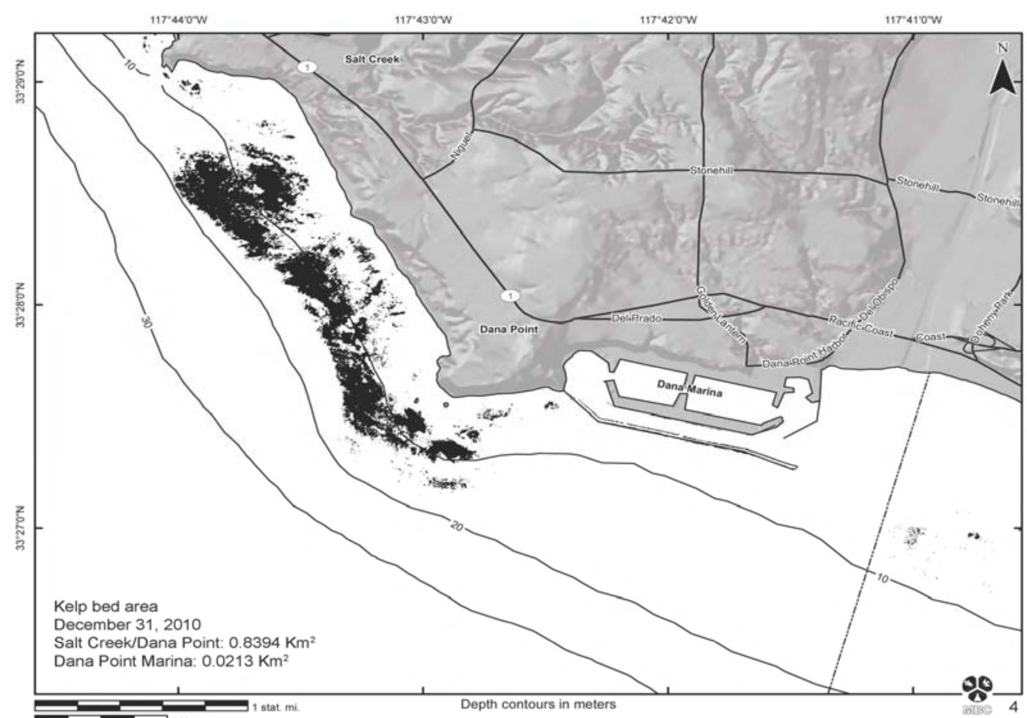
117°45'W
117°44'W
117°43'W
Aliso
Canyon
South
Laguna
Salt Creek
Kelp bed area
South Laguna: 0.0036 Km²
December 14, 2007
Depth contours in meters
3


117°46'W
117°45'W
117°44'W
117°43'W
N
Aliso
Canyon
South
Laguna
Salt Creek
Kelp bed area
South Laguna: 0.0226 Km²
December 31, 2008
Depth contours in meters
3


Aliso Cyn.
South Laguna
Salt Creek
Kelp bed area
South Laguna: 0.041 km^2
26 November 1989
Kelp bed area
South Laguna: 0.023 km^2
8 April 1990
Kelp bed area
South Laguna: 0.030 km^2
27 January 1991
Kelp bed area
South Laguna: 0.009 km^2
19 March 1992
Kelp bed area
South Laguna: 0.006 km^2
26 November 1993
Kelp bed area
South Laguna: 0.005 km^2
25 June 1994
Kelp bed area
South Laguna: none
2 December 1995
Kelp bed area
South Laguna: none
24 March 1996
Kelp bed area
South Laguna: none
7 January 1997
Kelp bed area
South Laguna: none
10 March 1998
Kelp bed area
South Laguna: none
23 November 1999
Kelp bed area
South Laguna: 0.003 km^2
21 December 2000
1 stat. mi.
1 km.
Depth contours in feet


117°44'0"W
117°43'0"W
117°42'0"W
117°41'0"W
33°29'0"N
33°28'0"N
33°27'0"N
N
Salt Creek
Niguel
Stonehill
Dana Point
Del Prado
Golden Lantern
Pacific Coast
Del Obispo
Dana Point Harbor
Doheny Park
Dana Marina
10
20
30
Kelp bed area
March 10, 2009
Salt Creek/Dana Point: 0.8922 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
4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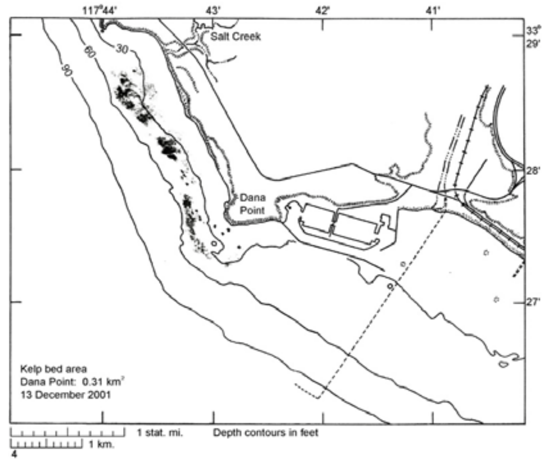
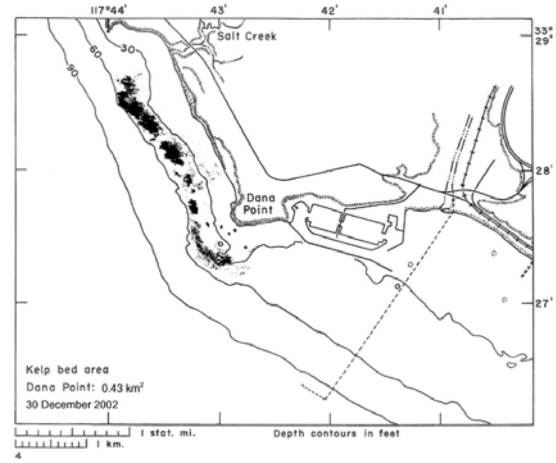
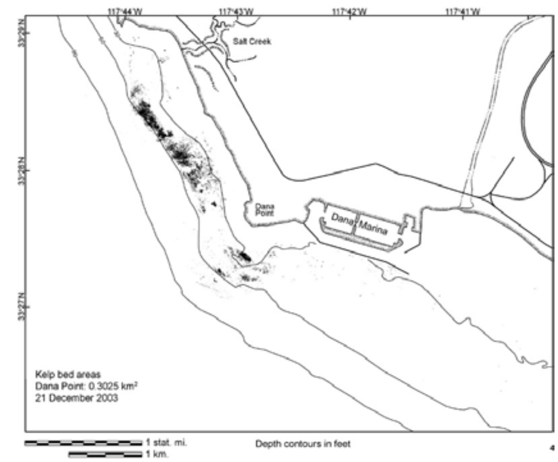
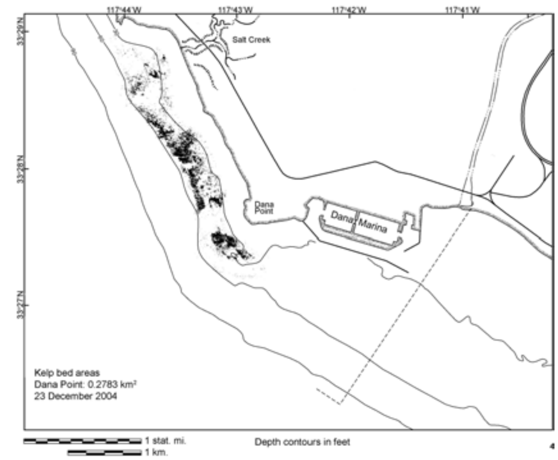
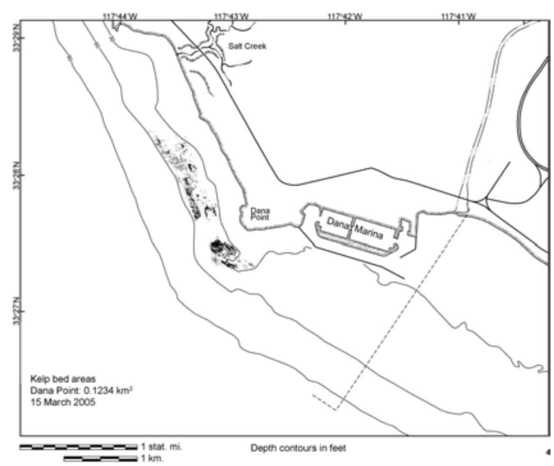
117°43'0"W
117°42'0"W
117°41'0"W
33°29'0"N
33°28'0"N
33°27'0"N
N
Salt Creek
Niguel
Stonehill
Dana Point
Del Prado
Golden Lantern
Pacific Coast
Del Obispo
Dana Point Harbor
Doheny Park
Dana Marina
10
20
30
Kelp bed area
December 31, 2010
Salt Creek/Dana Point: 0.8394 Km²
Dana Point Marina: 0.0213 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
4

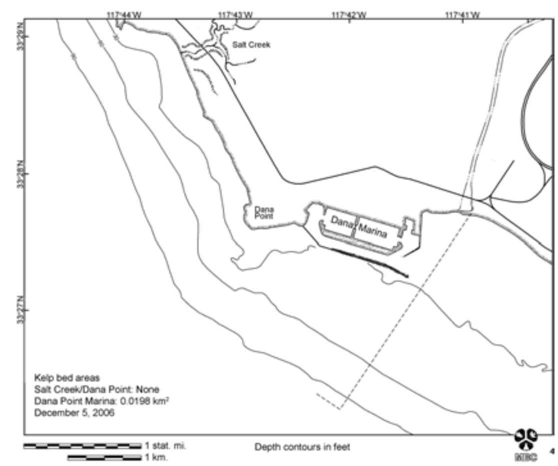

117°44'
43'
42'
41'
33°
29'
28'
27'
Salt Creek
Dana Point
30
60
90
Kelp bed area
Dana Point: 0.31 km²
13 December 2001
1 stat. mi.
1 km.
Depth contours in feet
4

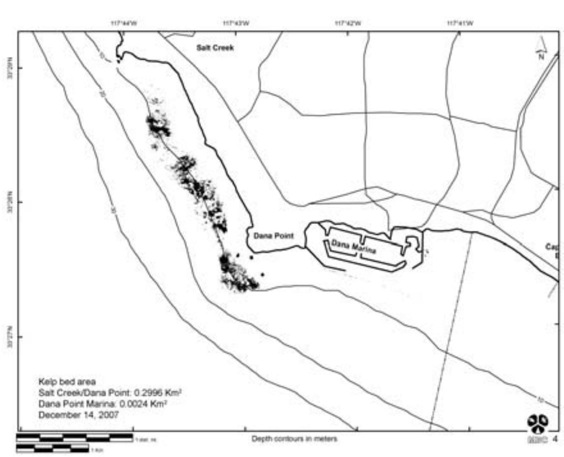

117°44'
43'
42'
41'
33°
29'
28'
27'
Salt Creek
Dana Point
30
60
90
Kelp bed area
Dana Point: 0.43 km²
30 December 2002
1 stat. mi.
1 km.
Depth contours in feet
4

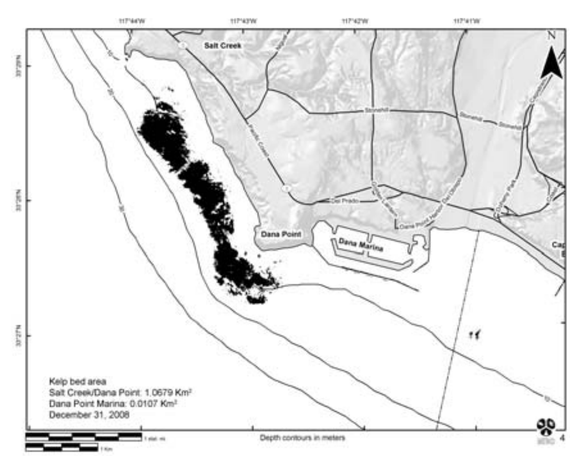

117°44'W
117°43'W
117°42'W
117°41'W
33°29'N
33°28'N
33°27'N
Salt Creek
Dana Point
Dana Marina
Kelp bed areas
Dana Point: 0.3025 km²
21 December 2003
1 stat. mi.
1 km.
Depth contours in feet
4

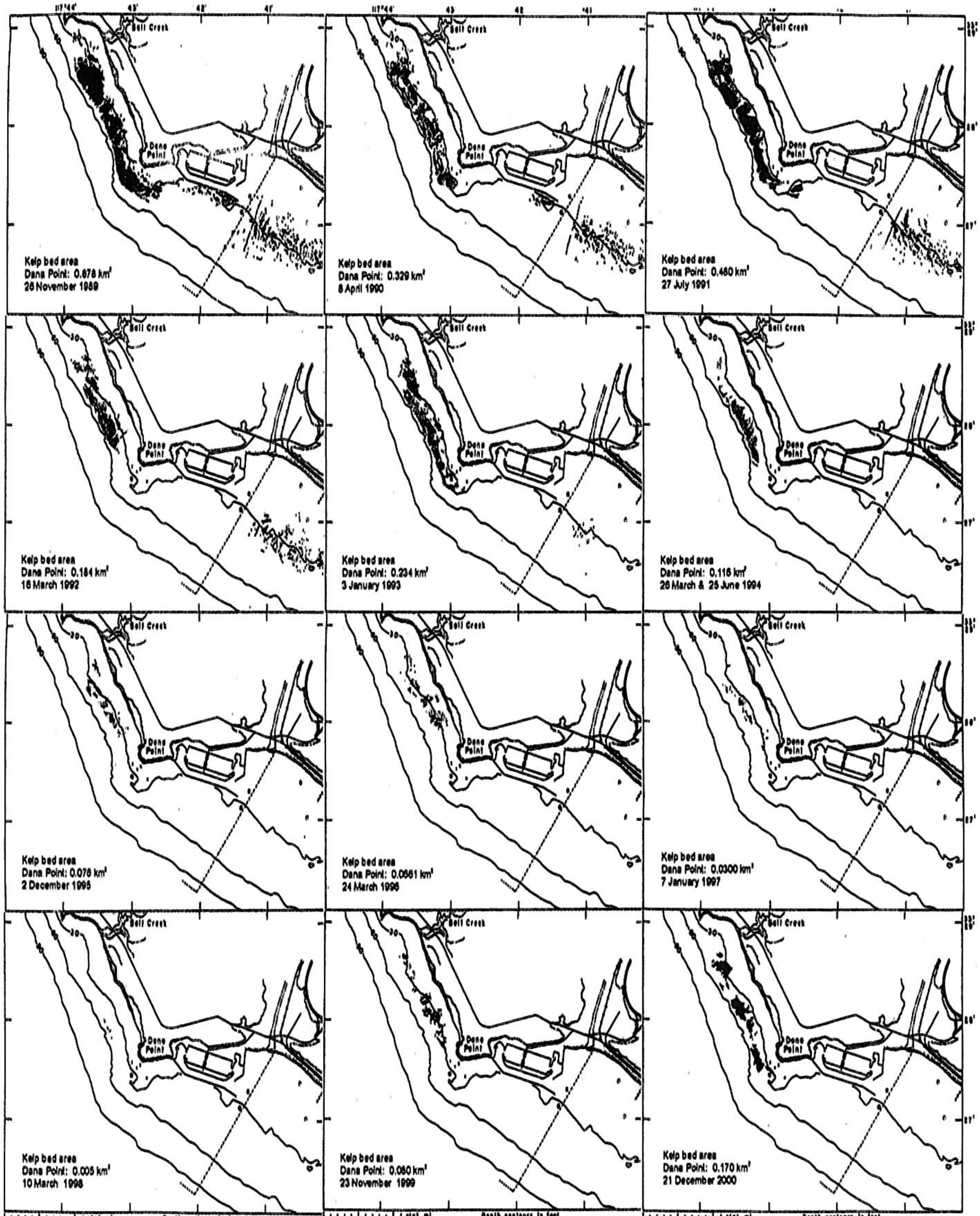

117°44'W
117°43'W
117°42'W
117°41'W
33°29'N
33°28'N
33°27'N
Salt Creek
Dana Point
Dana Marina
Kelp bed areas
Dana Point: 0.2783 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
4


117°44'W
117°43'W
117°42'W
117°41'W
33°29'N
33°28'N
33°27'N
Salt Creek
Dana Point
Dana Marina
Kelp bed areas
Dana Point: 0.1234 km²
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
4

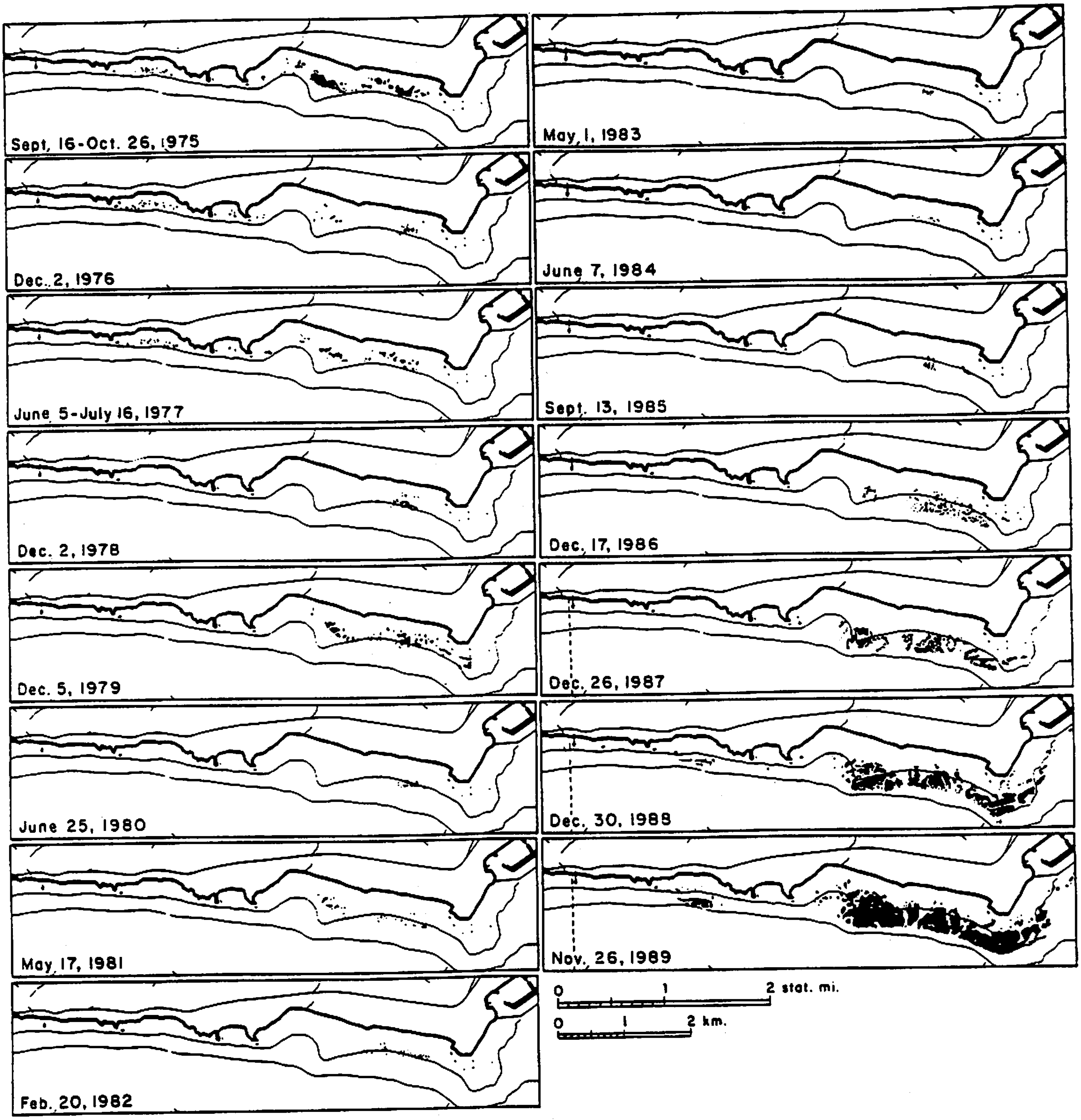

117°44'W
117°43'W
117°42'W
117°41'W
33°29'N
33°28'N
33°27'N
Salt Creek
Dana Point
Dana Marina
Kelp bed areas
Salt Creek/Dana Point: None
Dana Point Marina: 0.0198 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
4


Salt Creek
Dana Point
Dana Marina
Kelp bed area
Salt Creek/Dana Point: 0.2996 Km²
Dana Point Marina: 0.0024 Km²
December 14, 2007
Depth contours in meters
4

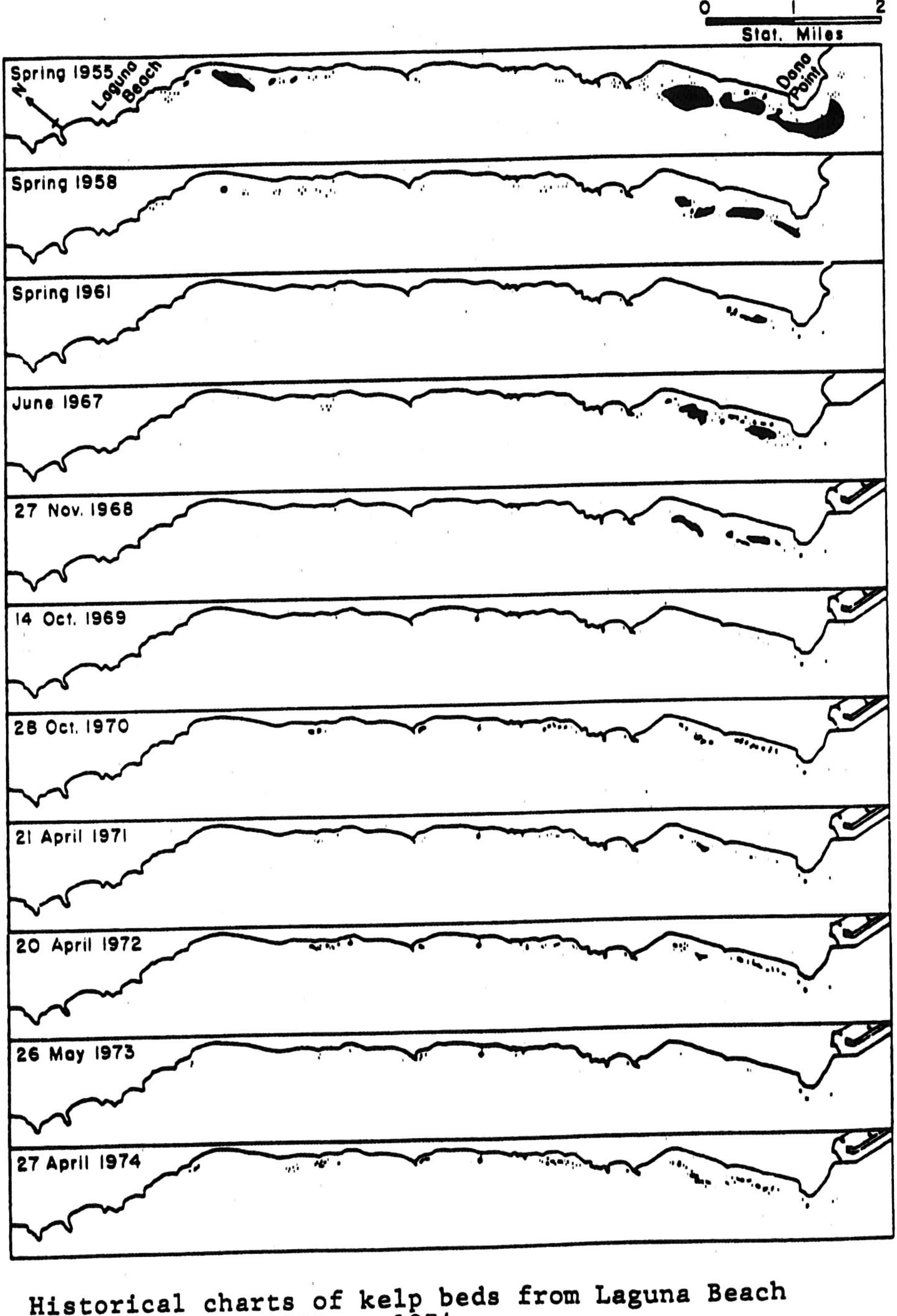

Salt Creek
Dana Point
Dana Marina
N
Kelp bed area
Salt Creek/Dana Point: 1.0679 Km²
Dana Point Marina: 0.0107 Km²
December 31, 2008
Depth contours in meters
4



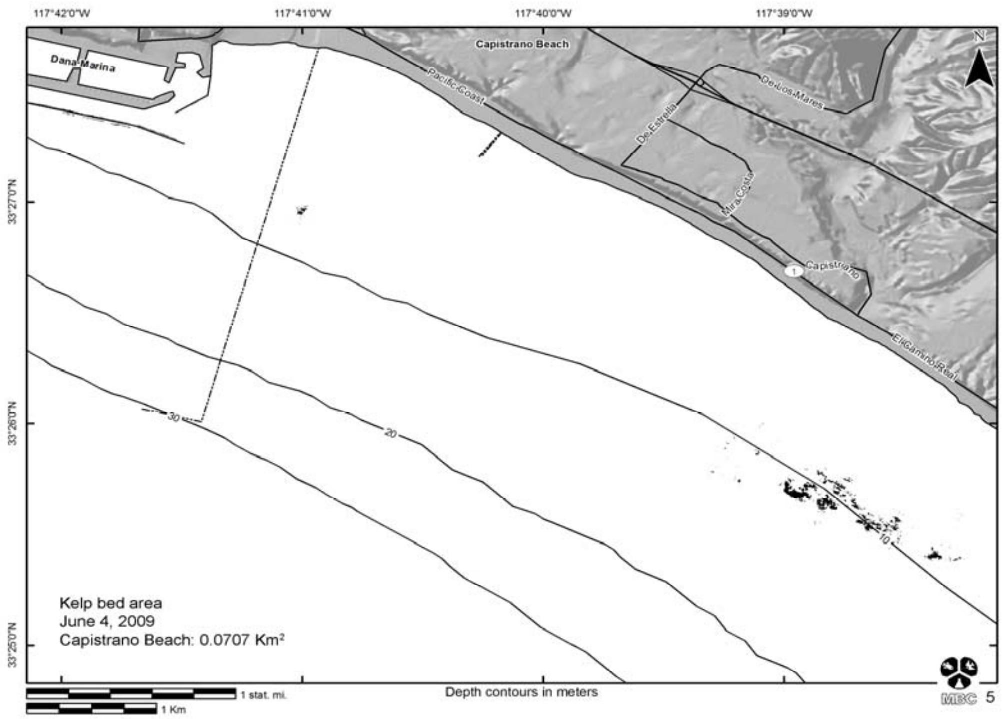
Bell Creek
Dana Point
Kelp bed area
Dana Point: 0.678 km²
26 November 1989
Kelp bed area
Dana Point: 0.329 km²
8 April 1990
Kelp bed area
Dana Point: 0.460 km²
27 July 1991
Kelp bed area
Dana Point: 0.184 km²
16 March 1992
Kelp bed area
Dana Point: 0.234 km²
3 January 1993
Kelp bed area
Dana Point: 0.116 km²
26 March & 25 June 1994
Kelp bed area
Dana Point: 0.076 km²
2 December 1995
Kelp bed area
Dana Point: 0.0661 km²
24 March 1996
Kelp bed area
Dana Point: 0.0300 km²
7 January 1997
Kelp bed area
Dana Point: 0.005 km²
10 March 1998
Kelp bed area
Dana Point: 0.060 km²
23 November 1999
Kelp bed area
Dana Point: 0.170 km²
21 December 2000
1 stat. mi.
1 km.
Depth contours in feet

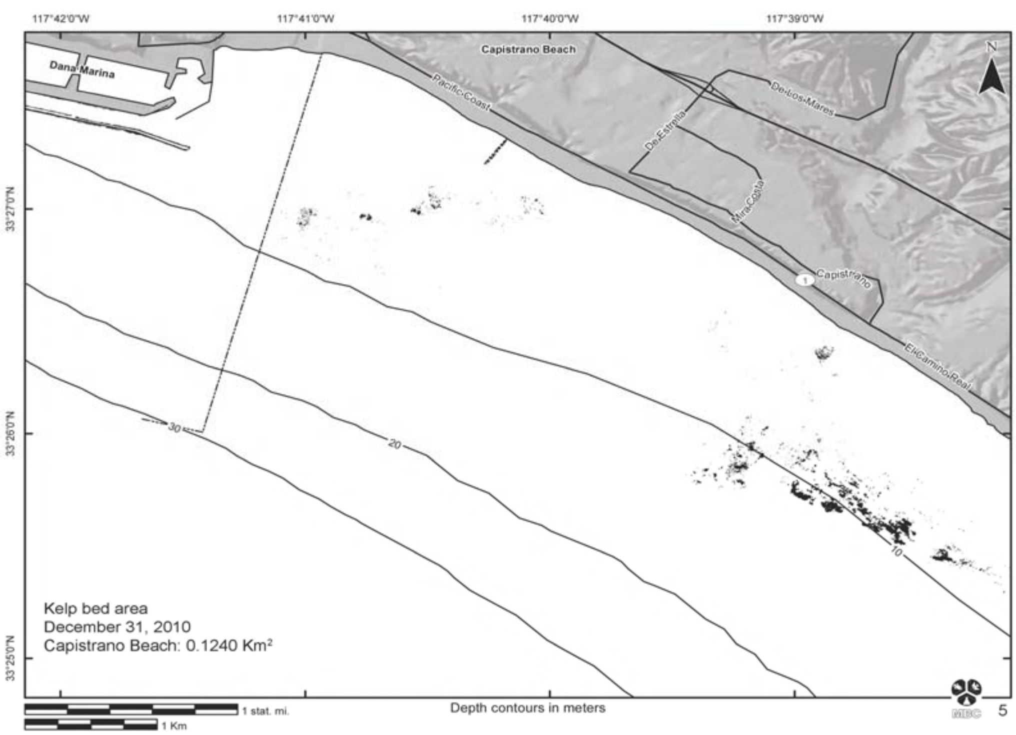


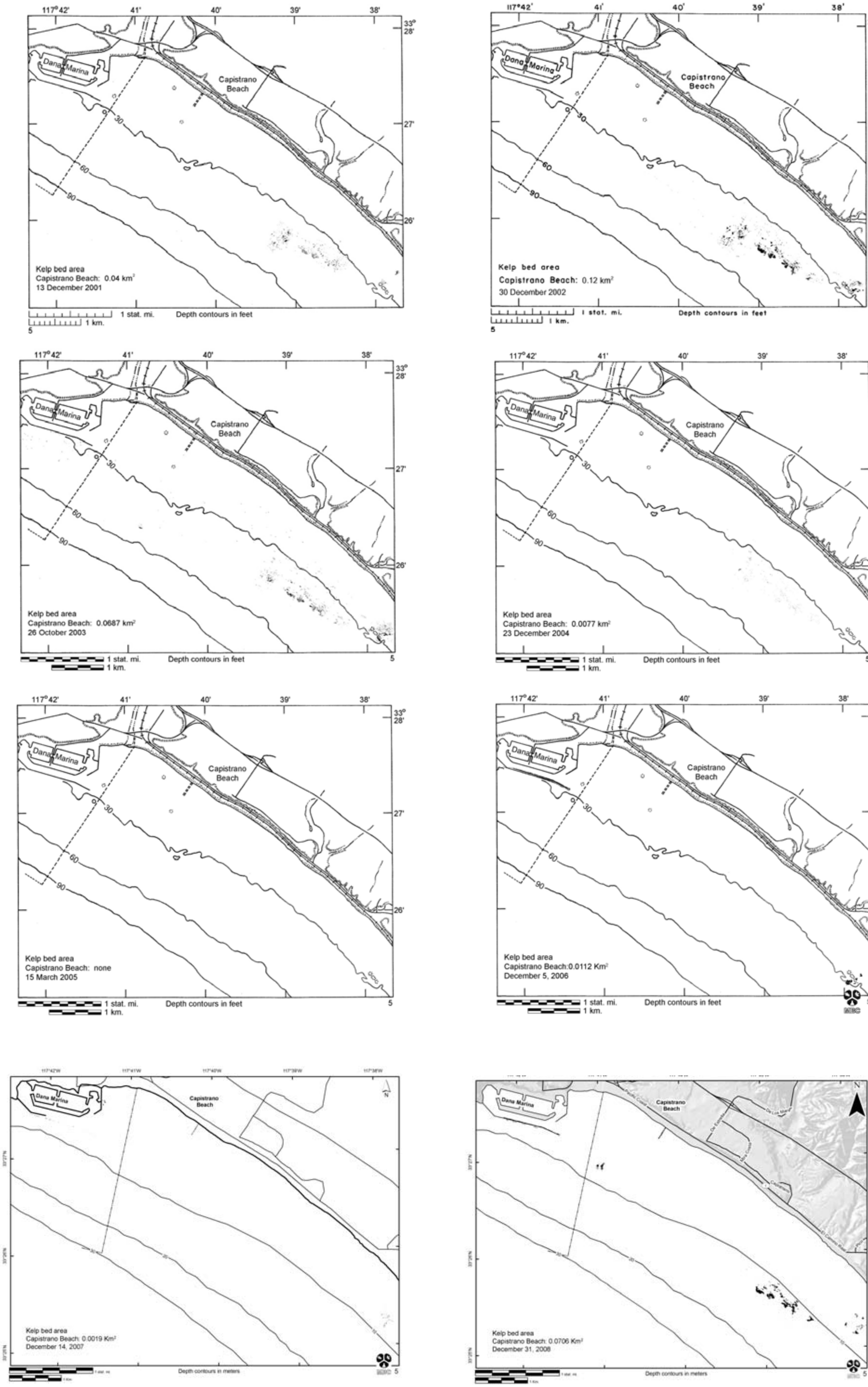
Historical charts of South Laguna kelp and Dana Pt kelp from 1975 to 1989.

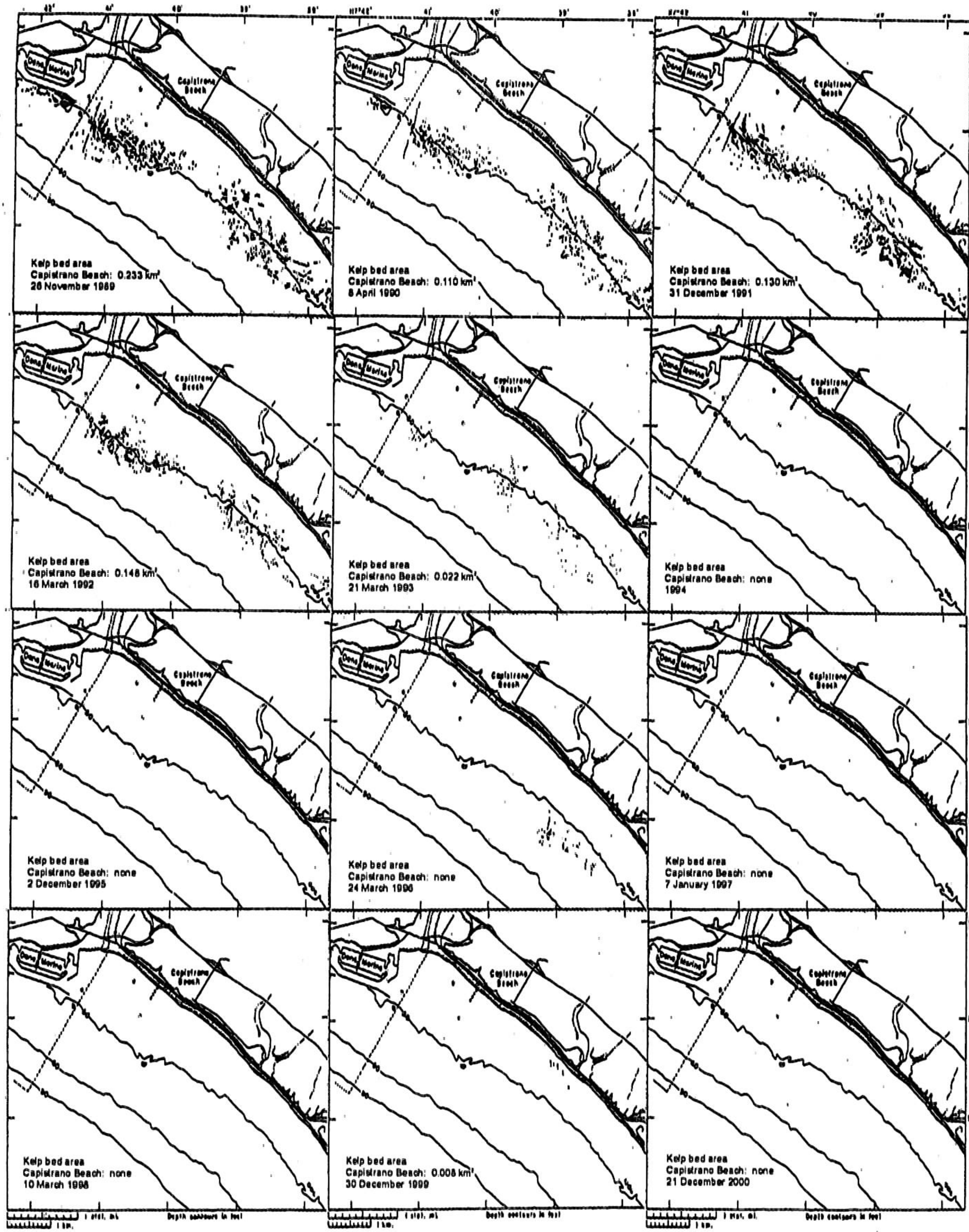


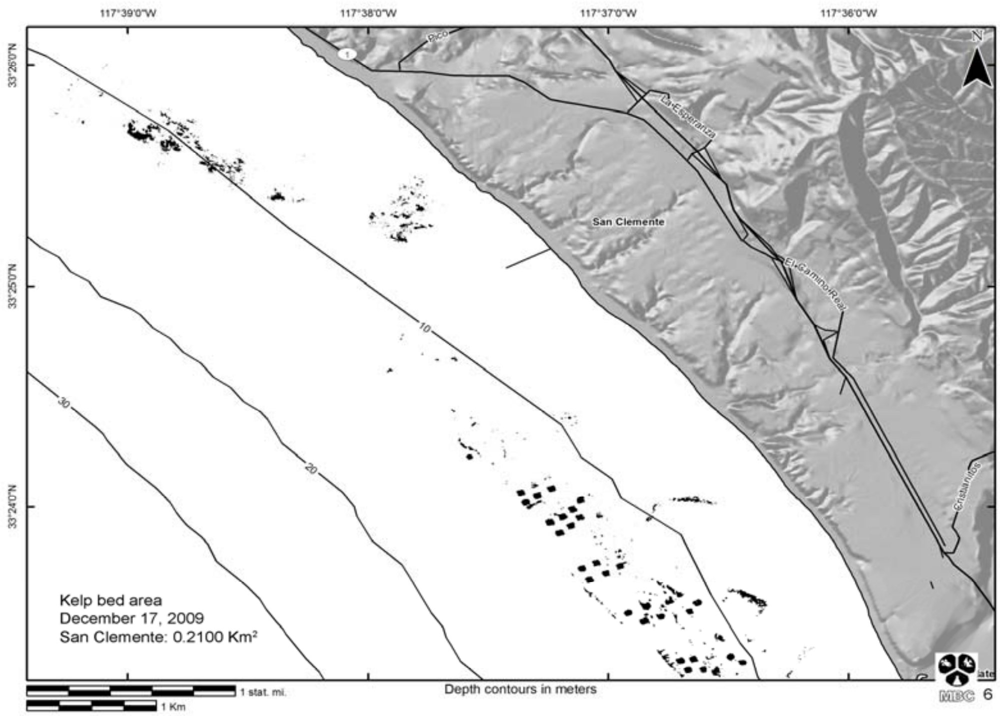
Historical charts of kelp beds from Laguna Beach to Dana Point, 1955 to 1974.

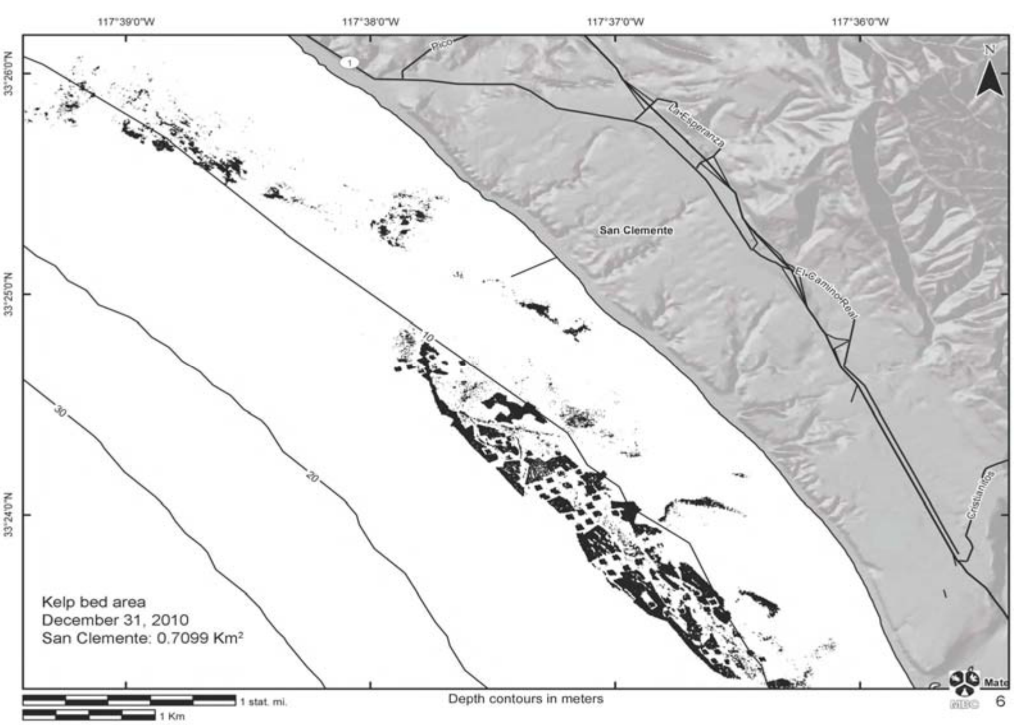

117°42'0"W
117°41'0"W
117°40'0"W
117°39'0"W
33°27'0"N
33°26'0"N
33°25'0"N
Capistrano Beach
Dana Marina
Pacific Coast
De Los Mares
De Estrella
Mira Costa
Capistrano
1
El Camino Real
30
20
10
N
Kelp bed area
June 4, 2009
Capistrano Beach: 0.0707 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
5

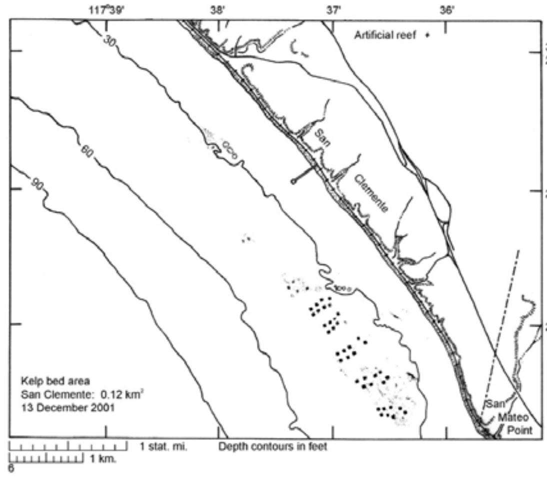

117°42'0"W
117°41'0"W
117°40'0"W
117°39'0"W
33°27'0"N
33°26'0"N
33°25'0"N
Capistrano Beach
Dana Marina
Pacific Coast
De Los Mares
De Estrella
Mira Costa
Capistrano
1
El Camino Real
30
20
10
N
Kelp bed area
December 31, 2010
Capistrano Beach: 0.1240 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
5

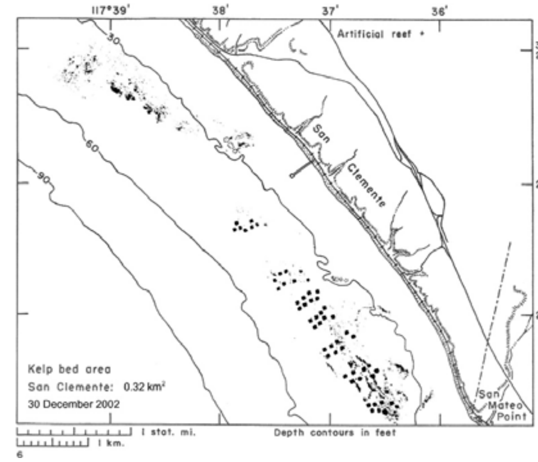

Kelp bed area
Capistrano Beach: 0.04 km^2
13 December 2001
Kelp bed area
Capistrano Beach: 0.12 km^2
30 December 2002
Kelp bed area
Capistrano Beach: 0.0687 km^2
26 October 2003
Kelp bed area
Capistrano Beach: 0.0077 km^2
23 December 2004
Kelp bed area
Capistrano Beach: none
15 March 2005
Kelp bed area
Capistrano Beach:0.0112 Km^2
December 5, 2006
Kelp bed area
Capistrano Beach: 0.0019 Km^2
December 14, 2007
Kelp bed area
Capistrano Beach: 0.0706 Km^2
December 31, 2008
Dana Marina
Capistrano Beach
1 stat. mi.
1 km.
Depth contours in feet
Depth contours in meters
117°42'
41'
40'
39'
38'
33° 28'
27'
26'

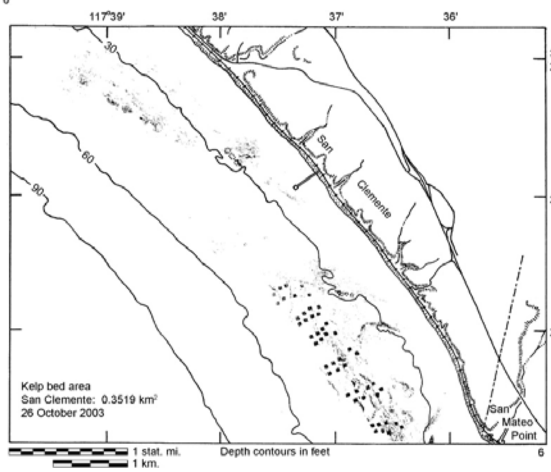

Kelp bed area
Capistrano Beach: 0.233 km²
26 November 1989
Kelp bed area
Capistrano Beach: 0.110 km²
8 April 1990
Kelp bed area
Capistrano Beach: 0.130 km²
31 December 1991
Kelp bed area
Capistrano Beach: 0.148 km²
16 March 1992
Kelp bed area
Capistrano Beach: 0.022 km²
21 March 1993
Kelp bed area
Capistrano Beach: none
1994
Kelp bed area
Capistrano Beach: none
2 December 1995
Kelp bed area
Capistrano Beach: none
24 March 1996
Kelp bed area
Capistrano Beach: none
7 January 1997
Kelp bed area
Capistrano Beach: none
10 March 1998
Kelp bed area
Capistrano Beach: 0.008 km²
30 December 1999
Kelp bed area
Capistrano Beach: none
21 December 2000
Dana Marina
Capistrano Beach
1 km.
Depth contours in feet

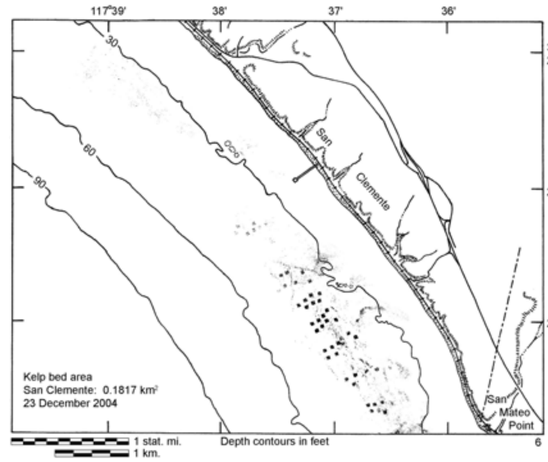

117°39'0"W
117°38'0"W
117°37'0"W
117°36'0"W
33°26'0"N
33°25'0"N
33°24'0"N
N
1
Pico
La Esperanza
San Clemente
El Camino Real
Cristianitos
10
20
30
Kelp bed area
December 17, 2009
San Clemente: 0.2100 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
6

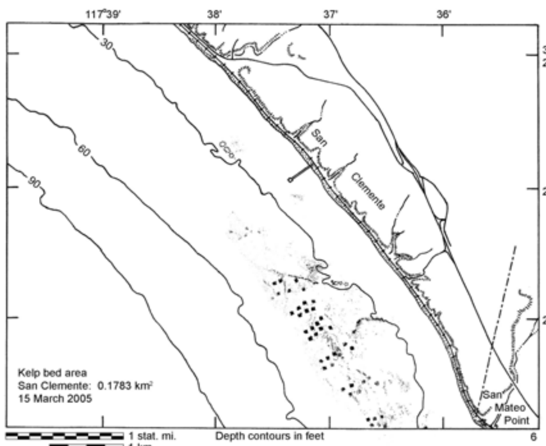

117°39'0"W
117°38'0"W
117°37'0"W
117°36'0"W
33°26'0"N
33°25'0"N
33°24'0"N
N
1
Pico
La Esperanza
San Clemente
El Camino Real
Cristianitos
10
20
30
Kelp bed area
December 31, 2010
San Clemente: 0.7099 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
6

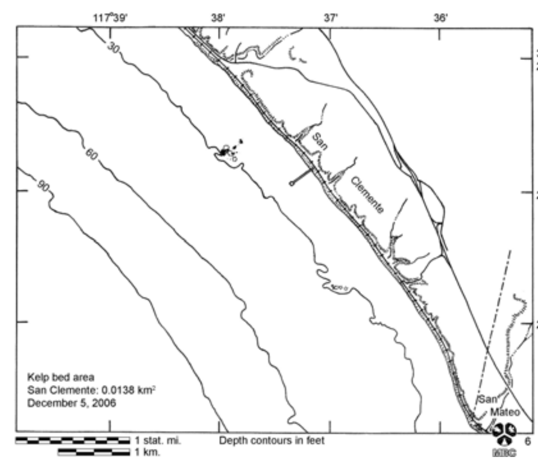

117°39'
38'
37'
36'
Artificial reef +
33°
26'
25'
24'
30
60
90
San
Clemente
San
Mateo
Point
Kelp bed area
San Clemente: 0.12 km²
13 December 2001
1 stat. mi.
1 km.
Depth contours in feet
6

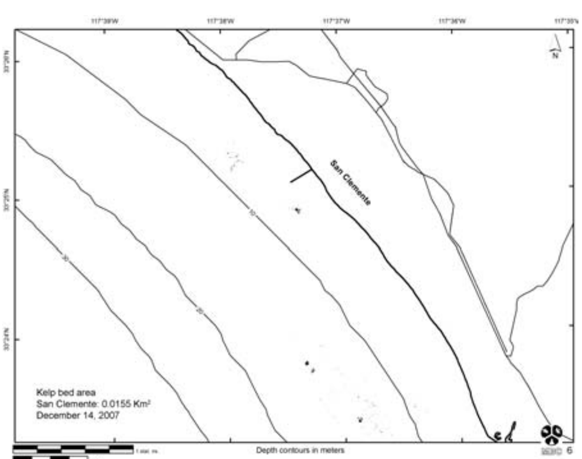

117°39'
38'
37'
36'
Artificial reef +
33°
26'
25'
24'
30
60
90
San
Clemente
San
Mateo
Point
Kelp bed area
San Clemente: 0.32 km²
30 December 2002
1 stat. mi.
1 km.
Depth contours in feet
6

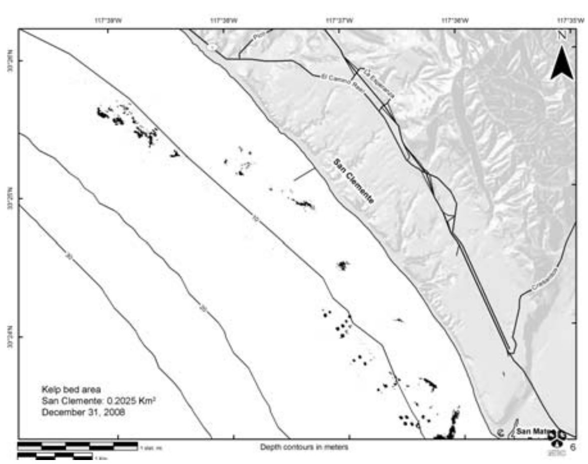

117°39'
38'
37'
36'
33°
26'
25'
24'
30
60
90
San
Clemente
San
Mateo
Point
Kelp bed area
San Clemente: 0.3519 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
6

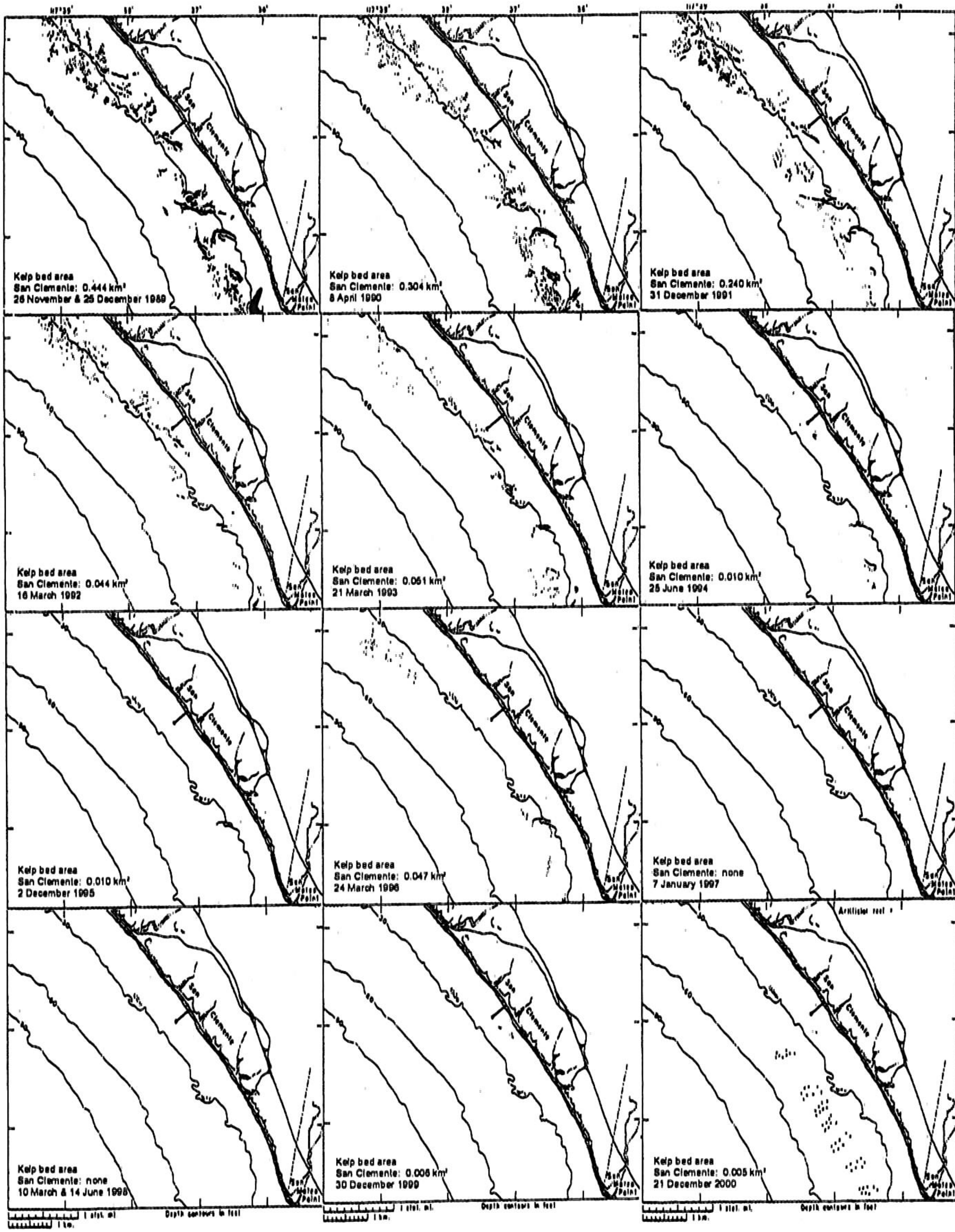

117°39'
38'
37'
36'
33°
26'
25'
24'
30
60
90
San
Clemente
San
Mateo
Point
Kelp bed area
San Clemente: 0.1817 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
6


117°39'
38'
37'
36'
33°
26'
25'
24'
30
60
90
San
Clemente
San
Mateo
Point
Kelp bed area
San Clemente: 0.1783 km²
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
6

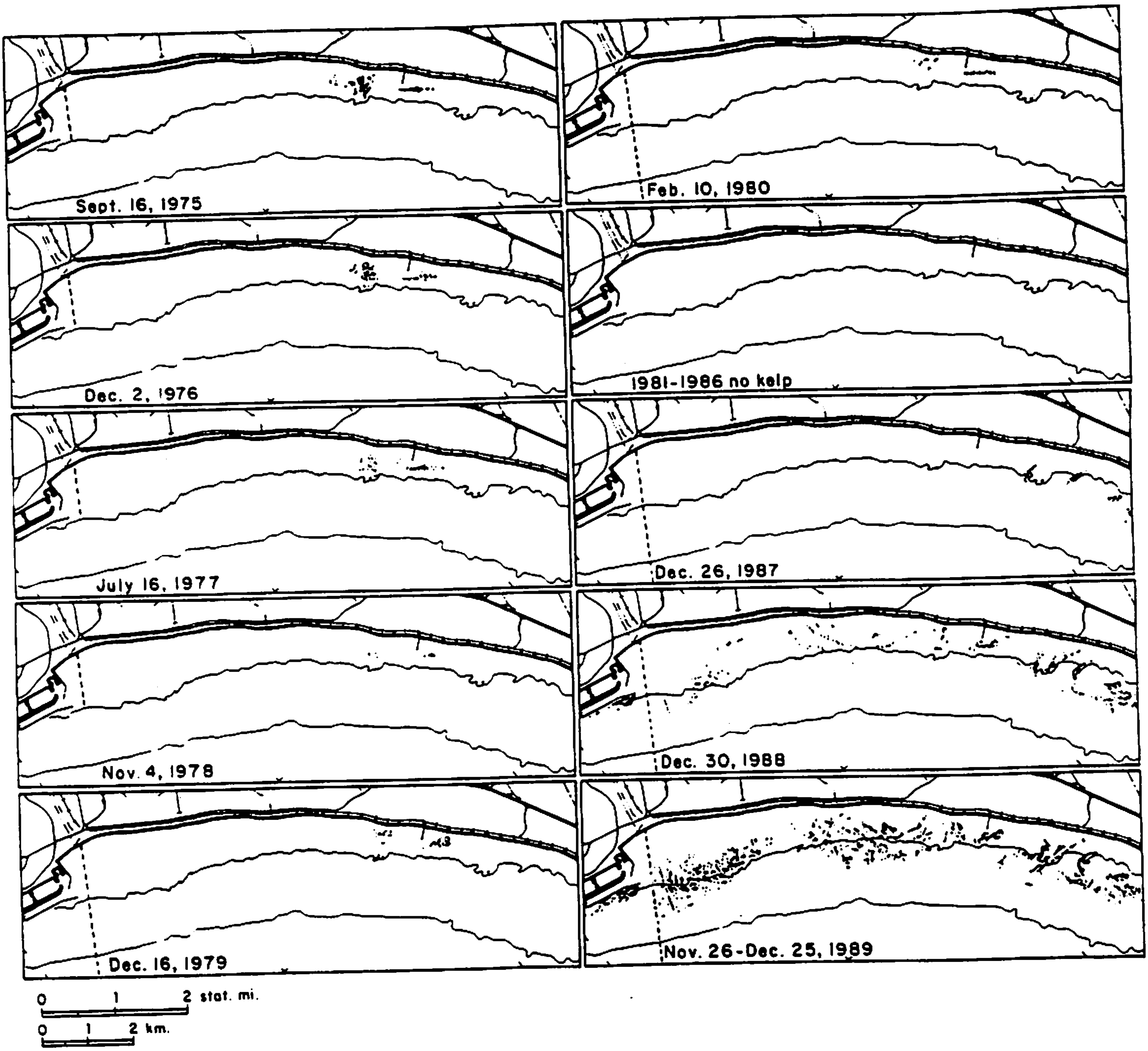

117°39'
38'
37'
36'
33°
26'
25'
24'
30
60
90
San
Clemente
San
Mateo
Kelp bed area
San Clemente: 0.0138 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
6


117°39'W
117°38'W
117°37'W
117°36'W
San Clemente
Kelp bed area
San Clemente: 0.0155 Km²
December 14, 2007
Depth contours in meters
6

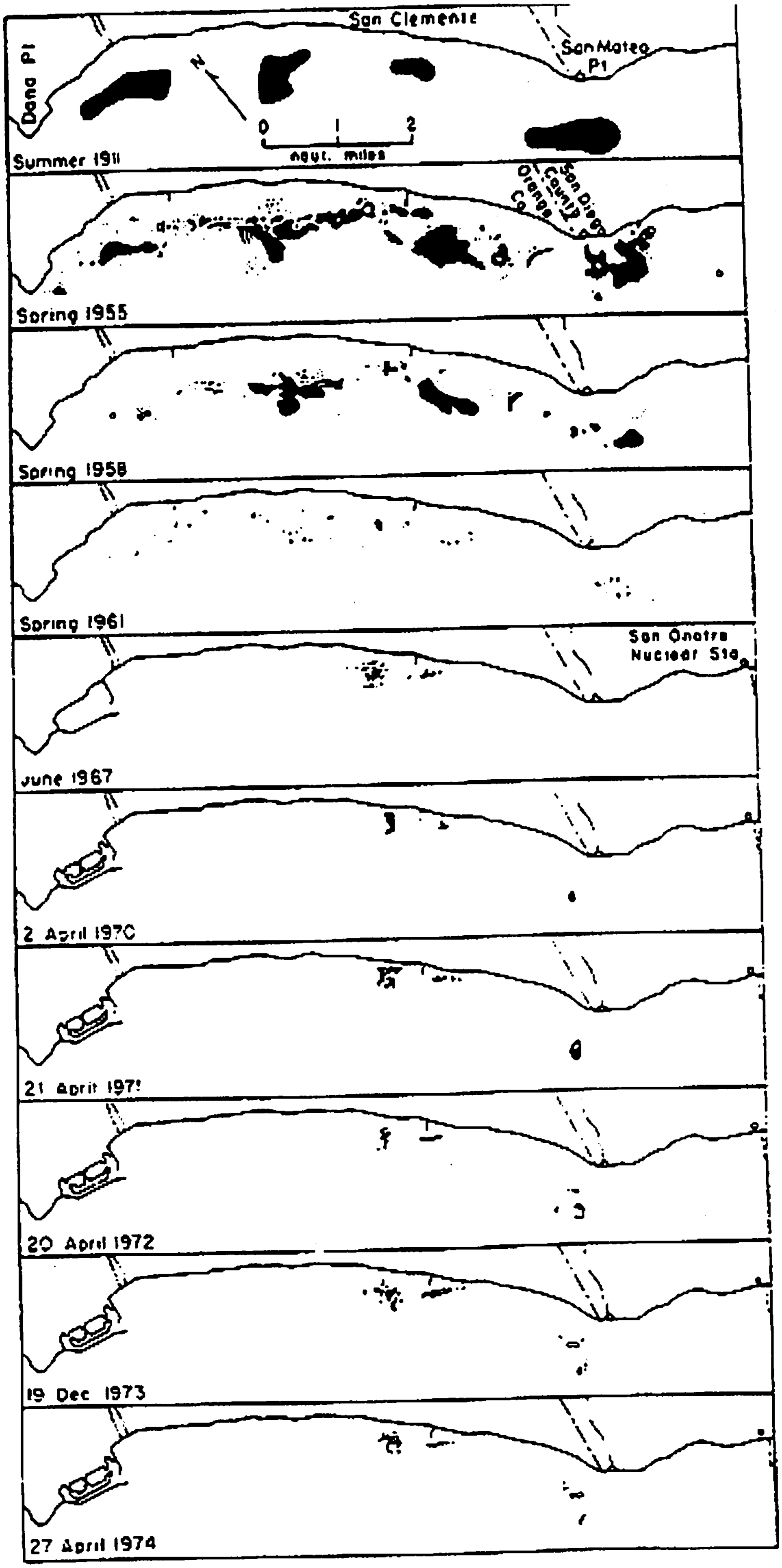

117°39'W
117°38'W
117°37'W
117°36'W
117°35'W
N
San Clemente
San Mateo
Kelp bed area
San Clemente: 0.2025 Km²
December 31, 2008
Depth contours in meters
6



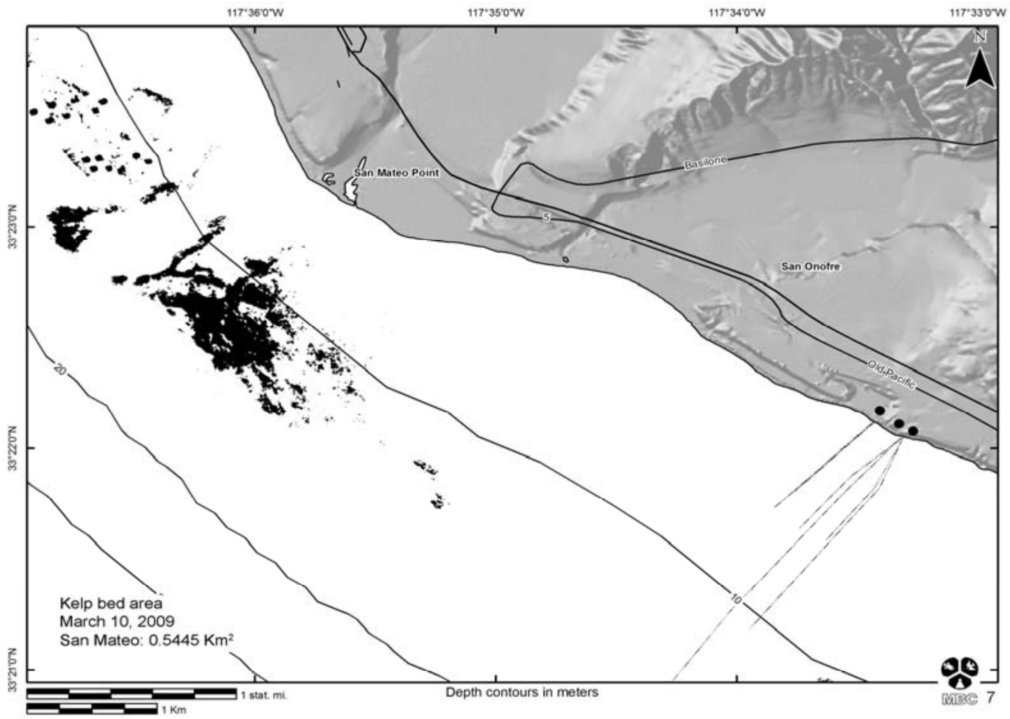
Kelp bed area
San Clemente: 0.444 km²
26 November & 25 December 1989
Kelp bed area
San Clemente: 0.304 km²
8 April 1990
Kelp bed area
San Clemente: 0.240 km²
31 December 1991
Kelp bed area
San Clemente: 0.044 km²
16 March 1992
Kelp bed area
San Clemente: 0.051 km²
21 March 1993
Kelp bed area
San Clemente: 0.010 km²
25 June 1994
Kelp bed area
San Clemente: 0.010 km²
2 December 1995
Kelp bed area
San Clemente: 0.047 km²
24 March 1996
Kelp bed area
San Clemente: none
7 January 1997
Kelp bed area
San Clemente: none
10 March & 14 June 1998
Kelp bed area
San Clemente: 0.006 km²
30 December 1999
Kelp bed area
San Clemente: 0.005 km²
21 December 2000
San Clemente
San Mateo Point
Artificial reef
1 stat. mi.
1 km.
Depth contours in feet



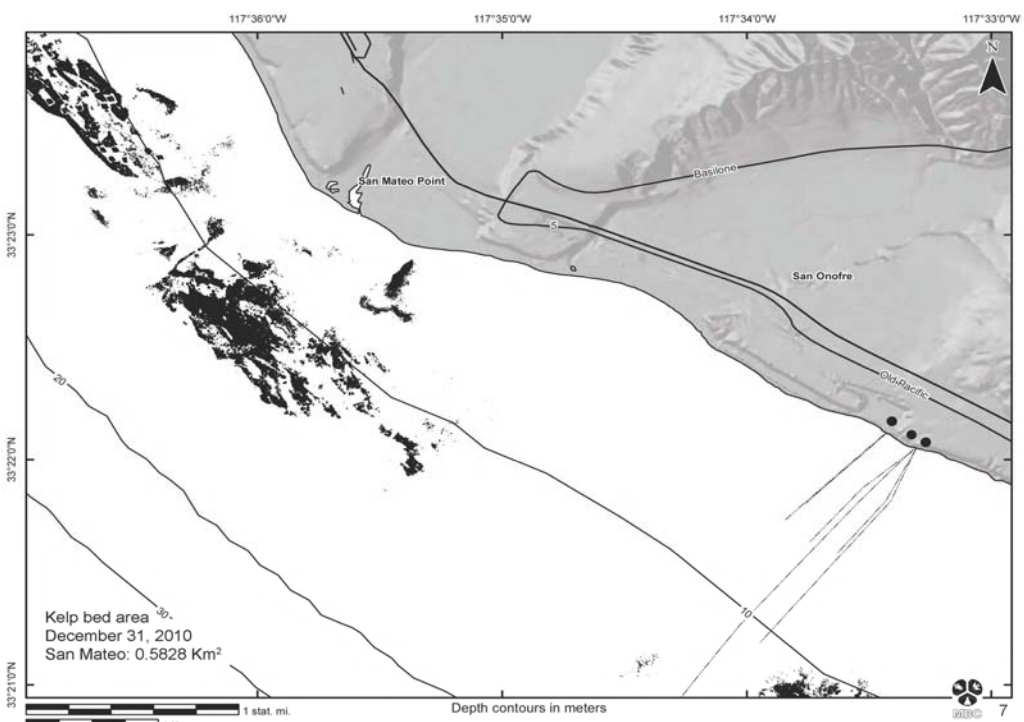
Historical charts of San Clemente kelp from 1975 to 1989.



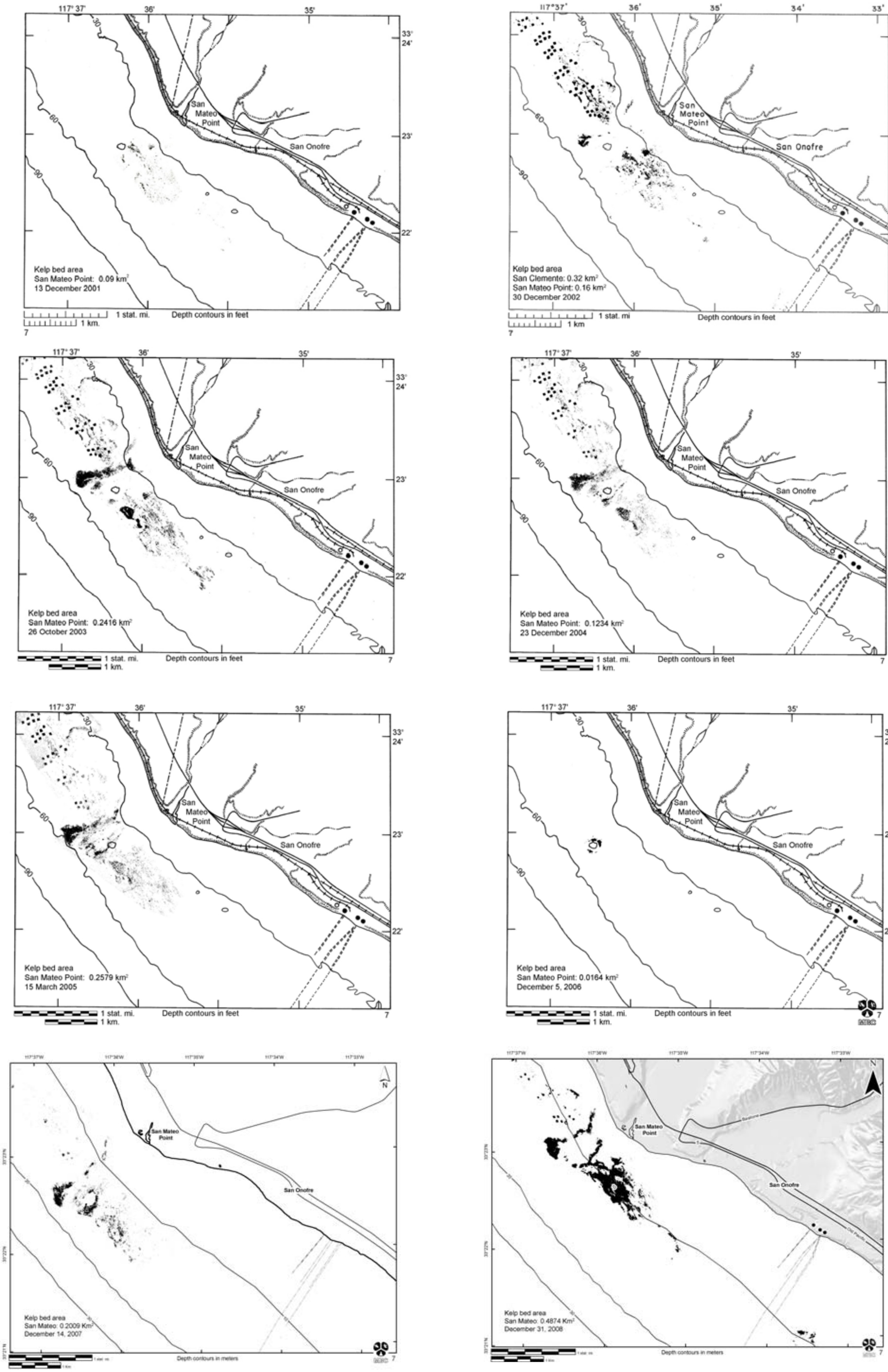
Historical charts of kelp beds from Doheny Beach to San Mateo Point from 1911 to 1974.



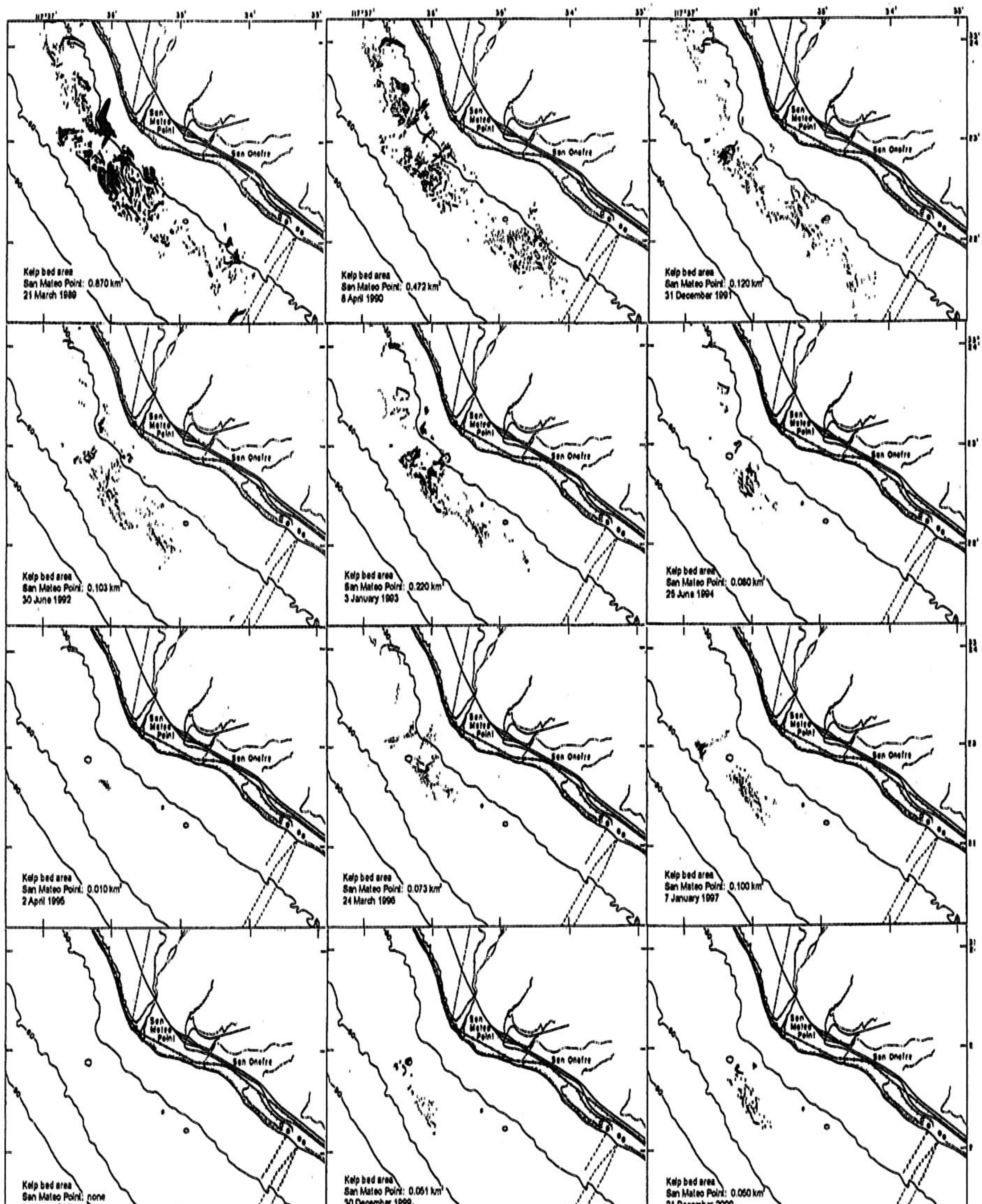
117°36'0"W
117°35'0"W
117°34'0"W
117°33'0"W
33°23'0"N
33°22'0"N
33°21'0"N
San Mateo Point
Basilone
San Onofre
Old Pacific
5
20
10
Kelp bed area
March 10, 2009
San Mateo: 0.5445 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
7

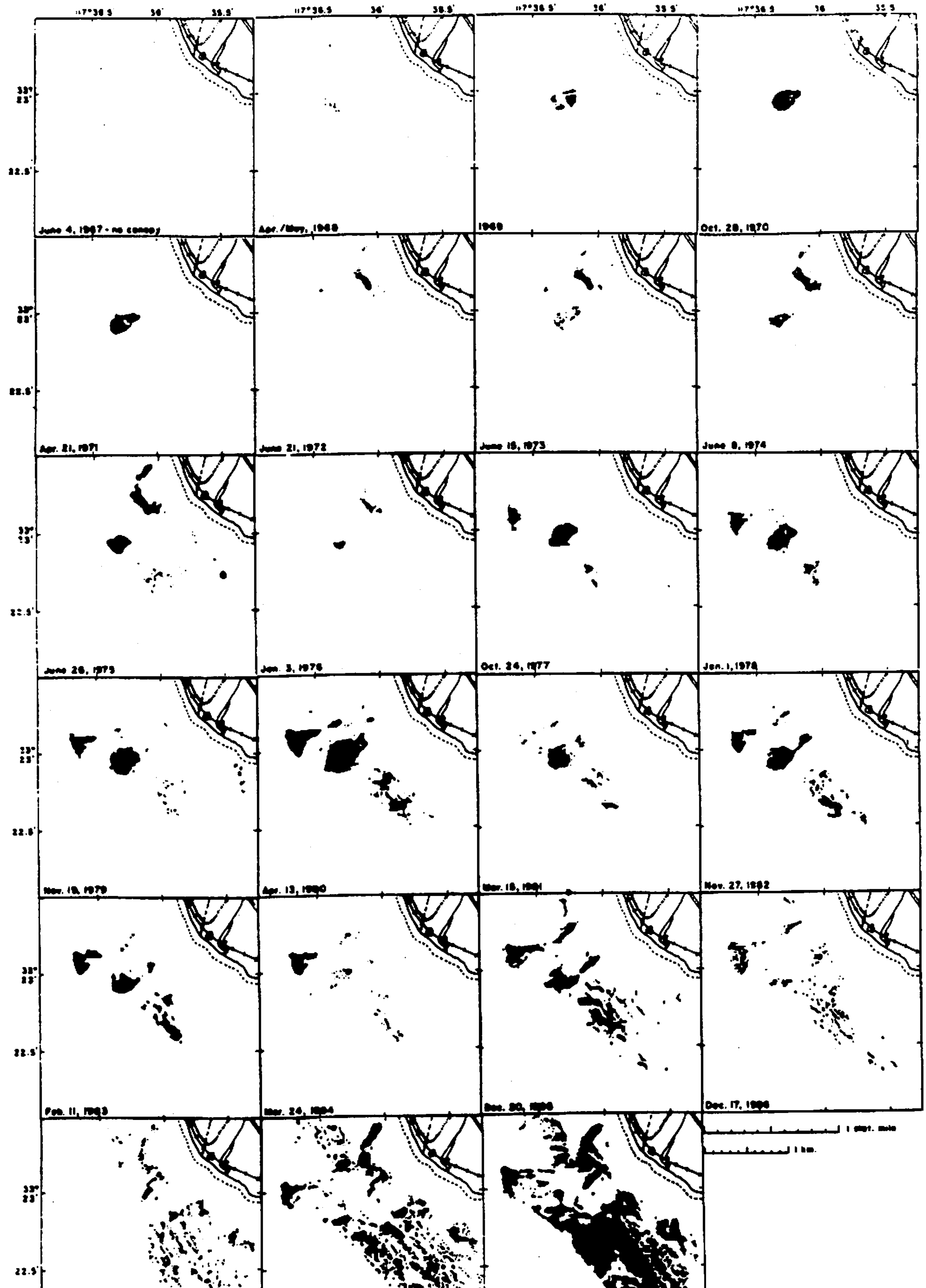


117°36'0"W
117°35'0"W
117°34'0"W
117°33'0"W
33°23'0"N
33°22'0"N
33°21'0"N
San Mateo Point
Basilone
San Onofre
Old Pacific
5
20
30
10
Kelp bed area
December 31, 2010
San Mateo: 0.5828 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
7

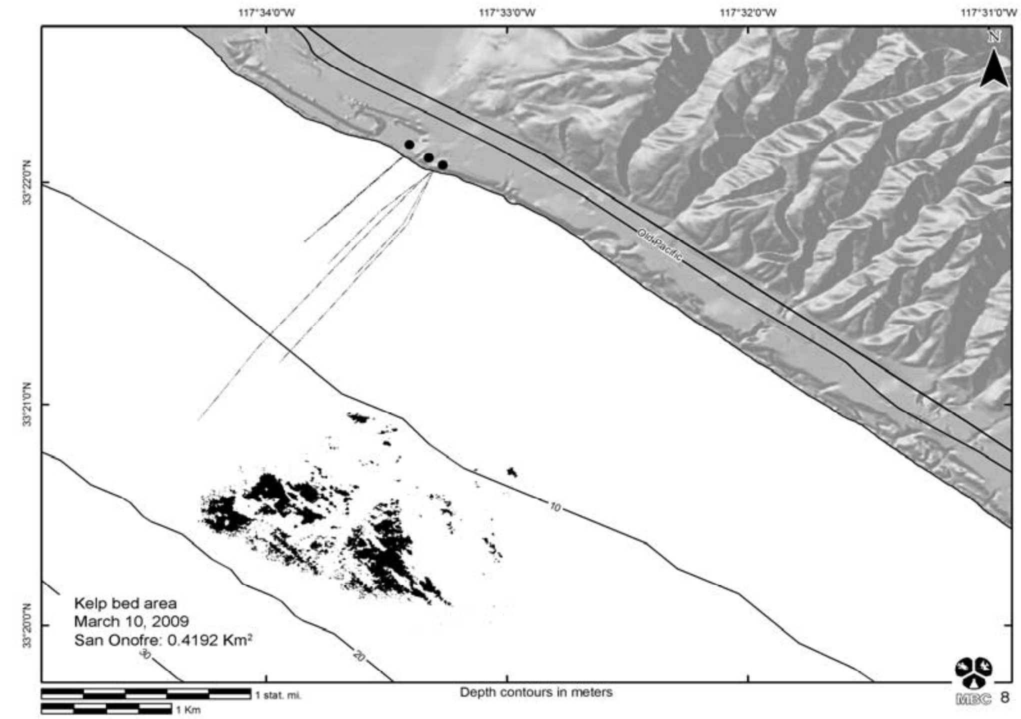


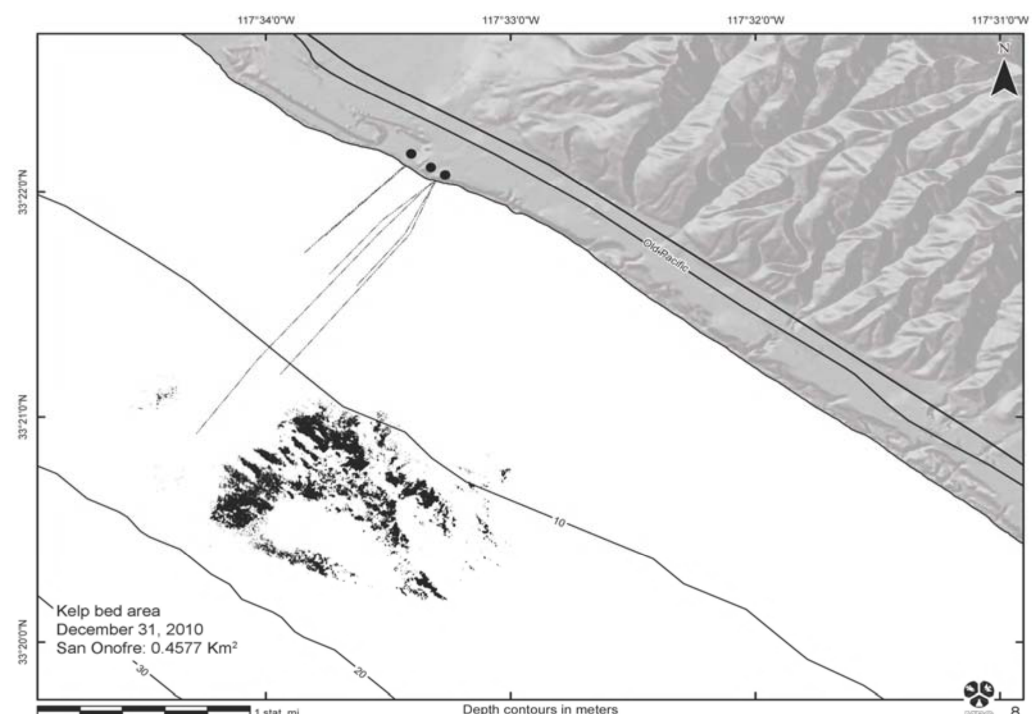
Kelp bed area
San Mateo Point: 0.09 km²
13 December 2001
1 stat. mi.
1 km.
Depth contours in feet
San Mateo Point
San Onofre
Kelp bed area
San Clemente: 0.32 km²
San Mateo Point: 0.16 km²
30 December 2002
Kelp bed area
San Mateo Point: 0.2416 km²
26 October 2003
Kelp bed area
San Mateo Point: 0.1234 km²
23 December 2004
Kelp bed area
San Mateo Point: 0.2579 km²
15 March 2005
Kelp bed area
San Mateo Point: 0.0164 km²
December 5, 2006
Kelp bed area
San Mateo: 0.2009 Km²
December 14, 2007
Kelp bed area
San Mateo: 0.4874 Km²
December 31, 2008
Depth contours in meters

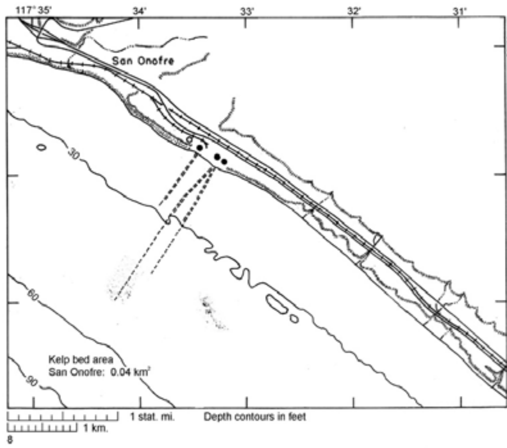

117°37'
36'
35'
34'
33'
San Mateo Point
San Onofre
Kelp bed area
San Mateo Point: 0.870 km²
21 March 1989
Kelp bed area
San Mateo Point: 0.472 km²
8 April 1990
Kelp bed area
San Mateo Point: 0.120 km²
31 December 1991
Kelp bed area
San Mateo Point: 0.103 km²
30 June 1992
Kelp bed area
San Mateo Point: 0.220 km²
3 January 1993
Kelp bed area
San Mateo Point: 0.080 km²
25 June 1994
Kelp bed area
San Mateo Point: 0.010 km²
2 April 1995
Kelp bed area
San Mateo Point: 0.073 km²
24 March 1996
Kelp bed area
San Mateo Point: 0.100 km²
7 January 1997
Kelp bed area
San Mateo Point: none
14 June 1998
Kelp bed area
San Mateo Point: 0.051 km²
30 December 1999
Kelp bed area
San Mateo Point: 0.050 km²
21 December 2000
1 stat. mi
1 km
Depth contours in feet

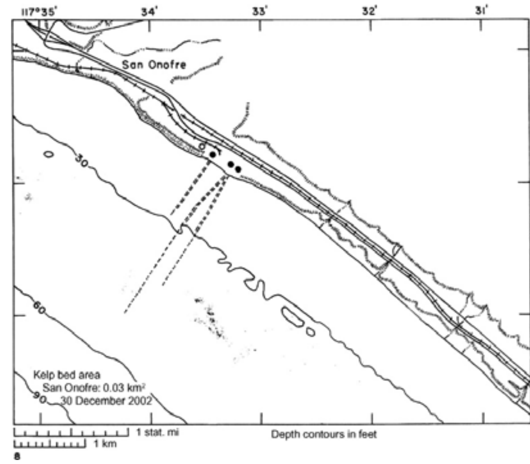


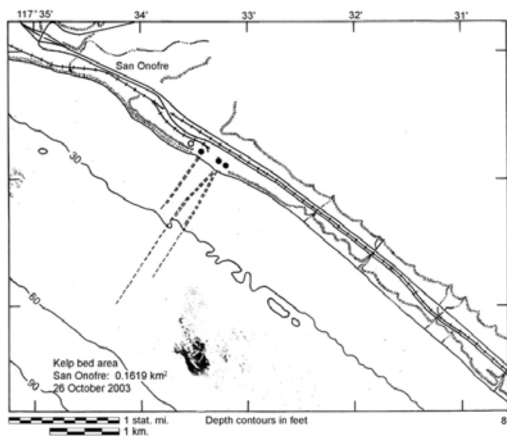
Historical charts of San Mateo kelp from 1967 to 1989.

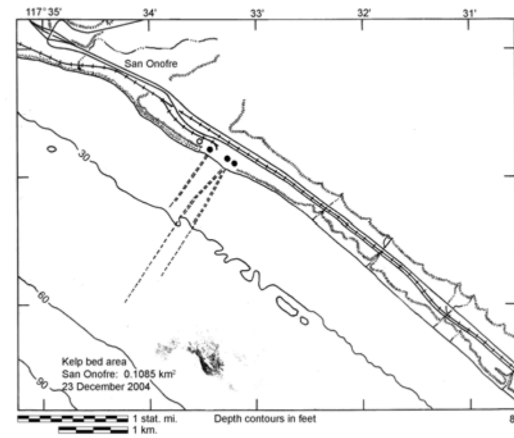

117°34'0"W
117°33'0"W
117°32'0"W
117°31'0"W
N
33°22'0"N
33°21'0"N
33°20'0"N
Old Pacific
10
20
30
Kelp bed area
March 10, 2009
San Onofre: 0.4192 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
8

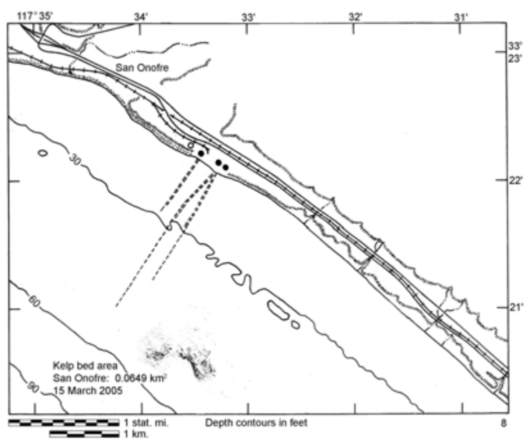

117°34'0"W
117°33'0"W
117°32'0"W
117°31'0"W
N
33°22'0"N
33°21'0"N
33°20'0"N
Old Pacific
10
20
30
Kelp bed area
December 31, 2010
San Onofre: 0.4577 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
8

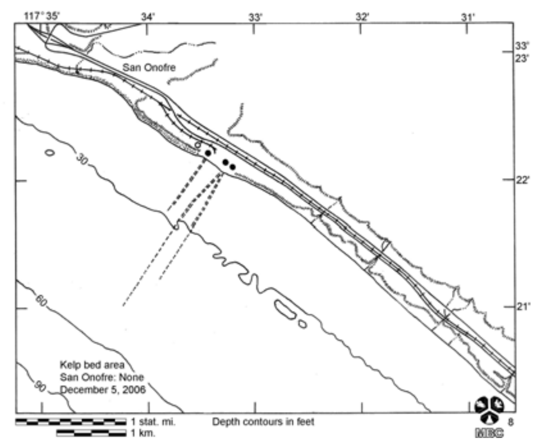

117° 35'
34'
33'
32'
31'
33°
23'
22'
21'
San Onofre
30
60
90
Kelp bed area
San Onofre: 0.04 km²
1 stat. mi.
1 km.
Depth contours in feet
8

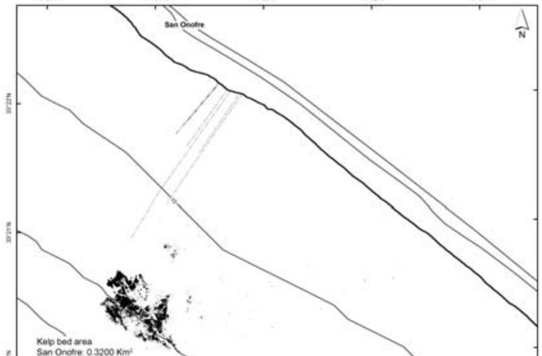

117°35'
34'
33'
32'
31'
33°
23'
22'
21'
San Onofre
30
60
90
Kelp bed area
San Onofre: 0.03 km²
30 December 2002
1 stat. mi
1 km
Depth contours in feet
8

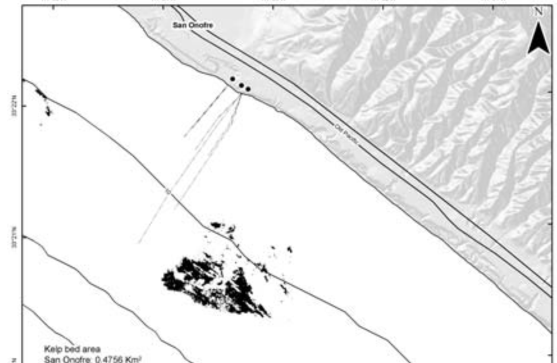

117° 35'
34'
33'
32'
31'
33°
23'
22'
21'
San Onofre
30
60
90
Kelp bed area
San Onofre: 0.1619 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
8

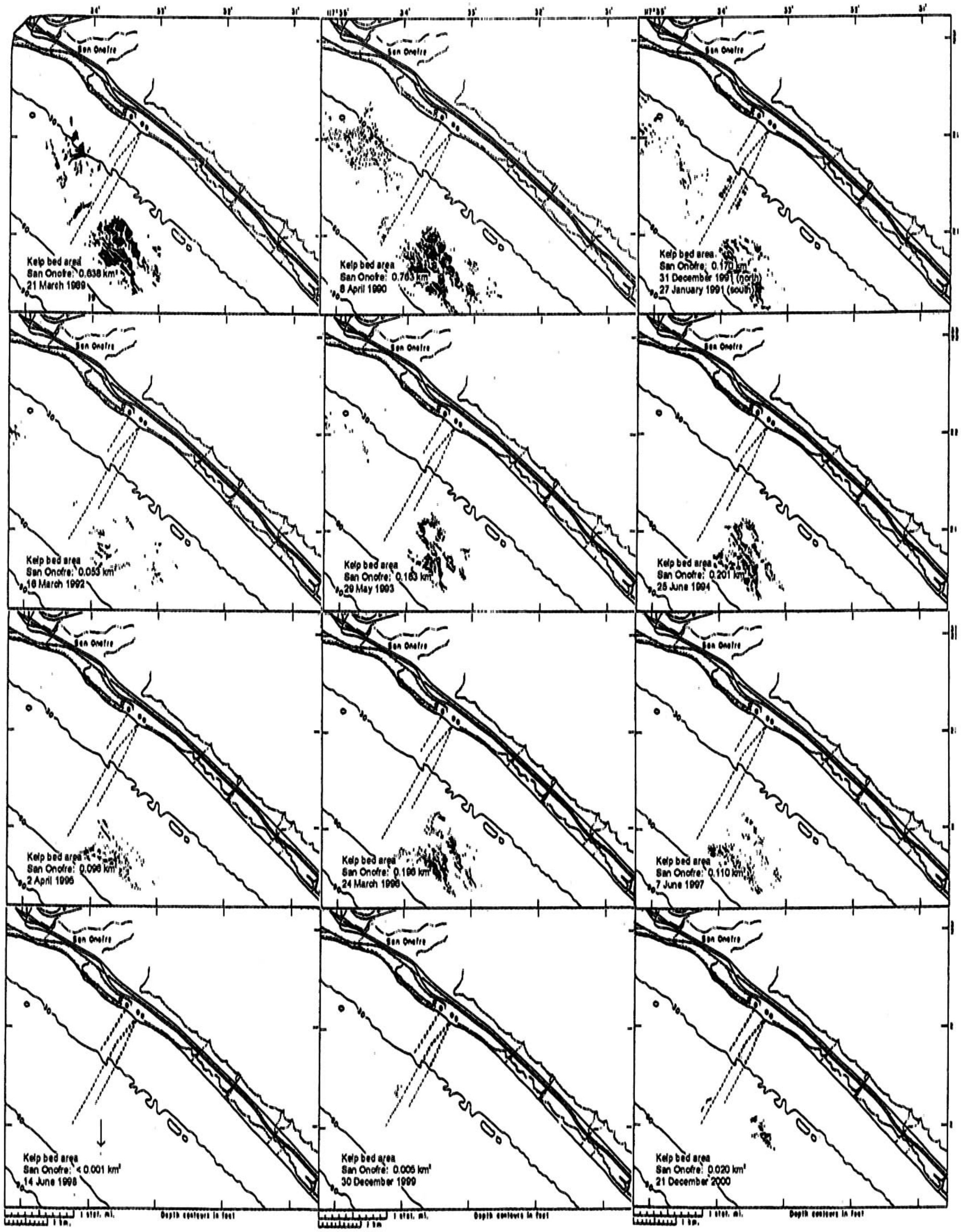

117° 35'
34'
33'
32'
31'
33°
23'
22'
21'
San Onofre
30
60
90
Kelp bed area
San Onofre: 0.1085 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
8


117° 35'
34'
33'
32'
31'
33°
23'
22'
21'
San Onofre
30
60
90
Kelp bed area
San Onofre: 0.0649 km²
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
8

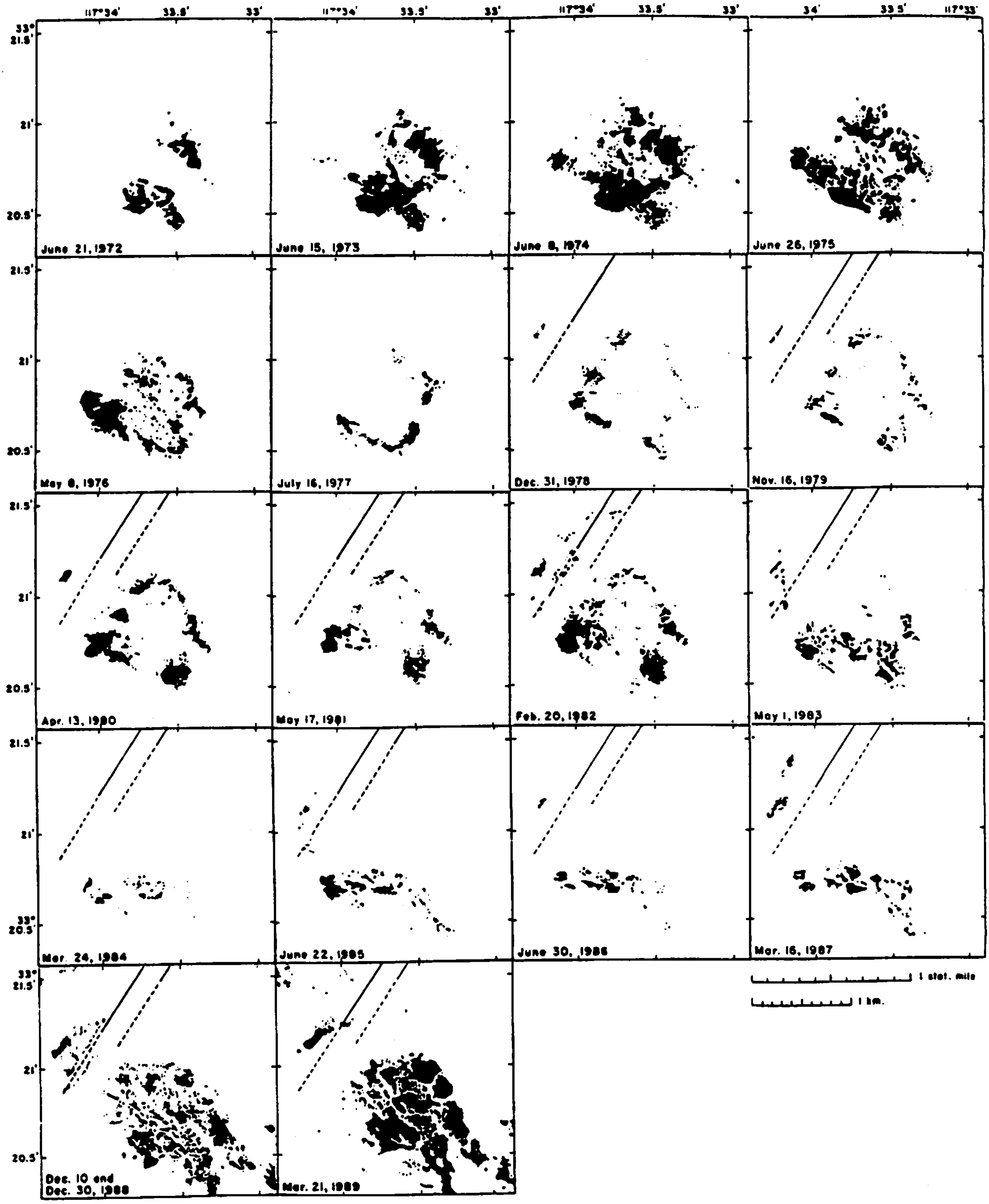

117° 35'
34'
33'
32'
31'
33°
23'
22'
21'
San Onofre
30
60
90
Kelp bed area
San Onofre: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
8


117°35'W
117°34'W
117°33'W
117°32'W
117°31'W
San Onofre
N
Kelp bed area
San Onofre: 0.3200 Km²
December 14, 2007
Depth contours in meters
8

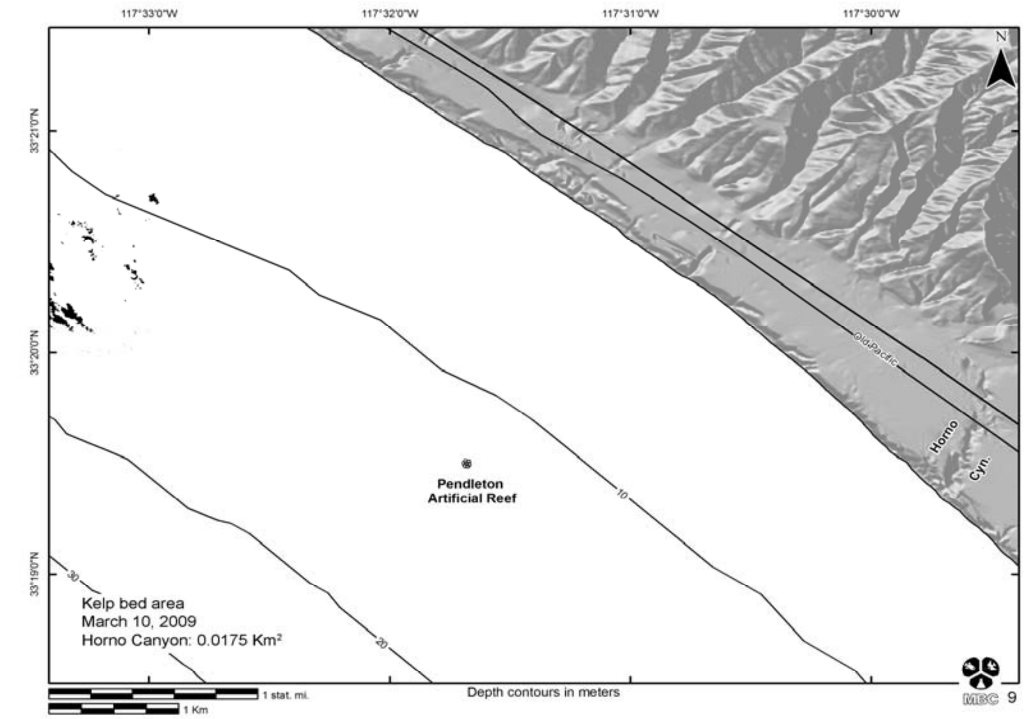

San Onofre
N
Kelp bed area
San Onofre: 0.4756 Km²
December 31, 2008
Depth contours in meters
8

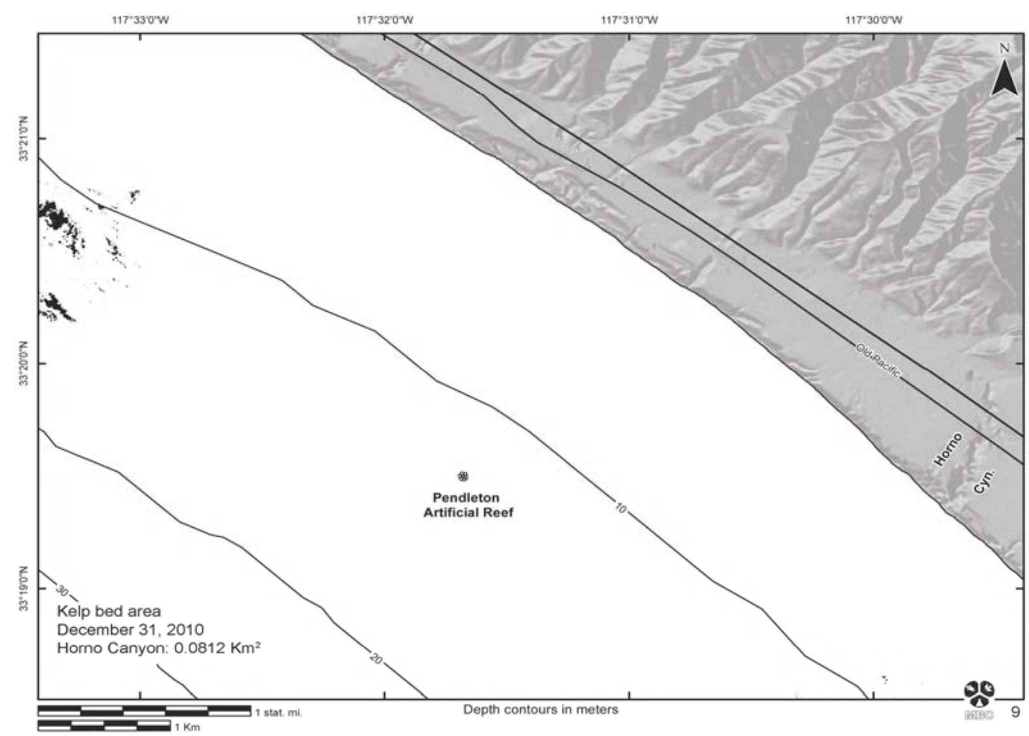


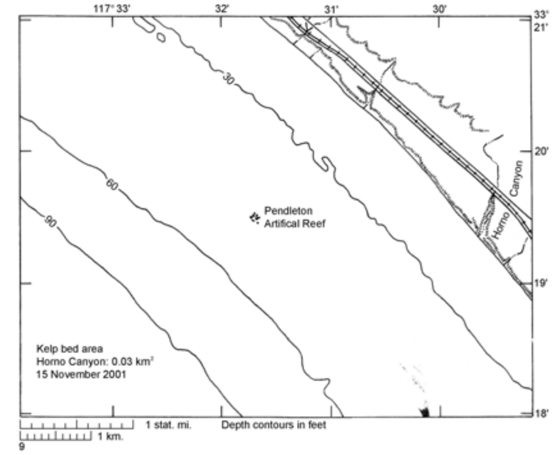
San Onofre
Kelp bed area
San Onofre: 0.638 km^2
21 March 1989
Kelp bed area
San Onofre: 0.763 km^2
8 April 1990
Kelp bed area
San Onofre: 0.170 km^2
31 December 1991 (north)
27 January 1991 (south)
Kelp bed area
San Onofre: 0.053 km^2
16 March 1992
Kelp bed area
San Onofre: 0.163 km^2
29 May 1993
Kelp bed area
San Onofre: 0.201 km^2
25 June 1994
Kelp bed area
San Onofre: 0.098 km^2
2 April 1995
Kelp bed area
San Onofre: 0.196 km^2
24 March 1996
Kelp bed area
San Onofre: 0.110 km^2
7 June 1997
Kelp bed area
San Onofre: < 0.001 km^2
14 June 1998
Kelp bed area
San Onofre: 0.005 km^2
30 December 1999
Kelp bed area
San Onofre: 0.020 km^2
21 December 2000
1 stat. mi.
1 km.
Depth contours in feet

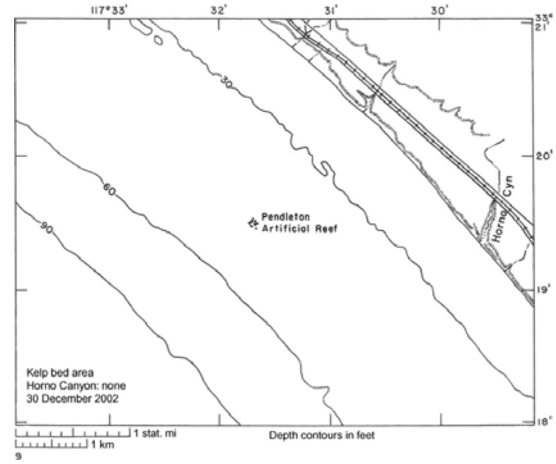


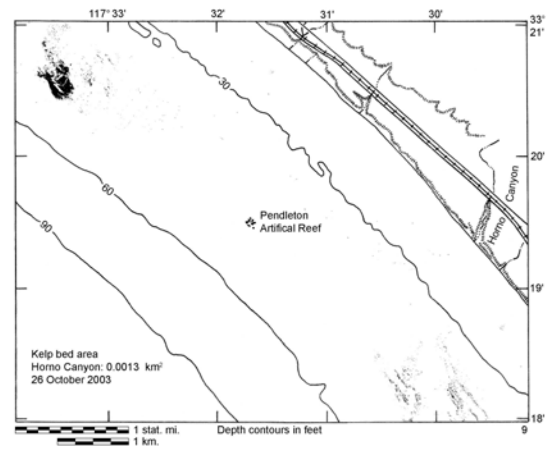
Historical charts of San Onofre kelp from 1972 to 1989.

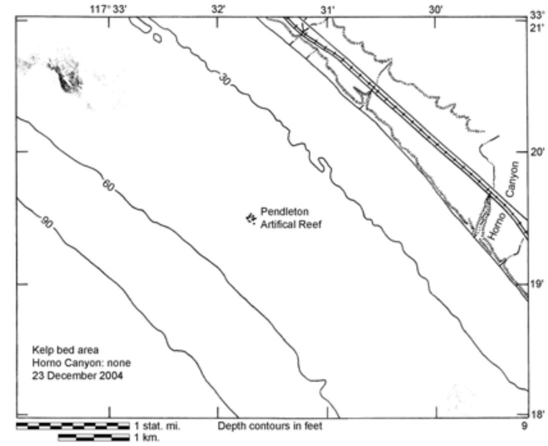

117°33'0"W
117°32'0"W
117°31'0"W
117°30'0"W
33°21'0"N
33°20'0"N
33°19'0"N
N
Old Pacific
Horno
Cyn.
Pendleton
Artificial Reef
10
20
30
Kelp bed area
March 10, 2009
Horno Canyon: 0.0175 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
9

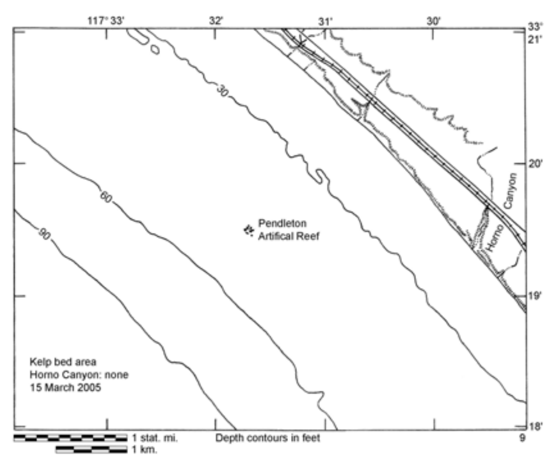

117°33'0"W
117°32'0"W
117°31'0"W
117°30'0"W
33°21'0"N
33°20'0"N
33°19'0"N
N
Old Pacific
Horno
Cyn.
Pendleton
Artificial Reef
10
20
30
Kelp bed area
December 31, 2010
Horno Canyon: 0.0812 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
9

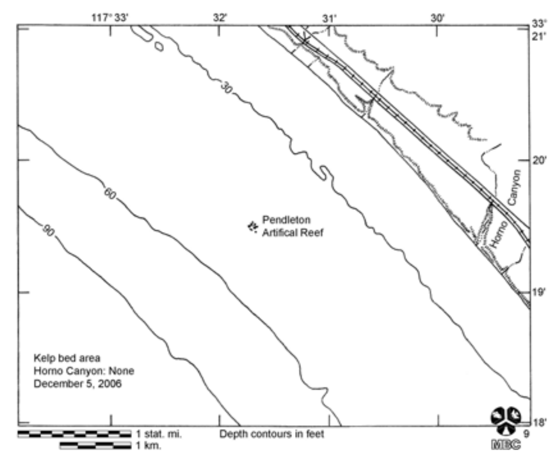

117° 33'
32'
31'
30'
33°
21'
20'
19'
18'
30
60
90
Horno
Canyon
Pendleton
Artifical Reef
Kelp bed area
Horno Canyon: 0.03 km²
15 November 2001
1 stat. mi.
1 km.
Depth contours in feet
9

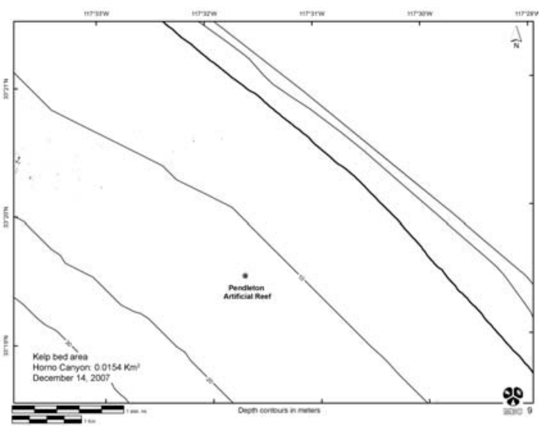

117°33'
32'
31'
30'
33°
21'
20'
19'
18'
30
60
90
Horno
Cyn
Pendleton
Artificial Reef
Kelp bed area
Horno Canyon: none
30 December 2002
1 stat. mi
1 km
Depth contours in feet
9

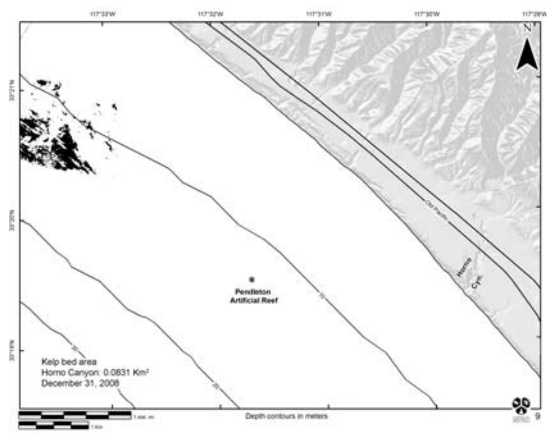

117° 33'
32'
31'
30'
33°
21'
20'
19'
18'
30
60
90
Horno
Canyon
Pendleton
Artifical Reef
Kelp bed area
Horno Canyon: 0.0013 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
9

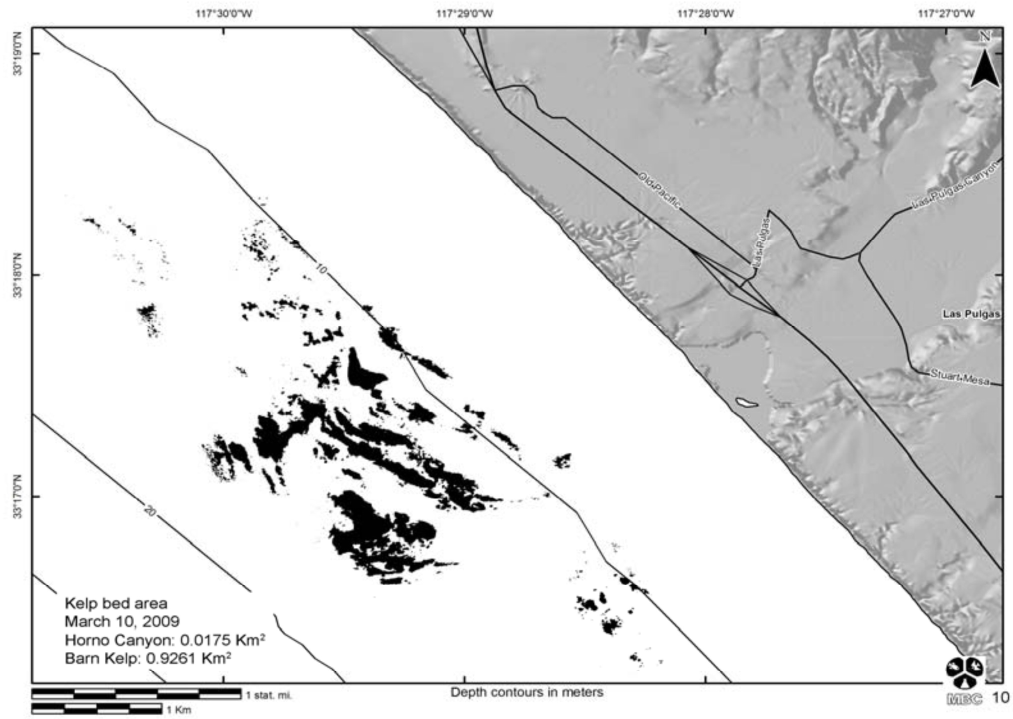

117° 33'
32'
31'
30'
33°
21'
20'
19'
18'
30
60
90
Horno
Canyon
Pendleton
Artifical Reef
Kelp bed area
Horno Canyon: none
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
9

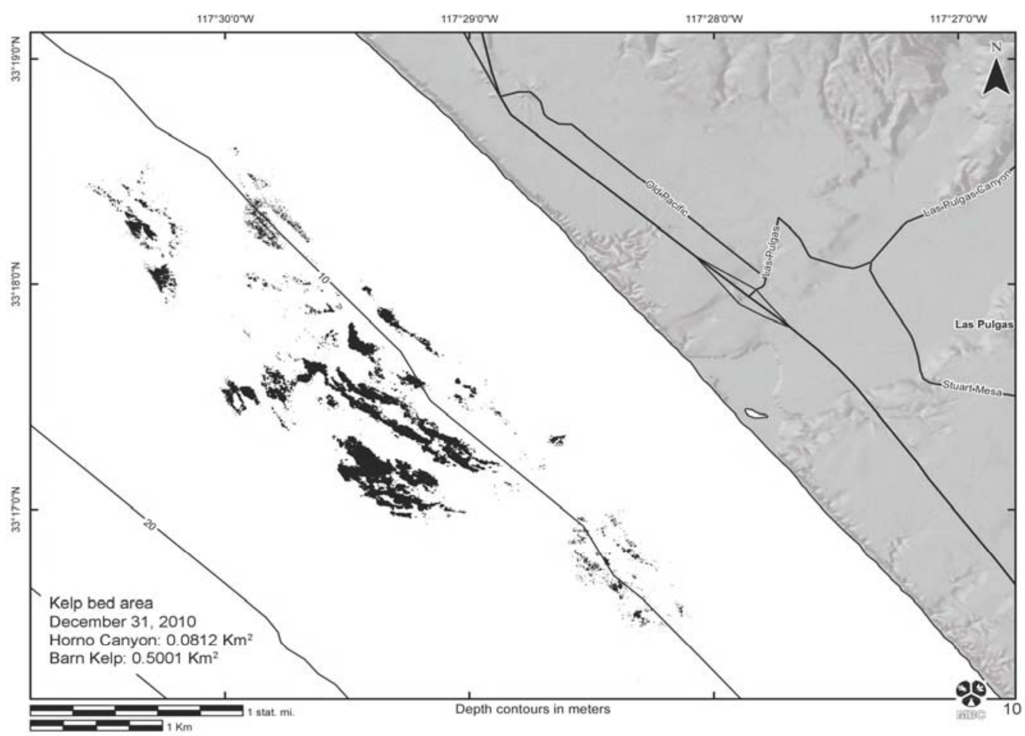

117° 33'
32'
31'
30'
33°
21'
20'
19'
18'
30
60
90
Horno
Canyon
Pendleton
Artifical Reef
Kelp bed area
Horno Canyon: none
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
9

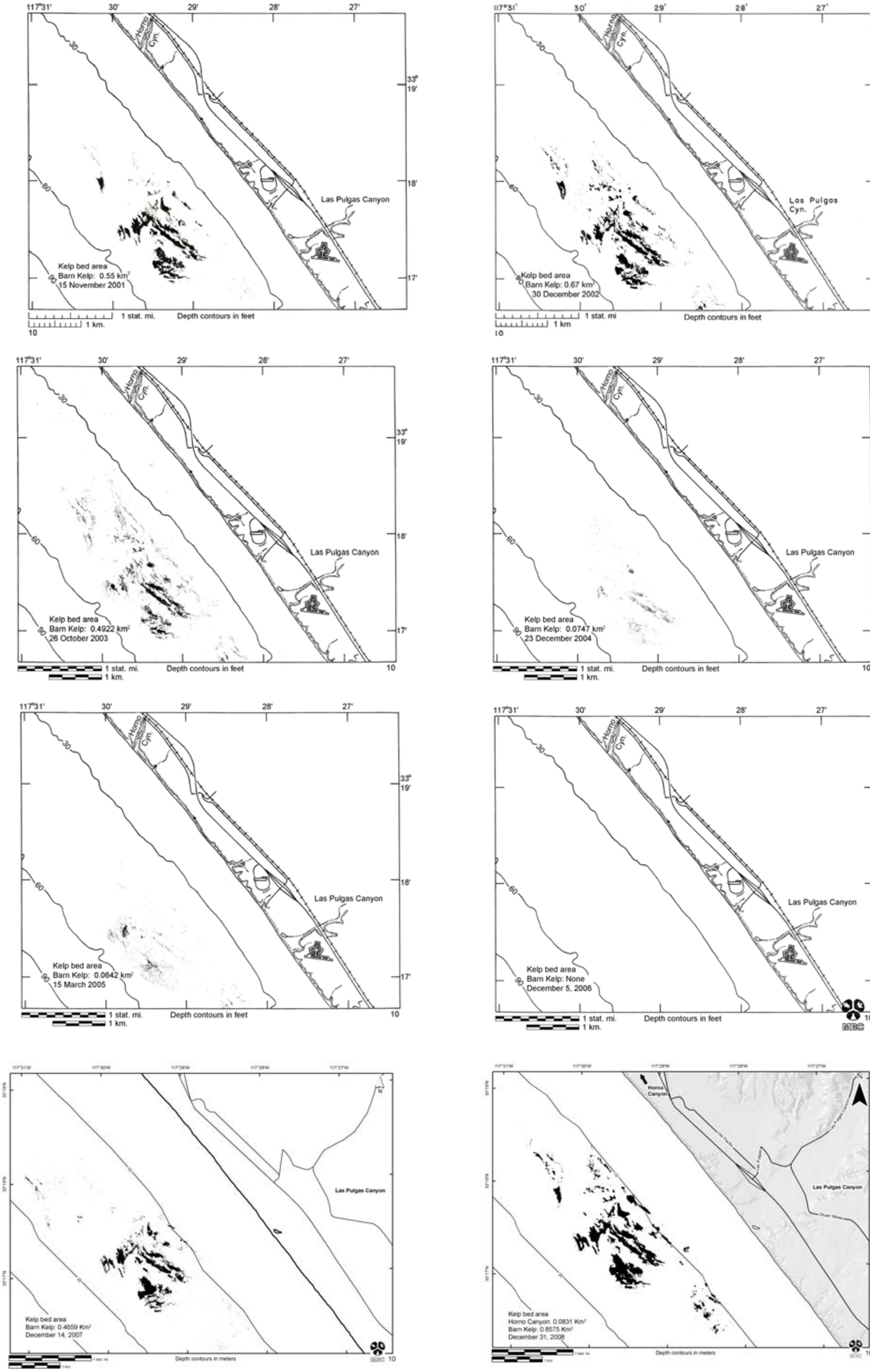

117° 33'
32'
31'
30'
33°
21'
20'
19'
18'
30
60
90
Horno
Canyon
Pendleton
Artifical Reef
Kelp bed area
Horno Canyon: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
9


Pendleton
Artificial Reef
Kelp bed area
Horno Canyon: 0.0154 Km²
December 14, 2007
Depth contours in meters
9

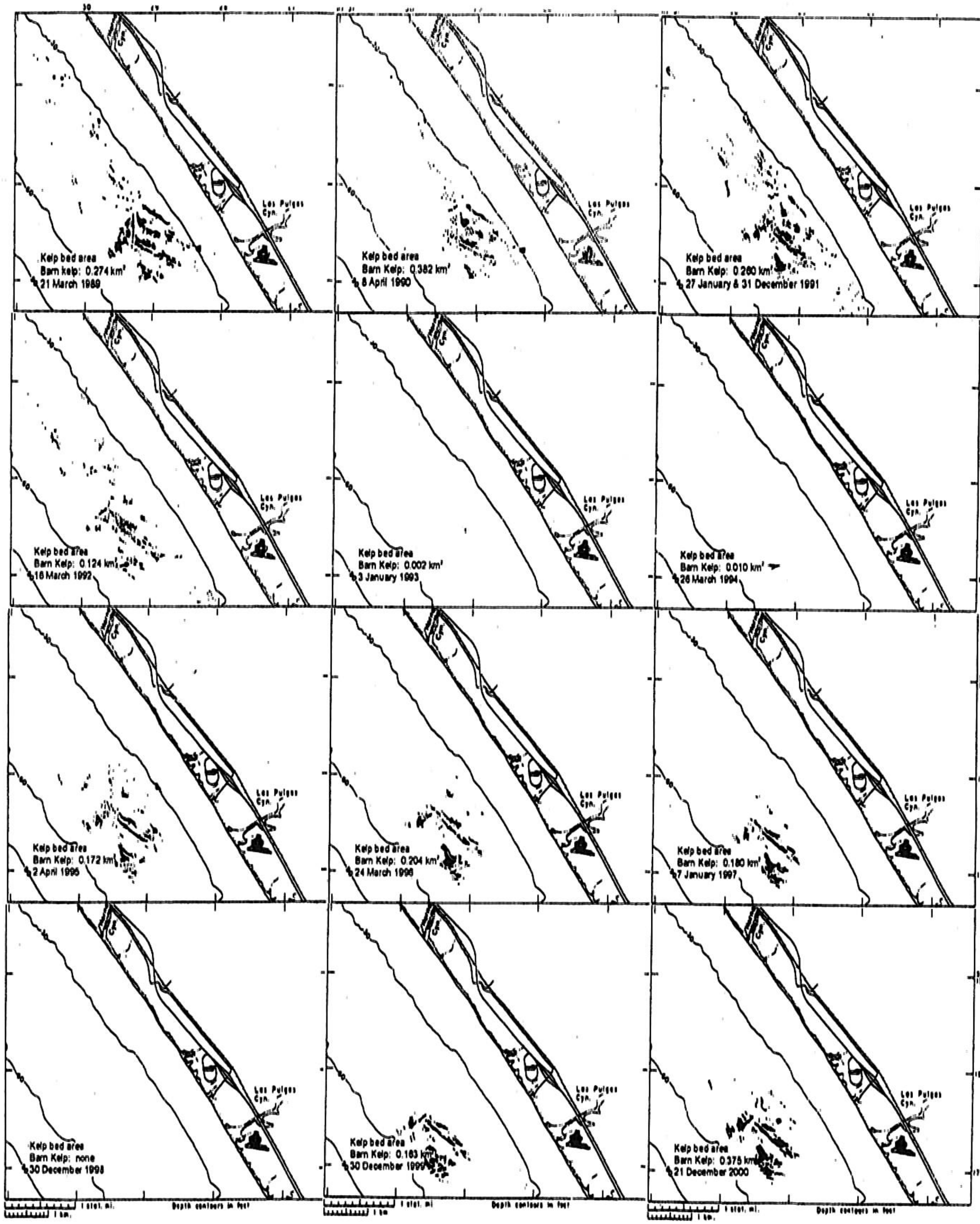

N
Pendleton
Artificial Reef
Horno
Cyn.
Kelp bed area
Horno Canyon: 0.0831 Km²
December 31, 2008
Depth contours in meters
9

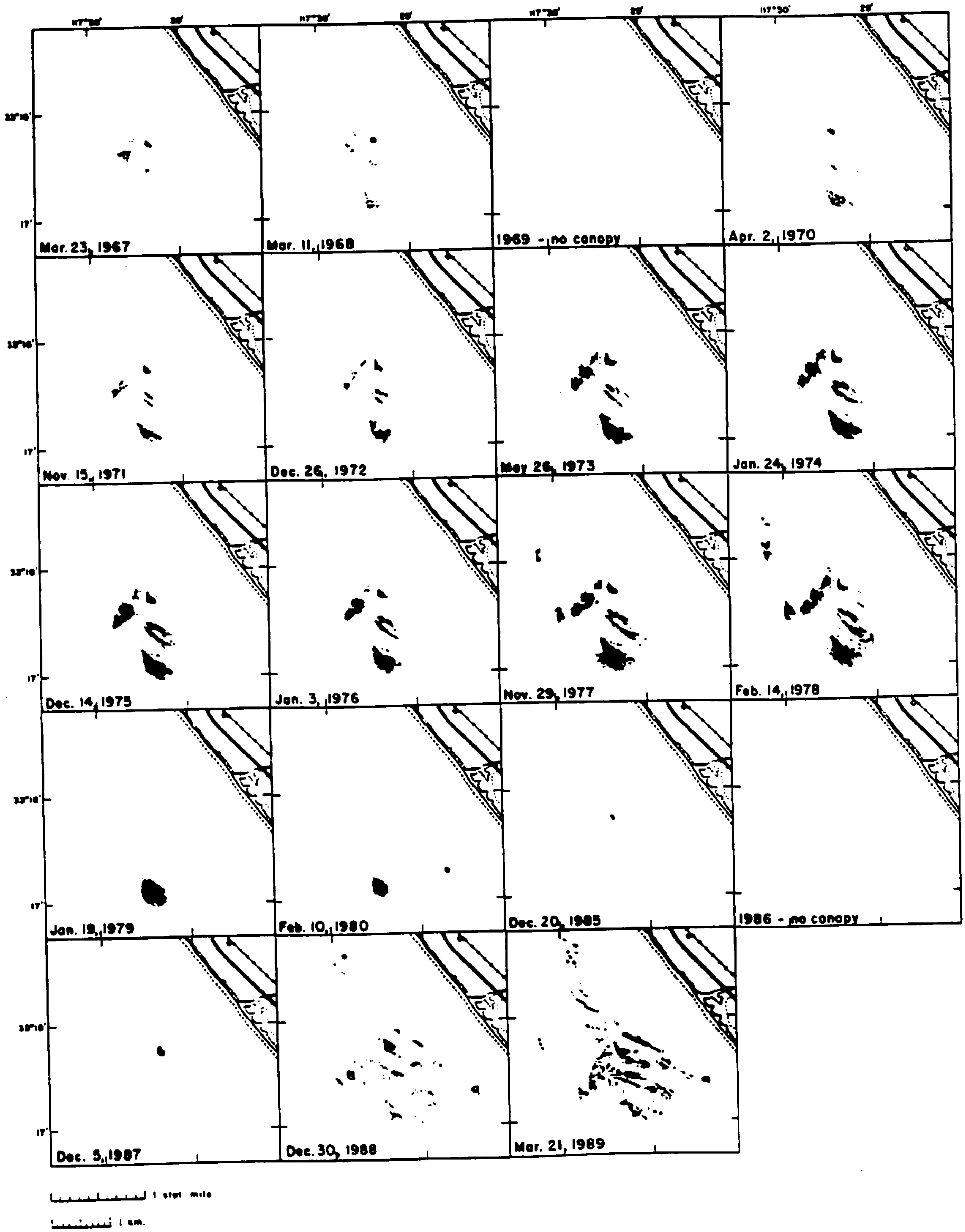

117°30'0"W
117°29'0"W
117°28'0"W
117°27'0"W
33°19'0"N
33°18'0"N
33°17'0"N
N
Old Pacific
Las Pulgas Canyon
Las Pulgas
Las Pulgas
Stuart Mesa
10
20
Kelp bed area
March 10, 2009
Horno Canyon: 0.0175 Km²
Barn Kelp: 0.9261 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
10


117°30'0"W
117°29'0"W
117°28'0"W
117°27'0"W
33°19'0"N
33°18'0"N
33°17'0"N
N
Old Pacific
Las Pulgas Canyon
Las Pulgas
Las Pulgas
Stuart Mesa
10
20
Kelp bed area
December 31, 2010
Horno Canyon: 0.0812 Km²
Barn Kelp: 0.5001 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
10

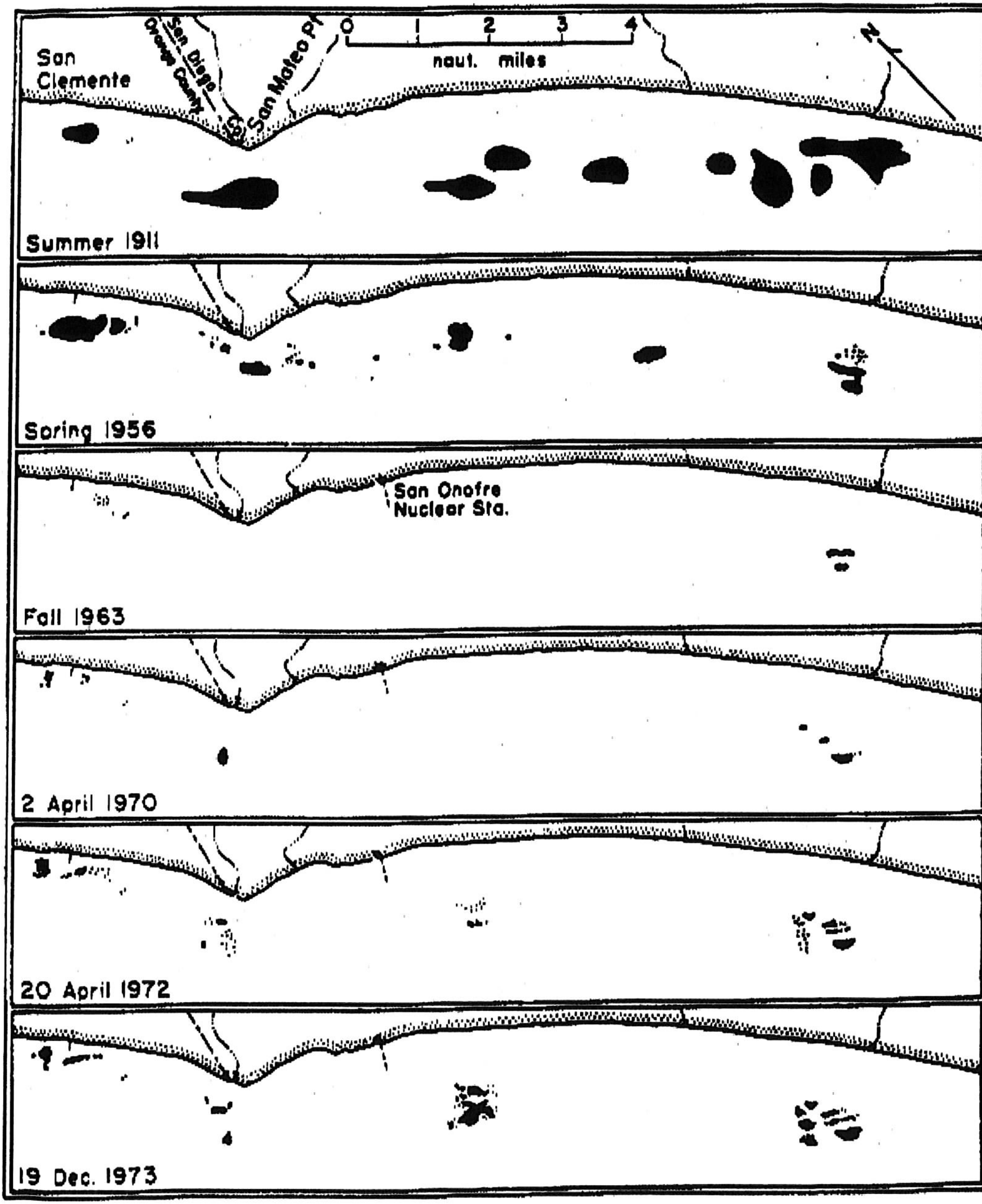


117°31'
30'
29'
28'
27'
33° 19'
18'
17'
Horno Cyn.
Las Pulgas Canyon
30
60
90
Kelp bed area
Barn Kelp: 0.55 km²
15 November 2001
1 stat. mi.
1 km.
Depth contours in feet
Las Pulgas Cyn.
Kelp bed area
Barn Kelp: 0.67 km²
30 December 2002
Kelp bed area
Barn Kelp: 0.4922 km²
26 October 2003
Kelp bed area
Barn Kelp: 0.0747 km²
23 December 2004
Kelp bed area
Barn Kelp: 0.0642 km²
15 March 2005
Kelp bed area
Barn Kelp: None
December 5, 2006
MBC
10
Las Pulgas Canyon
Kelp bed area
Barn Kelp: 0.4659 Km²
December 14, 2007
Depth contours in meters
Horno Canyon
Las Pulgas Canyon
Kelp bed area
Horno Canyon: 0.0831 Km²
Barn Kelp: 0.8575 Km²
December 31, 2008
Depth contours in meters

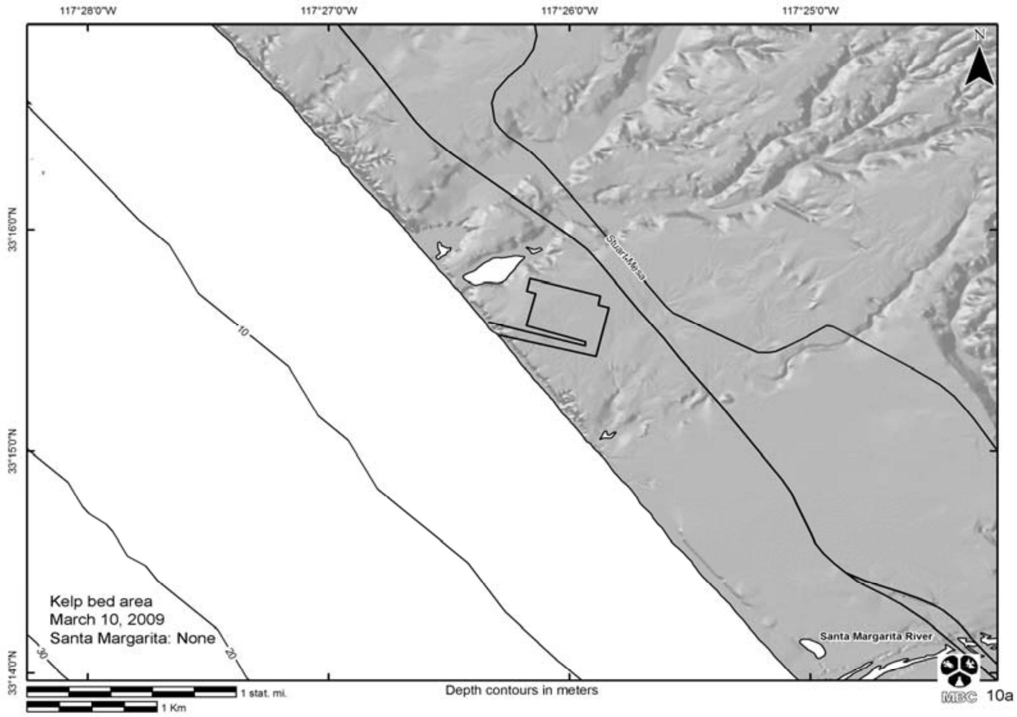

Kelp bed area
Barn kelp: 0.274 km²
21 March 1989
Kelp bed area
Barn Kelp: 0.382 km²
8 April 1990
Kelp bed area
Barn Kelp: 0.260 km²
27 January & 31 December 1991
Kelp bed area
Barn Kelp: 0.124 km²
16 March 1992
Kelp bed area
Barn Kelp: 0.002 km²
3 January 1993
Kelp bed area
Barn Kelp: 0.010 km²
26 March 1994
Kelp bed area
Barn Kelp: 0.172 km²
2 April 1995
Kelp bed area
Barn Kelp: 0.204 km²
24 March 1996
Kelp bed area
Barn Kelp: 0.180 km²
7 January 1997
Kelp bed area
Barn Kelp: none
30 December 1998
Kelp bed area
Barn Kelp: 0.163 km²
30 December 1999
Kelp bed area
Barn Kelp: 0.375 km²
21 December 2000
Las Pulgas Cyn.
1 stat. mi.
1 km.
Depth contours in feet



Historical charts of south Horno Canyon and of Barn kelp from 1967 to 1989.



Historical charts of kelp beds from San Clemente to Barn Kelp from 1911 to 1973.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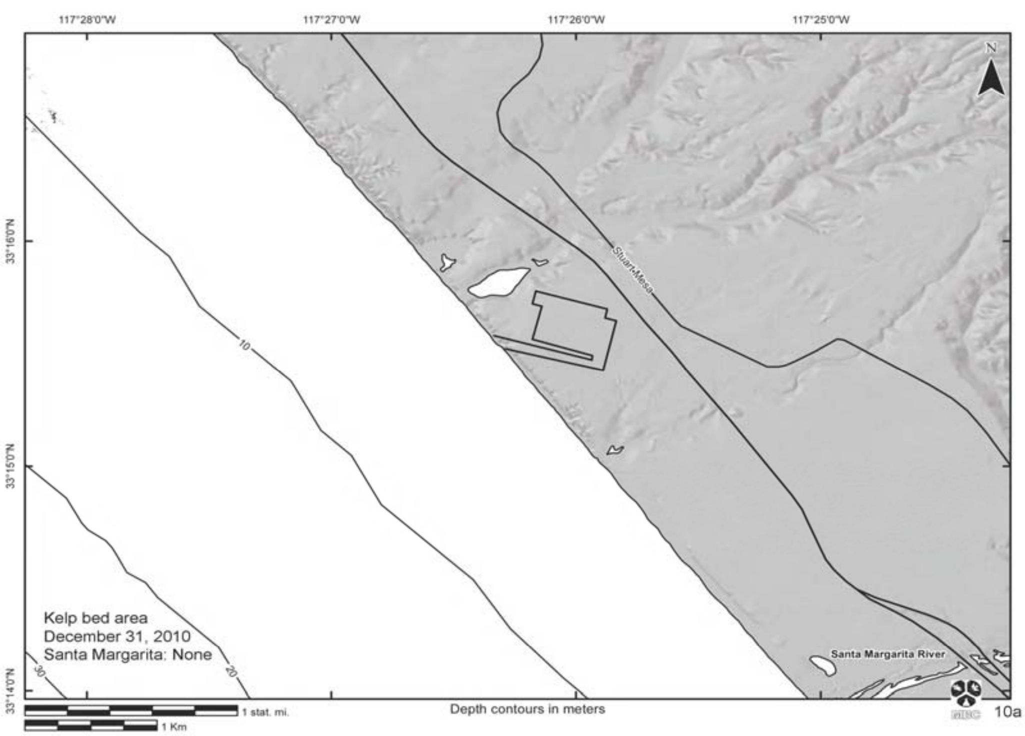
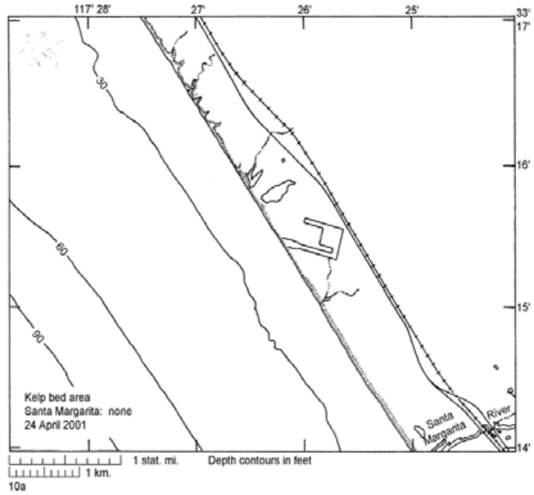
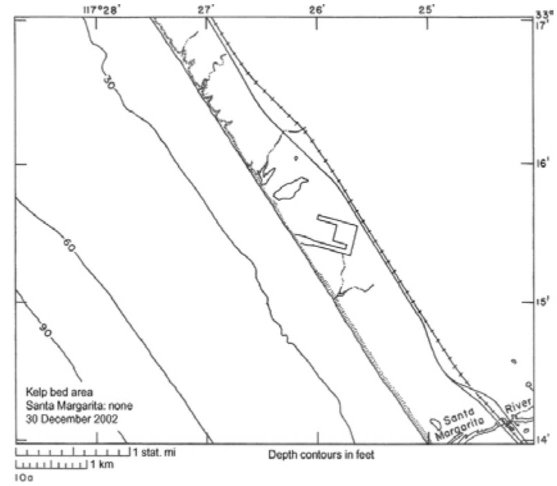
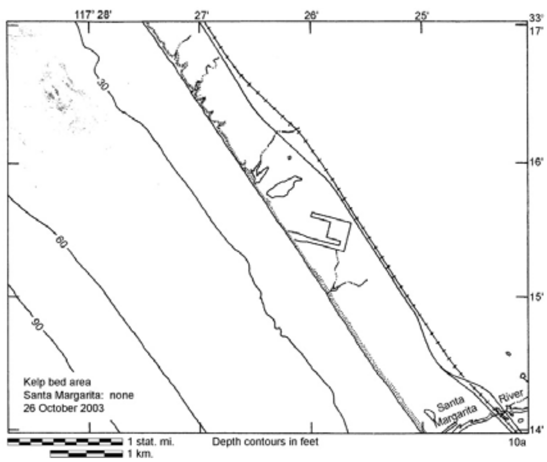
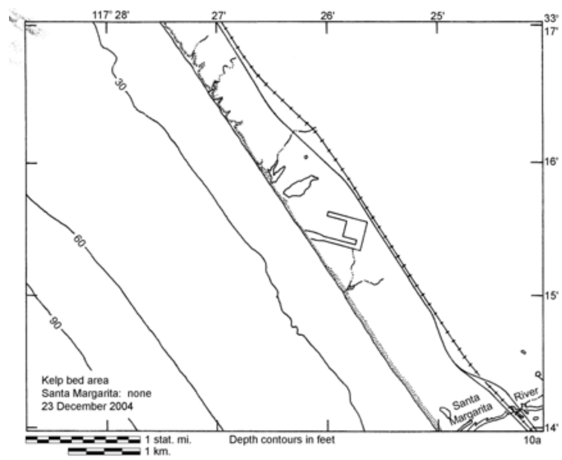
117°27'0"W
117°26'0"W
117°25'0"W
33°16'0"N
33°15'0"N
33°14'0"N
Stuart Mesa
10
20
30
Kelp bed area
March 10, 2009
Santa Margarita: None
Santa Margarita River
1 stat. mi.
1 Km
Depth contours in meters
MBC
10a

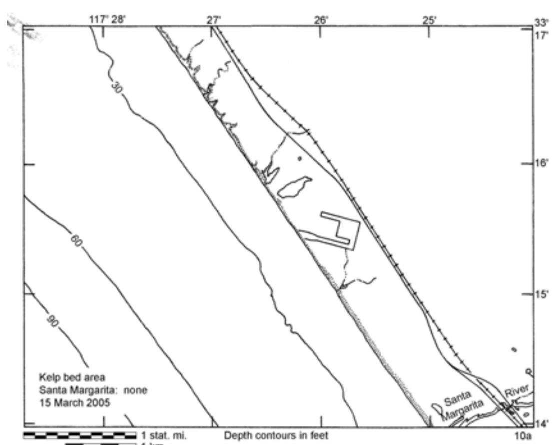

117°28'0"W
117°27'0"W
117°26'0"W
117°25'0"W
33°16'0"N
33°15'0"N
33°14'0"N
Stuart Mesa
10
20
30
Kelp bed area
December 31, 2010
Santa Margarita: None
Santa Margarita River
1 stat. mi.
1 Km
Depth contours in meters
MBC
10a

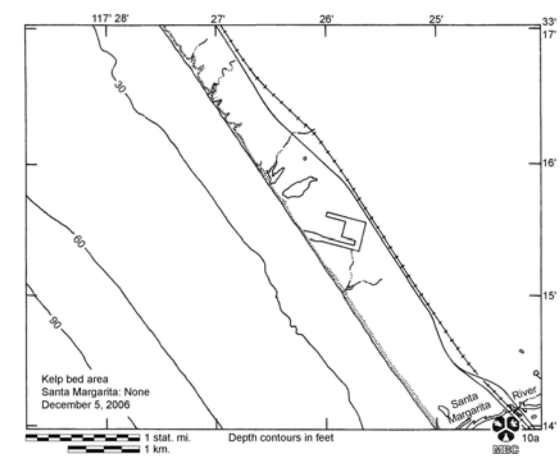

117° 28'
27'
26'
25'
33°
17'
16'
15'
14'
30
60
90
Santa
Margarita
River
Kelp bed area
Santa Margarita: none
24 April 2001
1 stat. mi.
1 km.
Depth contours in feet
10a

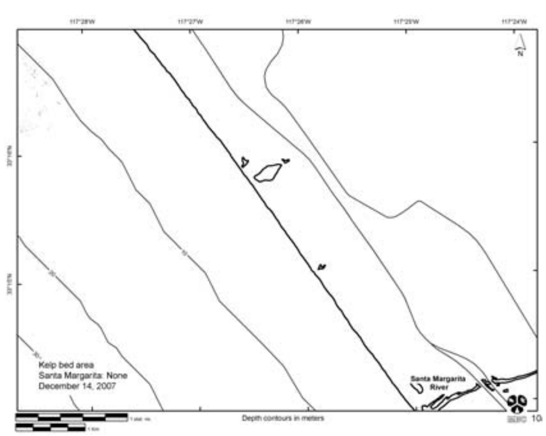

117°28'
27'
26'
25'
33°
17'
16'
15'
14'
30
60
90
Santa
Margarita
River
Kelp bed area
Santa Margarita: none
30 December 2002
1 stat. mi
1 km
Depth contours in feet
10a

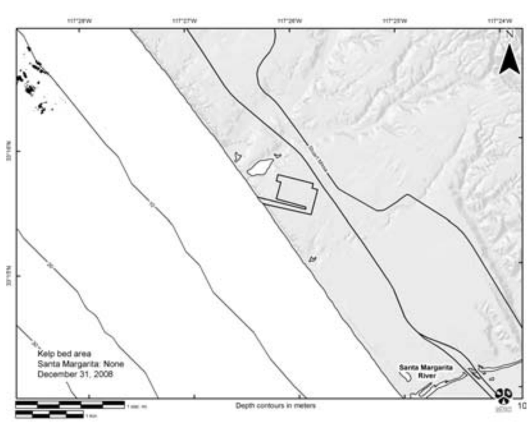

117° 28'
27'
26'
25'
33°
17'
16'
15'
14'
30
60
90
Santa
Margarita
River
Kelp bed area
Santa Margarita: none
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
10a

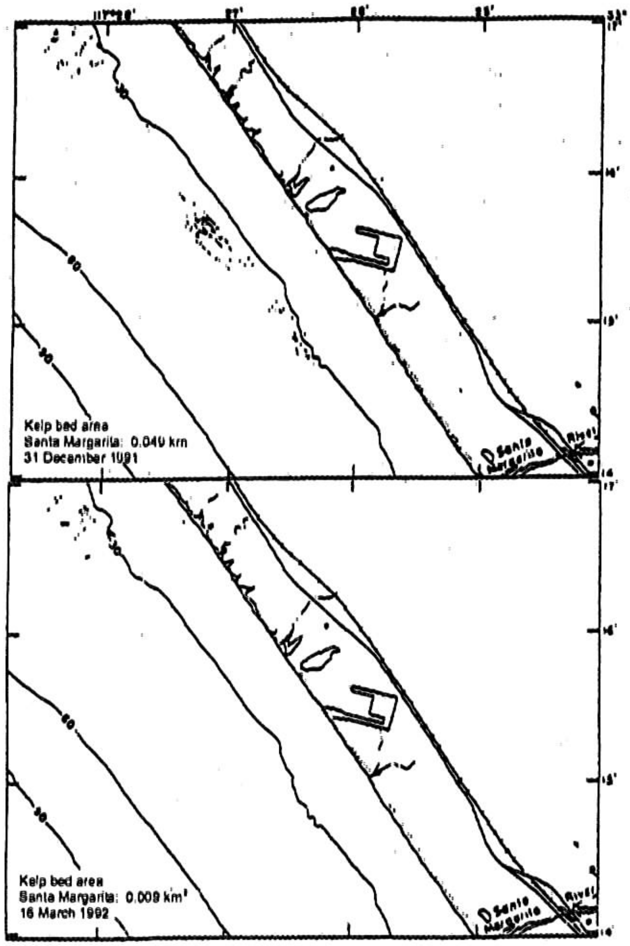

117° 28'
27'
26'
25'
33°
17'
16'
15'
14'
30
60
90
Santa
Margarita
River
Kelp bed area
Santa Margarita: none
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
10a


117° 28'
27'
26'
25'
33°
17'
16'
15'
14'
30
60
90
Santa
Margarita
River
Kelp bed area
Santa Margarita: none
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
10a

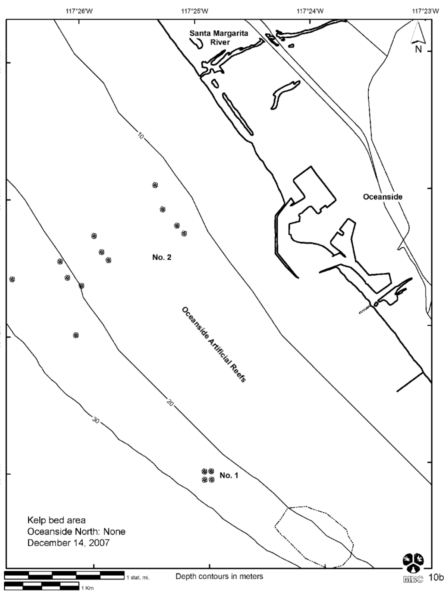

117° 28'
27'
26'
25'
33°
17'
16'
15'
14'
30
60
90
Santa
Margarita
River
Kelp bed area
Santa Margarita: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
10a

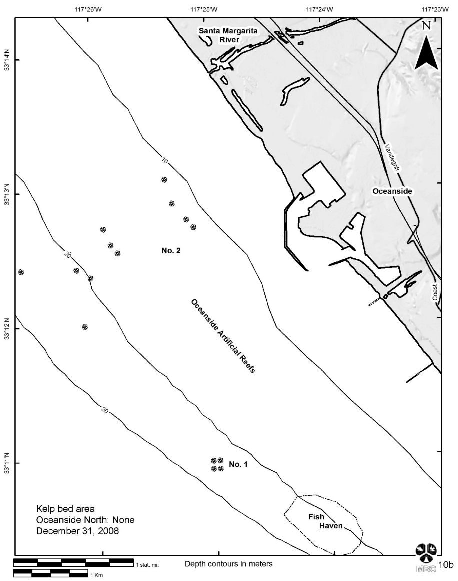

Santa Margarita
River
Kelp bed area
Santa Margarita: None
December 14, 2007
Depth contours in meters
10a

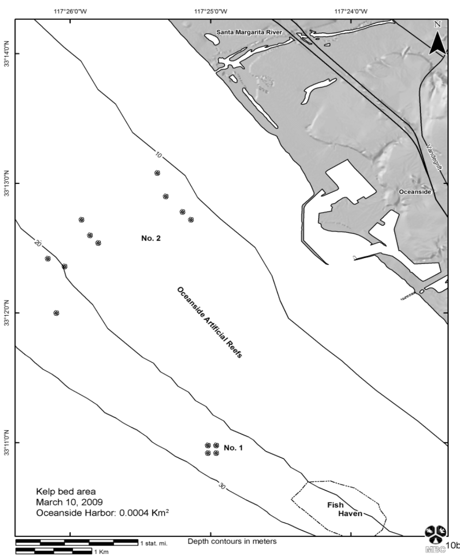

Santa Margarita
River
Kelp bed area
Santa Margarita: None
December 31, 2008
Depth contours in meters
10

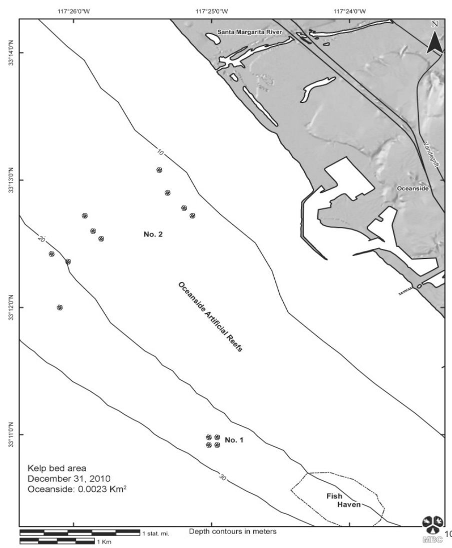


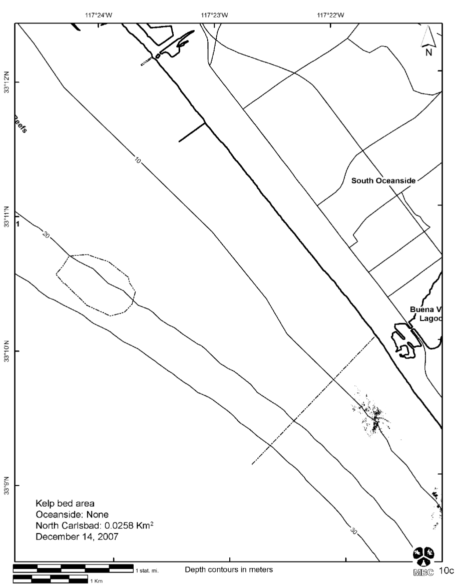
Kelp bed area
Santa Margarita: 0.049 km
31 December 1991
Kelp bed area
Santa Margarita: 0.009 km²
16 March 1992
Santa Margarita
River

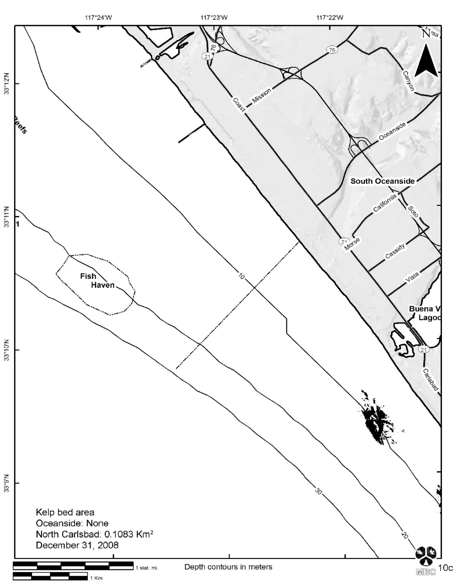

117°26'W
117°25'W
117°24'W
117°23'W
Santa Margarita River
Oceanside
No. 2
Oceanside Artificial Reefs
No. 1
Kelp bed area
Oceanside North: None
December 14, 2007
1 stat. mi.
1 Km
Depth contours in meters
10b

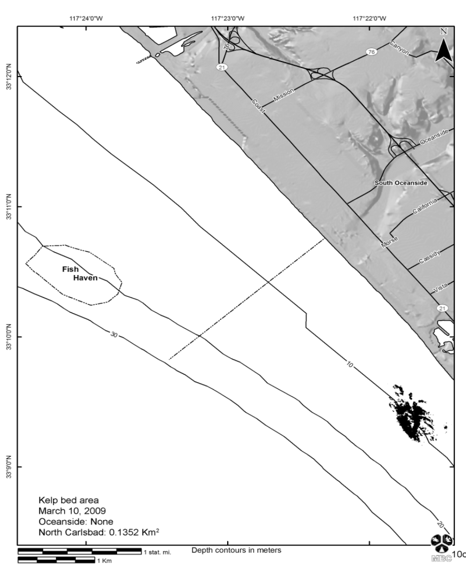

117°26'W
117°25'W
117°24'W
117°23'W
Santa Margarita River
Oceanside
No. 2
Oceanside Artificial Reefs
No. 1
Fish Haven
Kelp bed area
Oceanside North: None
December 31, 2008
1 stat. mi.
1 Km
Depth contours in meters
10b

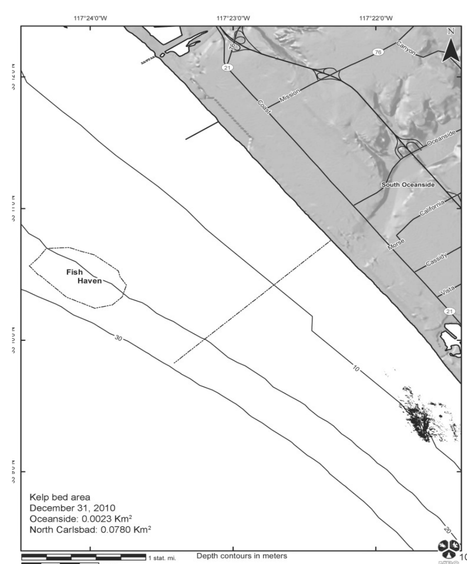

117°26'0"W
117°25'0"W
117°24'0"W
Santa Margarita River
Oceanside
No. 2
Oceanside Artificial Reefs
No. 1
Fish Haven
Kelp bed area
March 10, 2009
Oceanside Harbor: 0.0004 Km²
1 stat. mi.
1 Km
Depth contours in meters
10b

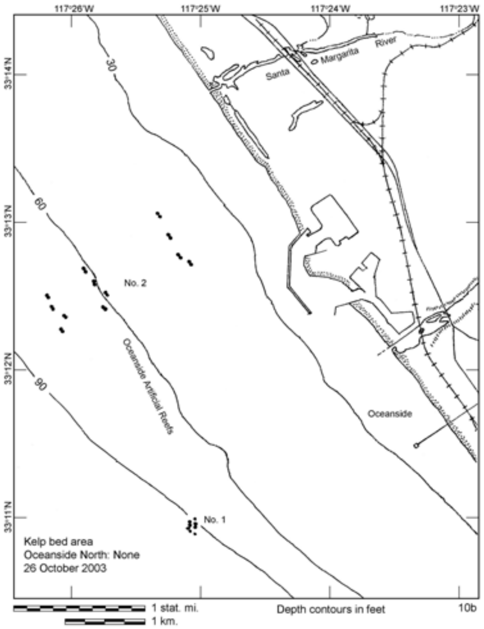

117°26'0"W
117°25'0"W
117°24'0"W
Santa Margarita River
Oceanside
No. 2
Oceanside Artificial Reefs
No. 1
Fish Haven
Kelp bed area
December 31, 2010
Oceanside: 0.0023 Km²
1 stat. mi.
1 Km
Depth contours in meters
10b

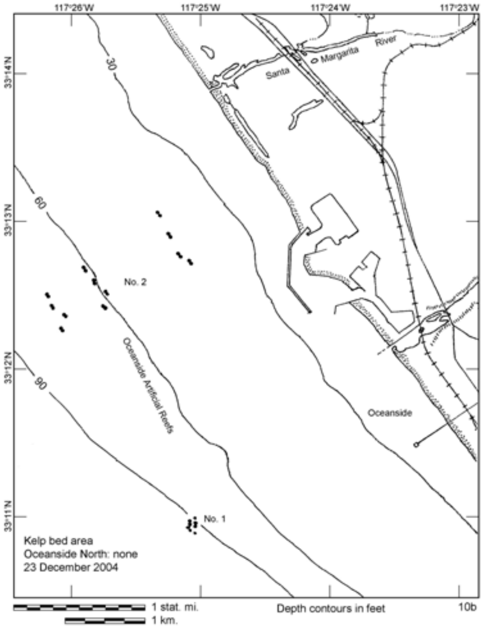

117°24'W
117°23'W
117°22'W
South Oceanside
Kelp bed area
Oceanside: None
North Carlsbad: 0.0258 Km²
December 14, 2007
1 stat. mi.
1 Km
Depth contours in meters
10c


117°24'W
117°23'W
117°22'W
South Oceanside
Fish Haven
Kelp bed area
Oceanside: None
North Carlsbad: 0.1083 Km²
December 31, 2008
1 stat. mi.
1 Km
Depth contours in meters
10c


117°24'0"W
117°23'0"W
117°22'0"W
South Oceanside
Fish Haven
Kelp bed area
March 10, 2009
Oceanside: None
North Carlsbad: 0.1352 Km²
1 stat. mi.
1 Km
Depth contours in meters
10c


117°24'0"W
117°23'0"W
117°22'0"W
South Oceanside
Fish Haven
Kelp bed area
December 31, 2010
Oceanside: 0.0023 Km²
North Carlsbad: 0.0780 Km²
1 stat. mi.
1 Km
Depth contours in meters
10c


117°26'W
117°25'W
117°24'W
117°23'W
33°14'N
33°13'N
33°12'N
33°11'N
Santa Margarita River
30
60
90
No. 2
Oceanside Artificial Reefs
Oceanside
No. 1
Kelp bed area
Oceanside North: None
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
10b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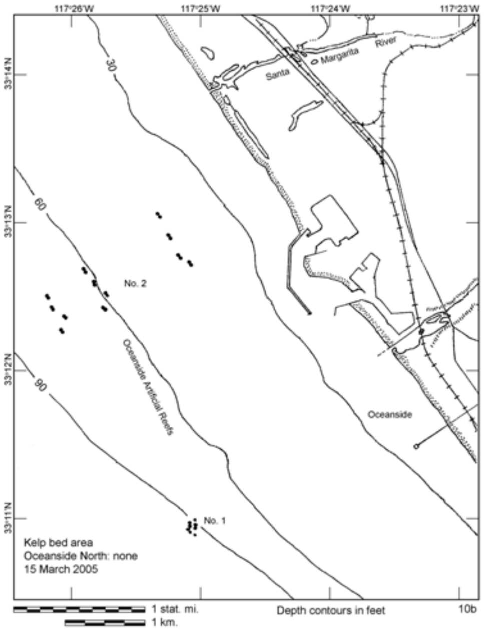
117°25'W
117°24'W
117°23'W
33°14'N
33°13'N
33°12'N
33°11'N
Santa Margarita River
30
60
90
No. 2
Oceanside Artificial Reefs
Oceanside
No. 1
Kelp bed area
Oceanside North: none
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
10b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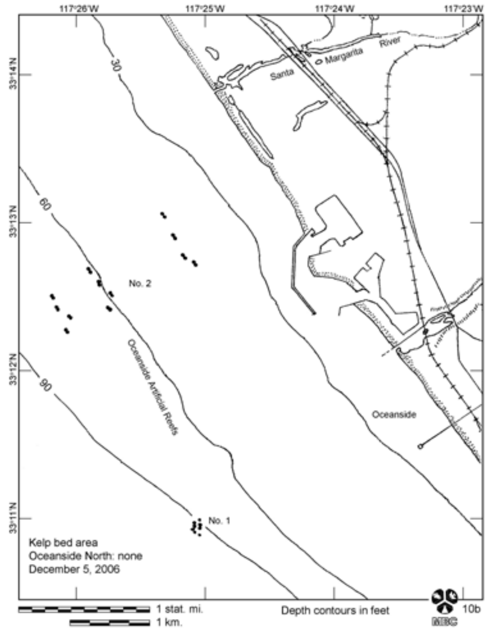
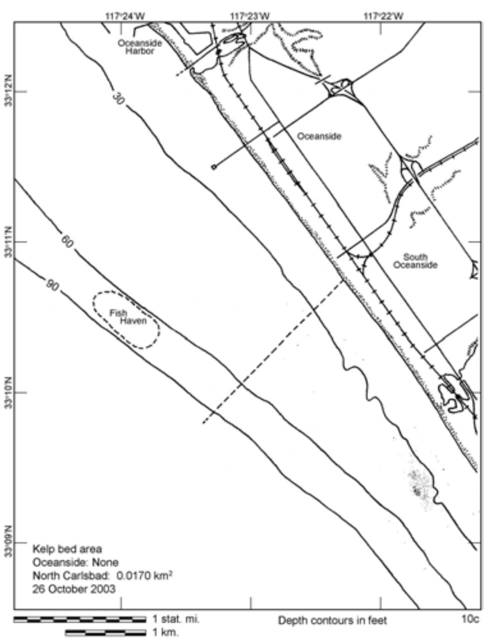
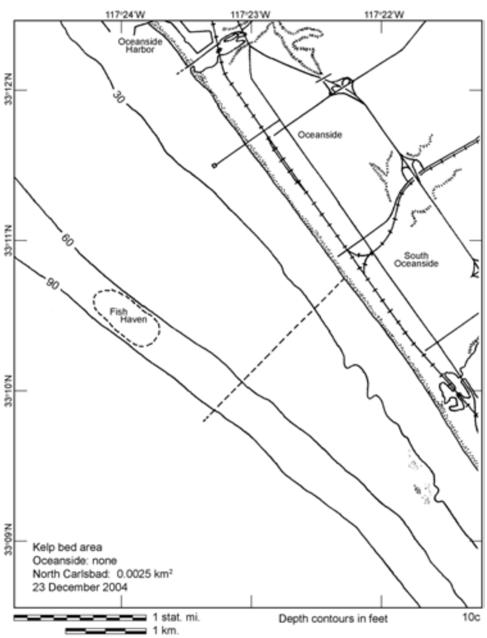
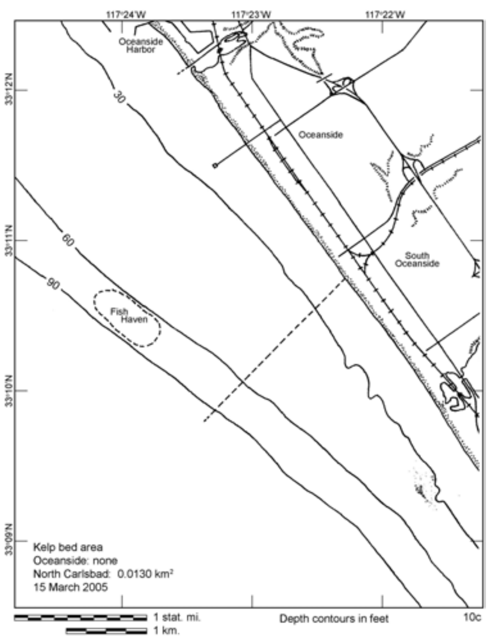
117°25'W
117°24'W
117°23'W
33°14'N
33°13'N
33°12'N
33°11'N
Santa Margarita River
30
60
90
No. 2
Oceanside Artificial Reefs
Oceanside
No. 1
Kelp bed area
Oceanside North: none
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
10b


117°26'W
117°25'W
117°24'W
117°23'W
33°14'N
33°13'N
33°12'N
33°11'N
Santa Margarita River
30
60
90
No. 2
Oceanside Artificial Reefs
Oceanside
No. 1
Kelp bed area
Oceanside North: none
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
10b


117°24'W
117°23'W
117°22'W
33°12'N
33°11'N
33°10'N
33°09'N
Oceanside Harbor
Oceanside
South Oceanside
30
60
90
Fish Haven
Kelp bed area
Oceanside: None
North Carlsbad: 0.0170 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
10c


117°24'W
117°23'W
117°22'W
33°12'N
33°11'N
33°10'N
33°09'N
Oceanside Harbor
Oceanside
South Oceanside
30
60
90
Fish Haven
Kelp bed area
Oceanside: none
North Carlsbad: 0.0025 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
10c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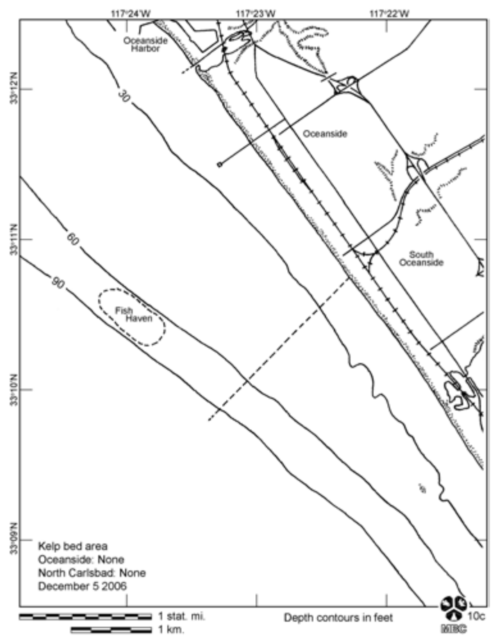
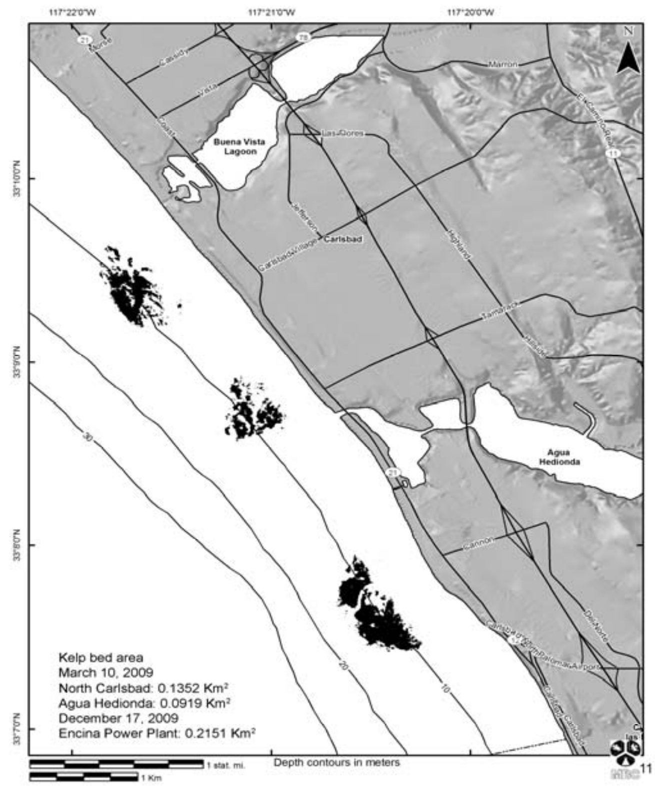
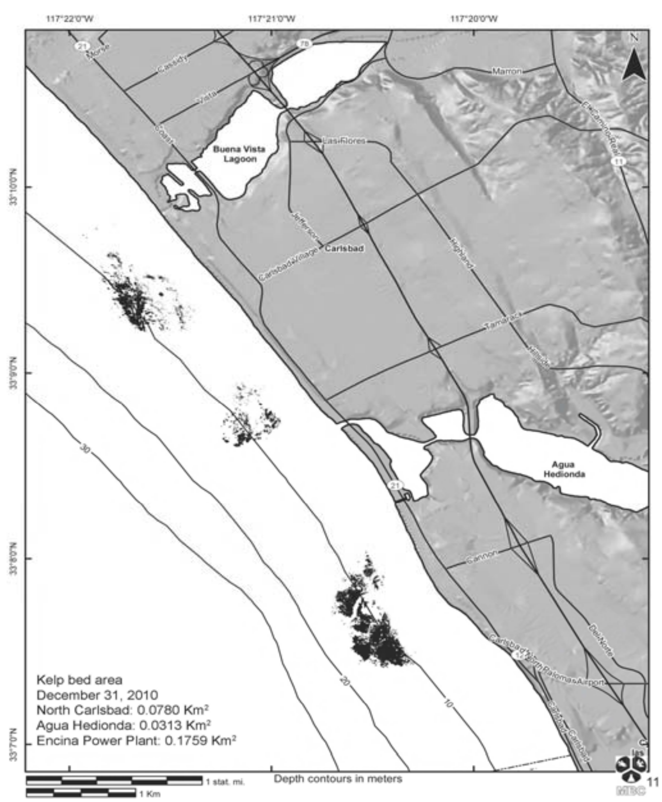
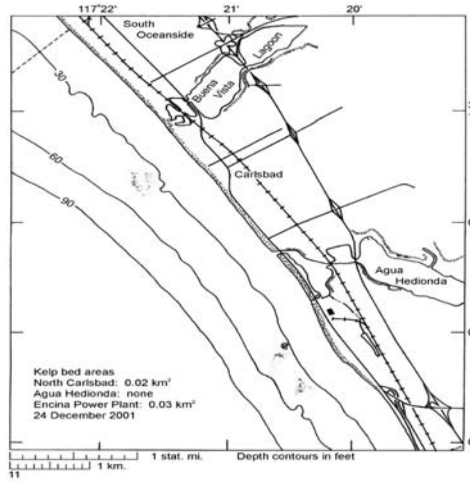
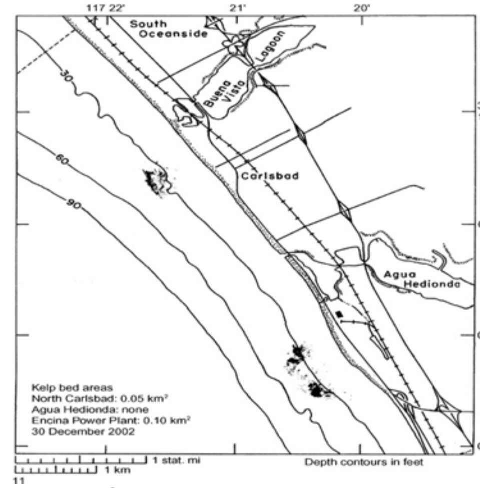
117°23'W
117°22'W
33°12'N
33°11'N
33°10'N
33°09'N
Oceanside Harbor
Oceanside
South Oceanside
30
60
90
Fish Haven
Kelp bed area
Oceanside: none
North Carlsbad: 0.0130 km²
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
10c

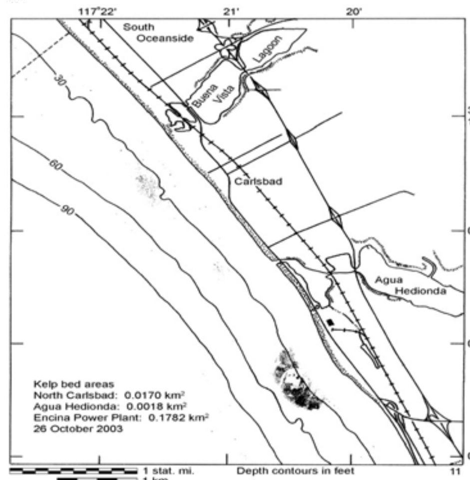

117°24'W
117°23'W
117°22'W
33°12'N
33°11'N
33°10'N
33°09'N
Oceanside Harbor
Oceanside
South Oceanside
30
60
90
Fish Haven
Kelp bed area
Oceanside: None
North Carlsbad: None
December 5 2006
1 stat. mi.
1 km.
Depth contours in feet
10c

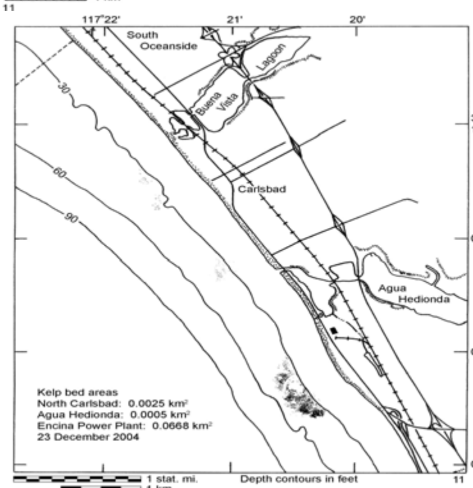

117°22'0"W
117°21'0"W
117°20'0"W
33°10'0"N
33°9'0"N
33°8'0"N
33°7'0"N
Buena Vista Lagoon
Carlsbad
Agua Hedionda
30
20
10
Kelp bed area
March 10, 2009
North Carlsbad: 0.1352 Km²
Agua Hedionda: 0.0919 Km²
December 17, 2009
Encina Power Plant: 0.2151 Km²
1 stat. mi.
1 Km
Depth contours in meters
11

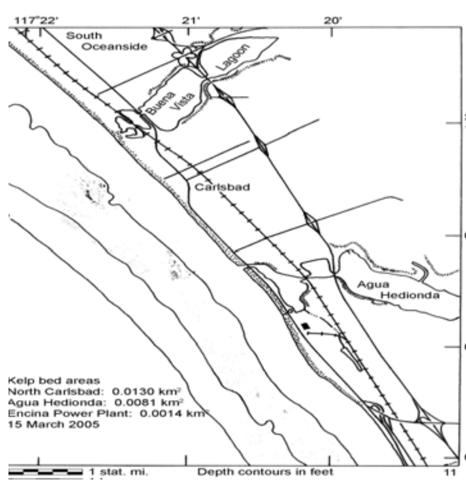

117°22'0"W
117°21'0"W
117°20'0"W
33°10'0"N
33°9'0"N
33°8'0"N
33°7'0"N
Buena Vista Lagoon
Carlsbad
Agua Hedionda
30
20
10
Kelp bed area
December 31, 2010
North Carlsbad: 0.0780 Km²
Agua Hedionda: 0.0313 Km²
Encina Power Plant: 0.1759 Km²
1 stat. mi.
1 Km
Depth contours in meters
11

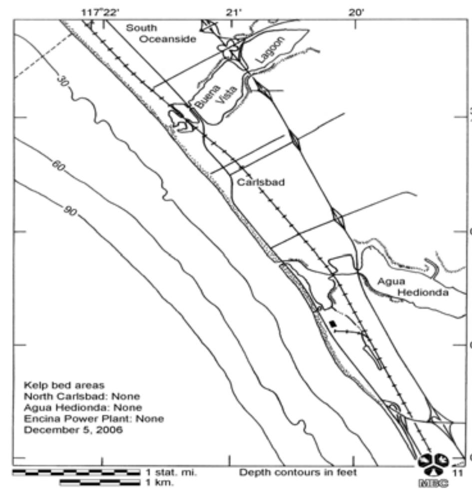

117°22'
21'
20'
South Oceanside
Buena Vista Lagoon
Carlsbad
Agua Hedionda
33° 10'
09'
08'
07'
30
60
90
Kelp bed areas
North Carlsbad: 0.02 km²
Agua Hedionda: none
Encina Power Plant: 0.03 km²
24 December 2001
1 stat. mi.
1 km.
Depth contours in feet
11

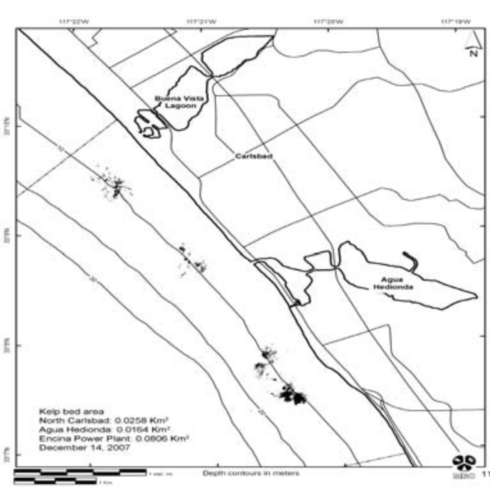

117 22'
21'
20'
South Oceanside
Buena Vista Lagoon
Carlsbad
Agua Hedionda
10'
09'
08'
07'
30
60
90
Kelp bed areas
North Carlsbad: 0.05 km²
Agua Hedionda: none
Encina Power Plant: 0.10 km²
30 December 2002
1 stat. mi
1 km
Depth contours in feet
11

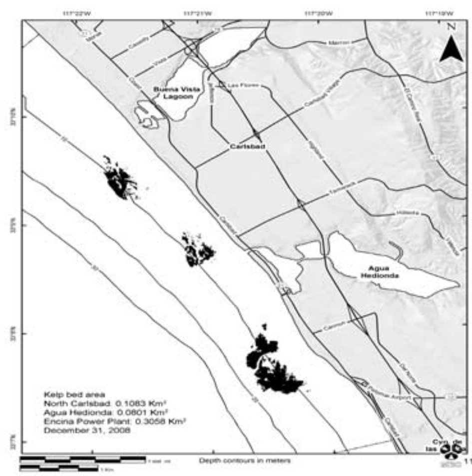

117°22'
21'
20'
South Oceanside
Buena Vista Lagoon
Carlsbad
Agua Hedionda
33° 10'
09'
08'
07'
30
60
90
Kelp bed areas
North Carlsbad: 0.0170 km²
Agua Hedionda: 0.0018 km²
Encina Power Plant: 0.1782 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
11

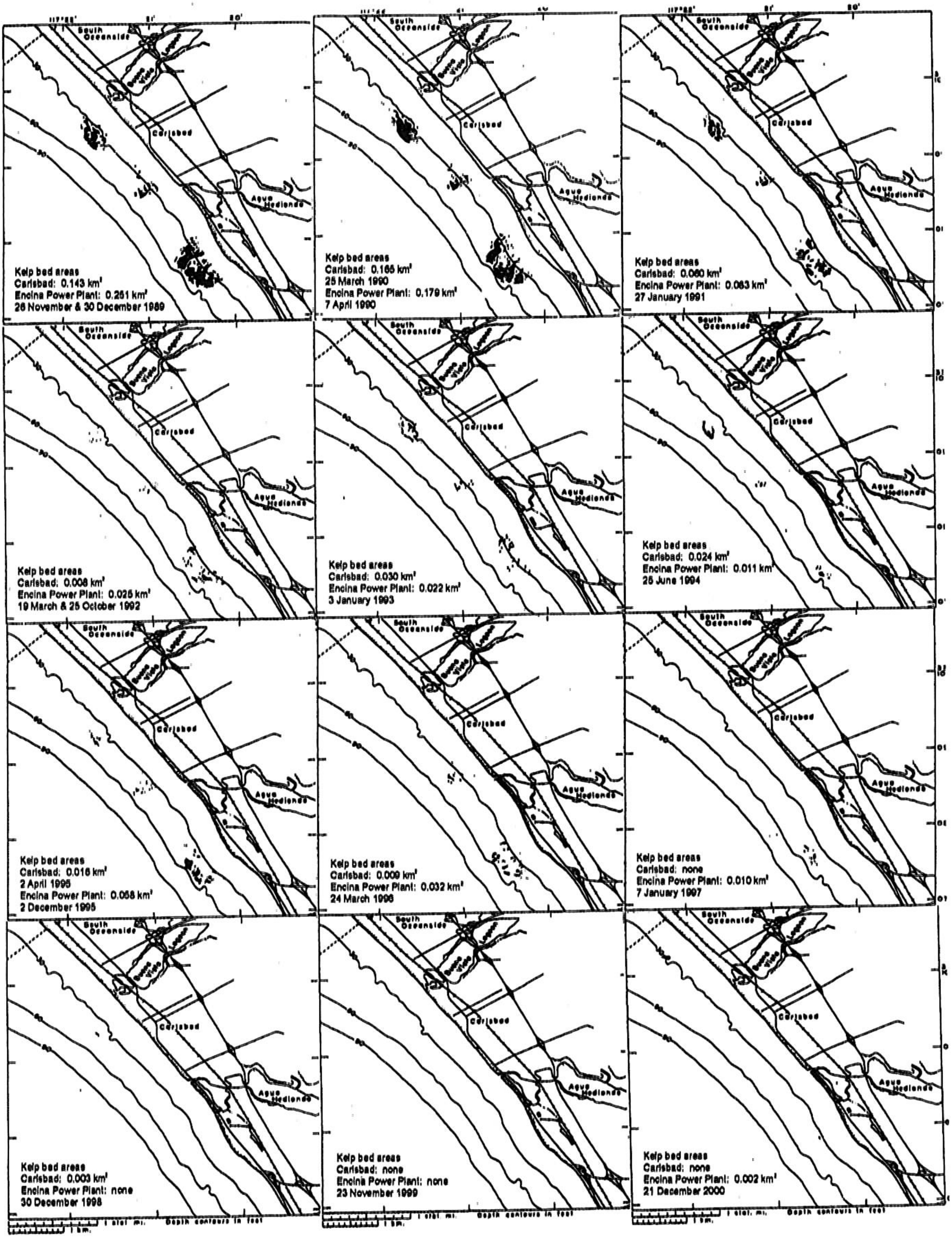

117°22'
21'
20'
South Oceanside
Buena Vista Lagoon
Carlsbad
Agua Hedionda
33° 10'
09'
08'
07'
30
60
90
Kelp bed areas
North Carlsbad: 0.0025 km²
Agua Hedionda: 0.0005 km²
Encina Power Plant: 0.0668 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
11


117°22'
21'
20'
South Oceanside
Buena Vista Lagoon
Carlsbad
Agua Hedionda
33° 10'
09'
08'
07'
Kelp bed areas
North Carlsbad: 0.0130 km²
Agua Hedionda: 0.0081 km²
Encina Power Plant: 0.0014 km²
15 March 2005
1 stat. mi.
Depth contours in feet
11

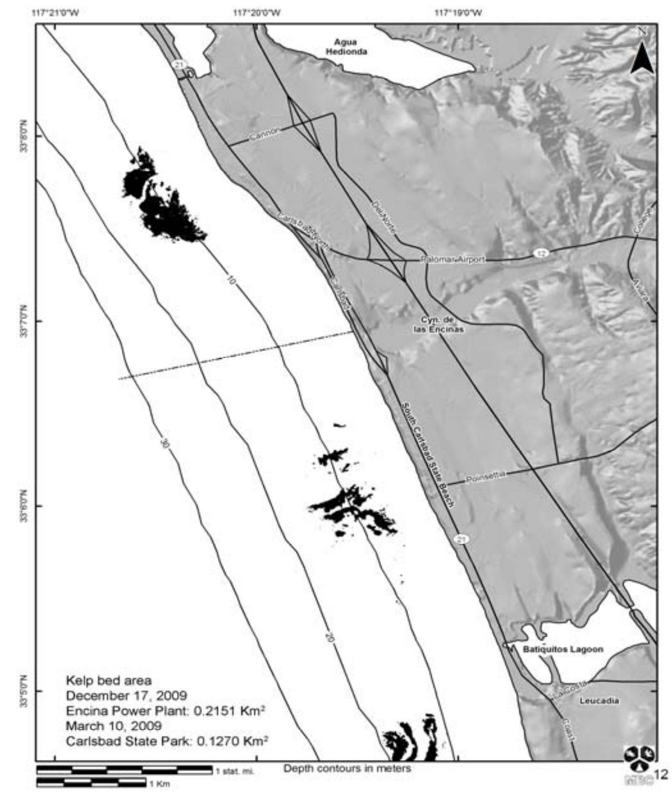

117°22'
21'
20'
South Oceanside
Buena Vista Lagoon
Carlsbad
Agua Hedionda
33° 10'
09'
08'
07'
30
60
90
Kelp bed areas
North Carlsbad: None
Agua Hedionda: None
Encina Power Plant: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
11

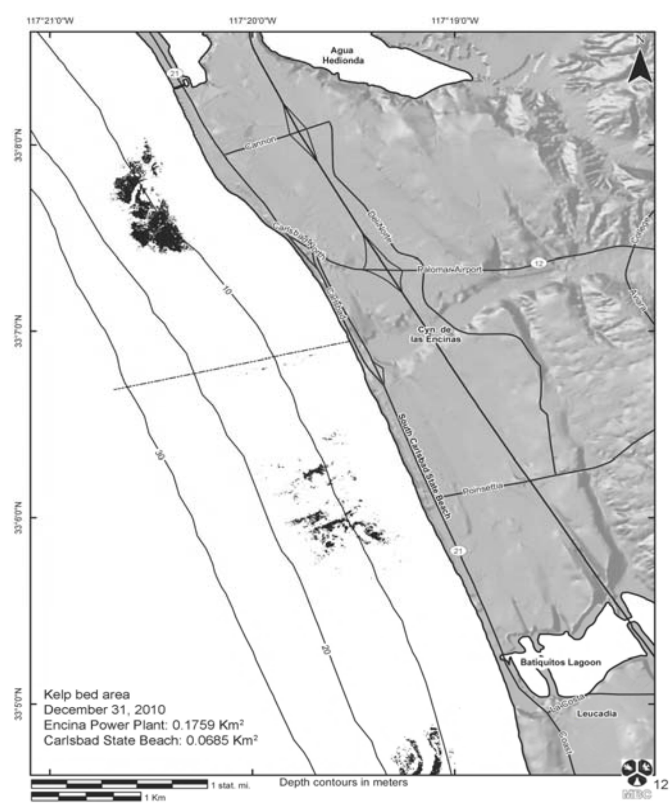

117°22'W
117°21'W
117°20'W
117°19'W
N
Buena Vista Lagoon
Carlsbad
Agua Hedionda
Kelp bed area
North Carlsbad: 0.0258 Km²
Agua Hedionda: 0.0164 Km²
Encina Power Plant: 0.0806 Km²
December 14, 2007
Depth contours in meters
MBC
11

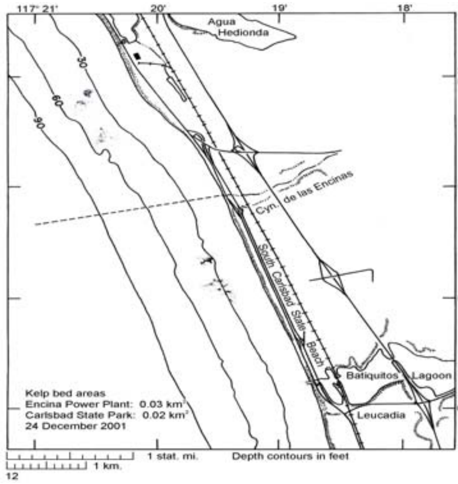

117°22'W
117°21'W
117°20'W
117°19'W
N
Buena Vista Lagoon
Carlsbad
Agua Hedionda
Kelp bed area
North Carlsbad: 0.1083 Km²
Agua Hedionda: 0.0801 Km²
Encina Power Plant: 0.3058 Km²
December 31, 2008
Depth contours in meters
Cyn de las
11

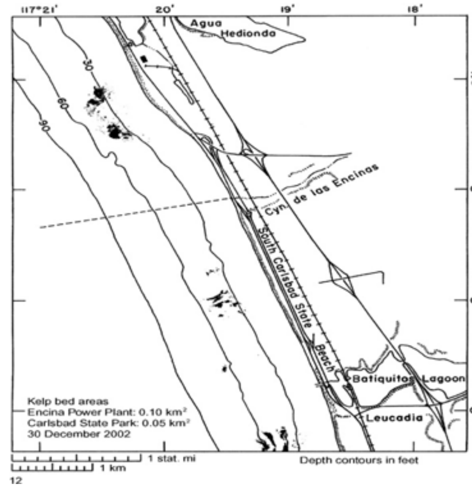


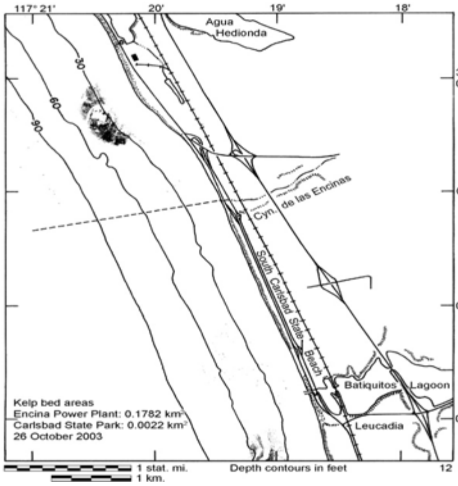
Kelp bed areas
Carlsbad: 0.143 km²
Encina Power Plant: 0.251 km²
26 November & 30 December 1989
Kelp bed areas
Carlsbad: 0.165 km²
25 March 1990
Encina Power Plant: 0.179 km²
7 April 1990
Kelp bed areas
Carlsbad: 0.060 km²
Encina Power Plant: 0.063 km²
27 January 1991
Kelp bed areas
Carlsbad: 0.008 km²
Encina Power Plant: 0.025 km²
19 March & 25 October 1992
Kelp bed areas
Carlsbad: 0.030 km²
Encina Power Plant: 0.022 km²
3 January 1993
Kelp bed areas
Carlsbad: 0.024 km²
Encina Power Plant: 0.011 km²
25 June 1994
Kelp bed areas
Carlsbad: 0.016 km²
2 April 1995
Encina Power Plant: 0.058 km²
2 December 1995
Kelp bed areas
Carlsbad: 0.009 km²
Encina Power Plant: 0.032 km²
24 March 1996
Kelp bed areas
Carlsbad: none
Encina Power Plant: 0.010 km²
7 January 1997
Kelp bed areas
Carlsbad: 0.003 km²
Encina Power Plant: none
30 December 1998
Kelp bed areas
Carlsbad: none
Encina Power Plant: none
23 November 1999
Kelp bed areas
Carlsbad: none
Encina Power Plant: 0.002 km²
21 December 2000
South Oceanside
Buena Vista Lagoon
Carlsbad
Agua Hedionda
1 stat. mi.
1 km.
Depth contours in feet

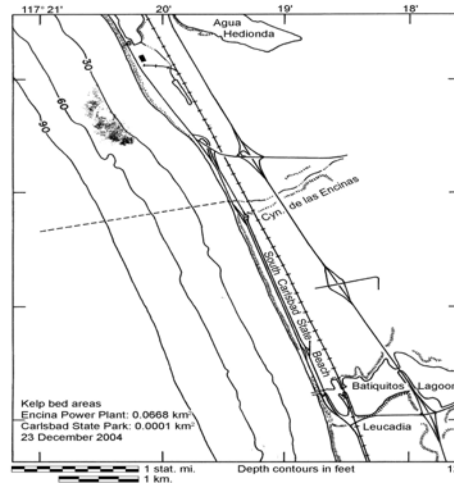

117°21'0"W
117°20'0"W
117°19'0"W
33°8'0"N
33°7'0"N
33°6'0"N
33°5'0"N
Agua Hedionda
Cannon
Palomar Airport
Cyn. de las Encinas
South Carlsbad State Beach
Poinsettia
Batiquitos Lagoon
Leucadia
10
20
30
Kelp bed area
December 17, 2009
Encina Power Plant: 0.2151 Km²
March 10, 2009
Carlsbad State Park: 0.1270 Km²
1 stat. mi.
1 Km
Depth contours in meters
12

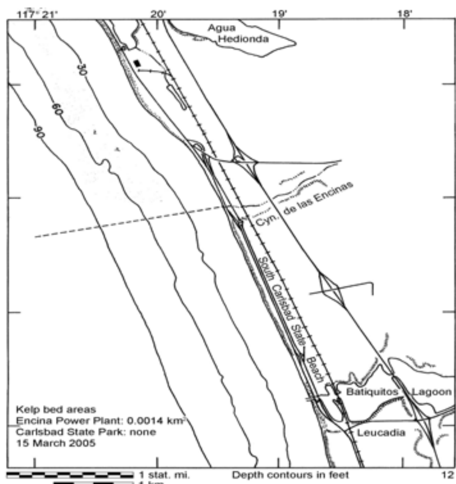

117°21'0"W
117°20'0"W
117°19'0"W
33°8'0"N
33°7'0"N
33°6'0"N
33°5'0"N
Agua Hedionda
Cannon
Palomar Airport
Cyn. de las Encinas
South Carlsbad State Beach
Poinsettia
Batiquitos Lagoon
Leucadia
10
20
30
Kelp bed area
December 31, 2010
Encina Power Plant: 0.1759 Km²
Carlsbad State Beach: 0.0685 Km²
1 stat. mi.
1 Km
Depth contours in meters
12

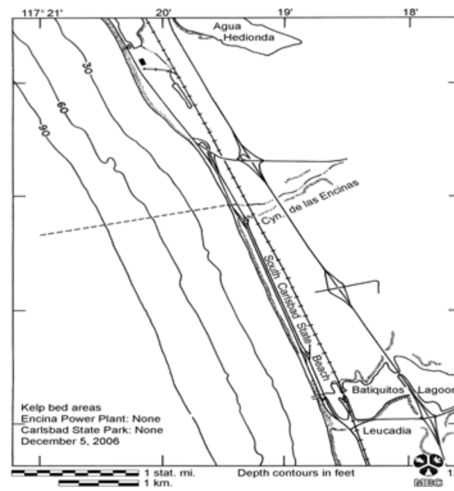

117° 21'
20'
19'
18'
Agua Hedionda
33° 08'
07'
06'
05'
30
60
90
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed areas
Encina Power Plant: 0.03 km²
Carlsbad State Park: 0.02 km²
24 December 2001
1 stat. mi.
1 km.
Depth contours in feet
12

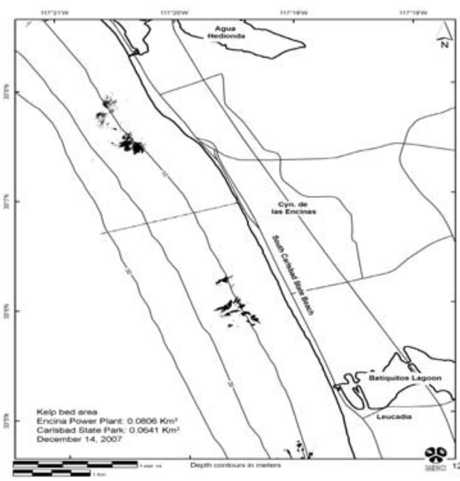

117° 21'
20'
19'
18'
Agua Hedionda
33° 08'
07'
06'
05'
30
60
90
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed areas
Encina Power Plant: 0.10 km²
Carlsbad State Park: 0.05 km²
30 December 2002
1 stat. mi.
1 km
Depth contours in feet
12

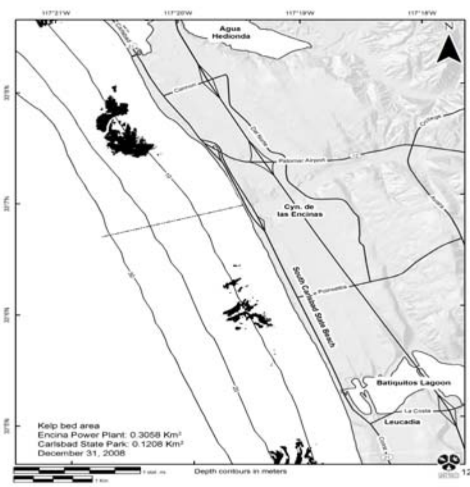

117° 21'
20'
19'
18'
Agua Hedionda
33° 08'
07'
06'
05'
30
60
90
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed areas
Encina Power Plant: 0.1782 km²
Carlsbad State Park: 0.0022 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
12

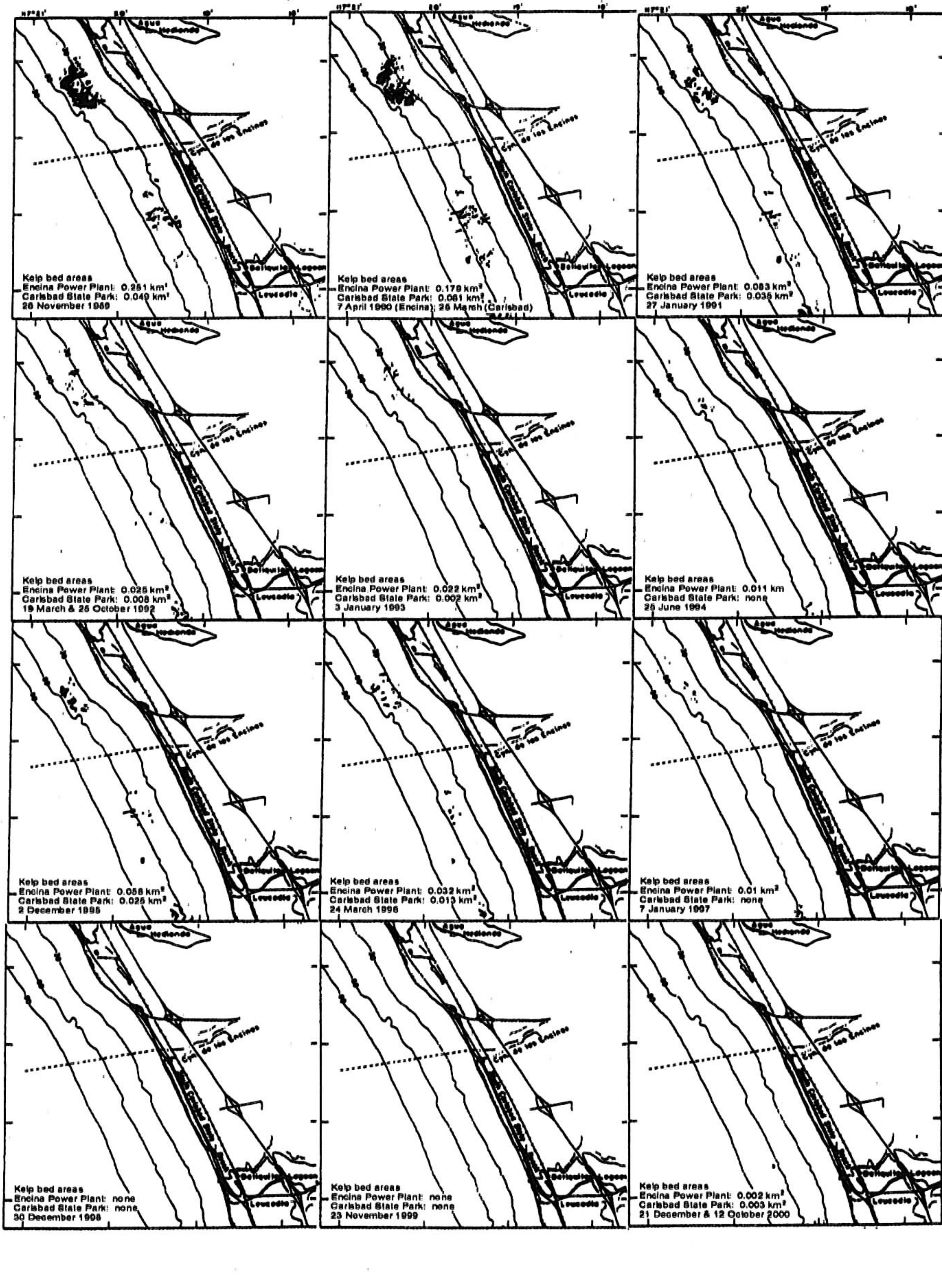

117° 21'
20'
19'
18'
Agua Hedionda
33° 08'
07'
06'
05'
30
60
90
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed areas
Encina Power Plant: 0.0668 km²
Carlsbad State Park: 0.0001 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
12

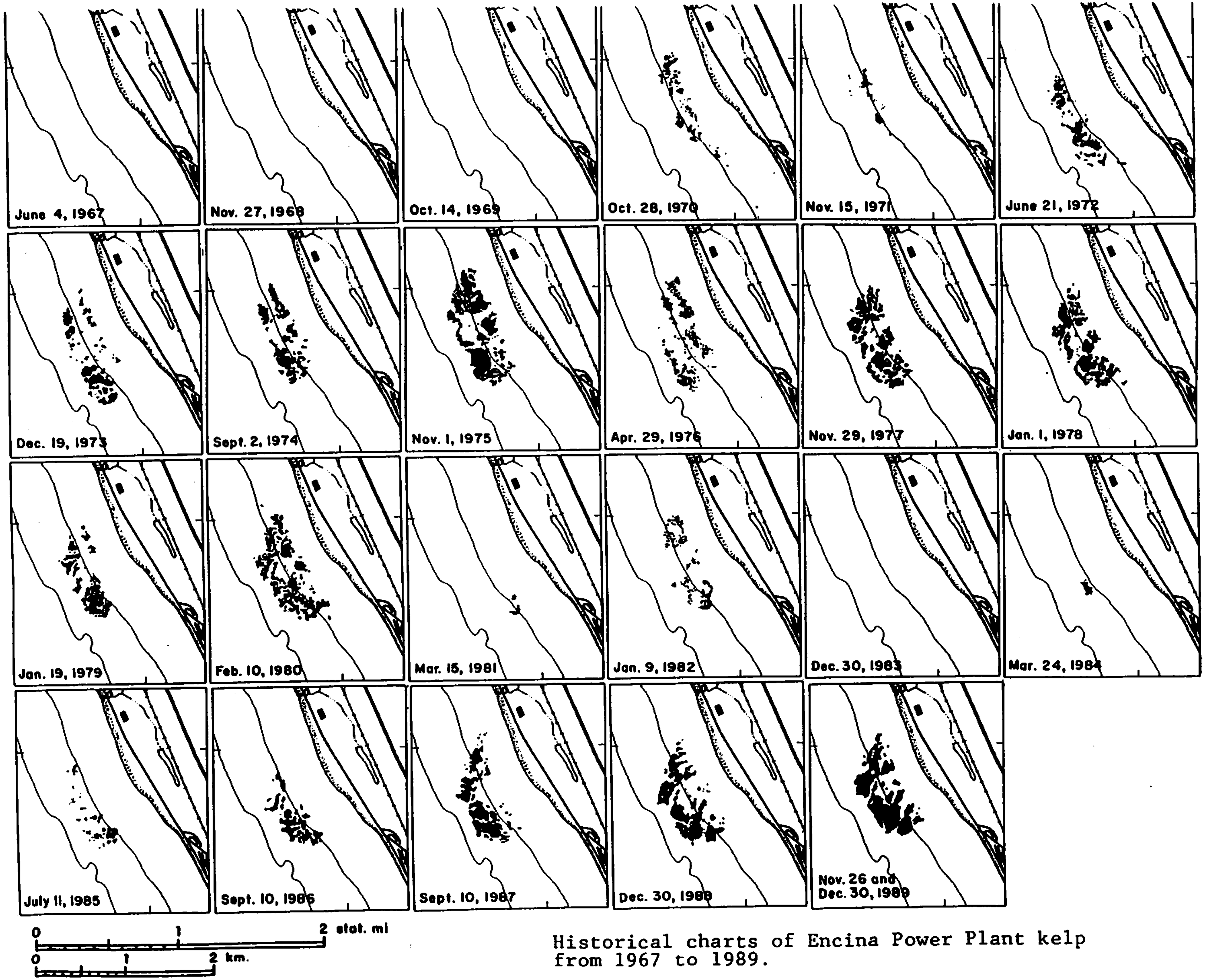

117° 21'
20'
19'
18'
Agua Hedionda
33° 08'
07'
06'
05'
30
60
90
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed areas
Encina Power Plant: 0.0014 km²
Carlsbad State Park: none
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
12


117° 21'
20'
19'
18'
Agua Hedionda
33° 08'
07'
06'
05'
30
60
90
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed areas
Encina Power Plant: None
Carlsbad State Park: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
12

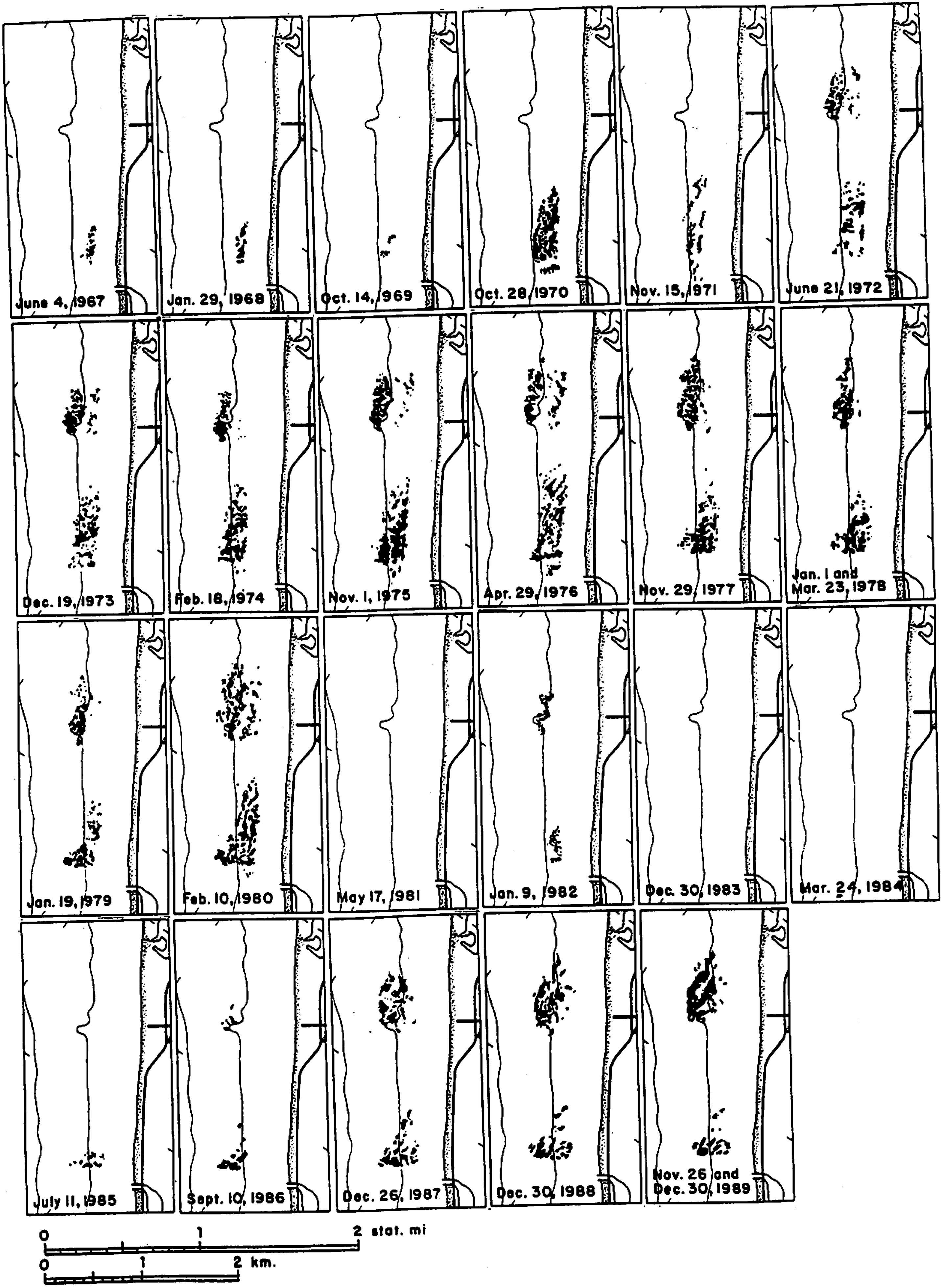

Agua Hedionda
N
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed area
Encina Power Plant: 0.0806 Km²
Carlsbad State Park: 0.0641 Km²
December 14, 2007
Depth contours in meters
MBC
12


Agua Hedionda
N
Cyn. de las Encinas
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed area
Encina Power Plant: 0.3058 Km²
Carlsbad State Park: 0.1208 Km²
December 31, 2008
Depth contours in meters
MBC
12

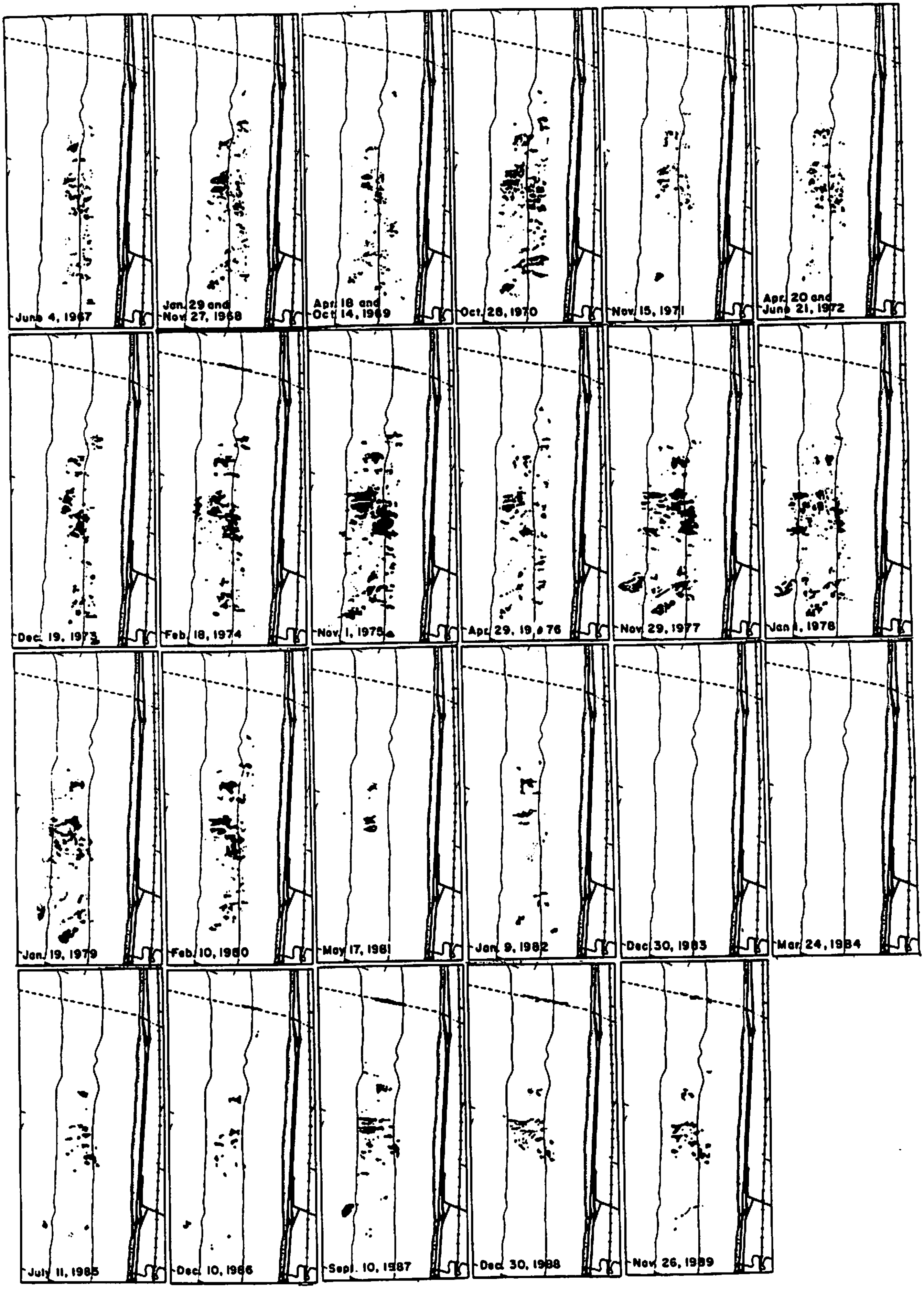

Kelp bed areas
Encina Power Plant: 0.251 km²
Carlsbad State Park: 0.049 km²
26 November 1989
Kelp bed areas
Encina Power Plant: 0.178 km²
Carlsbad State Park: 0.061 km²
7 April 1990 (Encina); 26 March (Carlsbad)
Kelp bed areas
Encina Power Plant: 0.083 km²
Carlsbad State Park: 0.035 km²
27 January 1991
Kelp bed areas
Encina Power Plant: 0.025 km²
Carlsbad State Park: 0.008 km²
19 March & 25 October 1992
Kelp bed areas
Encina Power Plant: 0.022 km²
Carlsbad State Park: 0.002 km²
3 January 1993
Kelp bed areas
Encina Power Plant: 0.011 km
Carlsbad State Park: none
25 June 1994
Kelp bed areas
Encina Power Plant: 0.058 km²
Carlsbad State Park: 0.025 km²
2 December 1995
Kelp bed areas
Encina Power Plant: 0.032 km²
Carlsbad State Park: 0.013 km²
24 March 1996
Kelp bed areas
Encina Power Plant: 0.01 km²
Carlsbad State Park: none
7 January 1997
Kelp bed areas
Encina Power Plant: none
Carlsbad State Park: none
30 December 1998
Kelp bed areas
Encina Power Plant: none
Carlsbad State Park: none
23 November 1999
Kelp bed areas
Encina Power Plant: 0.002 km²
Carlsbad State Park: 0.003 km²
21 December & 12 October 2000



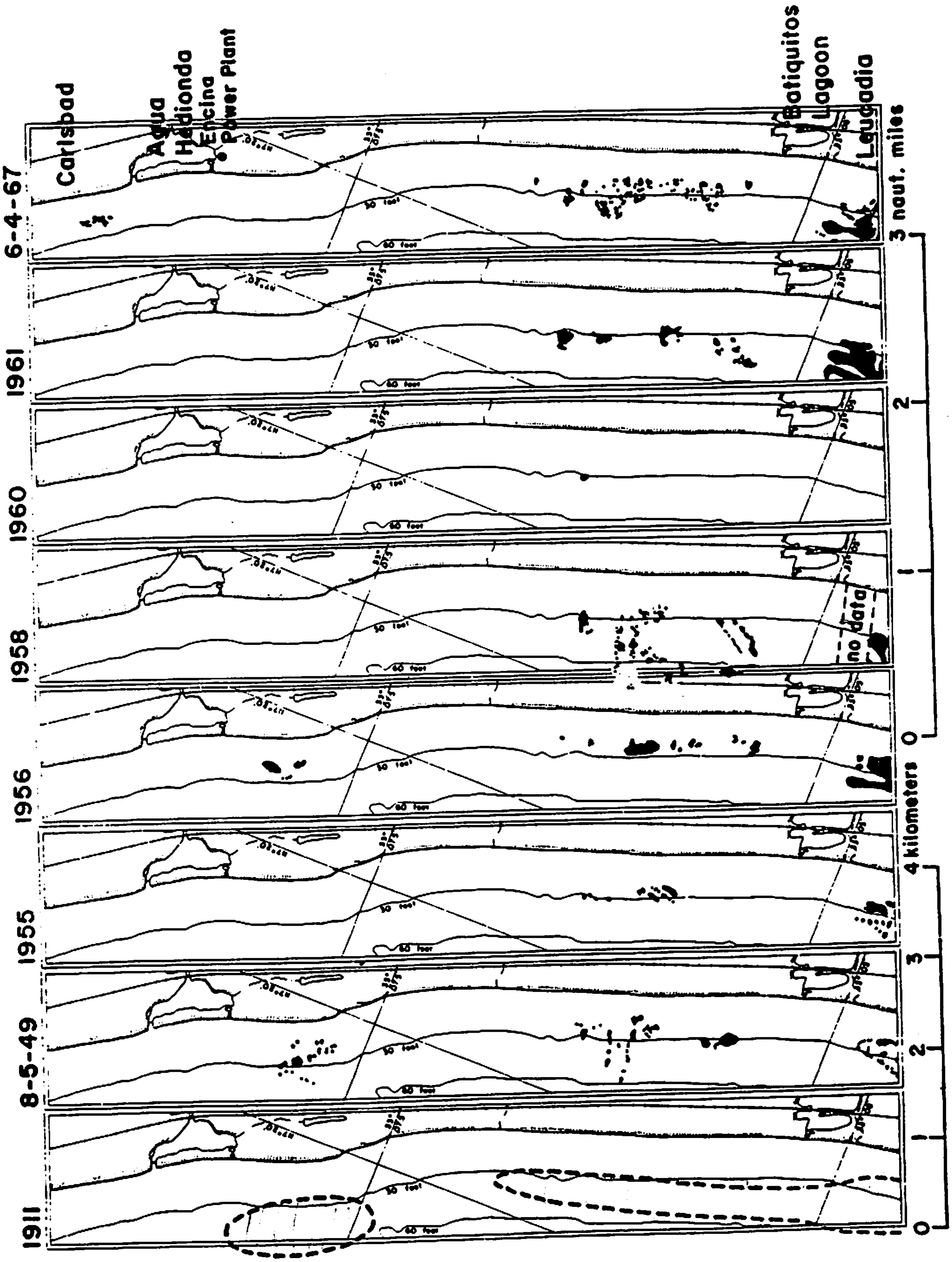
Historical charts of Encina Power Plant kelp from 1967 to 1989.



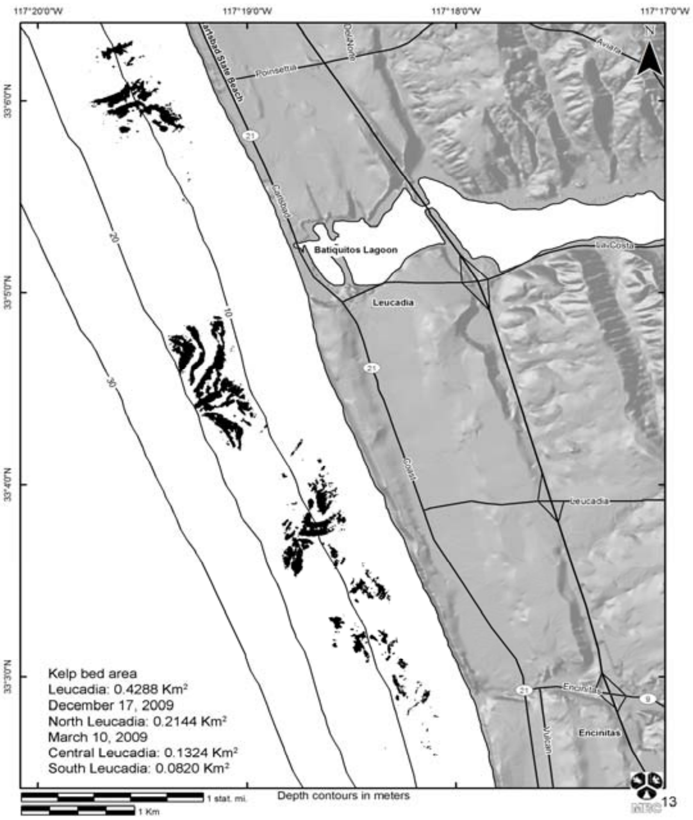
Historical charts of North Carlsbad from 1967 to 1989.

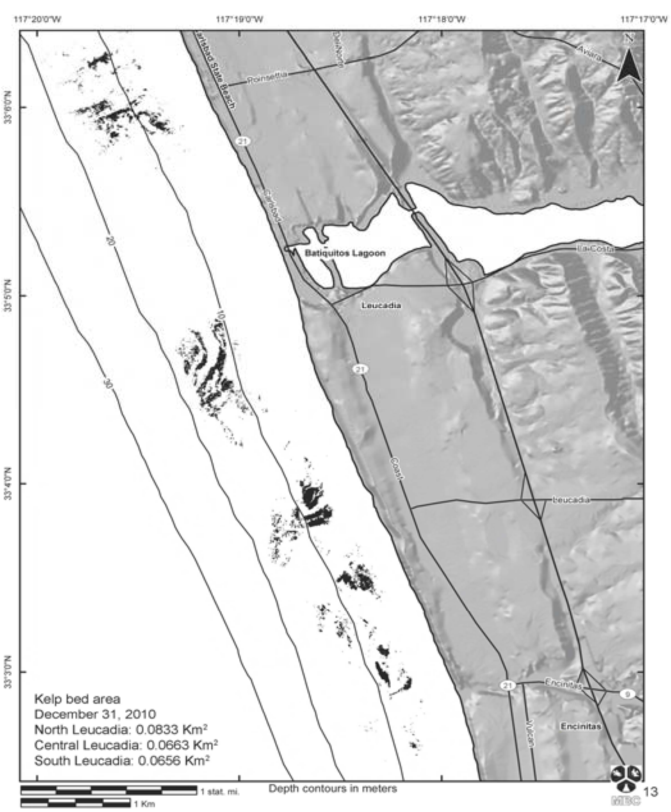


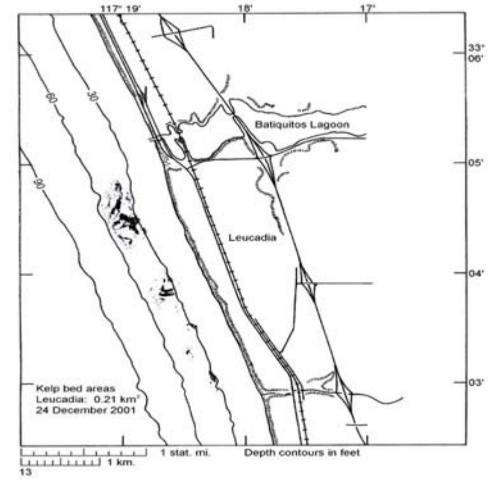
Historical charts of Carlsbad State Beach kelp from 1967 to 1989.

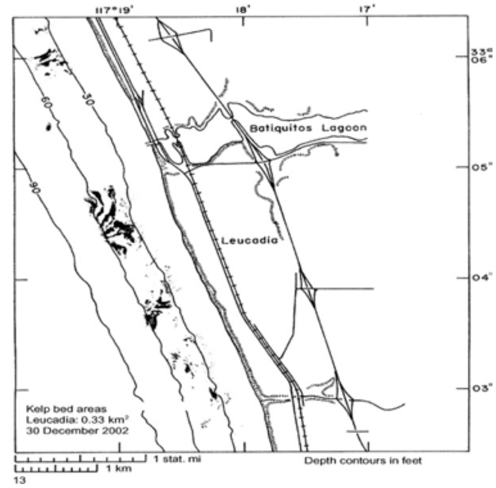


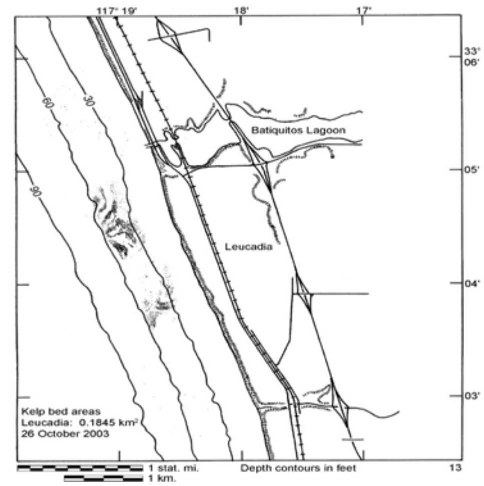
Historical charts of kelp beds from North Carlsbad to North Leucadia from 1911 to 1967.

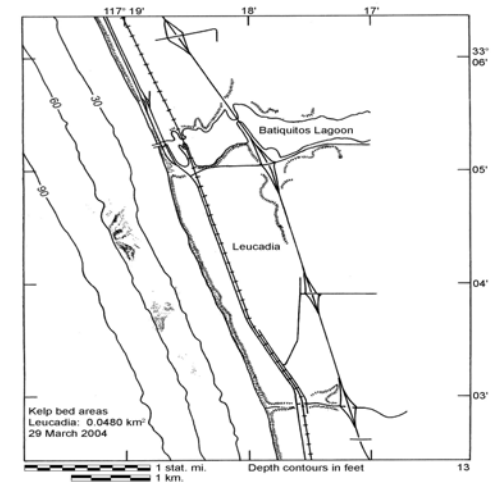

117°20'0"W
117°19'0"W
117°18'0"W
117°17'0"W
33°6'0"N
33°5'0"N
33°4'0"N
33°3'0"N
Carlsbad State Beach
Poinsettia
Aviara
Batiquitos Lagoon
La Costa
Leucadia
Coast
Encinitas
Vulcan
10
20
30
Kelp bed area
Leucadia: 0.4288 Km²
December 17, 2009
North Leucadia: 0.2144 Km²
March 10, 2009
Central Leucadia: 0.1324 Km²
South Leucadia: 0.0820 Km²
1 stat. mi.
1 Km
Depth contours in meters
13

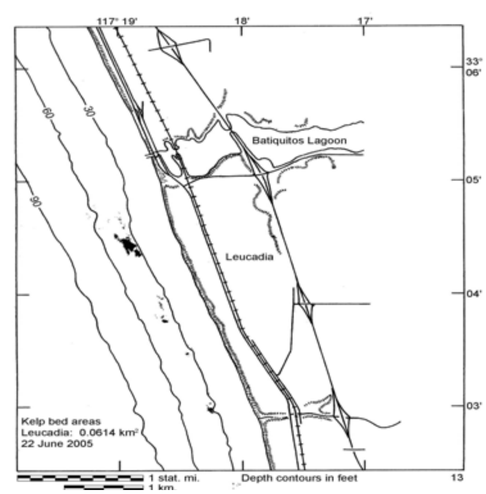

117°20'0"W
117°19'0"W
117°18'0"W
117°17'0"W
33°6'0"N
33°5'0"N
33°4'0"N
33°3'0"N
Carlsbad State Beach
Poinsettia
Aviara
Batiquitos Lagoon
La Costa
Leucadia
Coast
Encinitas
Vulcan
10
20
30
Kelp bed area
December 31, 2010
North Leucadia: 0.0833 Km²
Central Leucadia: 0.0663 Km²
South Leucadia: 0.0656 Km²
1 stat. mi.
1 Km
Depth contours in meters
13

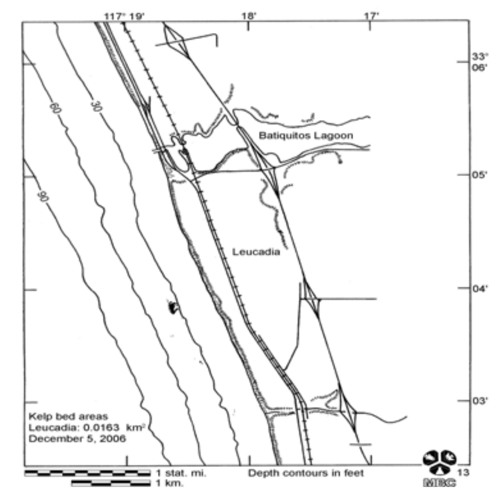

117° 19'
18'
17'
33° 06'
05'
04'
03'
60
30
90
Batiquitos Lagoon
Leucadia
Kelp bed areas
Leucadia: 0.21 km²
24 December 2001
1 stat. mi.
1 km.
Depth contours in feet
13

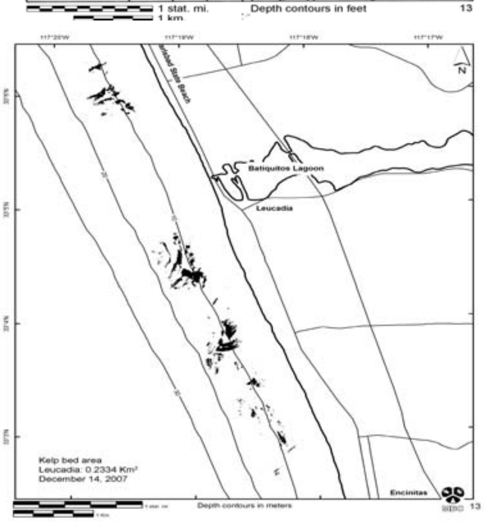

117° 19'
18'
17'
33° 06'
05'
04'
03'
60
30
90
Batiquitos Lagoon
Leucadia
Kelp bed areas
Leucadia: 0.33 km²
30 December 2002
1 stat. mi
1 km
Depth contours in feet
13

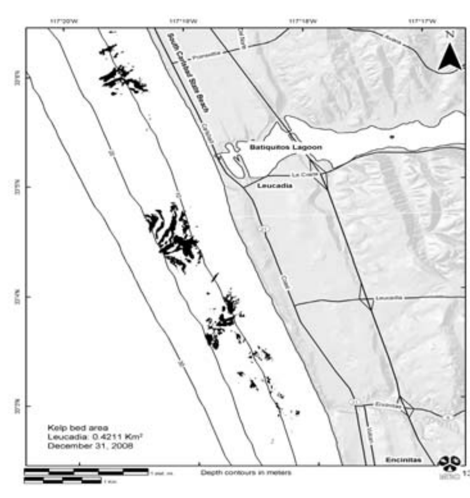

117° 19'
18'
17'
33° 06'
05'
04'
03'
60
30
90
Batiquitos Lagoon
Leucadia
Kelp bed areas
Leucadia: 0.1845 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
13

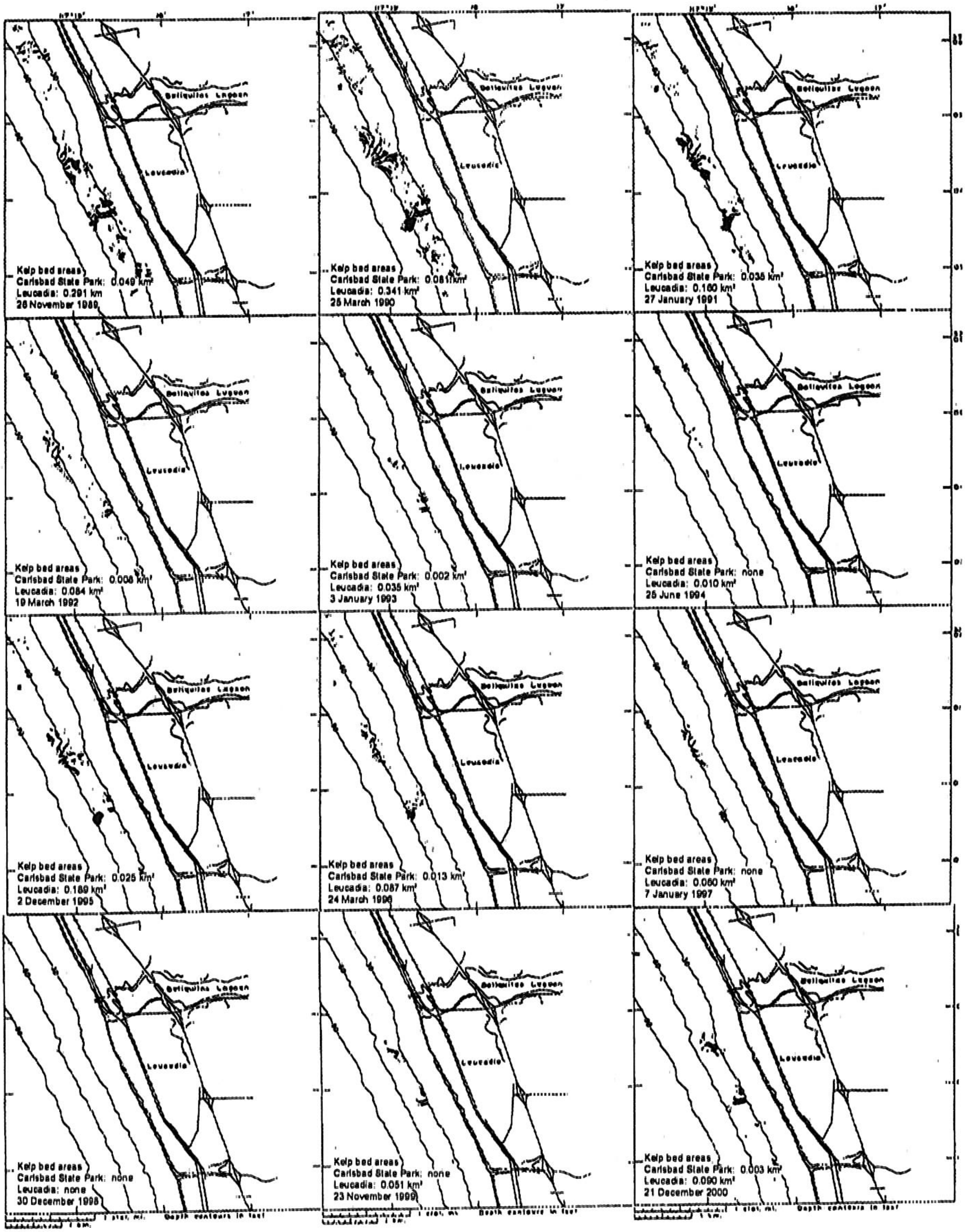

117° 19'
18'
17'
33° 06'
05'
04'
03'
60
30
90
Batiquitos Lagoon
Leucadia
Kelp bed areas
Leucadia: 0.0480 km²
29 March 2004
1 stat. mi.
1 km.
Depth contours in feet
13


117° 19'
18'
17'
33° 06'
05'
04'
03'
60
30
90
Batiquitos Lagoon
Leucadia
Kelp bed areas
Leucadia: 0.0614 km²
22 June 2005
1 stat. mi.
1 km.
Depth contours in feet
13

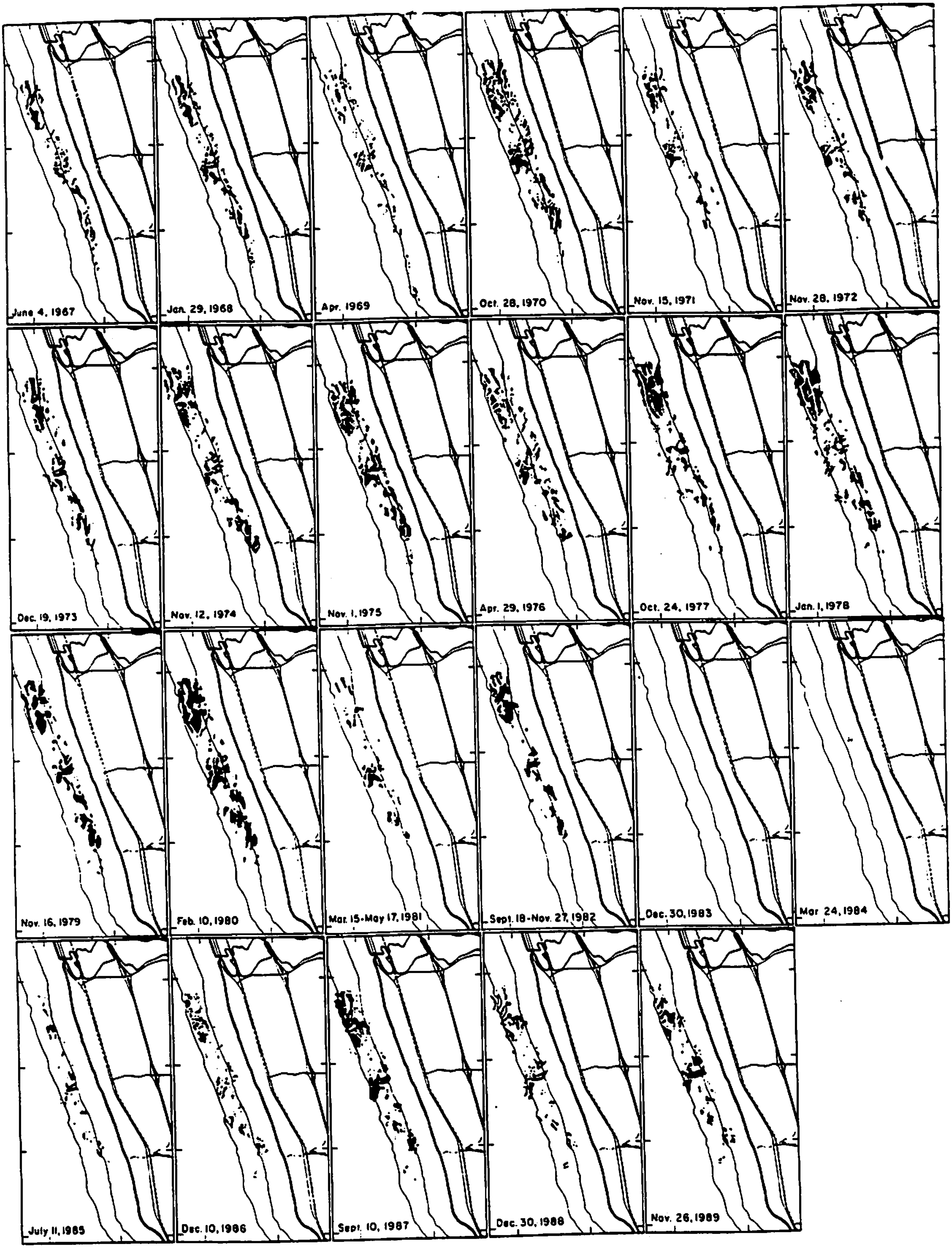

117° 19'
18'
17'
33° 06'
05'
04'
03'
60
30
90
Batiquitos Lagoon
Leucadia
Kelp bed areas
Leucadia: 0.0163 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
13

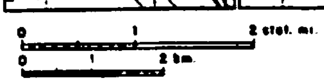

117°20'W
117°19'W
117°18'W
117°17'W
N
Batiquitos Lagoon
Leucadia
Kelp bed area
Leucadia: 0.2334 Km²
December 14, 2007
Depth contours in meters
Encinitas
MBC
13


117°20'W
117°19'W
117°18'W
117°17'W
N
South Carlsbad State Beach
Batiquitos Lagoon
Leucadia
Kelp bed area
Leucadia: 0.4211 Km²
December 31, 2008
Depth contours in meters
Encinitas
MBC
13

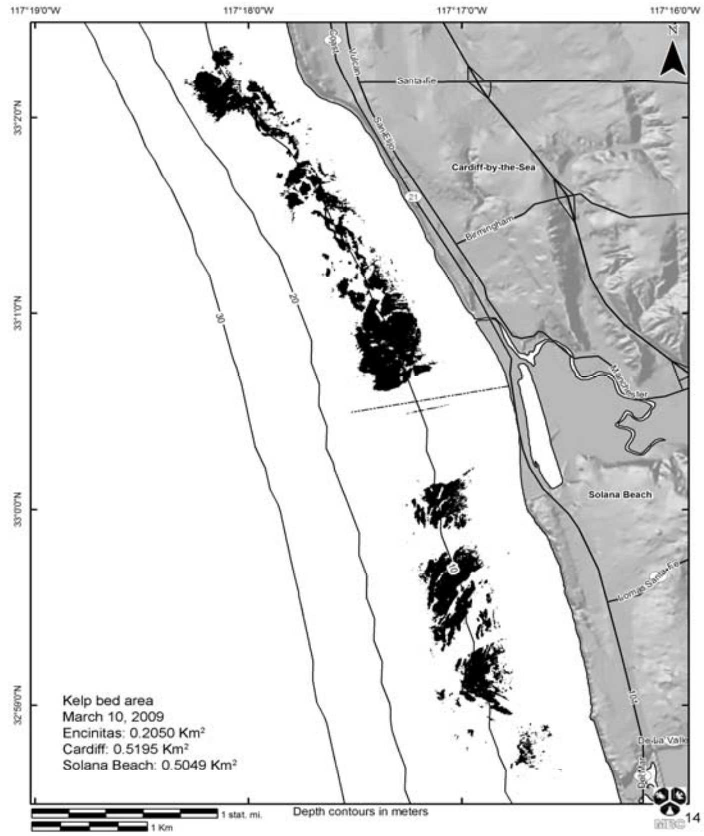


Batiquitos Lagoon
Leucadia
Kelp bed areas
Carlsbad State Park: 0.049 km²
Leucadia: 0.291 km
26 November 1989
Kelp bed areas
Carlsbad State Park: 0.081 km²
Leucadia: 0.341 km²
25 March 1990
Kelp bed areas
Carlsbad State Park: 0.035 km²
Leucadia: 0.160 km²
27 January 1991
Kelp bed areas
Carlsbad State Park: 0.008 km²
Leucadia: 0.084 km²
19 March 1992
Kelp bed areas
Carlsbad State Park: 0.002 km²
Leucadia: 0.035 km²
3 January 1993
Kelp bed areas
Carlsbad State Park: none
Leucadia: 0.010 km²
25 June 1994
Kelp bed areas
Carlsbad State Park: 0.025 km²
Leucadia: 0.189 km²
2 December 1995
Kelp bed areas
Carlsbad State Park: 0.013 km²
Leucadia: 0.087 km²
24 March 1996
Kelp bed areas
Carlsbad State Park: none
Leucadia: 0.060 km²
7 January 1997
Kelp bed areas
Carlsbad State Park: none
Leucadia: none
30 December 1998
Kelp bed areas
Carlsbad State Park: none
Leucadia: 0.051 km²
23 November 1999
Kelp bed areas
Carlsbad State Park: 0.003 km²
Leucadia: 0.090 km²
21 December 2000

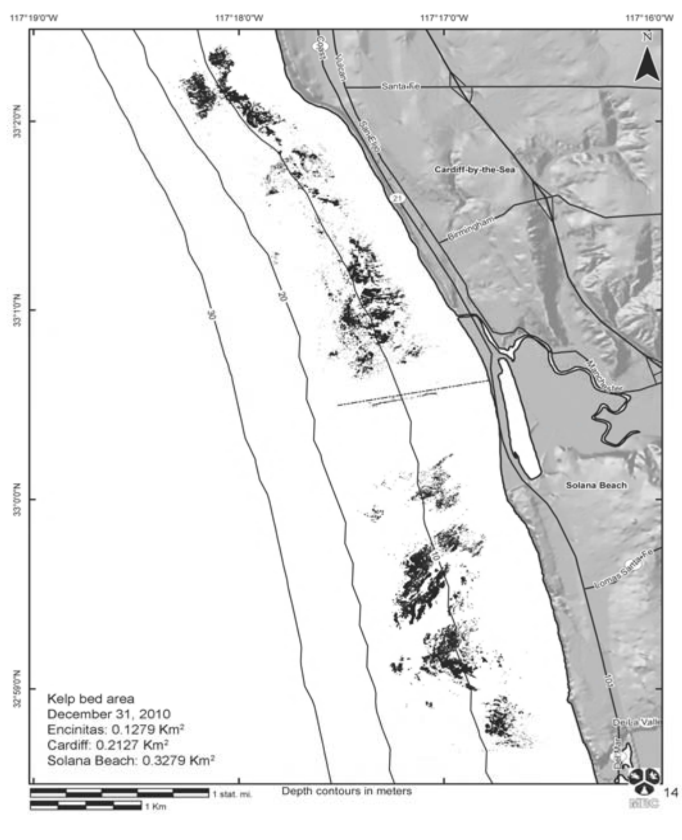




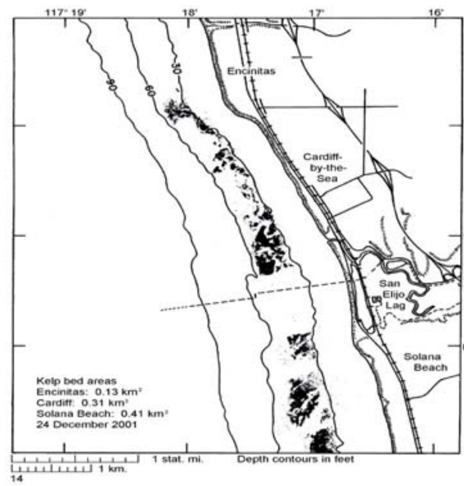
Historical charts of Leucadia kelp from 1967 to 1989.

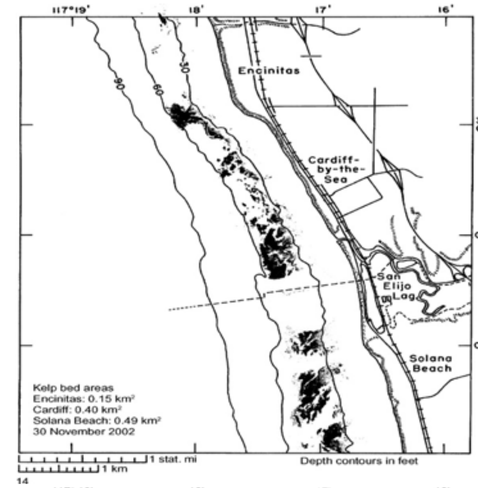


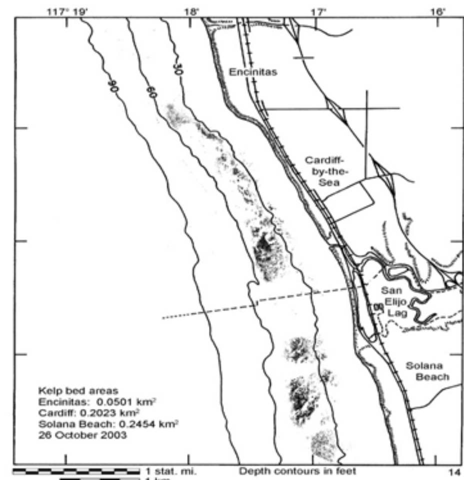
117°19'0"W
117°18'0"W
117°17'0"W
117°16'0"W
33°2'0"N
33°1'0"N
33°0'0"N
32°59'0"N
N
Santa Fe
Cardiff-by-the-Sea
Birmingham
Manchester
Solana Beach
Lomas Santa Fe
Del Mar
De La Valle
101
21
30
20
10
Kelp bed area
March 10, 2009
Encinitas: 0.2050 Km²
Cardiff: 0.5195 Km²
Solana Beach: 0.5049 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
14

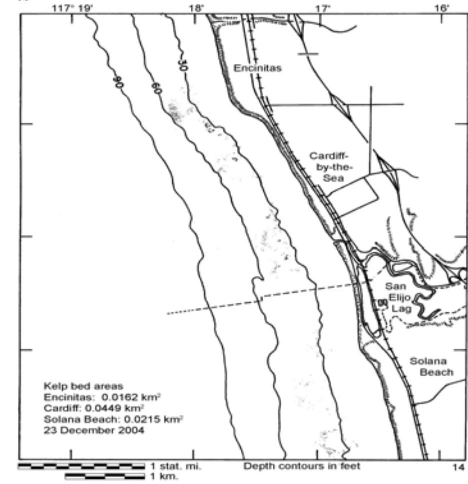


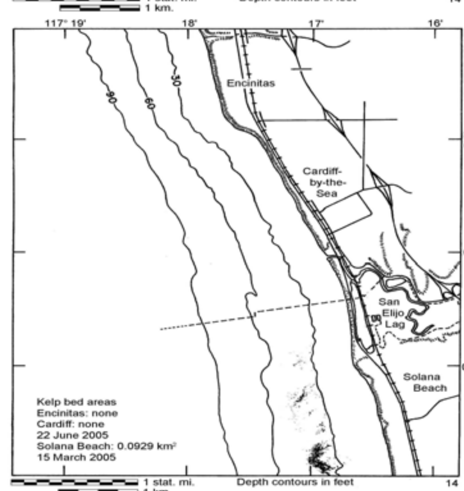
117°19'0"W
117°18'0"W
117°17'0"W
117°16'0"W
33°2'0"N
33°1'0"N
33°0'0"N
32°59'0"N
N
Santa Fe
Cardiff-by-the-Sea
Birmingham
Manchester
Solana Beach
Lomas Santa Fe
De La Valle
101
21
30
20
Kelp bed area
December 31, 2010
Encinitas: 0.1279 Km²
Cardiff: 0.2127 Km²
Solana Beach: 0.3279 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
14

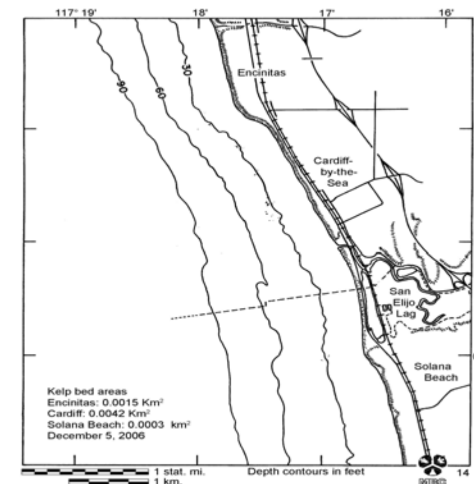

117° 19'
18'
17'
16'
Encinitas
Cardiff-by-the-Sea
San Elijo Lag
Solana Beach
33° 02'
01'
00'
90
60
30
Kelp bed areas
Encinitas: 0.13 km²
Cardiff: 0.31 km²
Solana Beach: 0.41 km²
24 December 2001
1 stat. mi.
1 km.
Depth contours in feet
14

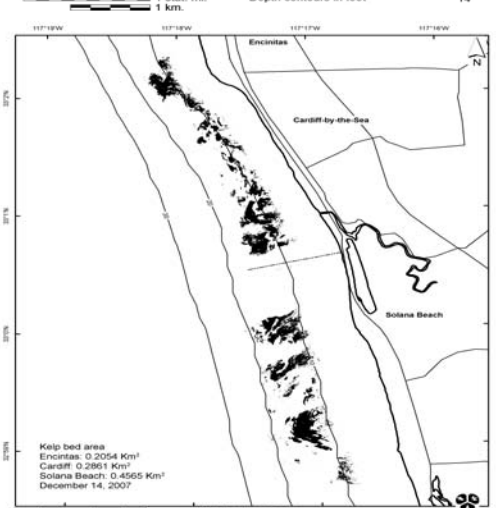

117°19'
18'
17'
16'
Encinitas
Cardiff-by-the-Sea
San Elijo Lag
Solana Beach
33° 02'
01'
00'
90
60
30
Kelp bed areas
Encinitas: 0.15 km²
Cardiff: 0.40 km²
Solana Beach: 0.49 km²
30 November 2002
1 stat. mi
1 km
Depth contours in feet
14

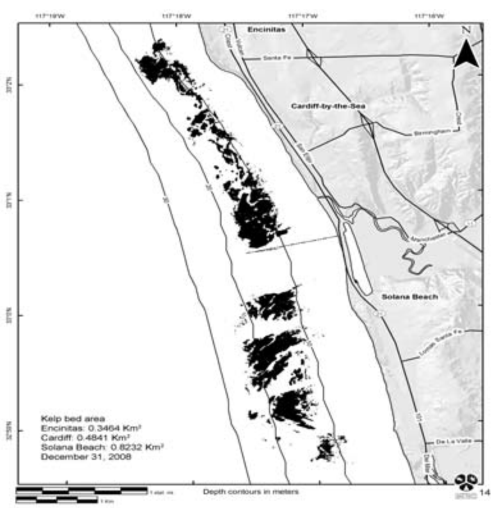

117° 19'
18'
17'
16'
Encinitas
Cardiff-by-the-Sea
San Elijo Lag
Solana Beach
33° 02'
01'
00'
90
60
30
Kelp bed areas
Encinitas: 0.0501 km²
Cardiff: 0.2023 km²
Solana Beach: 0.2454 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
14

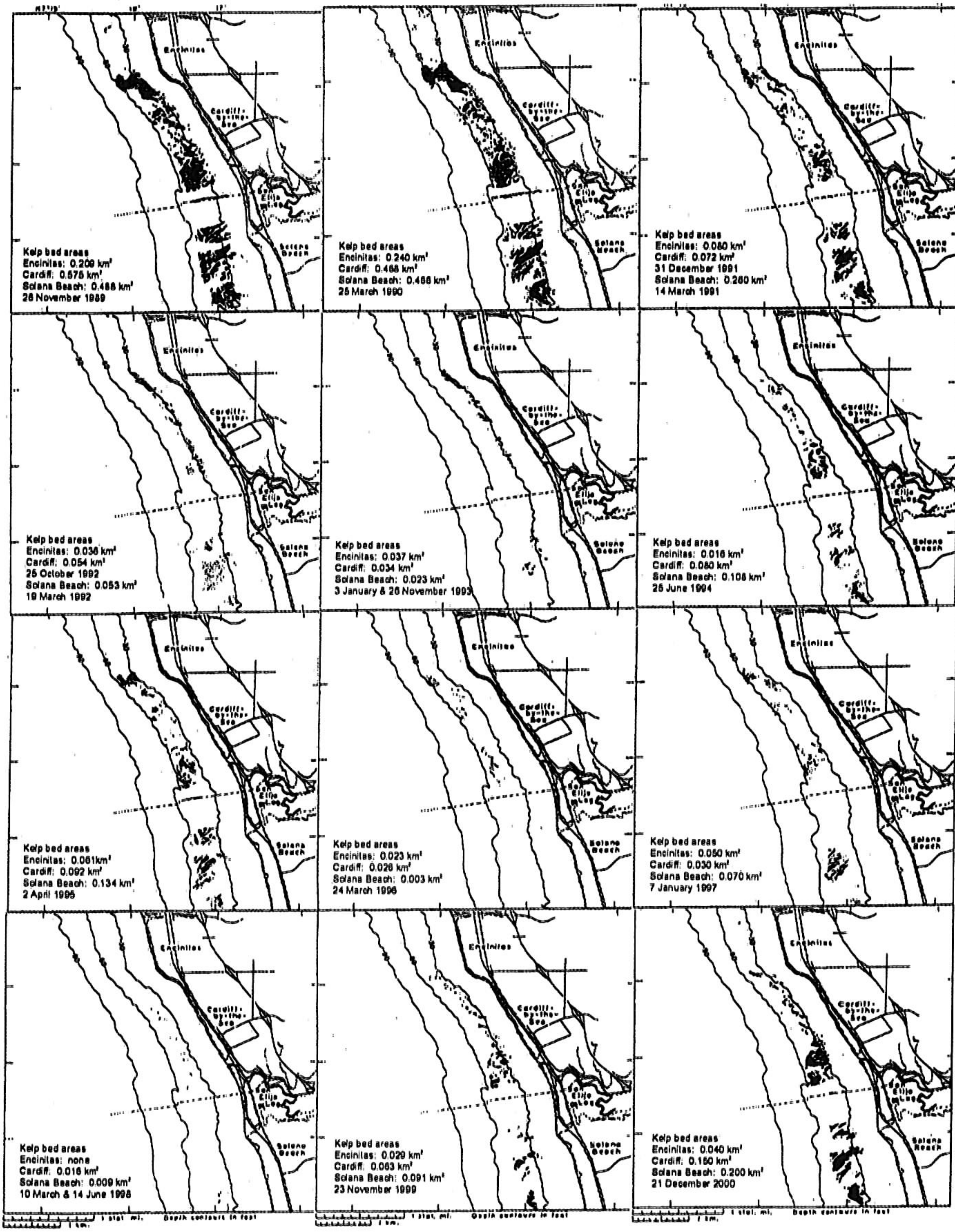

117° 19'
18'
17'
16'
Encinitas
Cardiff-by-the-Sea
San Elijo Lag
Solana Beach
33° 02'
01'
00'
90
60
30
Kelp bed areas
Encinitas: 0.0162 km²
Cardiff: 0.0449 km²
Solana Beach: 0.0215 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
14

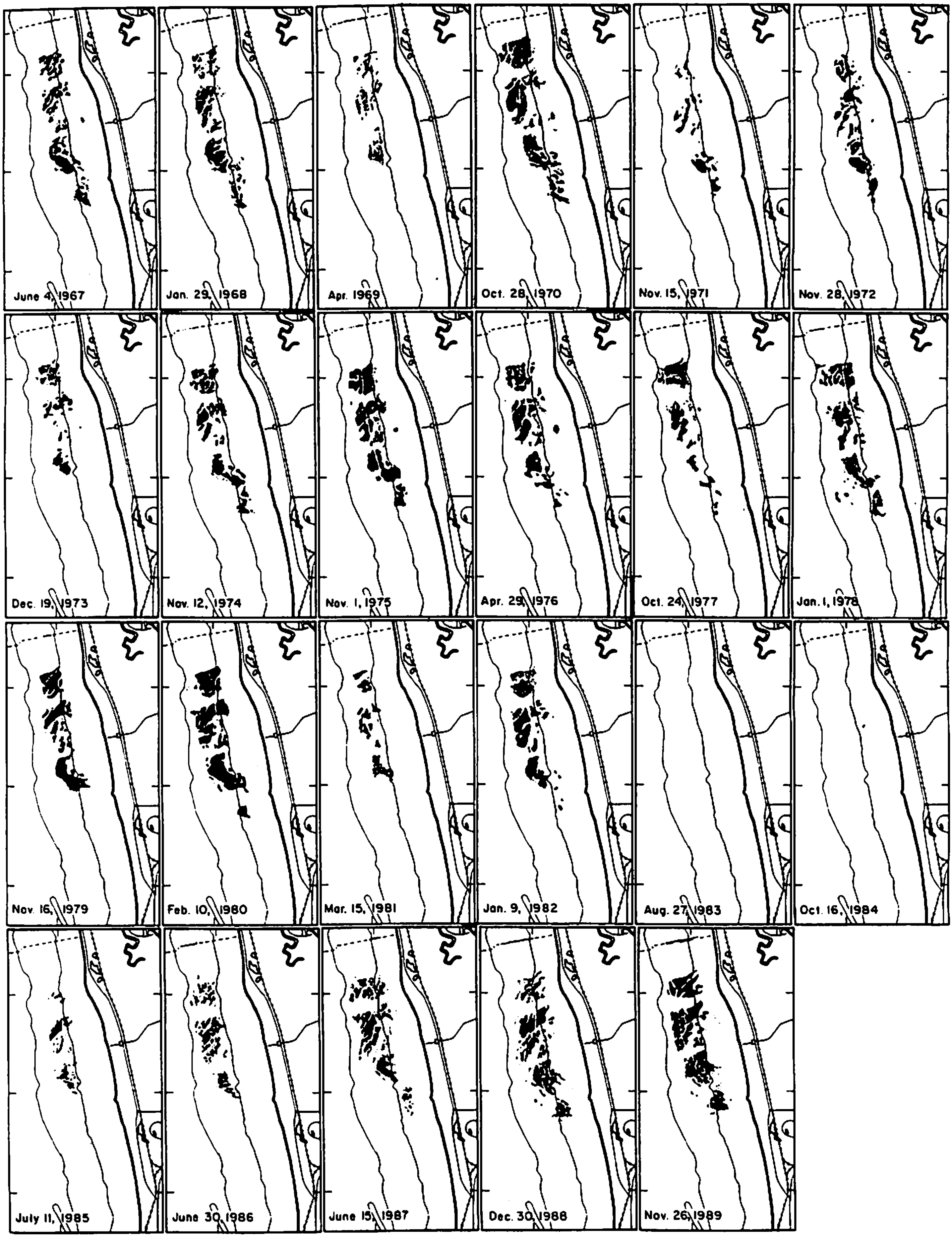

117° 19'
18'
17'
16'
Encinitas
Cardiff-by-the-Sea
San Elijo Lag
Solana Beach
33° 02'
01'
00'
90
60
30
Kelp bed areas
Encinitas: none
Cardiff: none
22 June 2005
Solana Beach: 0.0929 km²
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
14

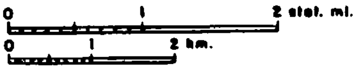

117° 19'
18'
17'
16'
Encinitas
Cardiff-by-the-Sea
San Elijo Lag
Solana Beach
33° 02'
01'
00'
90
60
30
Kelp bed areas
Encinitas: 0.0015 Km²
Cardiff: 0.0042 Km²
Solana Beach: 0.0003 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
14


Encinitas
Cardiff-by-the-Sea
Solana Beach
N
Kelp bed area
Encintas: 0.2054 Km²
Cardiff: 0.2861 Km²
Solana Beach: 0.4565 Km²
December 14, 2007
Depth contours in meters
14

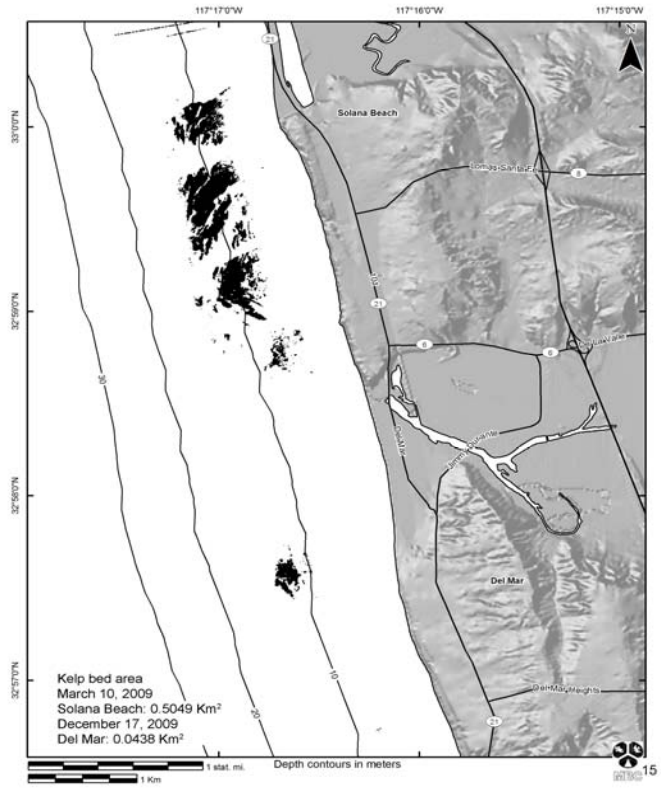

Encinitas
Santa Fe
Cardiff-by-the-Sea
Solana Beach
De La Valle
N
Kelp bed area
Encinitas: 0.3464 Km²
Cardiff: 0.4841 Km²
Solana Beach: 0.8232 Km²
December 31, 2008
Depth contours in meters
14

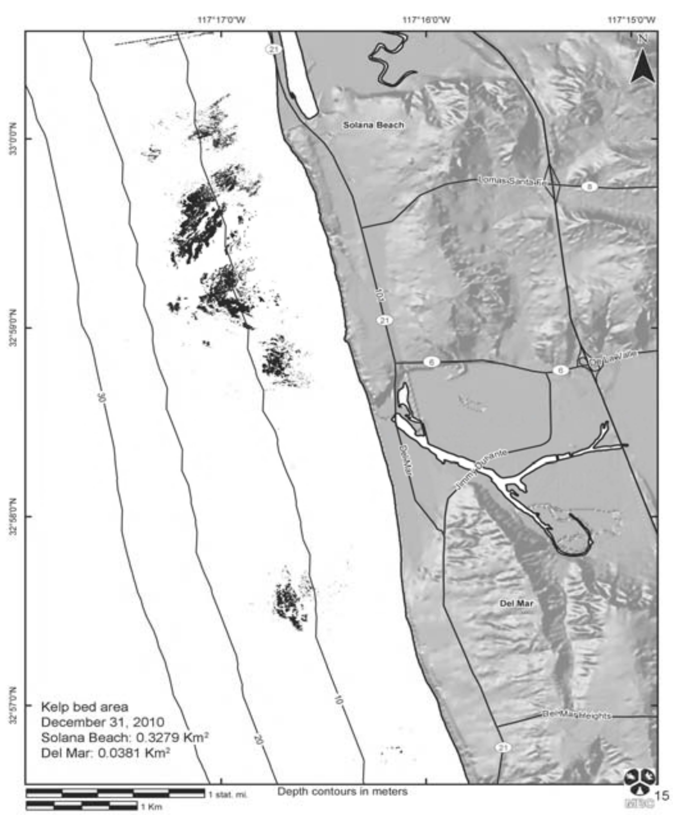

Encinitas
Cardiff-by-the-Sea
San Elijo Lagoon
Solana Beach
Kelp bed areas
Encinitas: 0.209 km^2
Cardiff: 0.575 km^2
Solana Beach: 0.466 km^2
26 November 1989
Kelp bed areas
Encinitas: 0.240 km^2
Cardiff: 0.468 km^2
Solana Beach: 0.466 km^2
25 March 1990
Kelp bed areas
Encinitas: 0.080 km^2
Cardiff: 0.072 km^2
31 December 1991
Solana Beach: 0.260 km^2
14 March 1991
Kelp bed areas
Encinitas: 0.036 km^2
Cardiff: 0.054 km^2
25 October 1992
Solana Beach: 0.053 km^2
19 March 1992
Kelp bed areas
Encinitas: 0.037 km^2
Cardiff: 0.034 km^2
Solana Beach: 0.023 km^2
3 January & 26 November 1993
Kelp bed areas
Encinitas: 0.016 km^2
Cardiff: 0.080 km^2
Solana Beach: 0.108 km^2
25 June 1994
Kelp bed areas
Encinitas: 0.061km^2
Cardiff: 0.092 km^2
Solana Beach: 0.134 km^2
2 April 1995
Kelp bed areas
Encinitas: 0.023 km^2
Cardiff: 0.026 km^2
Solana Beach: 0.003 km^2
24 March 1996
Kelp bed areas
Encinitas: 0.050 km^2
Cardiff: 0.030 km^2
Solana Beach: 0.070 km^2
7 January 1997
Kelp bed areas
Encinitas: none
Cardiff: 0.016 km^2
Solana Beach: 0.009 km^2
10 March & 14 June 1998
Kelp bed areas
Encinitas: 0.029 km^2
Cardiff: 0.063 km^2
Solana Beach: 0.091 km^2
23 November 1999
Kelp bed areas
Encinitas: 0.040 km^2
Cardiff: 0.150 km^2
Solana Beach: 0.200 km^2
21 December 2000
1 stat. mi.
1 km.
Depth contours in feet

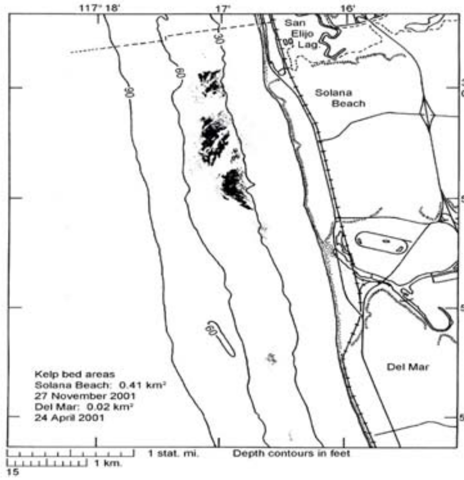


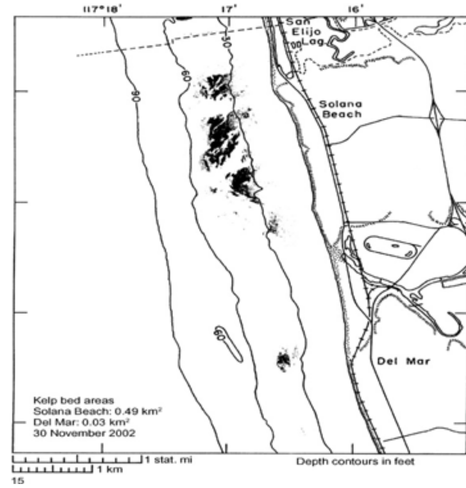


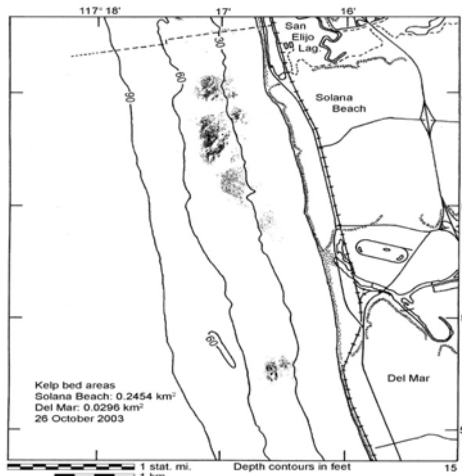
Historical charts of Solana Beach kelp from 1967 to 1989.

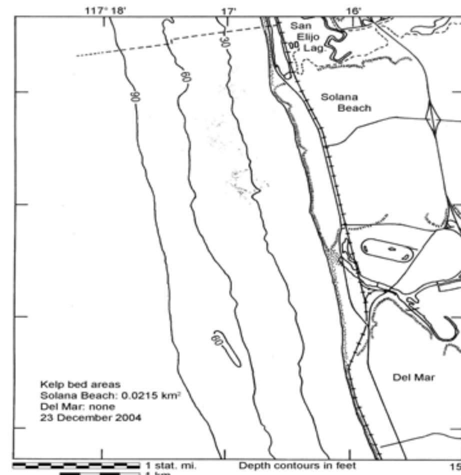

117°17'0"W
117°16'0"W
117°15'0"W
33°0'0"N
32°59'0"N
32°58'0"N
32°57'0"N
Solana Beach
Lomas Santa Fe
Del Mar
Del Mar Heights
30
20
10
Kelp bed area
March 10, 2009
Solana Beach: 0.5049 Km²
December 17, 2009
Del Mar: 0.0438 Km²
1 stat. mi.
1 Km
Depth contours in meters
15

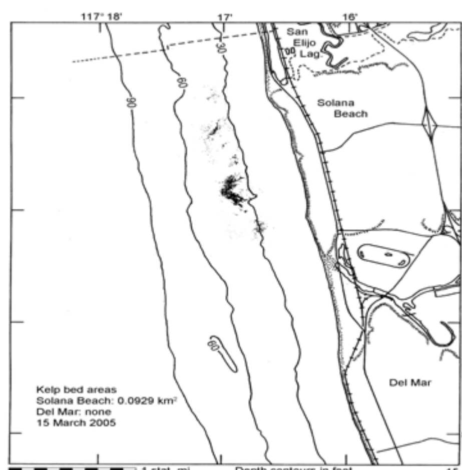

117°17'0"W
117°16'0"W
117°15'0"W
33°0'0"N
32°59'0"N
32°58'0"N
32°57'0"N
Solana Beach
Lomas Santa Fe
Del Mar
Del Mar Heights
30
20
10
Kelp bed area
December 31, 2010
Solana Beach: 0.3279 Km²
Del Mar: 0.0381 Km²
1 stat. mi.
1 Km
Depth contours in meters
15

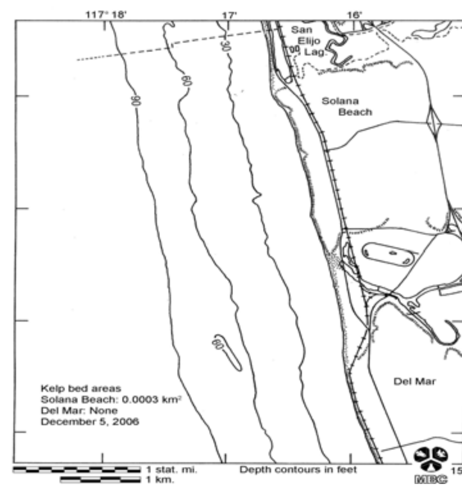

117° 18'
17'
16'
San Elijo Lag
Solana Beach
Del Mar
33° 00'
59'
58'
57'
90
60
30
Kelp bed areas
Solana Beach: 0.41 km²
27 November 2001
Del Mar: 0.02 km²
24 April 2001
1 stat. mi.
1 km.
Depth contours in feet
15


117° 18'
17'
16'
San Elijo Lag
Solana Beach
Del Mar
33° 00'
32° 59'
58'
57'
90
60
30
Kelp bed areas
Solana Beach: 0.49 km²
Del Mar: 0.03 km²
30 November 2002
1 stat. mi
1 km
Depth contours in feet
15

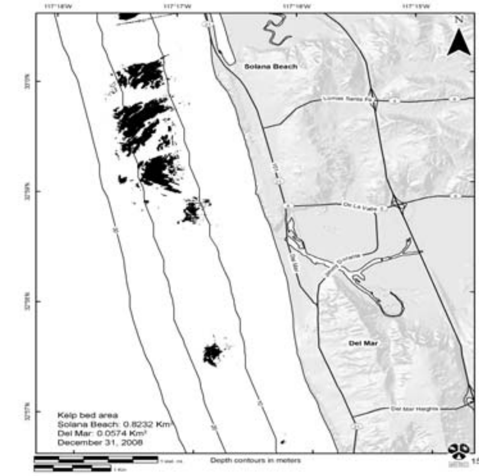

117° 18'
17'
16'
San Elijo Lag
Solana Beach
Del Mar
33° 00'
59'
58'
57'
90
60
30
Kelp bed areas
Solana Beach: 0.2454 km²
Del Mar: 0.0296 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
15

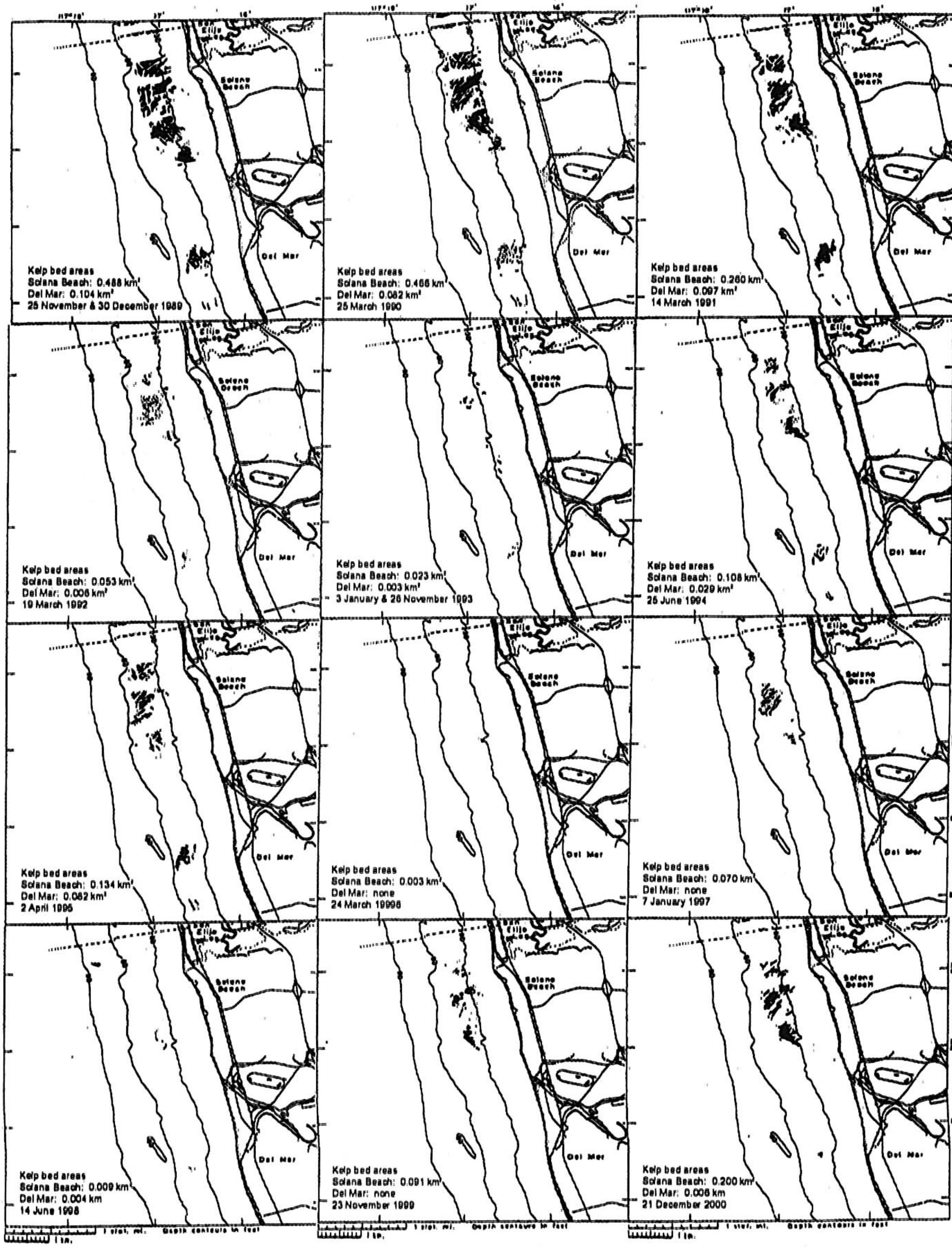

117° 18'
17'
16'
San Elijo Lag
Solana Beach
Del Mar
33° 00'
59'
58'
57'
90
60
30
Kelp bed areas
Solana Beach: 0.0215 km²
Del Mar: none
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
15

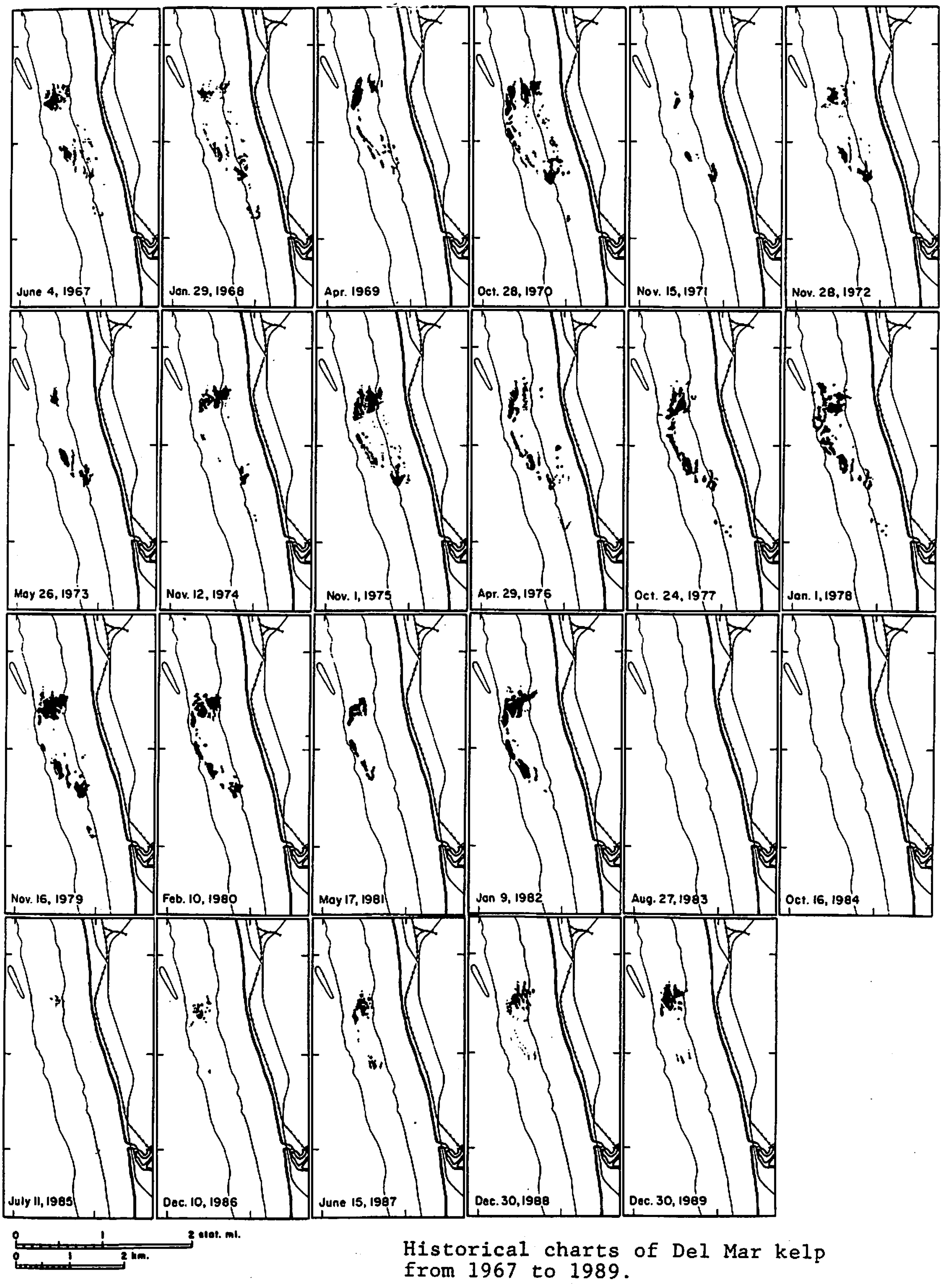

117° 18'
17'
16'
San Elijo Lag
Solana Beach
Del Mar
33° 00'
59'
58'
57'
90
60
30
Kelp bed areas
Solana Beach: 0.0929 km²
Del Mar: none
15 March 2005
1 stat. mi.
1 km.
Depth contours in feet
15


117° 18'
17'
16'
San Elijo Lag
Solana Beach
Del Mar
33° 00'
59'
58'
57'
90
60
30
Kelp bed areas
Solana Beach: 0.0003 km²
Del Mar: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
15

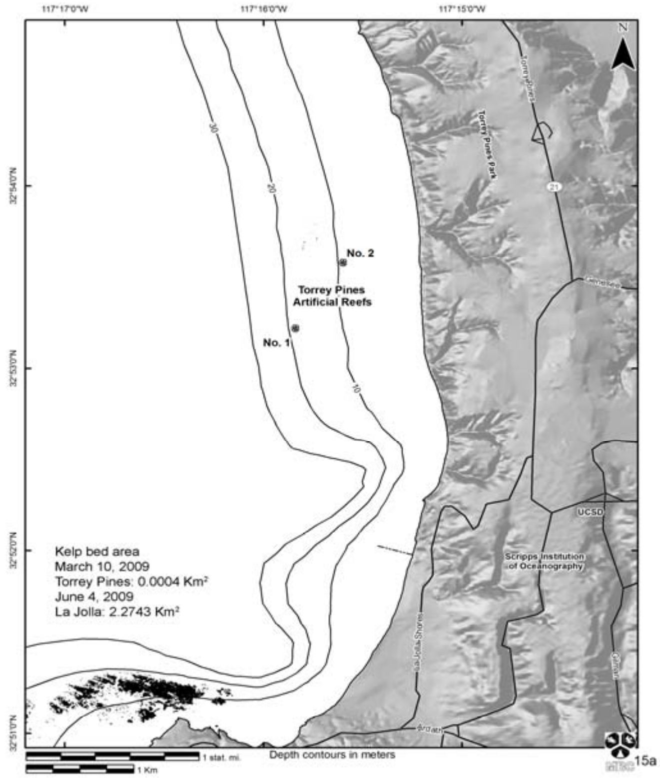

117°18'W
117°17'W
117°16'W
117°15'W
Solana Beach
Del Mar
Kelp bed area
Solana Beach: 0.4565 Km²
Del Mar: 0.0366 Km²
December 14, 2007
Depth contours in meters
15

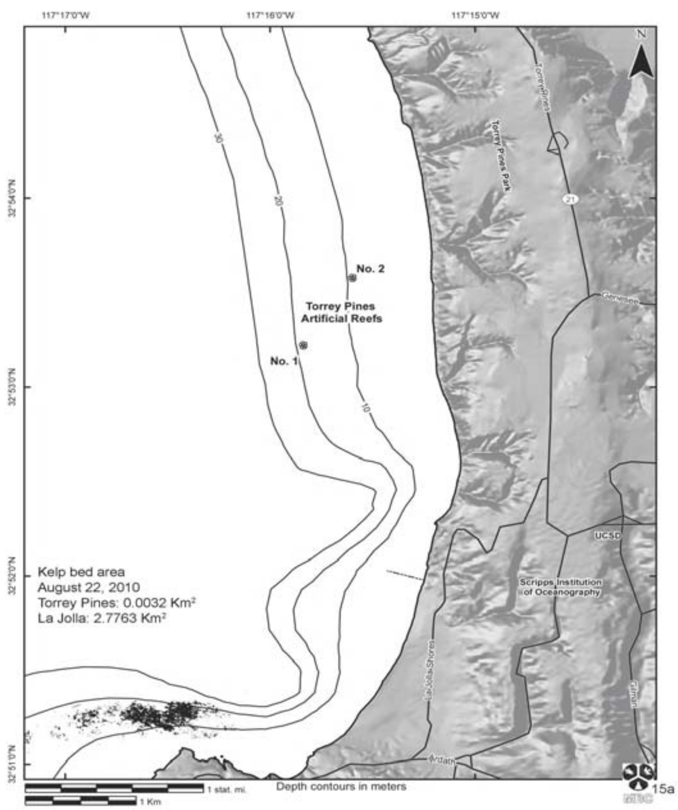

117°18'W
117°17'W
117°16'W
117°15'W
N
Solana Beach
Del Mar
Kelp bed area
Solana Beach: 0.8232 Km²
Del Mar: 0.0574 Km²
December 31, 2008
Depth contours in meters
15

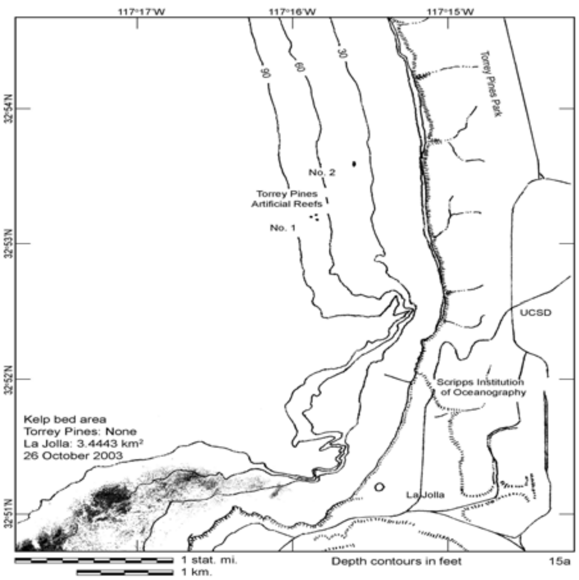

Kelp bed areas
Solana Beach: 0.488 km^2
Del Mar: 0.104 km^2
25 November & 30 December 1989
Kelp bed areas
Solana Beach: 0.466 km^2
Del Mar: 0.082 km^2
25 March 1990
Kelp bed areas
Solana Beach: 0.260 km^2
Del Mar: 0.097 km^2
14 March 1991
Kelp bed areas
Solana Beach: 0.053 km^2
Del Mar: 0.006 km^2
19 March 1992
Kelp bed areas
Solana Beach: 0.023 km^2
Del Mar: 0.003 km^2
3 January & 26 November 1993
Kelp bed areas
Solana Beach: 0.108 km^2
Del Mar: 0.029 km^2
26 June 1994
Kelp bed areas
Solana Beach: 0.134 km^2
Del Mar: 0.082 km^2
2 April 1995
Kelp bed areas
Solana Beach: 0.003 km^2
Del Mar: none
24 March 19996
Kelp bed areas
Solana Beach: 0.070 km^2
Del Mar: none
7 January 1997
Kelp bed areas
Solana Beach: 0.009 km^2
Del Mar: 0.004 km
14 June 1998
Kelp bed areas
Solana Beach: 0.091 km^2
Del Mar: none
23 November 1999
Kelp bed areas
Solana Beach: 0.200 km^2
Del Mar: 0.006 km
21 December 2000
Solana Beach
Del Mar
1 stat. mi.
Depth contours in feet
1 km

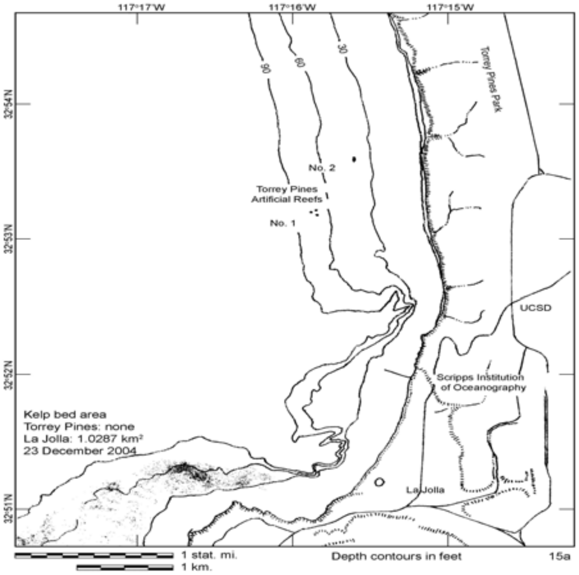


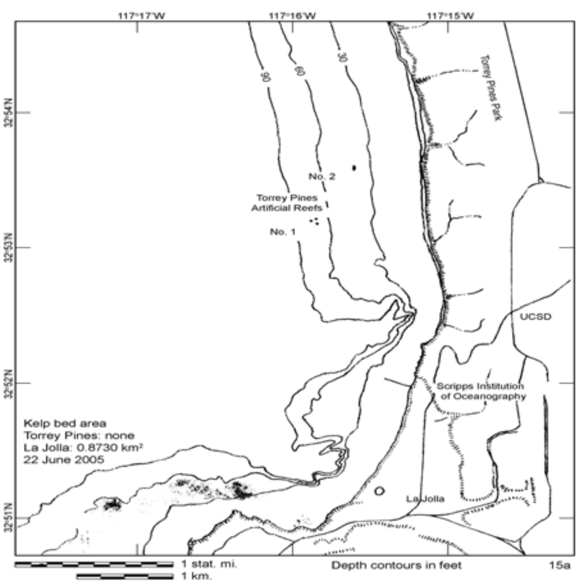
Historical charts of Del Mar kelp from 1967 to 1989.

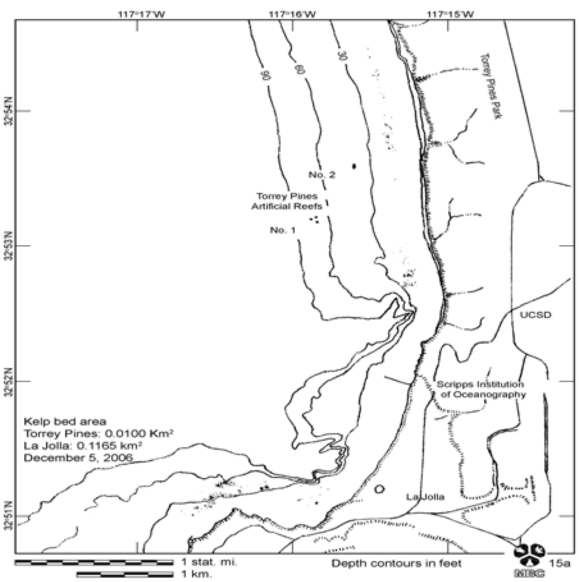

117°17'0"W
117°16'0"W
117°15'0"W
N
32°54'0"N
32°53'0"N
32°52'0"N
32°51'0"N
30
20
10
No. 2
Torrey Pines
Artificial Reefs
No. 1
Torrey Pines Park
21
Genesee
UCSD
Scripps Institution
of Oceanography
La Jolla Shores
Kelp bed area
March 10, 2009
Torrey Pines: 0.0004 Km²
June 4, 2009
La Jolla: 2.2743 Km²
1 stat. mi.
1 Km
Depth contours in meters
15a

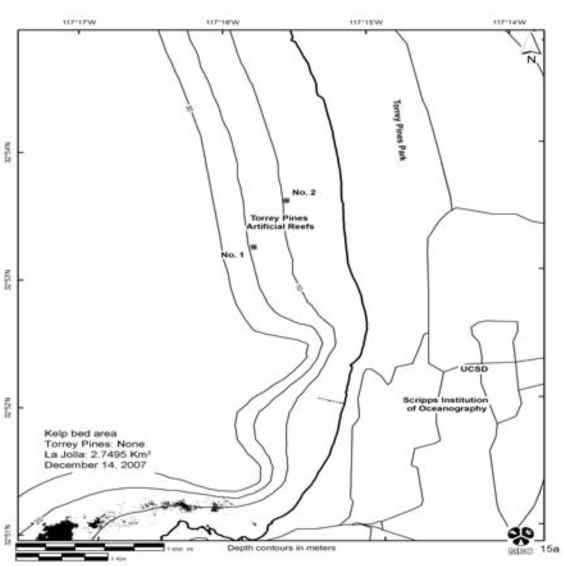

117°17'0"W
117°16'0"W
117°15'0"W
N
32°54'0"N
32°53'0"N
32°52'0"N
32°51'0"N
30
20
10
No. 2
Torrey Pines
Artificial Reefs
No. 1
Torrey Pines Park
21
Genesee
UCSD
Scripps Institution
of Oceanography
La Jolla Shores
Kelp bed area
August 22, 2010
Torrey Pines: 0.0032 Km²
La Jolla: 2.7763 Km²
1 stat. mi.
1 Km
Depth contours in meters
15a

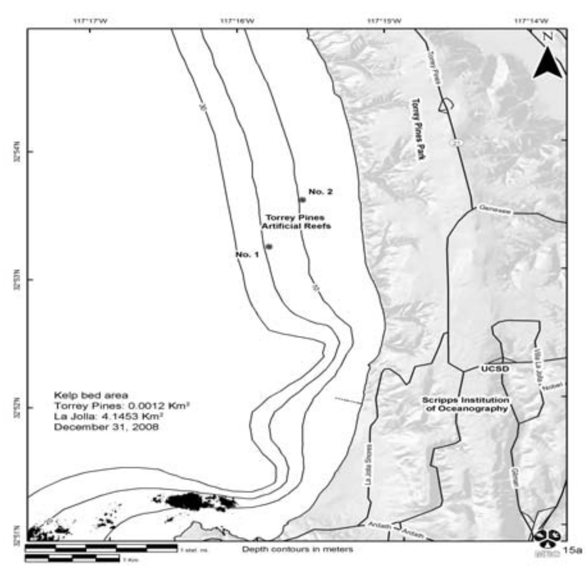

117°17'W
117°16'W
117°15'W
32°54'N
32°53'N
32°52'N
32°51'N
90
60
30
Torrey Pines Park
No. 2
Torrey Pines
Artificial Reefs
No. 1
UCSD
Scripps Institution
of Oceanography
La Jolla
Kelp bed area
Torrey Pines: None
La Jolla: 3.4443 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
15a

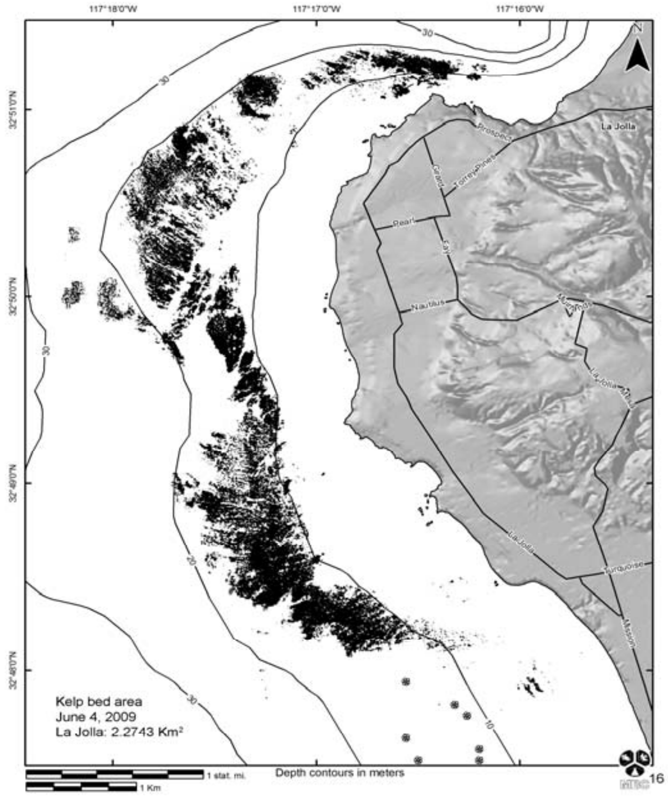

117°17'W
117°16'W
117°15'W
32°54'N
32°53'N
32°52'N
32°51'N
90
60
30
Torrey Pines Park
No. 2
Torrey Pines
Artificial Reefs
No. 1
UCSD
Scripps Institution
of Oceanography
La Jolla
Kelp bed area
Torrey Pines: none
La Jolla: 1.0287 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
15a

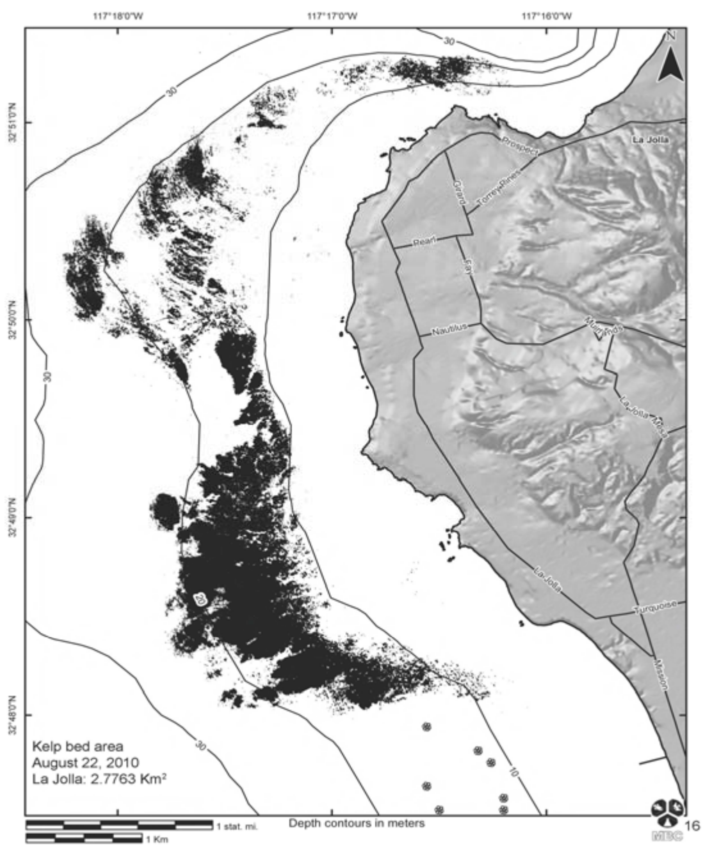

117°17'W
117°16'W
117°15'W
32°54'N
32°53'N
32°52'N
32°51'N
90
60
30
Torrey Pines Park
No. 2
Torrey Pines
Artificial Reefs
No. 1
UCSD
Scripps Institution
of Oceanography
La Jolla
Kelp bed area
Torrey Pines: none
La Jolla: 0.8730 km²
22 June 2005
1 stat. mi.
1 km.
Depth contours in feet
15a


117°17'W
117°16'W
117°15'W
32°54'N
32°53'N
32°52'N
32°51'N
90
60
30
Torrey Pines Park
No. 2
Torrey Pines
Artificial Reefs
No. 1
UCSD
Scripps Institution
of Oceanography
La Jolla
Kelp bed area
Torrey Pines: 0.0100 Km²
La Jolla: 0.1165 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
15a


117°17'W
117°16'W
117°15'W
117°14'W
N
Torrey Pines Park
No. 2
Torrey Pines
Artificial Reefs
No. 1
UCSD
Scripps Institution
of Oceanography
Kelp bed area
Torrey Pines: None
La Jolla: 2.7495 Km²
December 14, 2007
Depth contours in meters
15a


117°17'W
117°16'W
117°15'W
117°14'W
N
Torrey Pines Park
No. 2
Torrey Pines
Artificial Reefs
No. 1
UCSD
Scripps Institution
of Oceanography
La Jolla Shores
Kelp bed area
Torrey Pines: 0.0012 Km²
La Jolla: 4.1453 Km²
December 31, 2008
Depth contours in meters
15a


117°18'0"W
117°17'0"W
117°16'0"W
32°51'0"N
32°50'0"N
32°49'0"N
32°48'0"N
La Jolla
Prospect
Torrey Pines
Girard
Pearl
Fay
Nautilus
La Jolla Mesa
La Jolla
Turquoise
Mission
30
20
10
Kelp bed area
June 4, 2009
La Jolla: 2.2743 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
16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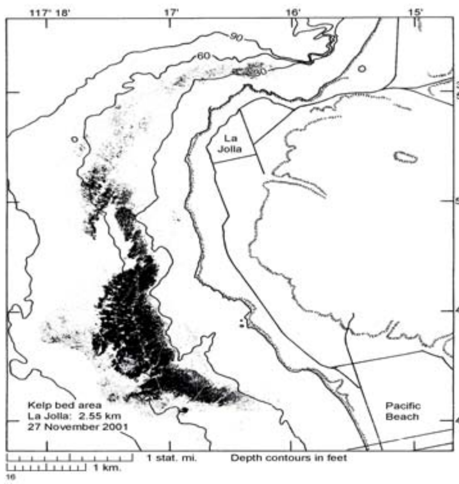
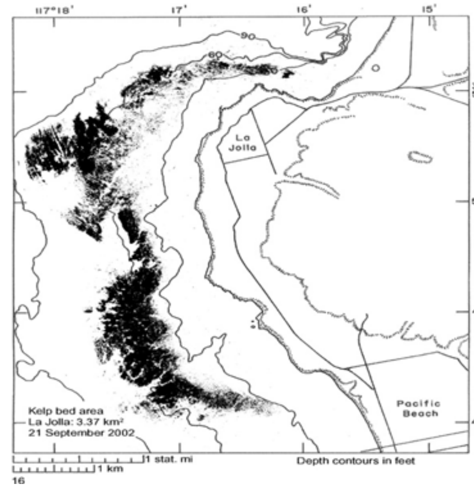
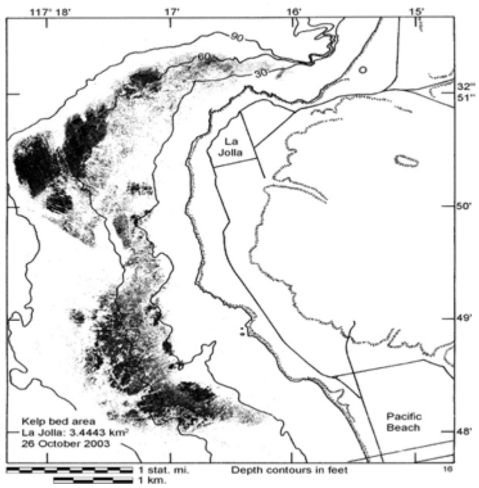
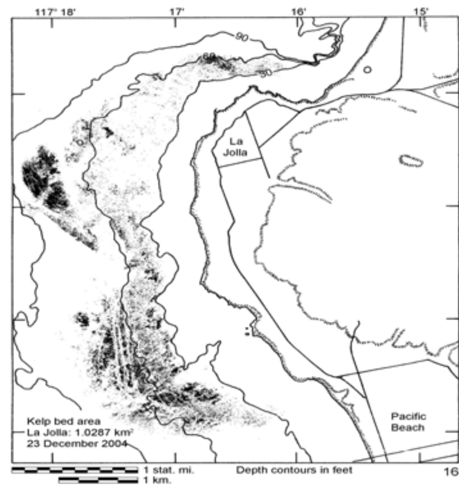
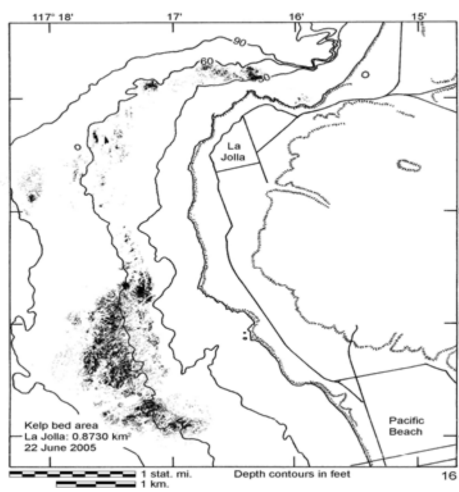
117°17'0"W
117°16'0"W
32°51'0"N
32°50'0"N
32°49'0"N
32°48'0"N
La Jolla
Prospect
Torrey Pines
Girard
Pearl
Fay
Nautilus
La Jolla Mesa
La Jolla
Turquoise
Mission
30
10
Kelp bed area
August 22, 2010
La Jolla: 2.7763 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
16

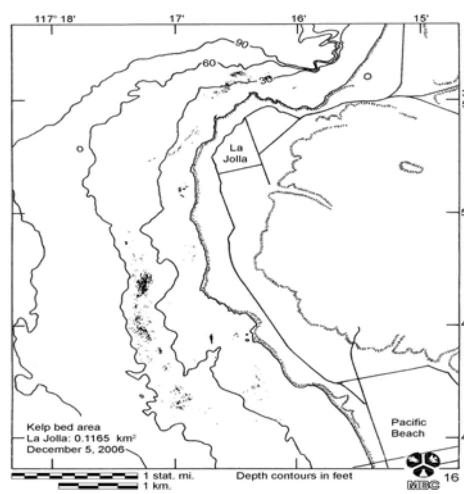

117° 18'
17'
16'
15'
90
60
30
32°
51'
La
Jolla
50'
49'
48'
Pacific
Beach
Kelp bed area
La Jolla: 2.55 km
27 November 2001
1 stat. mi.
1 km.
Depth contours in feet
16

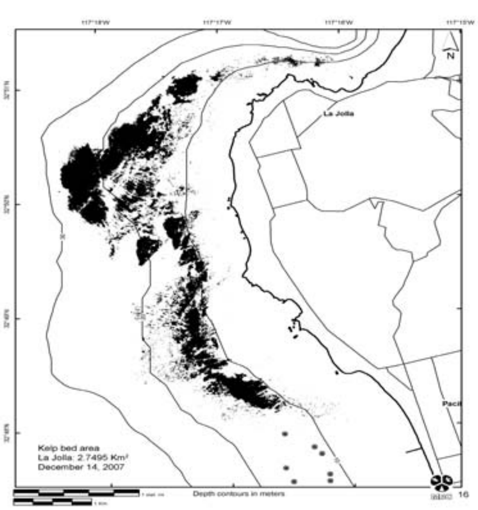

117° 18'
17'
16'
15'
90
60
32°
51'
La
Jolla
50'
49'
48'
Pacific
Beach
Kelp bed area
La Jolla: 3.37 km²
21 September 2002
1 stat. mi
1 km
Depth contours in feet
16

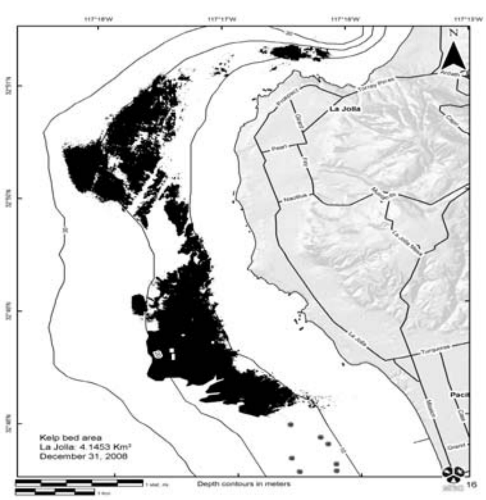

117° 18'
17'
16'
15'
90
60
30
32°
51'
La
Jolla
50'
49'
48'
Pacific
Beach
Kelp bed area
La Jolla: 3.4443 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
16

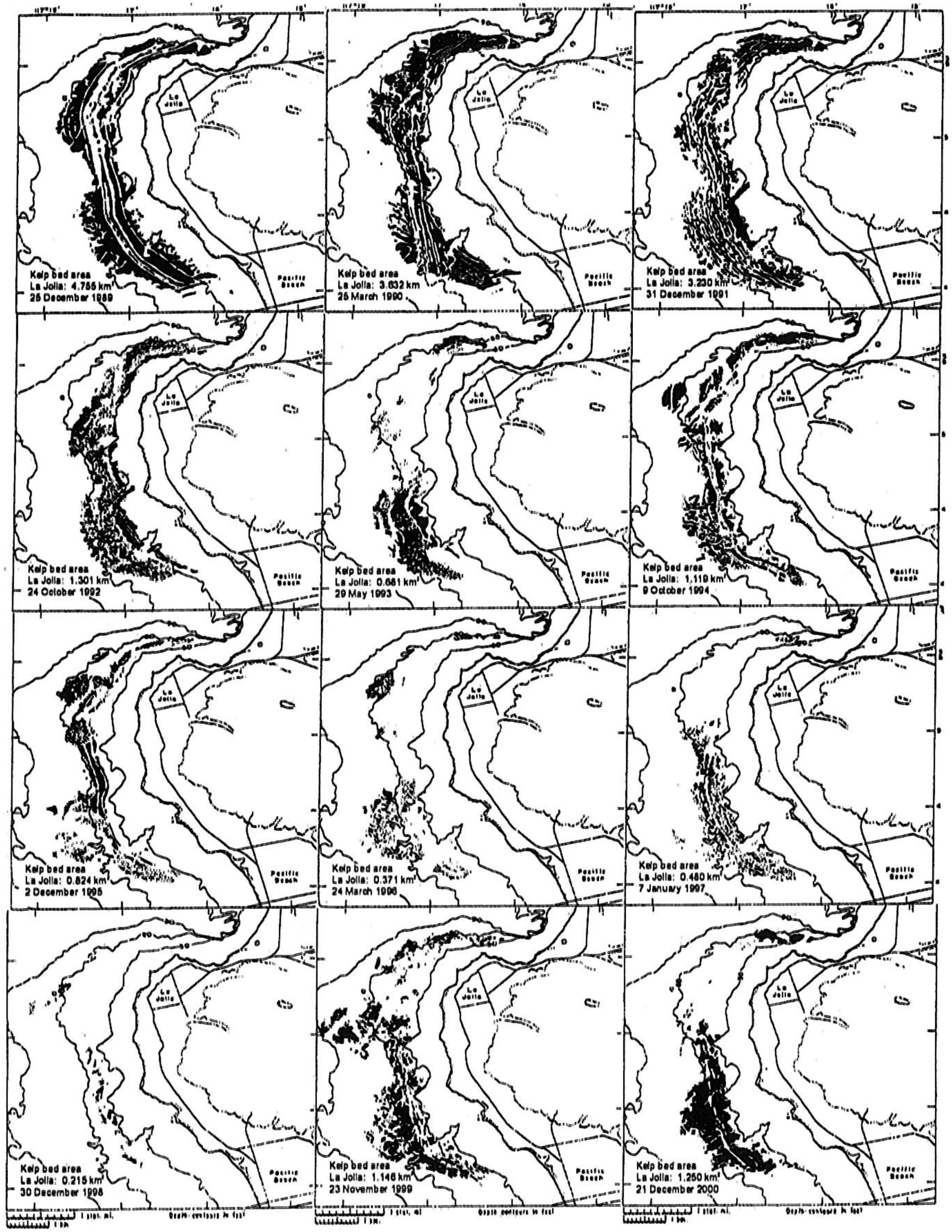

117° 18'
17'
16'
15'
90
60
30
32°
51'
La
Jolla
50'
49'
48'
Pacific
Beach
Kelp bed area
La Jolla: 1.0287 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
16


117° 18'
17'
16'
15'
90
60
30
32°
51'
La
Jolla
50'
49'
48'
Pacific
Beach
Kelp bed area
La Jolla: 0.8730 km²
22 June 2005
1 stat. mi.
1 km.
Depth contours in feet
16

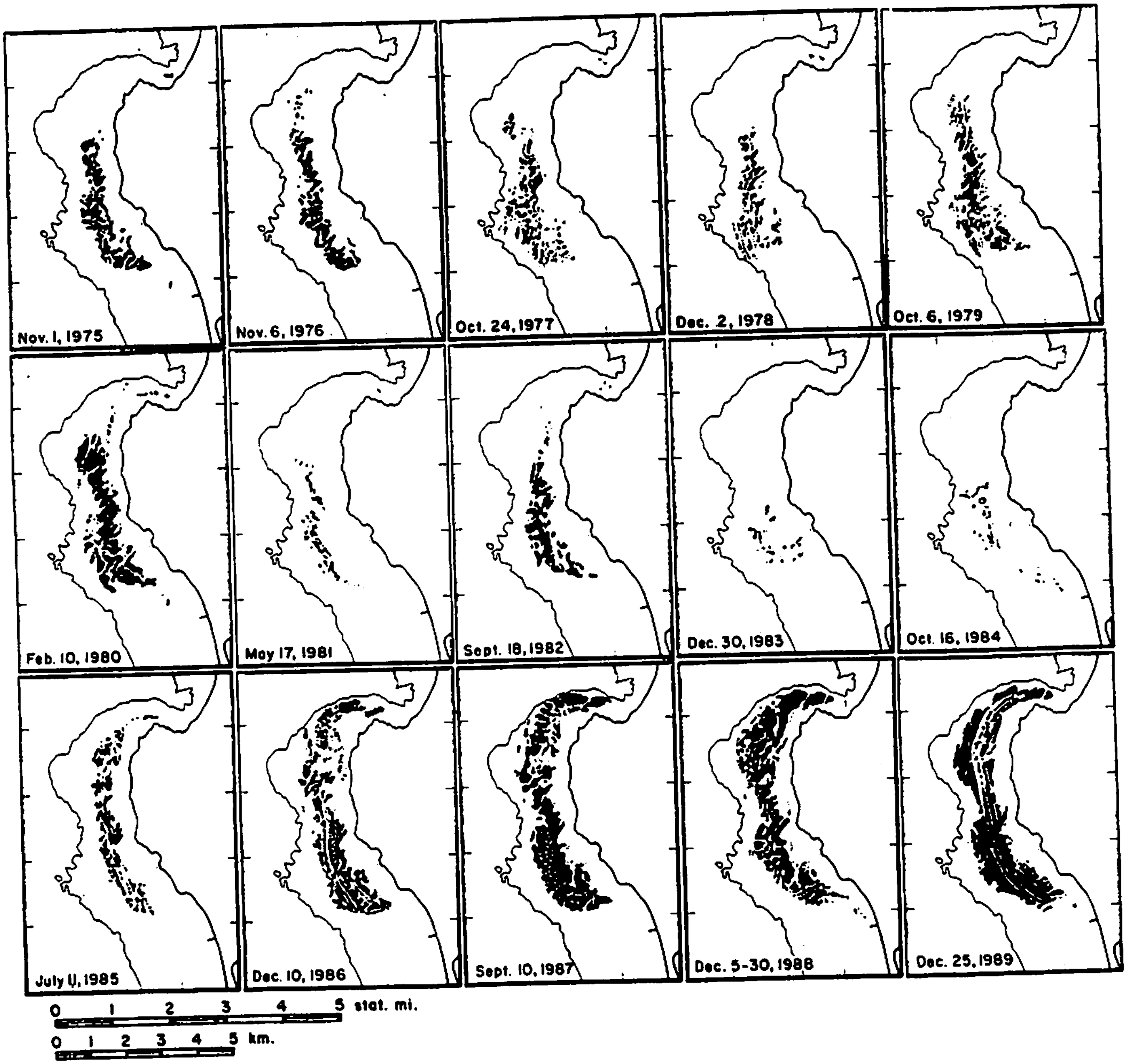

117° 18'
17'
16'
15'
90
60
30
32°
51'
La
Jolla
50'
49'
48'
Pacific
Beach
Kelp bed area
La Jolla: 0.1165 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
16


N
La Jolla
Kelp bed area
La Jolla: 2.7495 Km²
December 14, 2007
Depth contours in meters
16

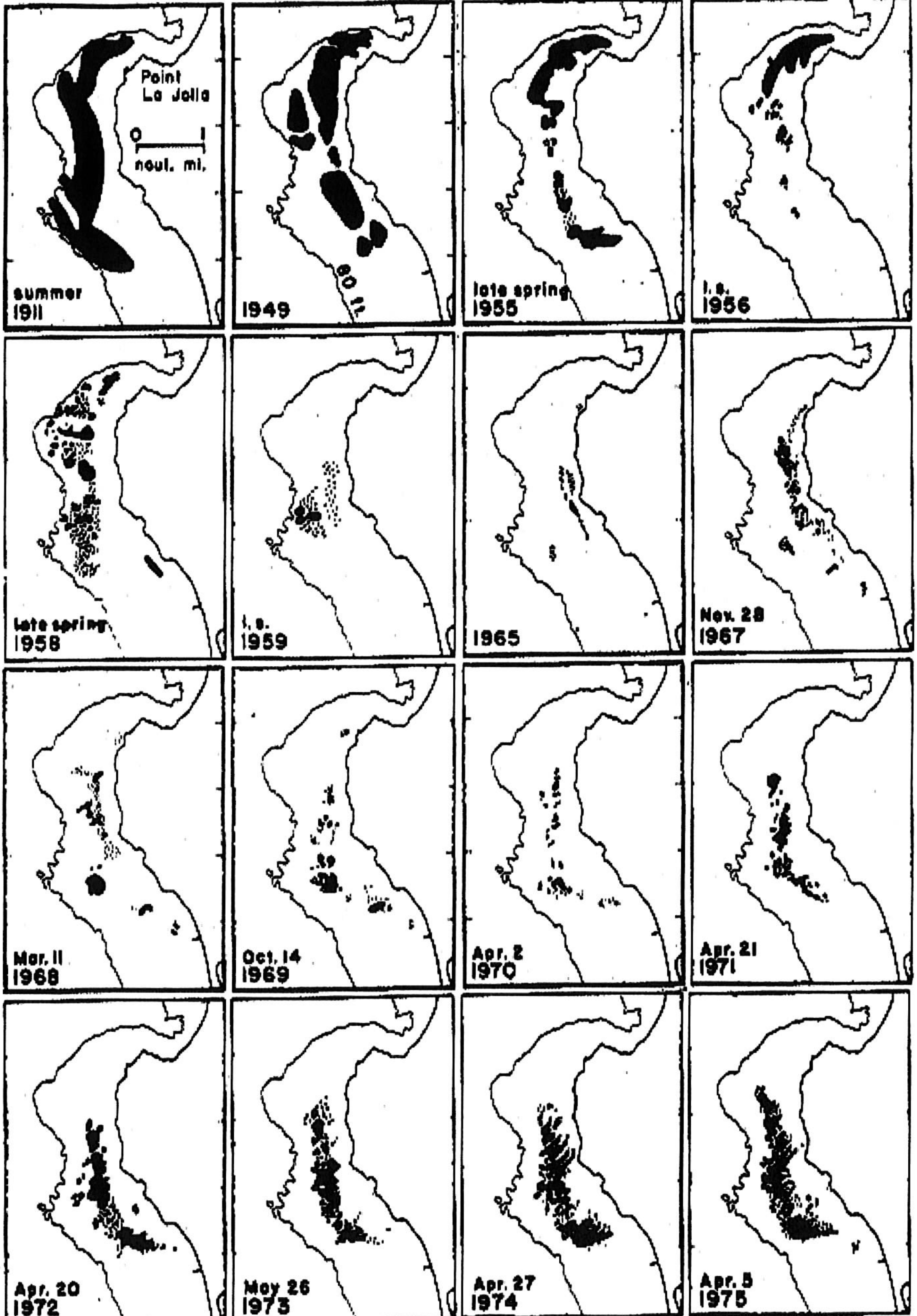

N
La Jolla
Kelp bed area
La Jolla: 4.1453 Km²
December 31, 2008
Depth contours in meters
16



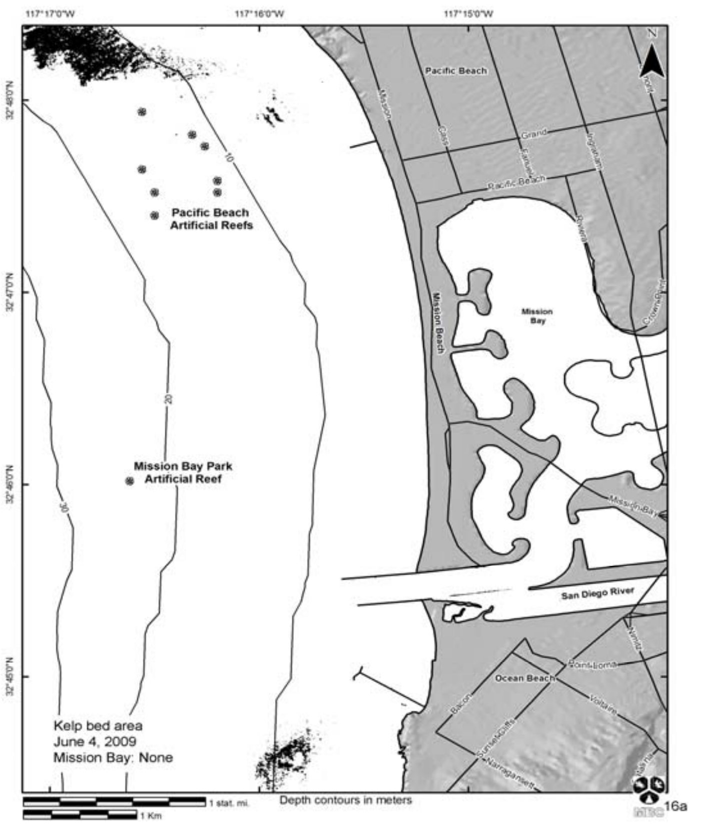
La Jolla
Pacific Beach
Kelp bed area
La Jolla: 4.755 km²
25 December 1989
Kelp bed area
La Jolla: 3.632 km
25 March 1990
Kelp bed area
La Jolla: 3.230 km²
31 December 1991
Kelp bed area
La Jolla: 1.301 km²
24 October 1992
Kelp bed area
La Jolla: 0.681 km²
29 May 1993
Kelp bed area
La Jolla: 1.119 km²
9 October 1994
Kelp bed area
La Jolla: 0.824 km²
2 December 1995
Kelp bed area
La Jolla: 0.371 km²
24 March 1996
Kelp bed area
La Jolla: 0.480 km²
7 January 1997
Kelp bed area
La Jolla: 0.215 km²
30 December 1998
Kelp bed area
La Jolla: 1.146 km²
23 November 1999
Kelp bed area
La Jolla: 1.250 km²
21 December 2000

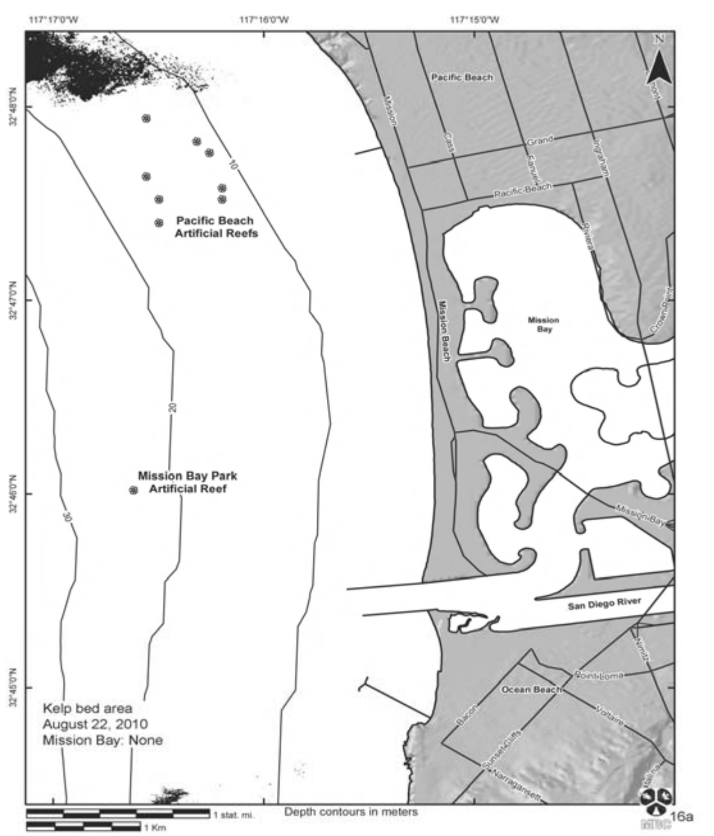


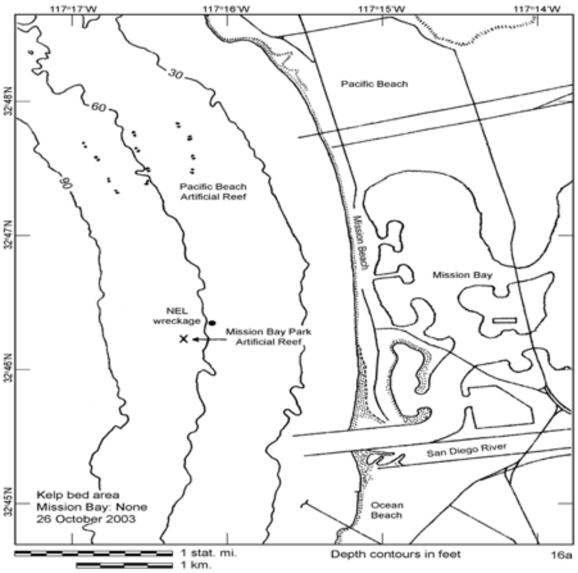
Historical charts of La Jolla kelp from 1975 to 1989.

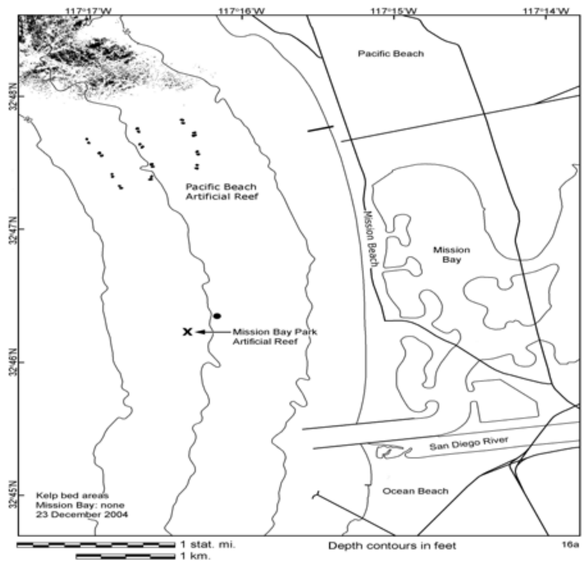


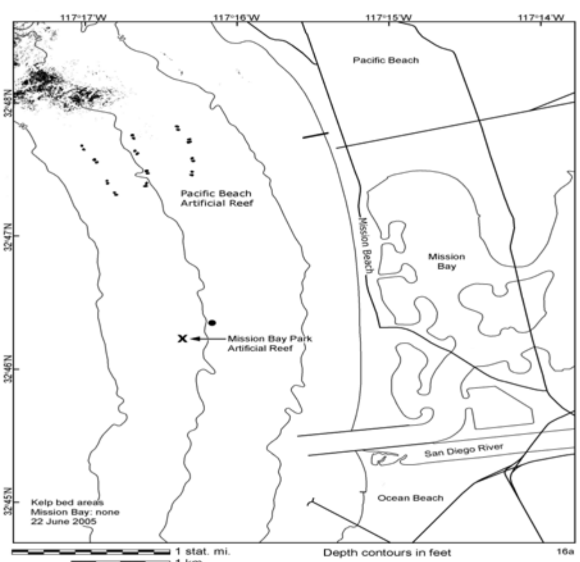
Historical charts of La Jolla kelp from 1911 to 1975.

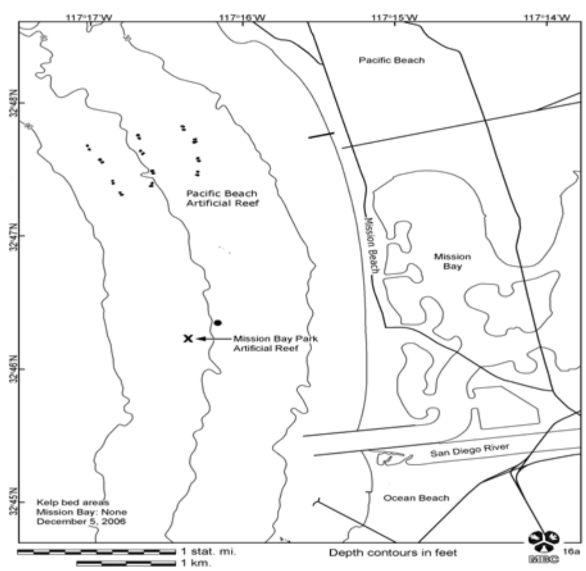

117°17'0"W
117°16'0"W
117°15'0"W
32°48'0"N
32°47'0"N
32°46'0"N
32°45'0"N
Pacific Beach
Mission
Cass
Grand
Ingraham
Garnet
Pacific Beach
Riviera
Crown Point
Pacific Beach Artificial Reefs
Mission Beach
Mission Bay
Mission Bay Park Artificial Reef
Mission Bay
San Diego River
Nimitz
Point Loma
Ocean Beach
Voltaire
Bacon
Sunset Cliffs
Narragansett
10
20
30
Kelp bed area
June 4, 2009
Mission Bay: None
1 stat. mi.
1 Km
Depth contours in meters
N
16a

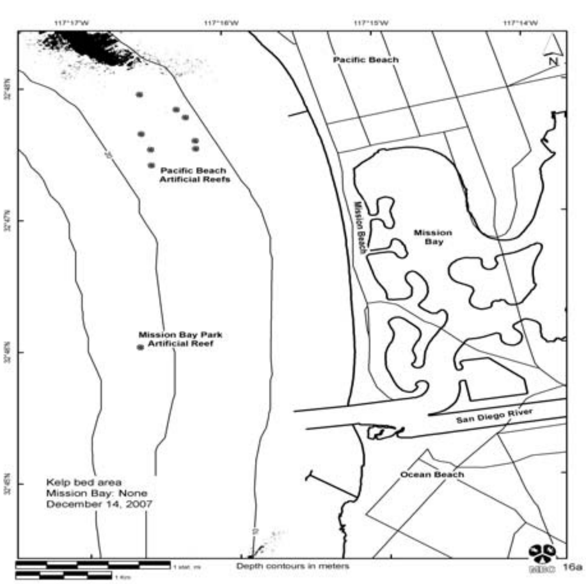

117°17'0"W
117°16'0"W
117°15'0"W
32°48'0"N
32°47'0"N
32°46'0"N
32°45'0"N
Pacific Beach
Mission
Cass
Grand
Ingraham
Garnet
Pacific Beach
Riviera
Crown Point
Pacific Beach Artificial Reefs
Mission Beach
Mission Bay
Mission Bay Park Artificial Reef
Mission Bay
San Diego River
Nimitz
Point Loma
Ocean Beach
Voltaire
Bacon
Sunset Cliffs
Narragansett
10
20
30
Kelp bed area
August 22, 2010
Mission Bay: None
1 stat. mi.
1 Km
Depth contours in meters
N
16a


117°17'W
117°16'W
117°15'W
117°14'W
32°48'N
32°47'N
32°46'N
32°45'N
30
60
90
Pacific Beach
Pacific Beach
Artificial Reef
Mission Beach
Mission Bay
NEL
wreckage
Mission Bay Park
Artificial Reef
San Diego River
Ocean
Beach
Kelp bed area
Mission Bay: None
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
16a

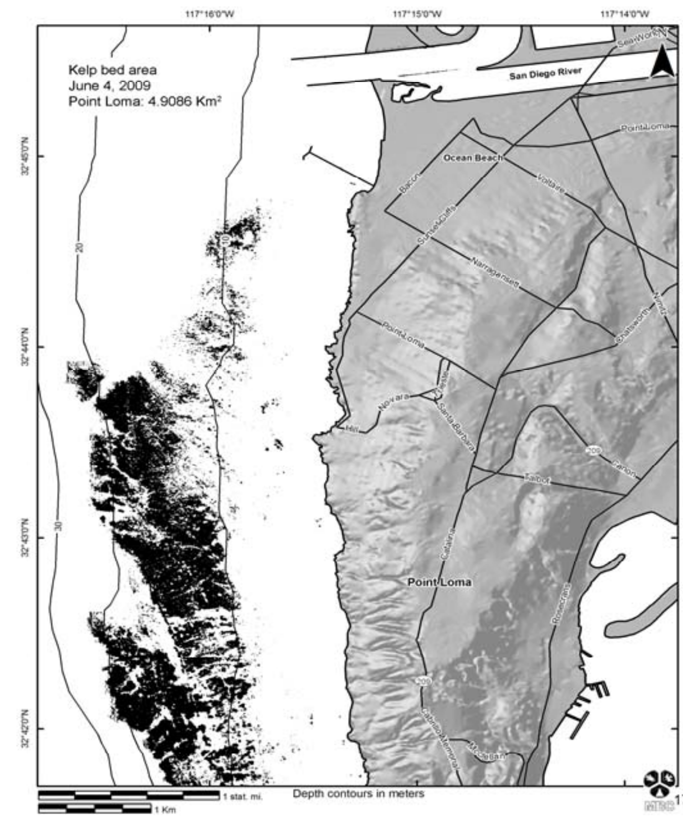

117°17'W
117°16'W
117°15'W
117°14'W
32°48'N
32°47'N
32°46'N
32°45'N
Pacific Beach
Pacific Beach
Artificial Reef
Mission Beach
Mission
Bay
Mission Bay Park
Artificial Reef
San Diego River
Ocean Beach
Kelp bed areas
Mission Bay: none
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
16a


117°17'W
117°16'W
117°15'W
117°14'W
32°48'N
32°47'N
32°46'N
32°45'N
Pacific Beach
Pacific Beach
Artificial Reef
Mission Beach
Mission
Bay
Mission Bay Park
Artificial Reef
San Diego River
Ocean Beach
Kelp bed areas
Mission Bay: none
22 June 2005
1 stat. mi.
1 km.
Depth contours in feet
16a


117°17'W
117°16'W
117°15'W
117°14'W
32°48'N
32°47'N
32°46'N
32°45'N
Pacific Beach
Pacific Beach
Artificial Reef
Mission Beach
Mission
Bay
Mission Bay Park
Artificial Reef
San Diego River
Ocean Beach
Kelp bed areas
Mission Bay: None
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
16a

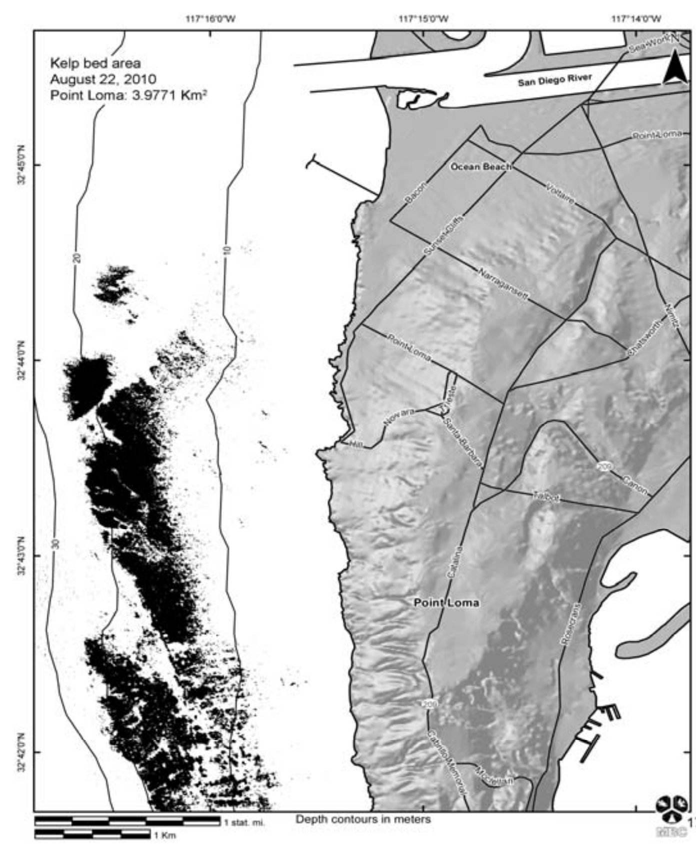

117°17'W
117°16'W
117°15'W
117°14'W
N
Pacific Beach
Pacific Beach
Artificial Reefs
Mission Beach
Mission
Bay
Mission Bay Park
Artificial Reef
San Diego River
Ocean Beach
Kelp bed area
Mission Bay: None
December 14, 2007
Depth contours in meters
MBC
16a


117°17'W
117°16'W
117°15'W
117°14'W
N
Pacific Beach
Grand
Pacific Beach
Pacific Beach
Artificial Reefs
Mission Beach
Mission
Bay
Mission Bay Park
Artificial Reef
San Diego River
Ocean Beach
Point Loma
Kelp bed area
Mission Bay: None
December 31, 2008
Depth contours in meters
MBC
16a



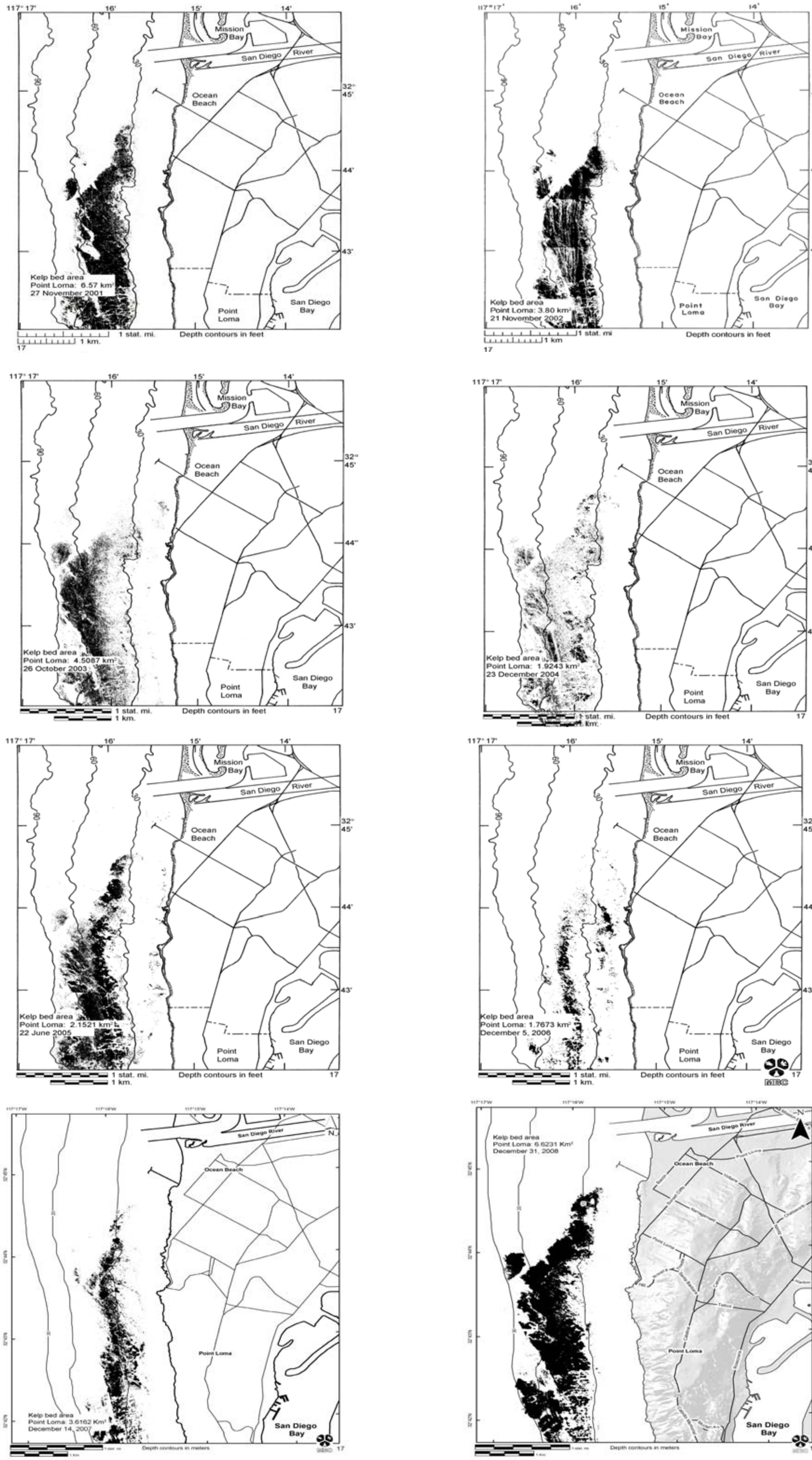
Kelp bed area
June 4, 2009
Point Loma: 4.9086 Km²
117°16'0"W
117°15'0"W
117°14'0"W
32°45'0"N
32°44'0"N
32°43'0"N
32°42'0"N
San Diego River
Ocean Beach
Point Loma
1 stat. mi.
1 Km
Depth contours in meters

17

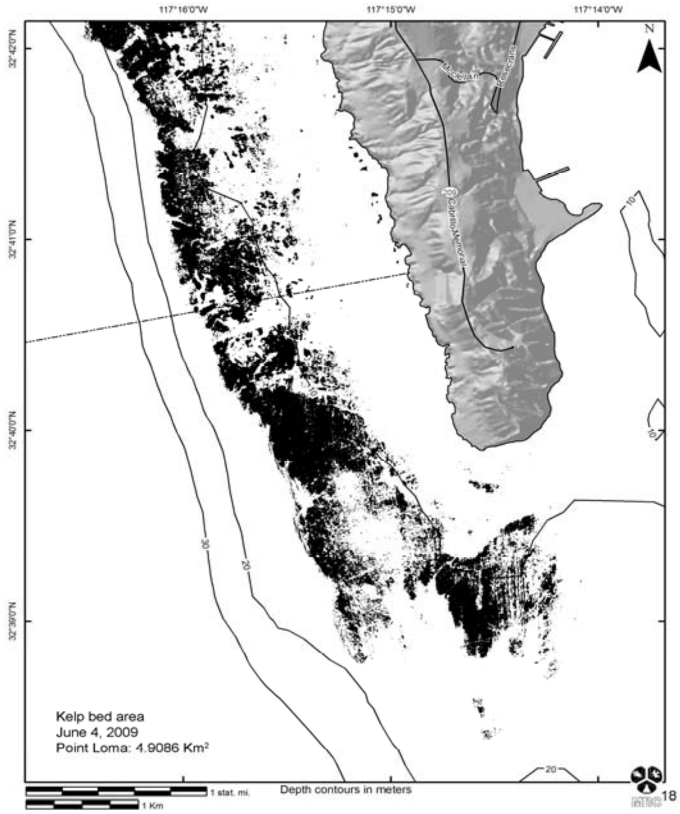


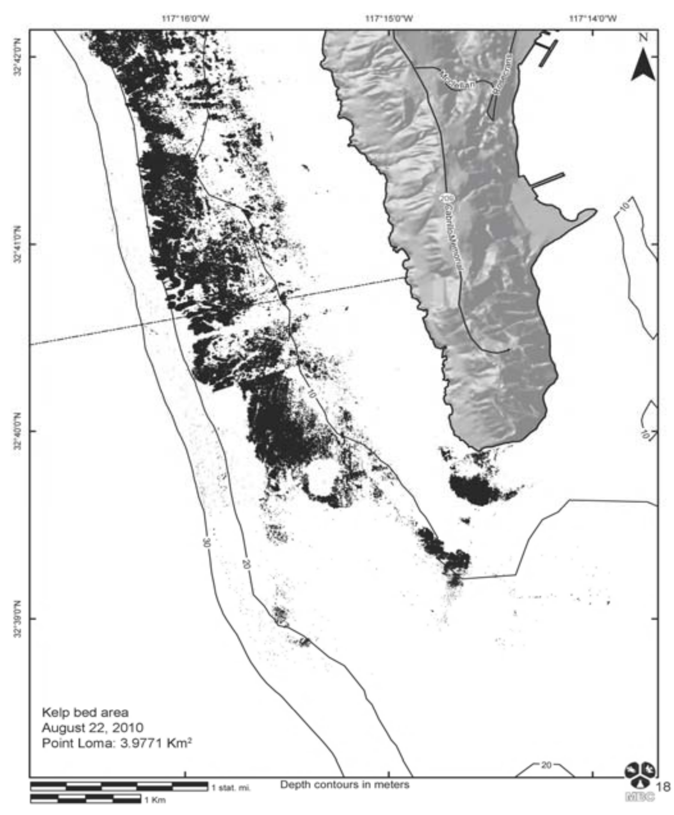
Kelp bed area
August 22, 2010
Point Loma: 3.9771 Km²
117°16'0"W
117°15'0"W
117°14'0"W
32°45'0"N
32°44'0"N
32°43'0"N
32°42'0"N
San Diego River
Ocean Beach
Point Loma
1 stat. mi.
1 Km
Depth contours in meters

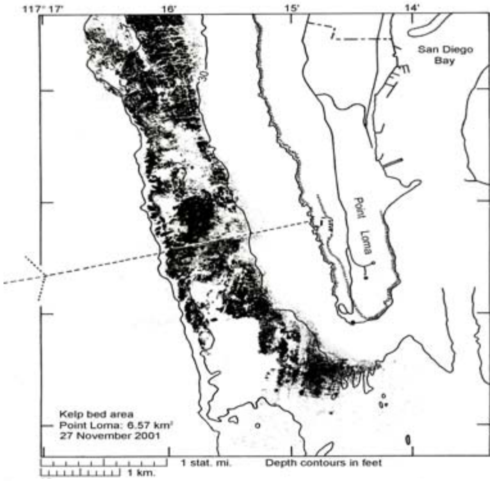
17

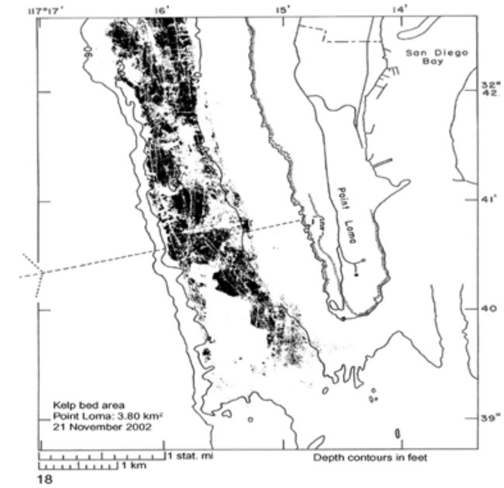


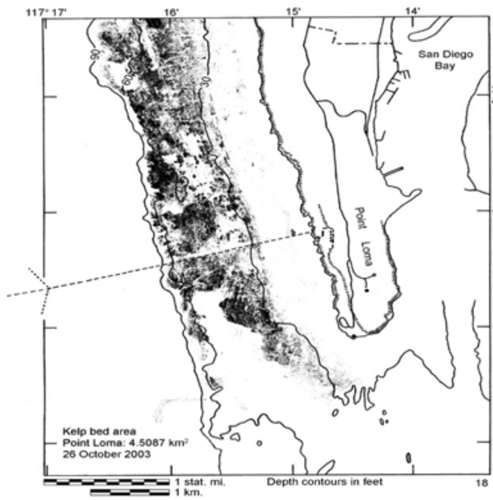
Kelp bed area
Point Loma: 6.57 km²
27 November 2001
Kelp bed area
Point Loma: 3.80 km²
21 November 2002
Kelp bed area
Point Loma: 4.5087 km²
26 October 2003
Kelp bed area
Point Loma: 1.9243 km²
23 December 2004
Kelp bed area
Point Loma: 2.1521 km²
22 June 2005
Kelp bed area
Point Loma: 1.7673 km²
December 5, 2006
Kelp bed area
Point Loma: 3.6162 Km²
December 14, 2007
Kelp bed area
Point Loma: 6.6231 Km²
December 31, 2008
Mission Bay
San Diego River
Ocean Beach
Point Loma
San Diego Bay
1 stat. mi.
1 km.
Depth contours in feet
Depth contours in meters

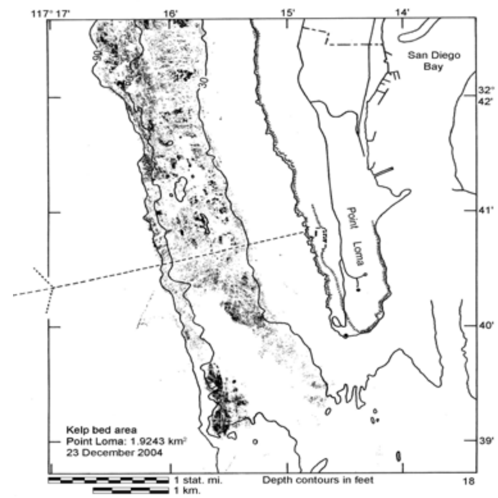

117°16'0"W
117°15'0"W
117°14'0"W
32°42'0"N
32°41'0"N
32°40'0"N
32°39'0"N
N
30
20
10
Kelp bed area
June 4, 2009
Point Loma: 4.9086 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
18

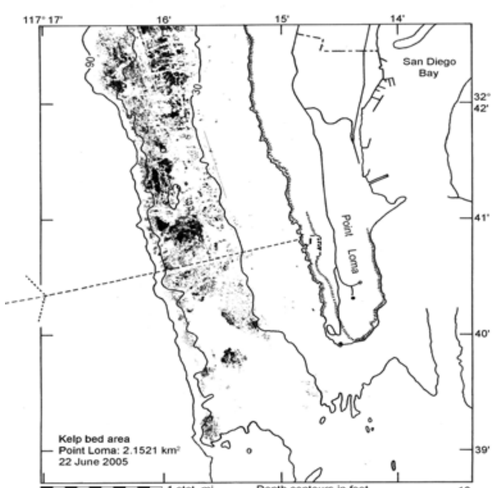

117°16'0"W
117°15'0"W
117°14'0"W
32°42'0"N
32°41'0"N
32°40'0"N
32°39'0"N
N
30
20
10
Kelp bed area
August 22, 2010
Point Loma: 3.9771 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
18

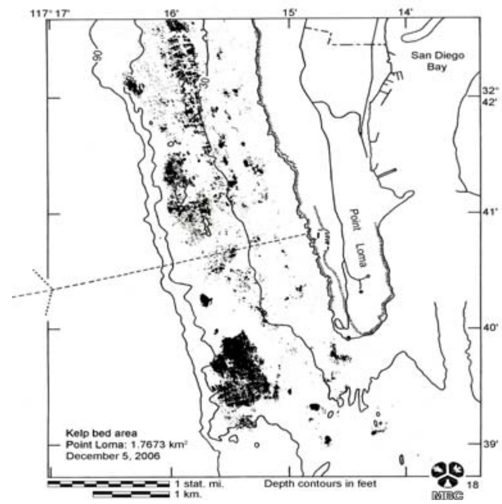

117° 17'
16'
15'
14'
San Diego Bay
32° 42'
41'
40'
39'
30
Point Loma
Kelp bed area
Point Loma: 6.57 km²
27 November 2001
1 stat. mi.
1 km.
Depth contours in feet

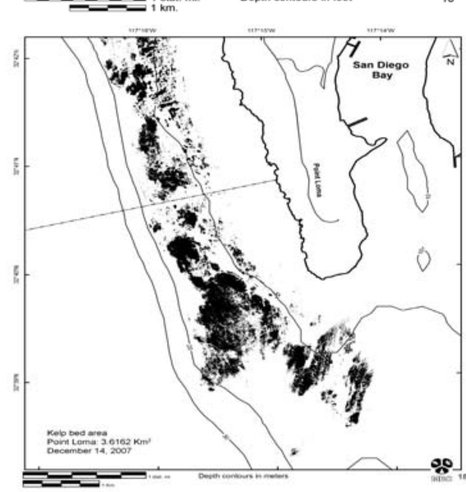

117° 17'
16'
15'
14'
San Diego Bay
32° 42'
41'
40
39'
30
Point Loma
Kelp bed area
Point Loma: 3.80 km²
21 November 2002
1 stat. mi
1 km
Depth contours in feet
18

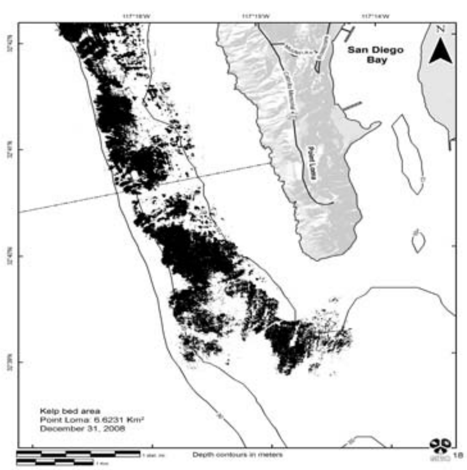

117° 17'
16'
15'
14'
San Diego Bay
32° 42'
41'
40'
39'
30
Point Loma
Kelp bed area
Point Loma: 4.5087 km²
26 October 2003
1 stat. mi.
1 km.
Depth contours in feet
18

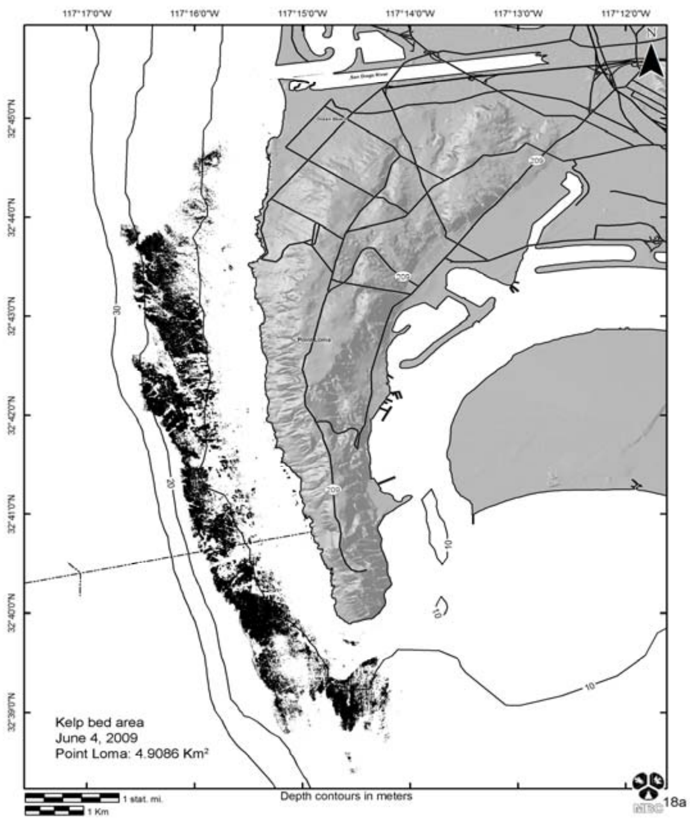

117° 17'
16'
15'
14'
San Diego Bay
32° 42'
41'
40'
39'
Point Loma
Kelp bed area
Point Loma: 1.9243 km²
23 December 2004
1 stat. mi.
1 km.
Depth contours in feet
18

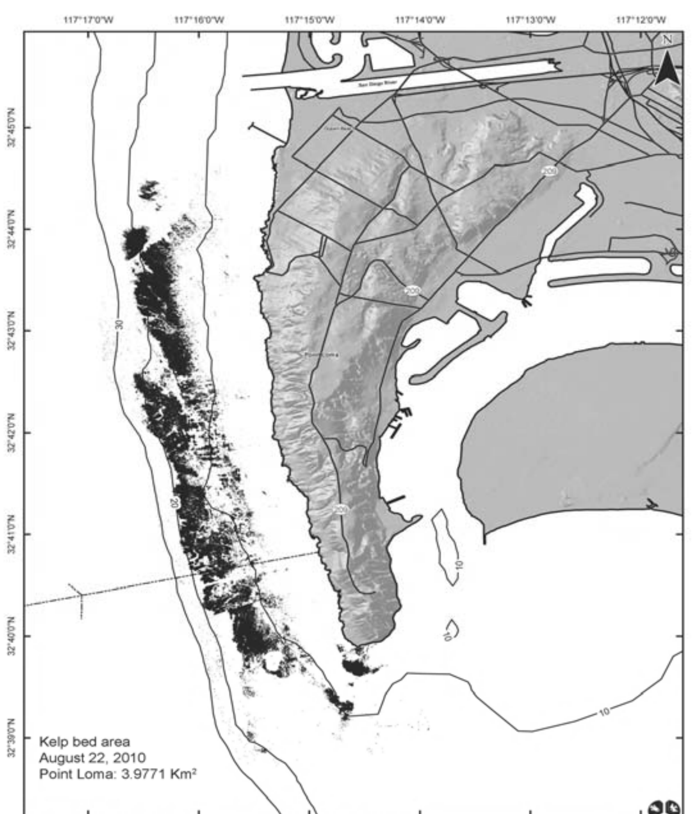

117° 17'
16'
15'
14'
San Diego Bay
32° 42'
41'
40'
39'
90
30
Point Loma
Kelp bed area
Point Loma: 2.1521 km²
22 June 2005
1 stat. mi.
1 km.
Depth contours in feet
18

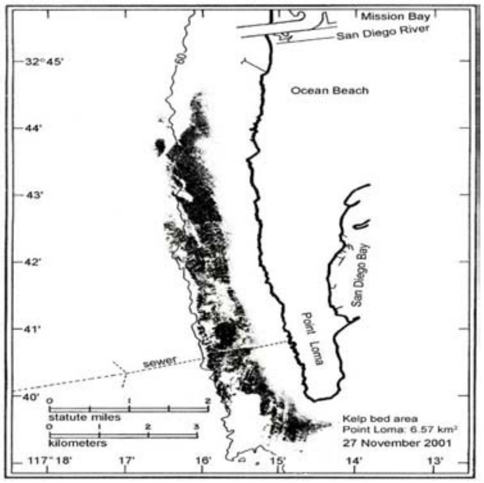

117° 17'
16'
15'
14'
San Diego Bay
32° 42'
41'
40'
39'
90
Point Loma
Kelp bed area
Point Loma: 1.7673 km²
December 5, 2006
1 stat. mi.
1 km.
Depth contours in feet
MBC
18

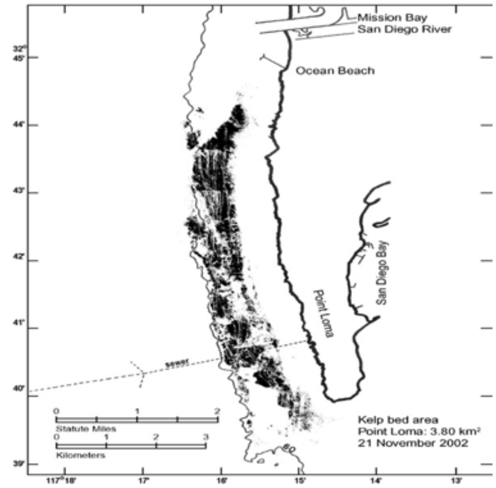

San Diego Bay
N
Point Loma
Kelp bed area
Point Loma: 3.6162 Km²
December 14, 2007
Depth contours in meters
18

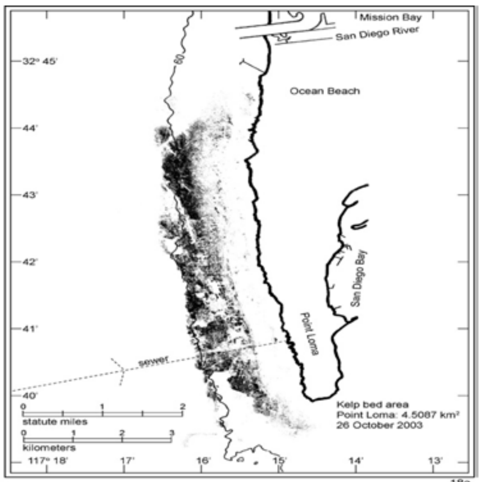

San Diego Bay
N
Point Loma
Kelp bed area
Point Loma: 6.6231 Km²
December 31, 2008
Depth contours in meters
18


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
30
20
10
Kelp bed area
June 4, 2009
Point Loma: 4.9086 Km²
1 stat. mi.
1 Km
Depth contours in meters
18a


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
30
20
10
Kelp bed area
August 22, 2010
Point Loma: 3.9771 Km²
1 stat. mi.
1 Km
Depth contours in meters
18a







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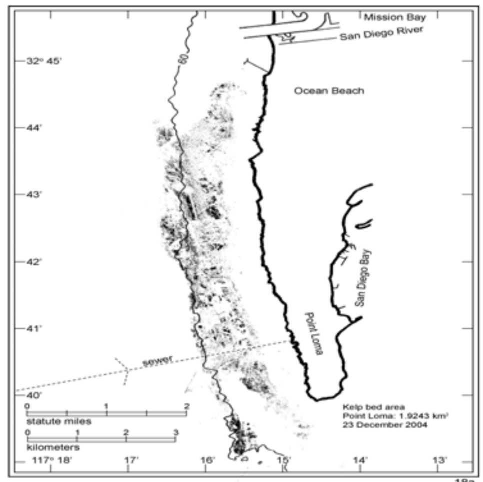

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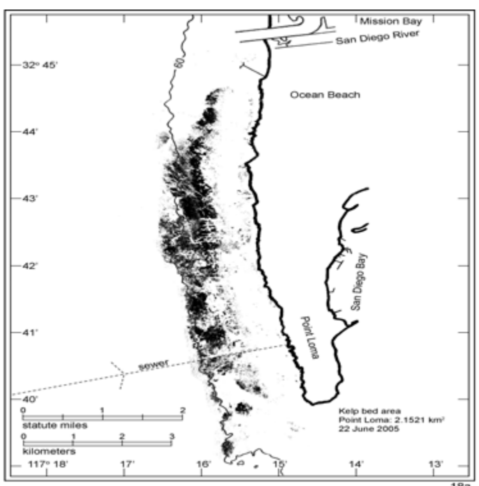

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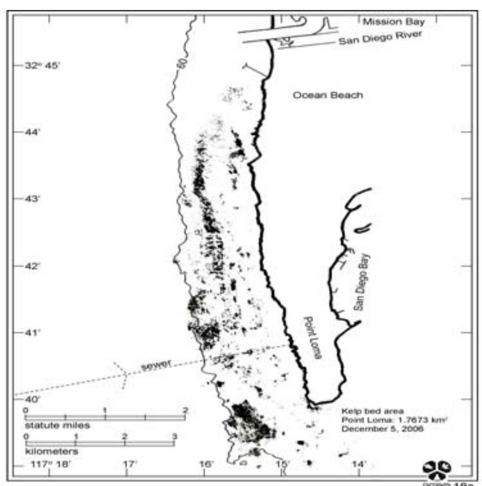

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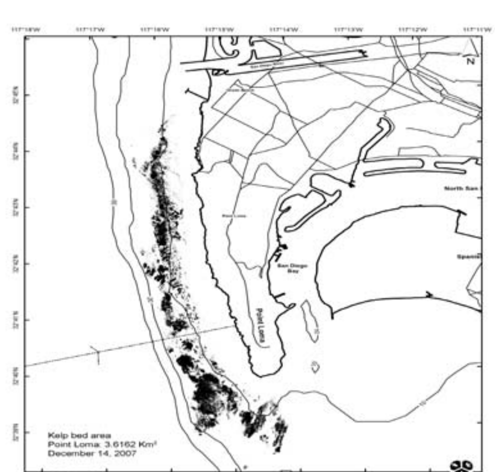

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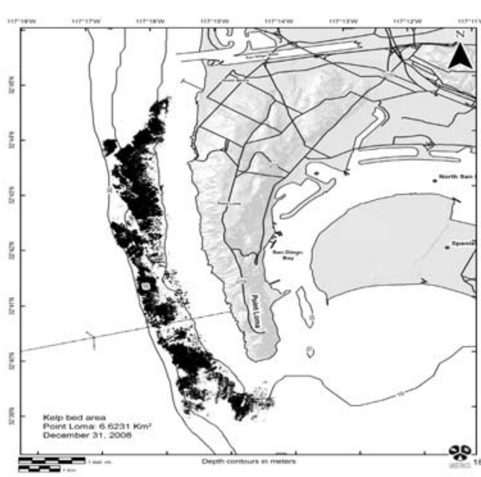
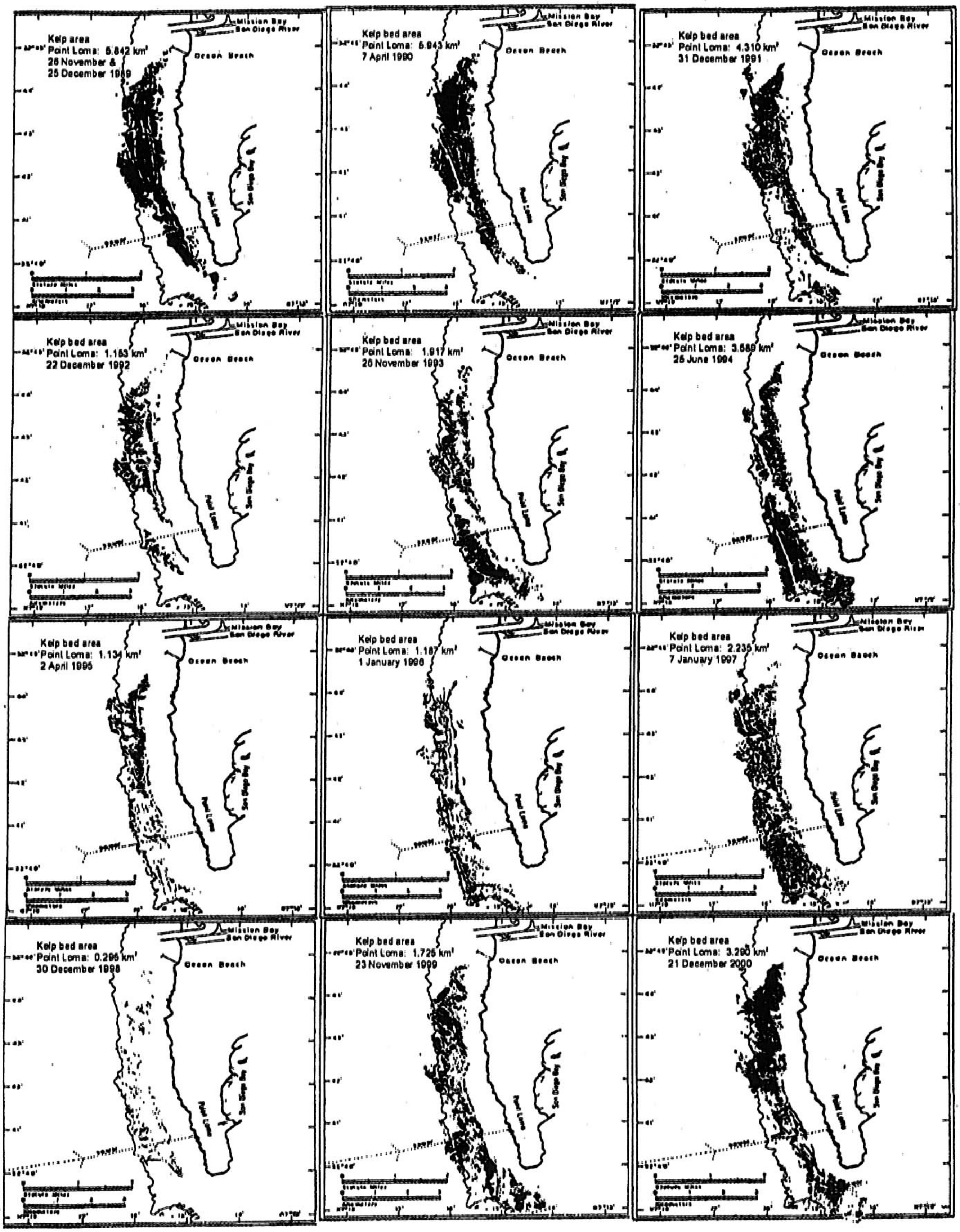
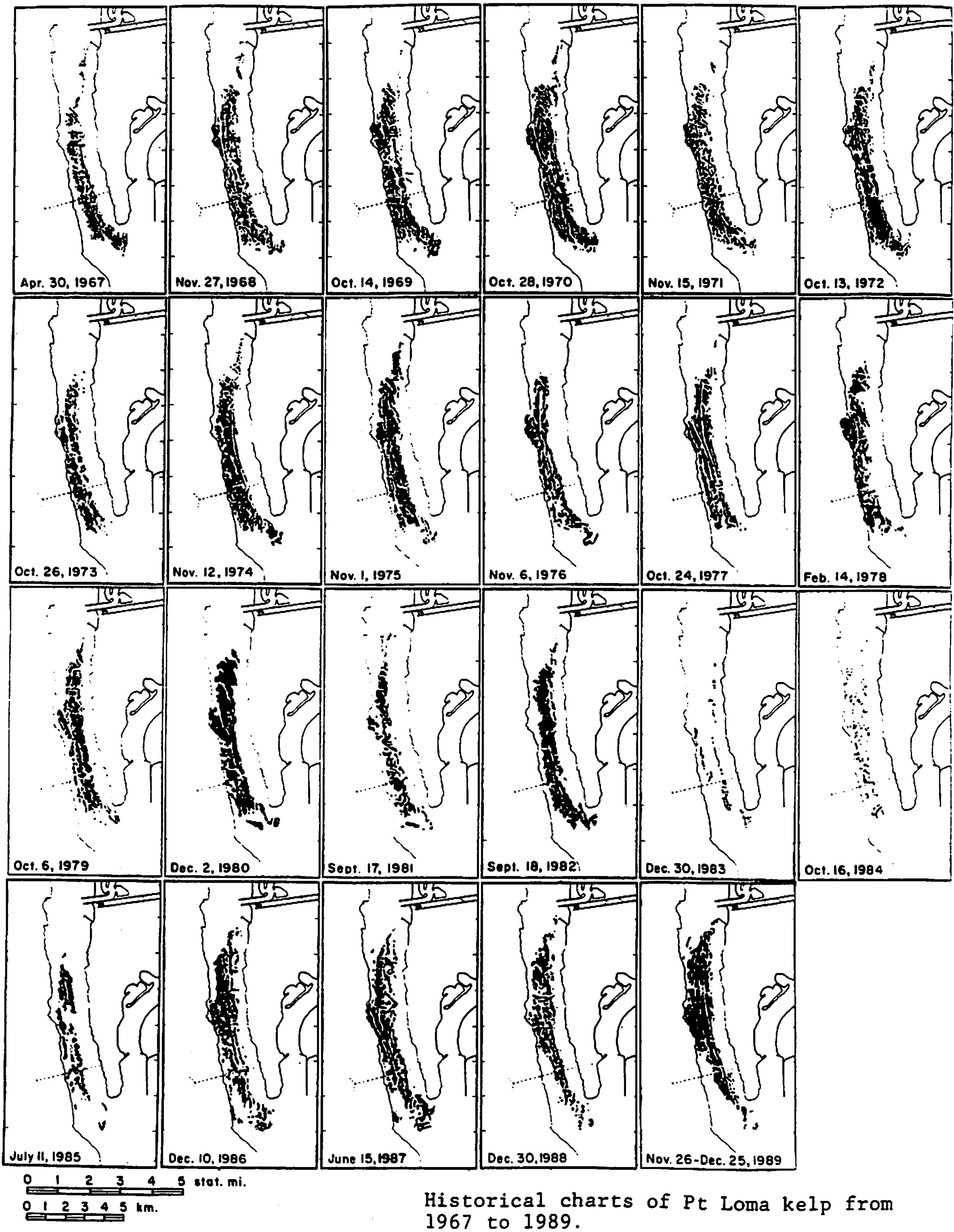


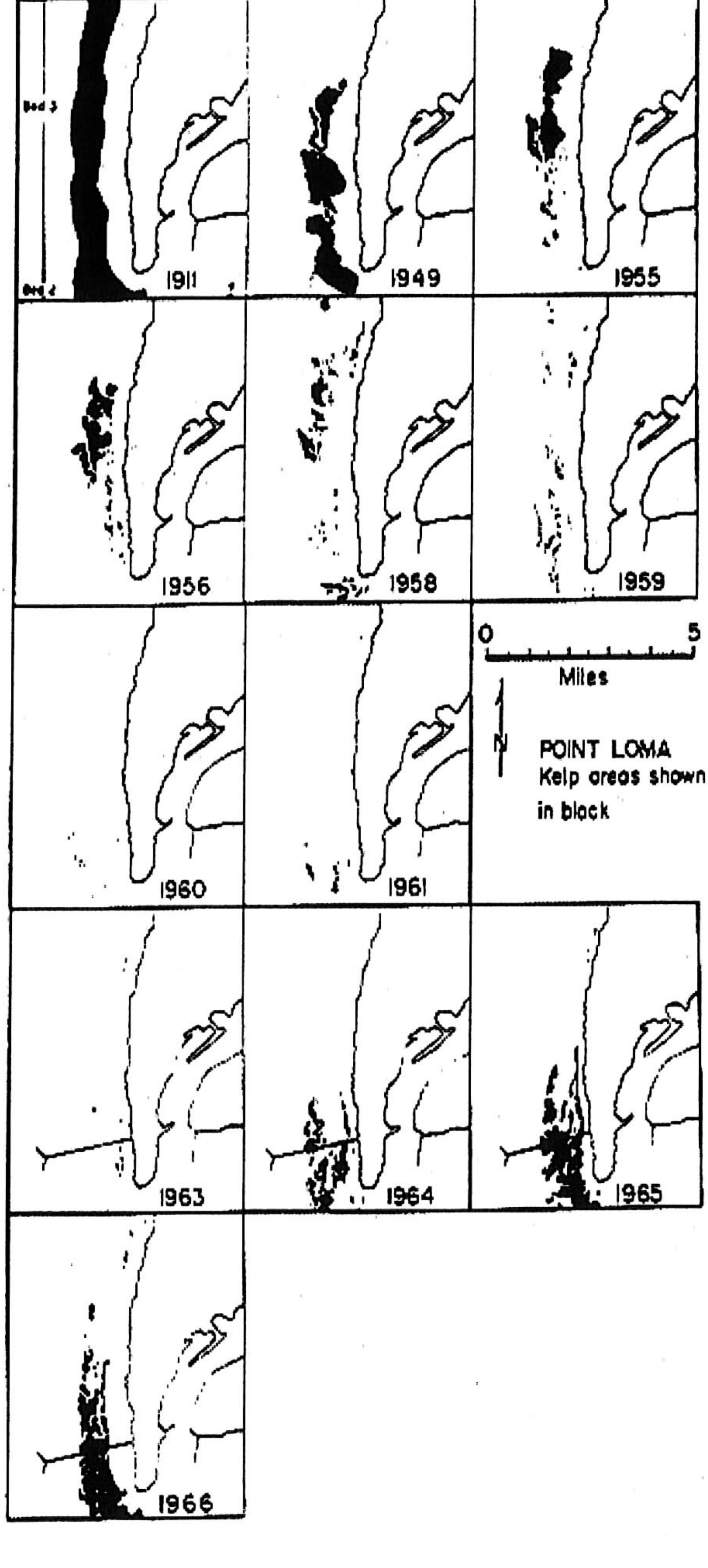
18a



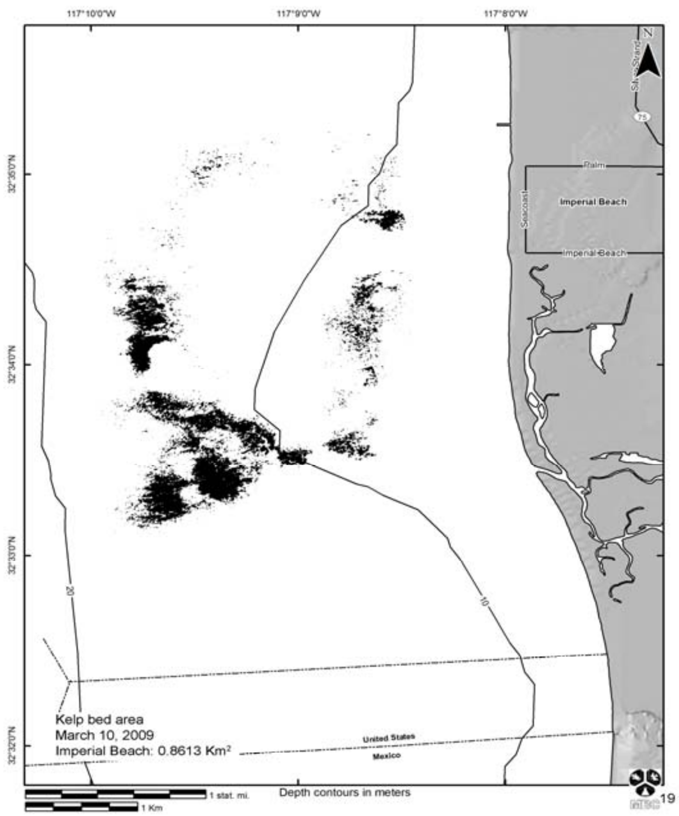
Kelp area
Point Loma: 5.842 km²
28 November &
25 December 1989
Kelp bed area
Point Loma: 5.943 km²
7 April 1990
Kelp bed area
Point Loma: 4.310 km²
31 December 1991
Kelp bed area
Point Loma: 1.153 km²
22 December 1992
Kelp bed area
Point Loma: 1.917 km²
26 November 1993
Kelp bed area
Point Loma: 3.689 km²
25 June 1994
Kelp bed area
Point Loma: 1.134 km²
2 April 1995
Kelp bed area
Point Loma: 1.187 km²
1 January 1996
Kelp bed area
Point Loma: 2.235 km²
7 January 1997
Kelp bed area
Point Loma: 0.295 km²
30 December 1998
Kelp bed area
Point Loma: 1.725 km²
23 November 1999
Kelp bed area
Point Loma: 3.290 km²
21 December 2000
Mission Bay
San Diego River
Ocean Beach
Point Loma
San Diego Bay
Statute Miles
Kilometers

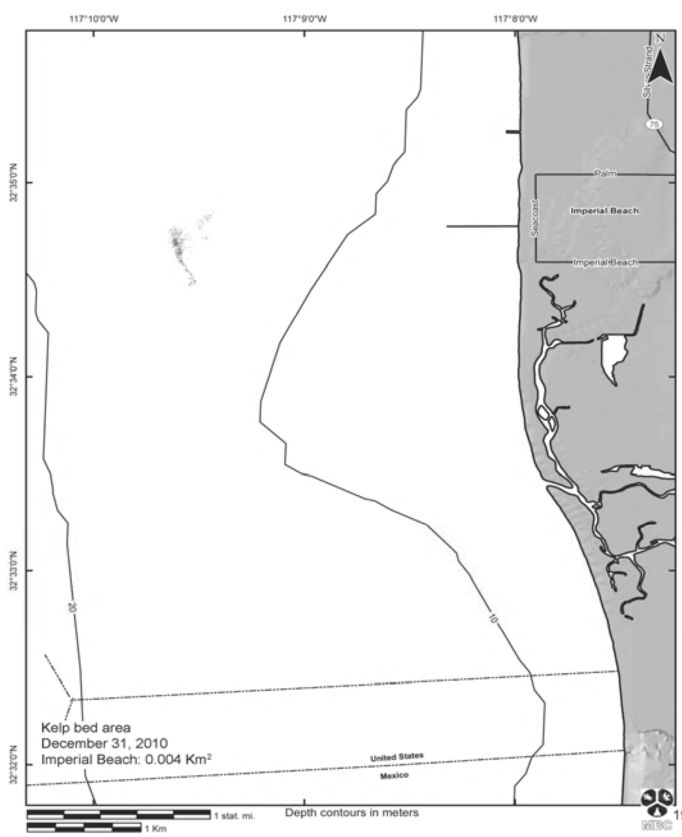


Historical charts of Pt Loma kelp from 1967 to 1989.

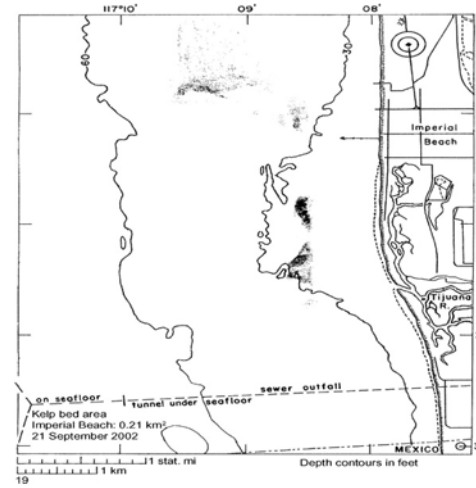


Historical charts of Pt Loma kelp from 1911 to 1989.
The years 1963 through 1965 were sketched from oblique
photos provided by Kelco Company.

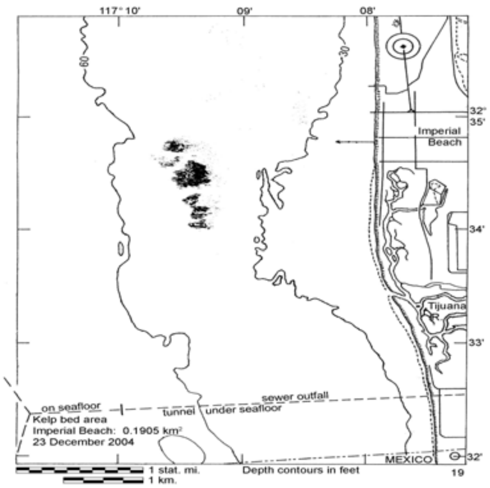

117°10'0"W
117°9'0"W
117°8'0"W
32°35'0"N
32°34'0"N
32°33'0"N
32°32'0"N
Imperial Beach
Palm
Seacoast
Imperial Beach
75
20
10
United States
Mexico
Kelp bed area
March 10, 2009
Imperial Beach: 0.8613 Km²
1 stat. mi.
1 Km
Depth contours in meters
19

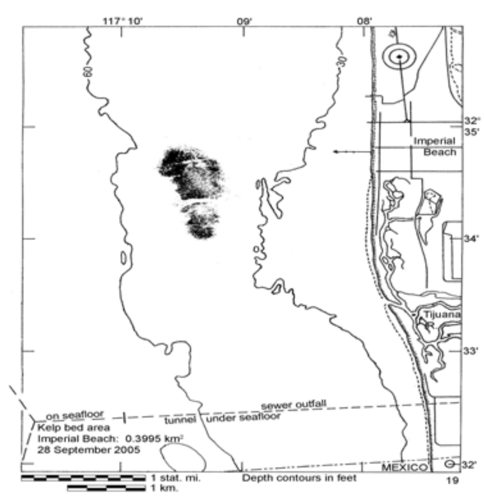

117°10'0"W
117°9'0"W
117°8'0"W
32°35'0"N
32°34'0"N
32°33'0"N
32°32'0"N
Imperial Beach
Palm
Seacoast
Imperial Beach
75
20
10
United States
Mexico
Kelp bed area
December 31, 2010
Imperial Beach: 0.004 Km²
1 stat. mi.
1 Km
Depth contours in meters
19

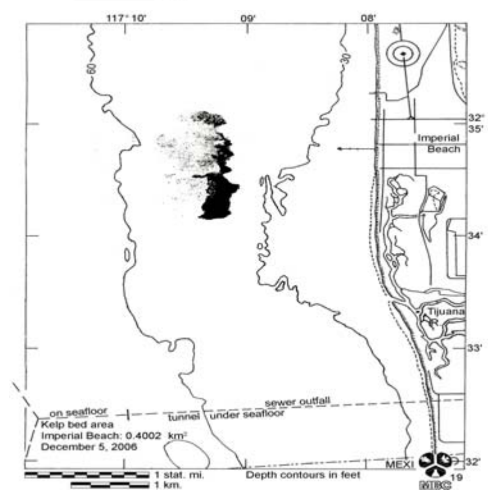

117° 10'
09'
08'
32° 35'
34'
33'
32'
60
30
Imperial Beach
Tijuana R.
sewer outfall
on seafloor
tunnel under seafloor
Kelp bed area
Imperial Beach: 0.08 km²
27 November 2001
MEXICO
1 stat. mi.
1 km.
Depth contours in feet
19

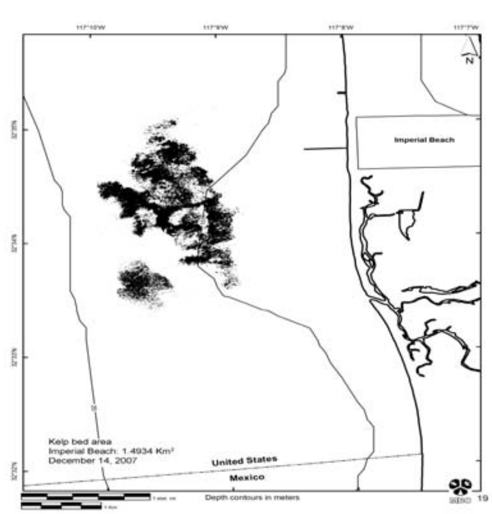

117°10'
09'
08'
32° 35'
34'
33'
32'
60
30
Imperial Beach
Tijuana R.
sewer outfall
on seafloor
Tunnel under seafloor
Kelp bed area
Imperial Beach: 0.21 km²
21 September 2002
MEXICO
1 stat. mi
1 km
Depth contours in feet
19

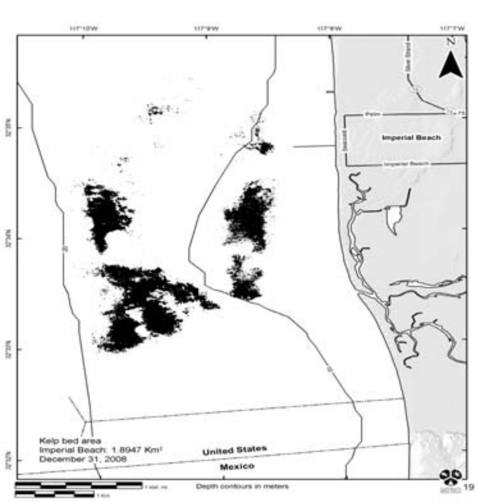

117° 10'
09'
08'
32° 35'
34'
33'
32'
60
30
Imperial Beach
Tijuana
sewer outfall
on seafloor
tunnel under seafloor
Kelp bed area
Imperial Beach: 0.0830 km²
26 October 2003
MEXICO
1 stat. mi.
1 km.
Depth contours in feet
19

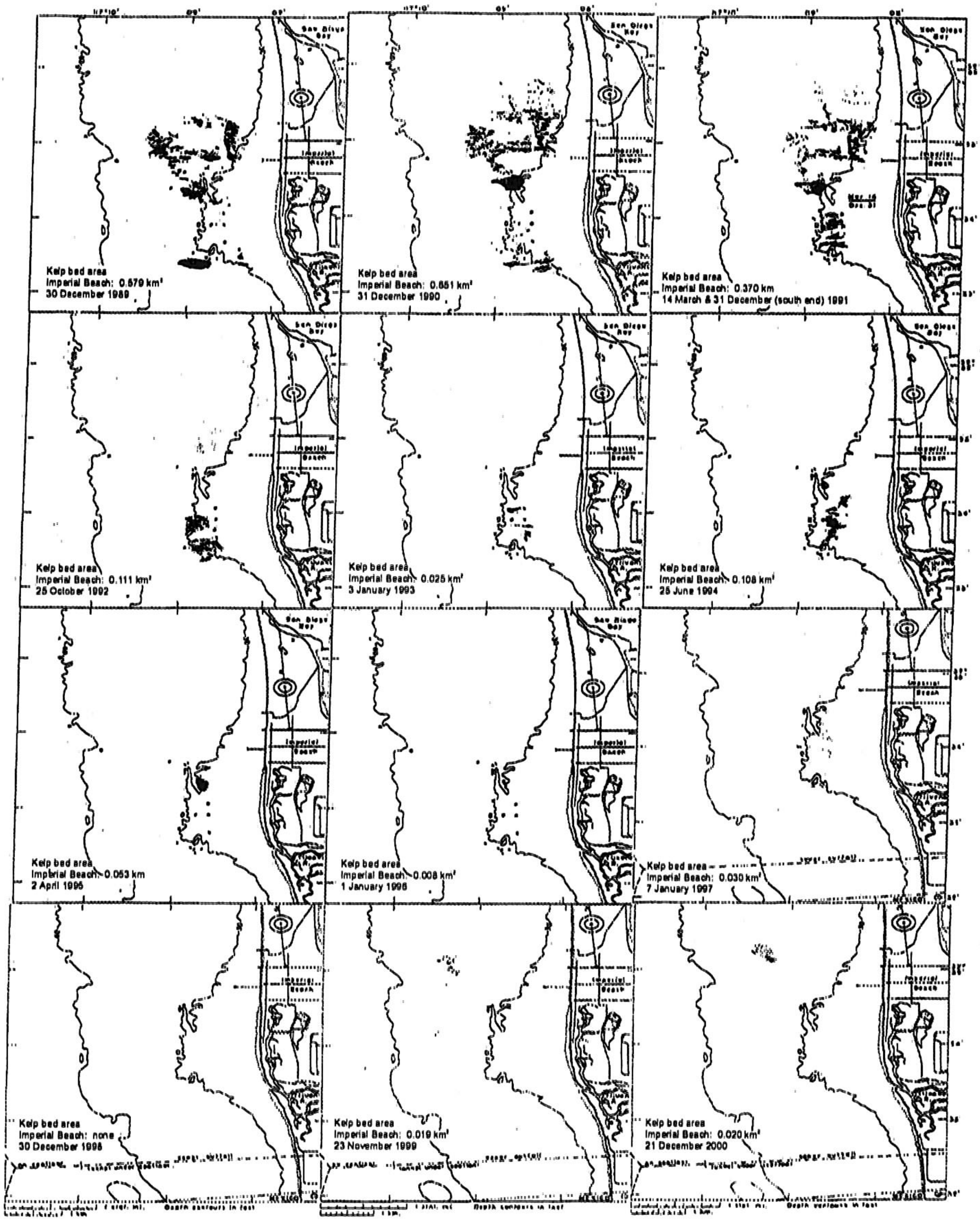

117° 10'
09'
08'
32° 35'
34'
33'
32'
60
30
Imperial Beach
Tijuana
sewer outfall
on seafloor
tunnel under seafloor
Kelp bed area
Imperial Beach: 0.1905 km²
23 December 2004
MEXICO
1 stat. mi.
1 km.
Depth contours in feet
19

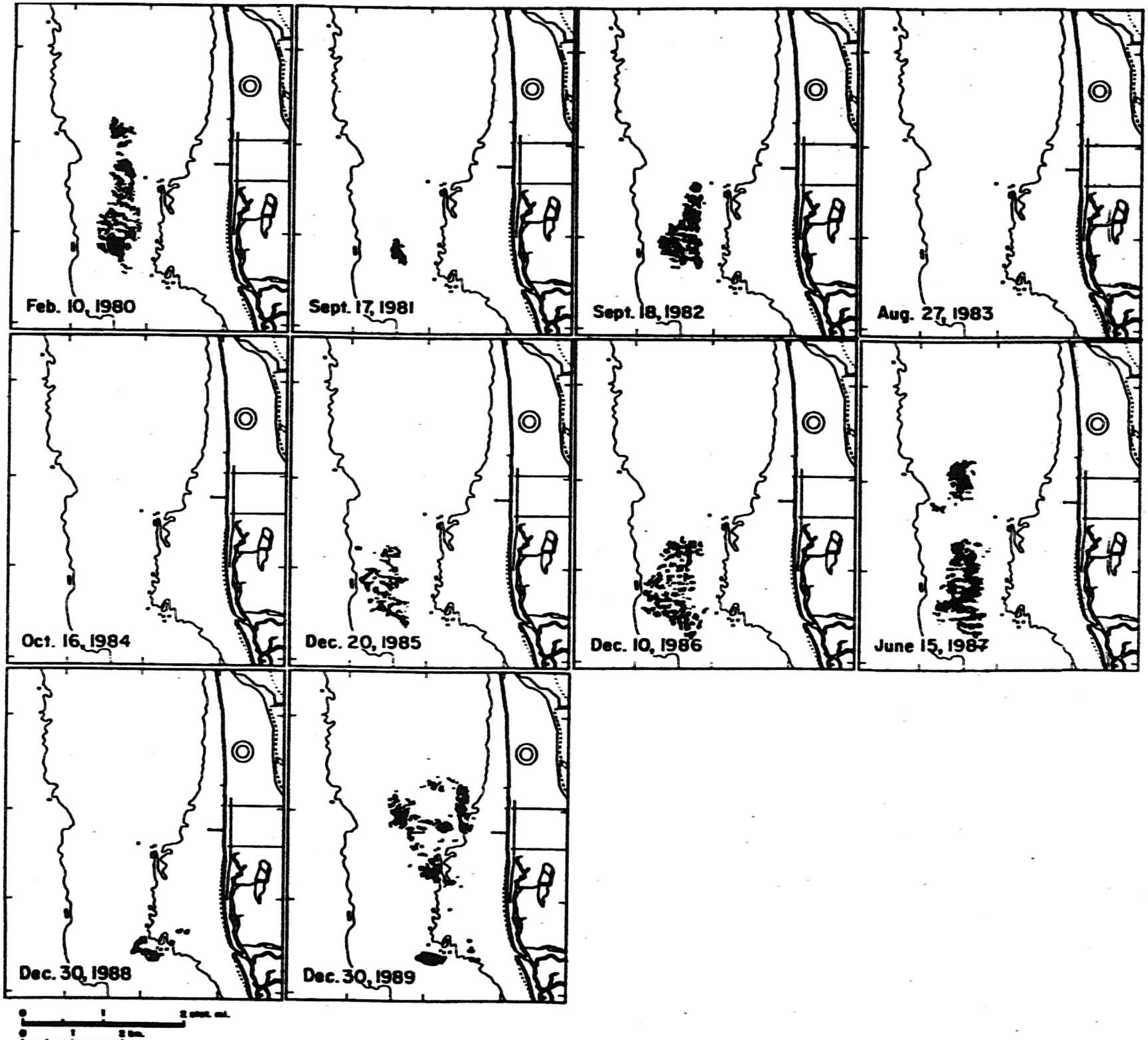

117° 10'
09'
08'
32° 35'
34'
33'
32'
60
30
Imperial Beach
Tijuana
sewer outfall
on seafloor
tunnel under seafloor
Kelp bed area
Imperial Beach: 0.3995 km²
28 September 2005
MEXICO
1 stat. mi.
1 km.
Depth contours in feet
19


117° 10'
09'
08'
32° 35'
34'
33'
32'
60
30
Imperial Beach
Tijuana
sewer outfall
on seafloor
tunnel under seafloor
Kelp bed area
Imperial Beach: 0.4002 km²
December 5, 2006
MEXI
1 stat. mi.
1 km.
Depth contours in feet
MBC
19

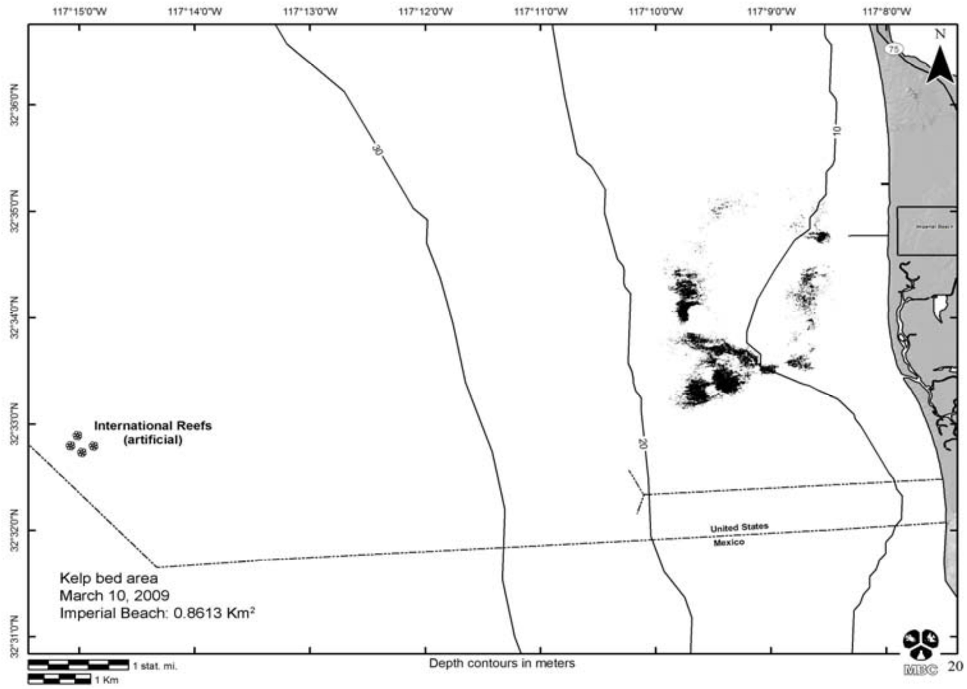

117°10'W
117°9'W
117°8'W
117°7'W
N
Imperial Beach
Kelp bed area
Imperial Beach: 1.4934 Km²
December 14, 2007
United States
Mexico
Depth contours in meters
19

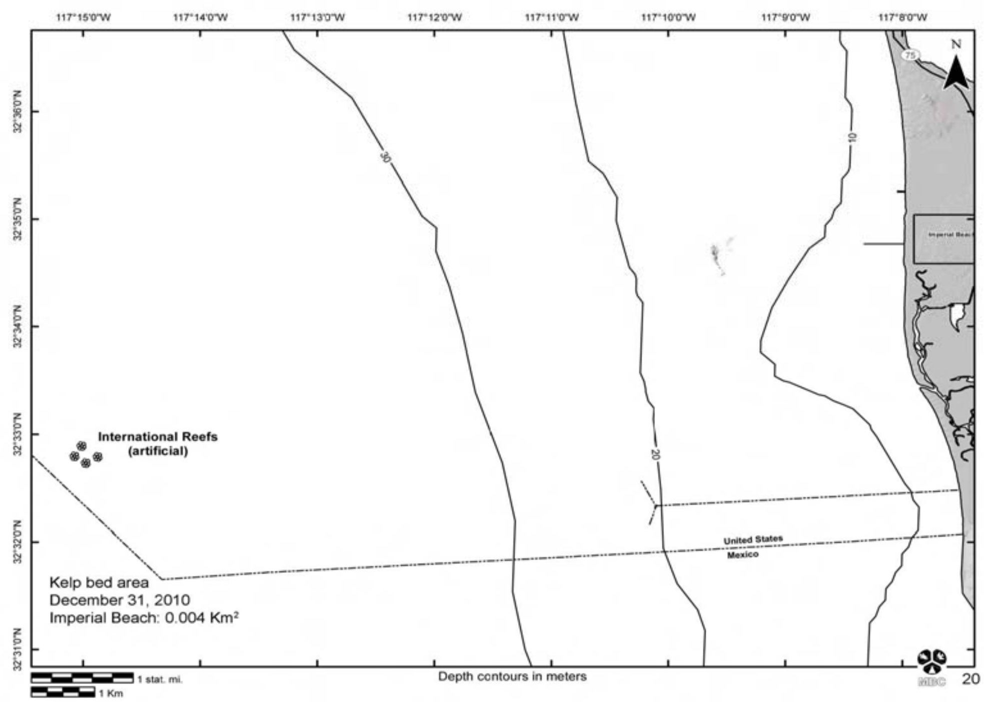

117°10'W
117°9'W
117°8'W
117°7'W
N
Imperial Beach
Kelp bed area
Imperial Beach: 1.8947 Km²
December 31, 2008
United States
Mexico
Depth contours in meters
19

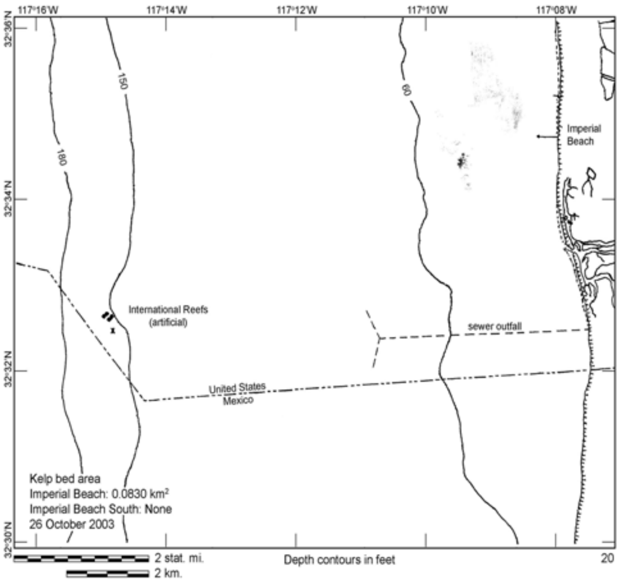

San Diego Bay
Imperial Beach
Tijuana
Kelp bed area
Imperial Beach: 0.579 km²
30 December 1989
Kelp bed area
Imperial Beach: 0.651 km²
31 December 1990
Kelp bed area
Imperial Beach: 0.370 km
14 March & 31 December (south end) 1991
Kelp bed area
Imperial Beach: 0.111 km²
25 October 1992
Kelp bed area
Imperial Beach: 0.025 km²
3 January 1993
Kelp bed area
Imperial Beach: 0.108 km²
25 June 1994
Kelp bed area
Imperial Beach: 0.053 km
2 April 1995
Kelp bed area
Imperial Beach: 0.008 km²
1 January 1996
Kelp bed area
Imperial Beach: 0.030 km²
7 January 1997
Kelp bed area
Imperial Beach: none
30 December 1998
Kelp bed area
Imperial Beach: 0.019 km²
23 November 1999
Kelp bed area
Imperial Beach: 0.020 km²
21 December 2000
sewer outfall
Depth contours in feet

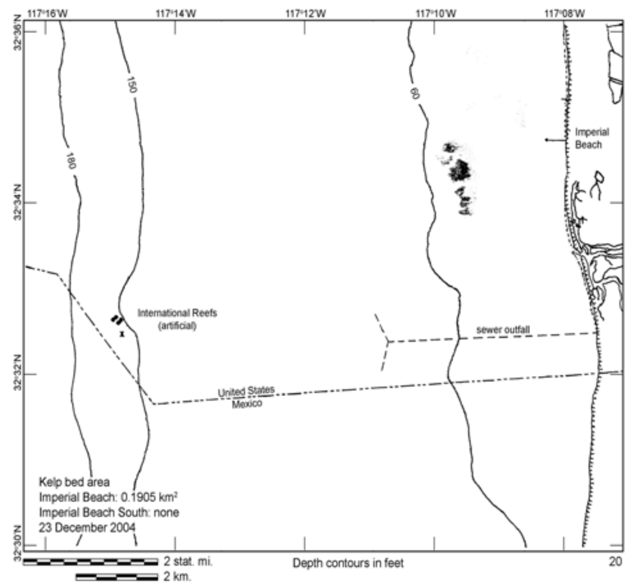


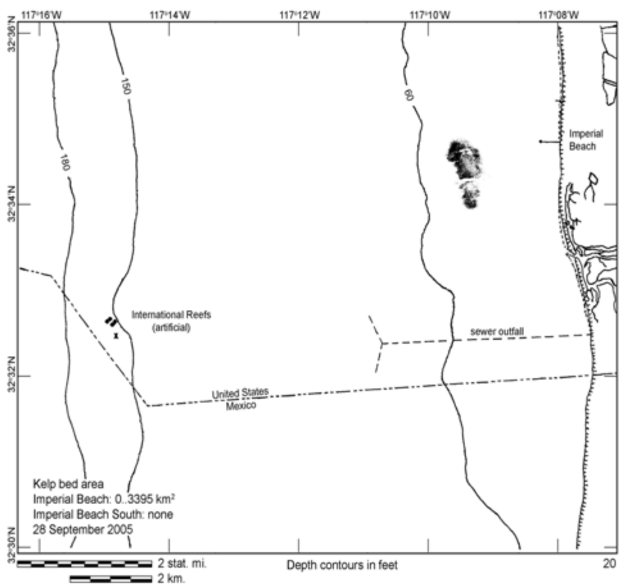
Historical charts of Imperial Beach from 1980 to 1989.

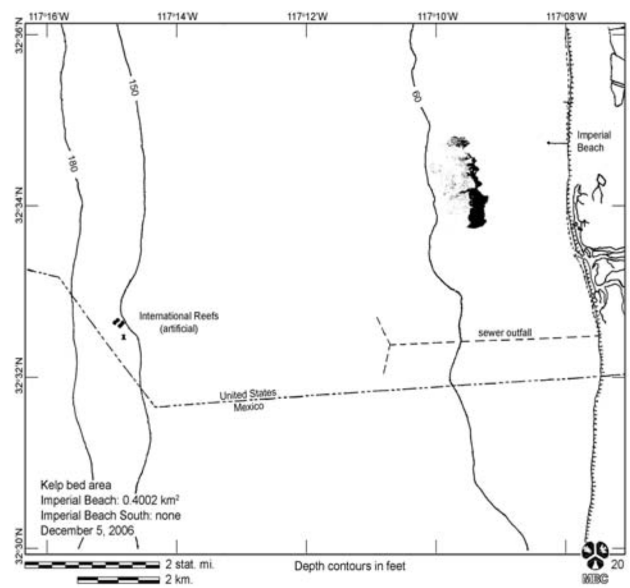

117°15'0"W
117°14'0"W
117°13'0"W
117°12'0"W
117°11'0"W
117°10'0"W
117°9'0"W
117°8'0"W
32°36'0"N
32°35'0"N
32°34'0"N
32°33'0"N
32°32'0"N
32°31'0"N
N
30
20
10
International Reefs
(artificial)
United States
Mexico
Kelp bed area
March 10, 2009
Imperial Beach: 0.8613 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
20

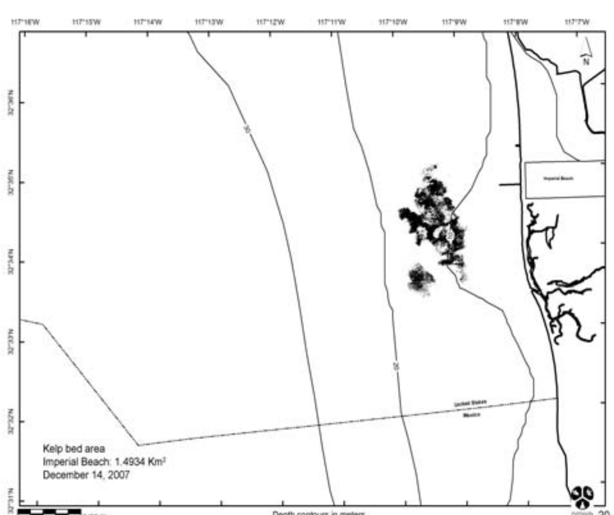

117°15'0"W
117°14'0"W
117°13'0"W
117°12'0"W
117°11'0"W
117°10'0"W
117°9'0"W
117°8'0"W
32°36'0"N
32°35'0"N
32°34'0"N
32°33'0"N
32°32'0"N
32°31'0"N
N
30
20
10
International Reefs
(artificial)
United States
Mexico
Kelp bed area
December 31, 2010
Imperial Beach: 0.004 Km²
1 stat. mi.
1 Km
Depth contours in meters
MBC
20

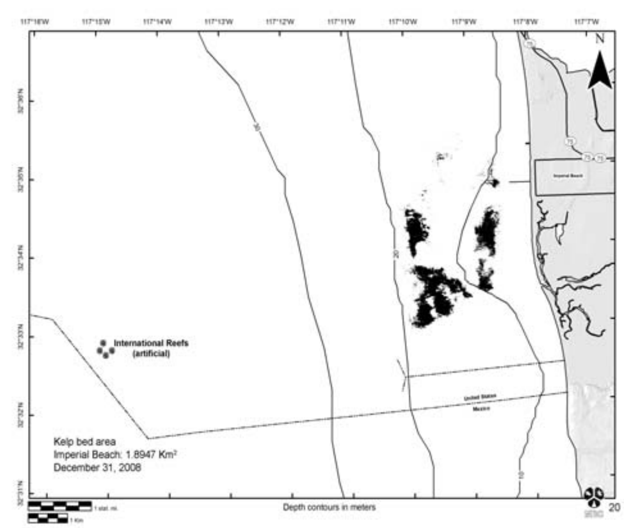

117°16'W
117°14'W
117°12'W
117°10'W
117°08'W
32°36'N
32°34'N
32°32'N
32°30'N
150
180
60
Imperial Beach
International Reefs (artificial)
sewer outfall
United States
Mexico
Kelp bed area
Imperial Beach: 0.0830 km²
Imperial Beach South: None
26 October 2003
2 stat. mi.
2 km.
Depth contours in feet
20


117°16'W
117°14'W
117°12'W
117°10'W
117°08'W
32°36'N
32°34'N
32°32'N
32°30'N
150
180
60
Imperial Beach
International Reefs (artificial)
sewer outfall
United States
Mexico
Kelp bed area
Imperial Beach: 0.1905 km²
Imperial Beach South: none
23 December 2004
2 stat. mi.
2 km.
Depth contours in feet
20


117°16'W
117°14'W
117°12'W
117°10'W
117°08'W
32°36'N
32°34'N
32°32'N
32°30'N
150
180
60
Imperial Beach
International Reefs (artificial)
sewer outfall
United States
Mexico
Kelp bed area
Imperial Beach: 0..3395 km²
Imperial Beach South: none
28 September 2005
2 stat. mi.
2 km.
Depth contours in feet
20


117°16'W
117°14'W
117°12'W
117°10'W
117°08'W
32°36'N
32°34'N
32°32'N
32°30'N
150
180
60
Imperial Beach
International Reefs (artificial)
sewer outfall
United States
Mexico
Kelp bed area
Imperial Beach: 0.4002 km²
Imperial Beach South: none
December 5, 2006
2 stat. mi.
2 km.
Depth contours in feet
MBC
20


Imperial Beach
United States
Mexico
Kelp bed area
Imperial Beach: 1.4934 Km²
December 14, 2007
Depth contours in meters
MBC
20


N
Imperial Beach
International Reefs (artificial)
United States
Mexico
Kelp bed area
Imperial Beach: 1.8947 Km²
December 31, 2008
Depth contours in meters
MBC
20

APPENDIX C

Flight Data Reports

2011 Quarterly Kelp Survey Flight Schedule

Mid-March	Tide (Scripps Pier)	Sea/Swell (feet)	Wind (knots)	Weather	Flight Status	Reason/Comments
16-Mar-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
17-Mar-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
18-Mar-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast partial range	Survey Cancelled	Cloud cover
19-Mar-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
28-Mar-11	Less than 1' MLLW	7 Feet	15 - 20 knots	Partly cloudy entire range	Survey Cancelled	Winds, seas, cloud cover
29-Mar-11	Less than 1' MLLW	7 Feet	15 - 20 knots	Partly cloudy entire range	Survey Cancelled	Winds, seas, cloud cover
30-Mar-11	Less than 1' MLLW	7 Feet	15 - 20 knots	Partly cloudy entire range	Survey Cancelled	Winds, seas, cloud cover
31-Mar-11	Less than 1' MLLW	7 Feet	15 - 20 knots	Partly cloudy entire range	Survey Cancelled	Winds, seas, cloud cover
14-Apr-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast partial range	Survey Cancelled	Cloud cover
15-Apr-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
16-Apr-11	0.0' - 0.7' MLLW	3-5 Feet	Calm	Clear	Survey Flown	Optimum Conditions
Mid-June	**Tide (Scripps Pier)**	**Sea/Swell (feet)**	**Wind (knots)**	**Weather**	**Flight Status**	**Reason/Comments**
15-Jun-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
16-Jun-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
17-Jun-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
18-Jun-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
19-Jun-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
29-Jun-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
30-Jun-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
1-Jul-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
2-Jul-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
3-Jul-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
4-Jul-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
14-Jul-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
15-Jul-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
16-Jul-11	Less than 1.5' MLLW	Less than 5 Feet	Less than 10 knots	Overcast entire range	Survey Cancelled	Cloud cover
1-Aug-11	1.2' - 1.4' MLLW	3-5 Feet	Calm	Clear	Survey Flown	Optimum Conditions
Mid-Sept. - Mid Oct.	**Tide (Scripps Pier)**	**Sea/Swell (feet)**	**Wind (knots)**	**Weather**	**Flight Status**	**Reason/Comments**
23-Oct-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
24-Oct-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
25-Oct-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
26-Oct-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
27-Oct-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy entire range	Survey Cancelled	Cloud cover
28-Oct-11	2.4' - 0.2' MLLW	3-5 Feet	Calm	Clear	Survey Flown	Optimum Conditions
Mid-December	**Tide (Scripps Pier)**	**Sea/Swell (feet)**	**Wind (knots)**	**Weather**	**Flight Status**	**Reason/Comments**
19-Dec-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy partial range	Survey Cancelled	Cloud cover
20-Dec-11	Less than 1' MLLW	Less than 5 Feet	Less than 10 knots	Partly cloudy partial range	Survey Cancelled	Cloud cover
21-Dec-11	0.9' - 0.0' MLLW	3-5 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:	3/2011
City/State/Zip:	Costa Mesa, CA 92626	Data Acquisition Completed:	4/16/2011
Phone 1/Phone 2:	(714) 850-4830	Draft Report Materials Due:	
Fax/E-Mail:	(714) 850-4840	Final Report Materials Due:	5/2011

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

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach - April 16, 2011**
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:		April 16, 2011			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear to partly overcast
	Photographic Film Imagery - 35 mm	Altitude:	12,500' MSL	Sun Angle:	> 30 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:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1150-1306
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	0.0' to 0.7' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Optimum Conditions

Range (s) Surveyed	Ventura to Imperial Beach Note: This quarterly survey scheduled for March 2011 could not be completed within the month due to adverse weather from 3/10-3/31/11. Excellent weather/tidal conditions were present on the selected survey date (4/16/11).	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed throughout and larger than normal spring extent.
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

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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:	6/2011
City/State/Zip:	Costa Mesa, CA 92626	Data Acquisition Completed:	8/1/2011
Phone 1/Phone 2:	(714) 850-4830	Draft Report Materials Due:	
Fax/E-Mail:	(714) 850-4840	Final Report Materials Due:	8/2011

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

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach - August 1, 2011**
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:		August 1, 2011			
	Survey Type	**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear to partly overcast
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 30 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:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1615-1800
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	1.2' (+) to 1.4' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Optimum Conditions

Range (s) Surveyed	Ventura to Imperial Beach Note: This quarterly survey scheduled for June 2011 could not be completed within the month due to adverse weather (mainly coastal fog). Optimum weather/tidal conditions were present on the selected survey date (8/1/11).	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed.
Imagery Quality/ Comments	Excellent	All surface kelp canopies, were photographed within the above range and the image processing was conducted normally. All of the imagery was judged of excellent quality and was useable for the subsequent maping of the kelp resource.
	Lens Note	30mm (digital SLR camera) is similiar focal length to 50mm (35mm film SLR camera)

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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:	10/2011
City/State/Zip:	Costa Mesa, CA 92626	Data Acquisition Completed:	10/28/2011
Phone 1/Phone 2:	(714) 850-4830	Draft Report Materials Due:	
Fax/E-Mail:	(714) 850-4840	Final Report Materials Due:	11/2011

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow		
Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach - October 28, 2011**
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:		October 28, 2011			
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:	> 30 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:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1404-1543
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	3.0' (+) to 0.2' (-) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Optimum Conditions

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

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(831) 728-5900 (ph./fax)

Signed: ______________________ Bob Van Wagenen, Director

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Data Acquisition
Flight Data Report

Contracting Agency/Contact		Contract/Order #/Agency File #	
Contracting Agency:	MBC Applied Environmental Sciences	Contract/Order #:	
Division:		Agency File #:	
Contact/Title:	Michael Curtis	**Calendar**	
Address:	3000 Redhill Ave.	Services Ordered:	12/2011
City/State/Zip:	Costa Mesa, CA 92626	Data Acquisition Completed:	12/11/2011
Phone 1/Phone 2:	(714) 850-4830	Draft Report Materials Due:	
Fax/E-Mail:	(714) 850-4840	Final Report Materials Due:	1/2012

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow		
Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach - December 21, 2011**
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 21, 2011			
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:	> 30 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:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1330-1500
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	0.9' (-) to 0.0' MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Optimum Conditions

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

Ecoscan Resource Data
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Watsonville, CA 95076
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Signed: ____________________ Bob Van Wagenen, Director

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Data Acquisition

Flight Data Report

Contracting Agency/Contact		**Contract/Order #/Agency File #**	
Contracting Agency:	MBC Applied Environmental Sciences	**Contract/Order #:**	
Division:		**Agency File #:**	
Contact/Title:	Michael Curtis	**Calendar**	
Address:	3000 Redhill Ave.	**Services Ordered:**	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

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Watsonville, CA 95076

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Signed: ____________________ Bob Van Wagenen, Director

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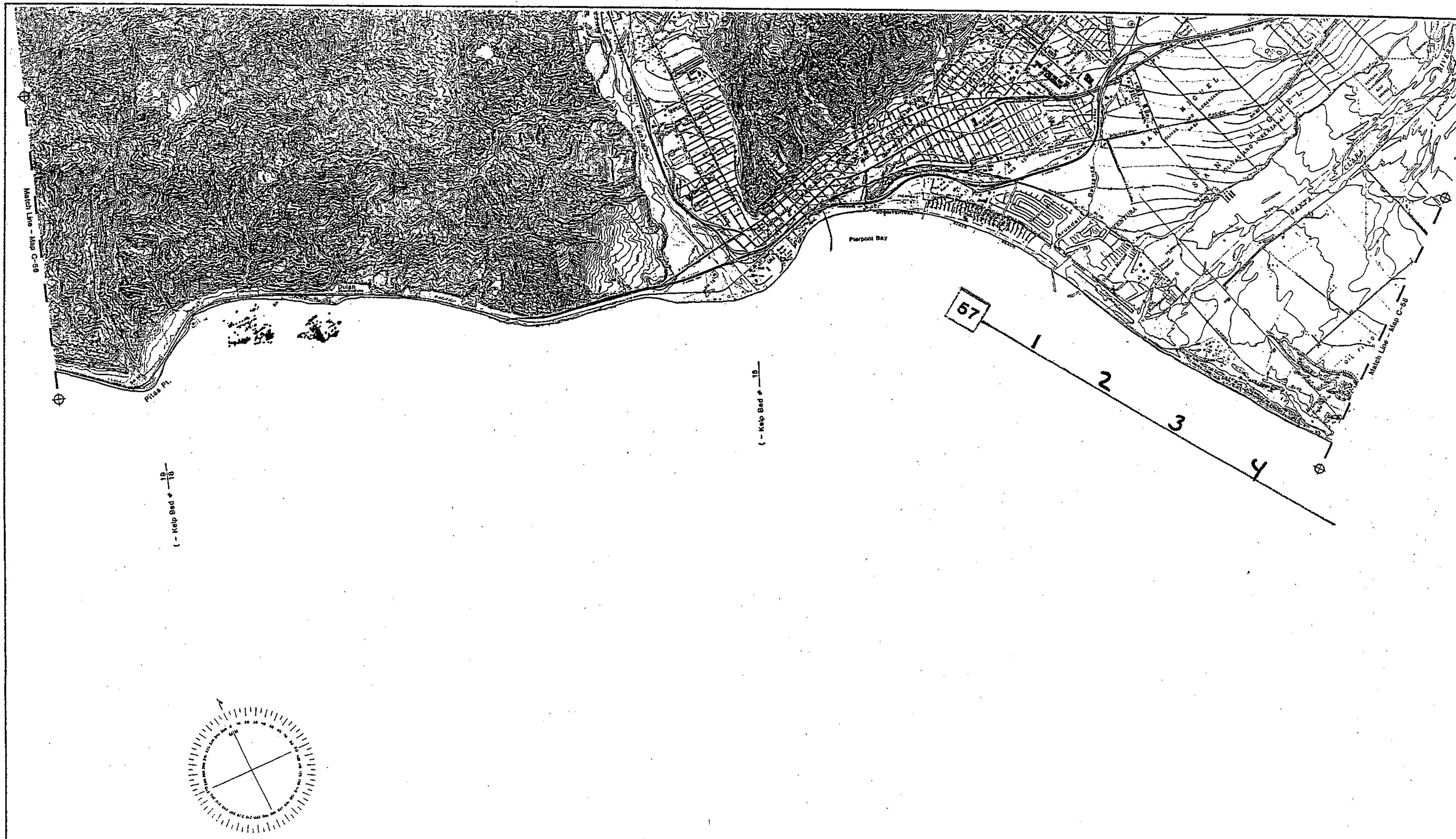


SCALE 1:24000

ROAD CLASSIFICATION

Heavy-duty ——— Light-duty ———

Medium-duty ——— Unimproved dirt - - - - -

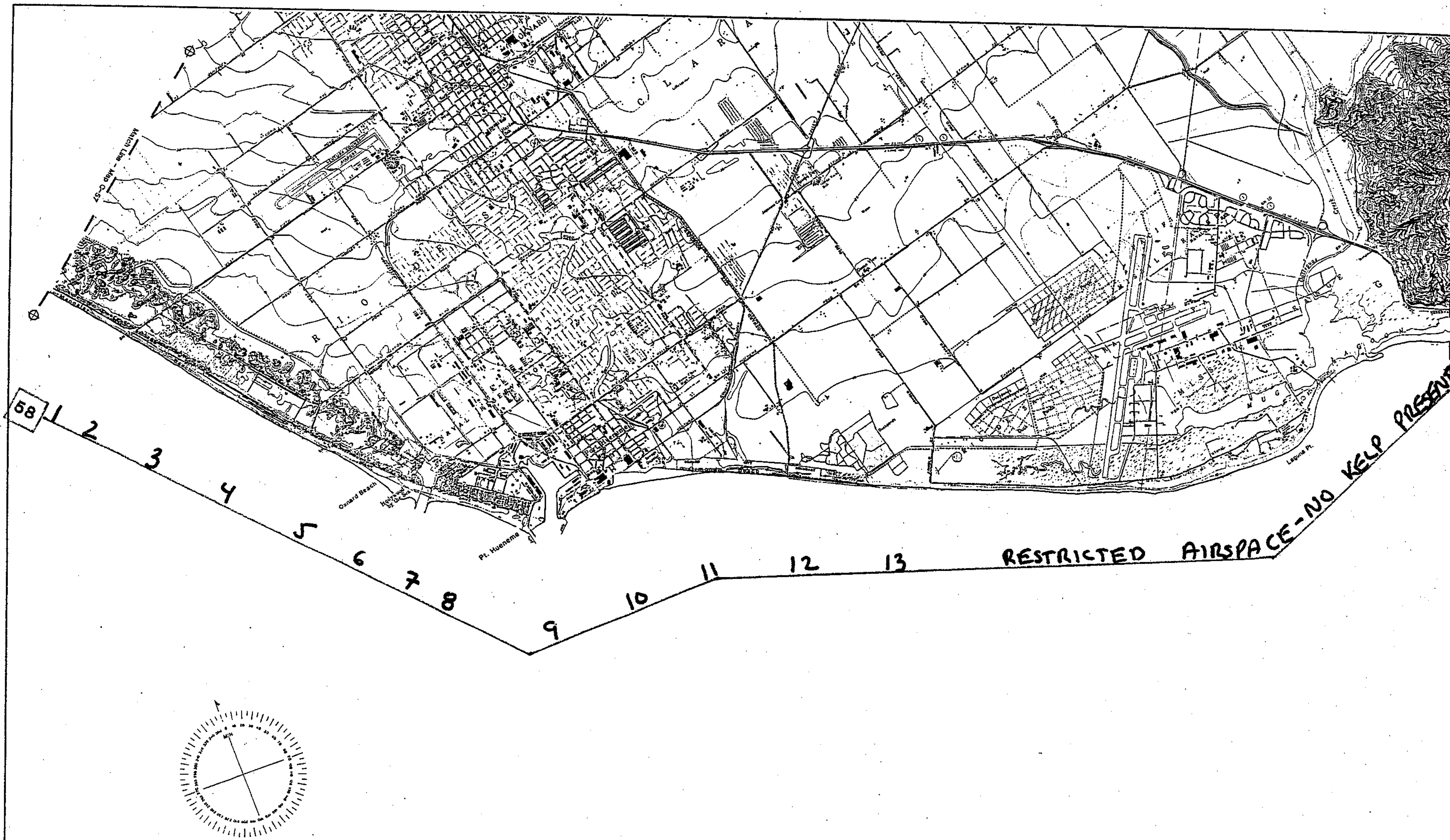
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA

LEGEND

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

Survey Date: DEC 2 1 2011

CALIFORNIA COASTAL KELP RESOURCES		
SCALE: 1:24,000 / DATE: 7/89	APPROVED BY:	DRAWN BY / REVISED 1.0
Ventura		
© 89 ECOSCAN		DRAWING NUMBER C - 57



SCALE 1:24000

ROAD CLASSIFICATION

Heavy-duty — Light-duty

Medium-duty — Unimproved dirt

CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929

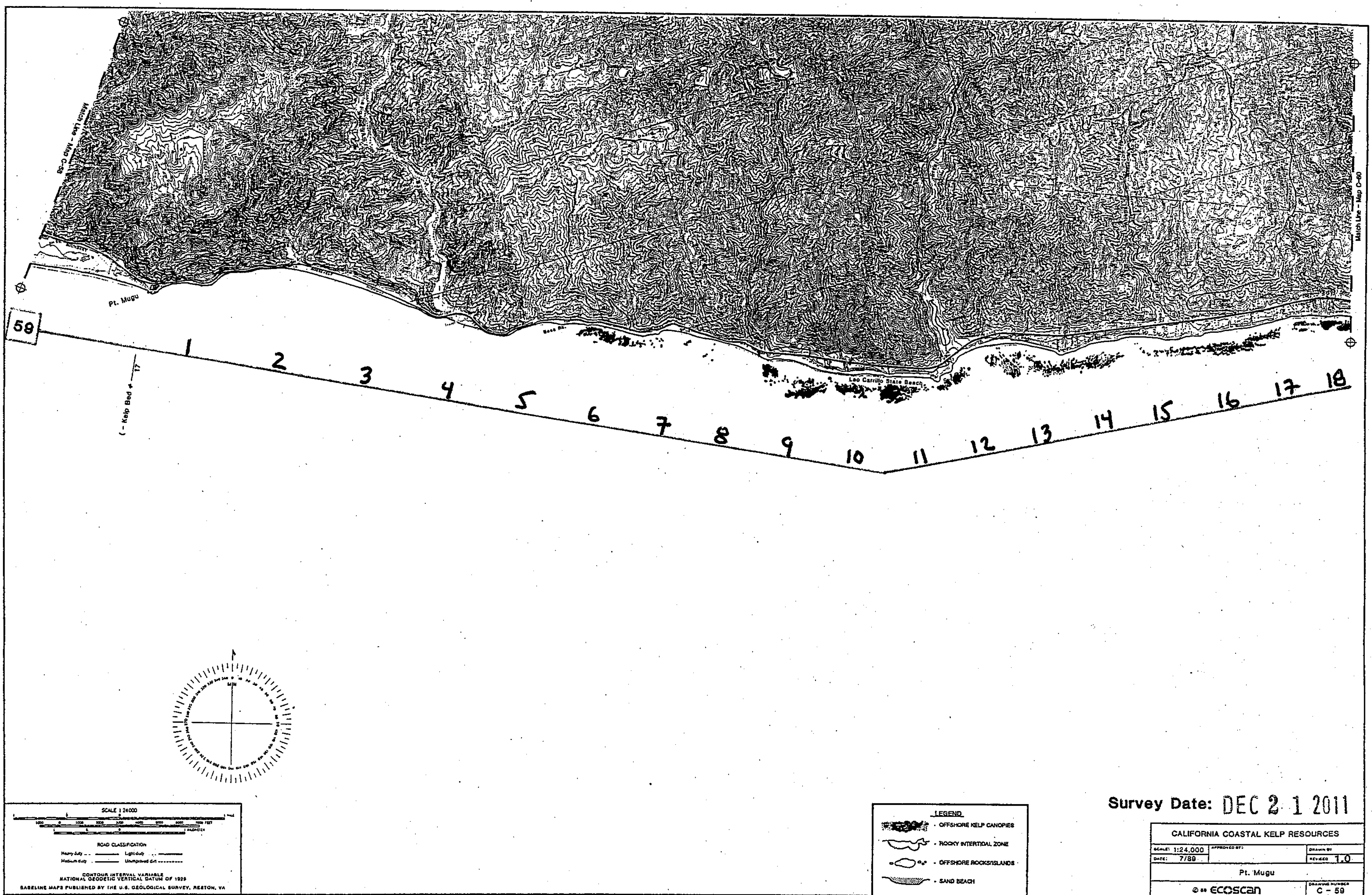
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA

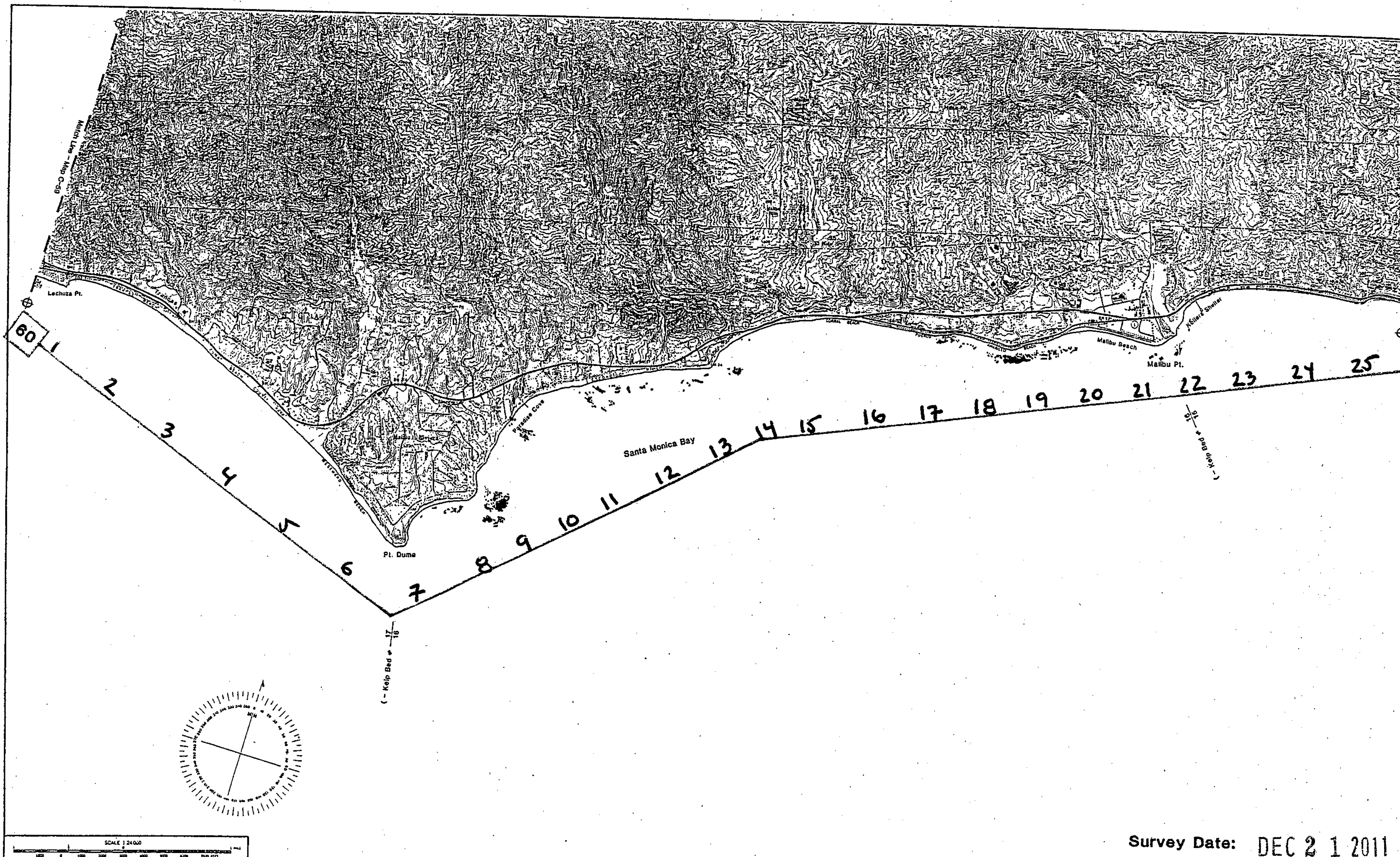
LEGEND

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

Survey Date: DEC 2 1 2011

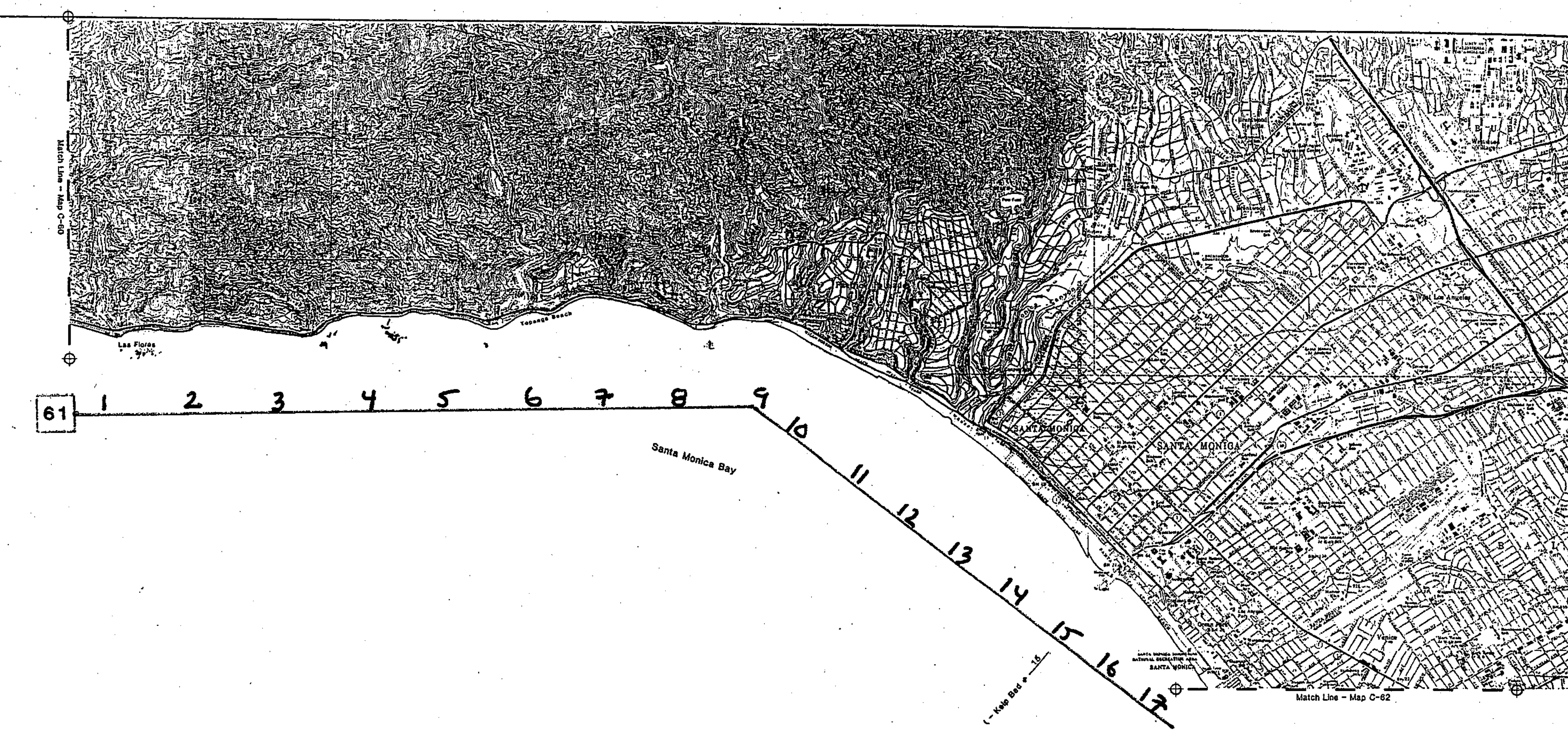
CALIFORNIA COASTAL KELP RESOURCES		
SCALE: 1:24,000	APPROVED BY:	DRAWN BY
DATE: 7/89		REVISED 1.0
Port Hueneme		
ECOSCAN		DRAWING NUMBER C - 58

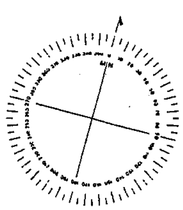

Match Line - Map C-58
Match Line - Map C-60
Pt. Mugu
Leo Carrillo State Beach
58
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
(- Kelp Bed + 17
SCALE 1:24000
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH
Survey Date: DEC 21 2011
CALIFORNIA COASTAL KELP RESOURCES
SCALE: 1:24,000
DATE: 7/89
REVISED 1.0
Pt. Mugu
ECOSCAN
DRAWING NUMBER C - 59



Survey Date: DEC 2 1 2011

CALIFORNIA COASTAL KELP RESOURCES		
SCALE: 1:24,000	APPROVED BY:	DRAWN BY
DATE: 7/89		REVISED 1.0
Pt. Dume		
ECOSCAN		DRAWING NUMBER C - 60





SCALE 1:24000

ROAD CLASSIFICATION

Heavy-duty — Light-duty

Medium-duty — Unimproved dirt

CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929

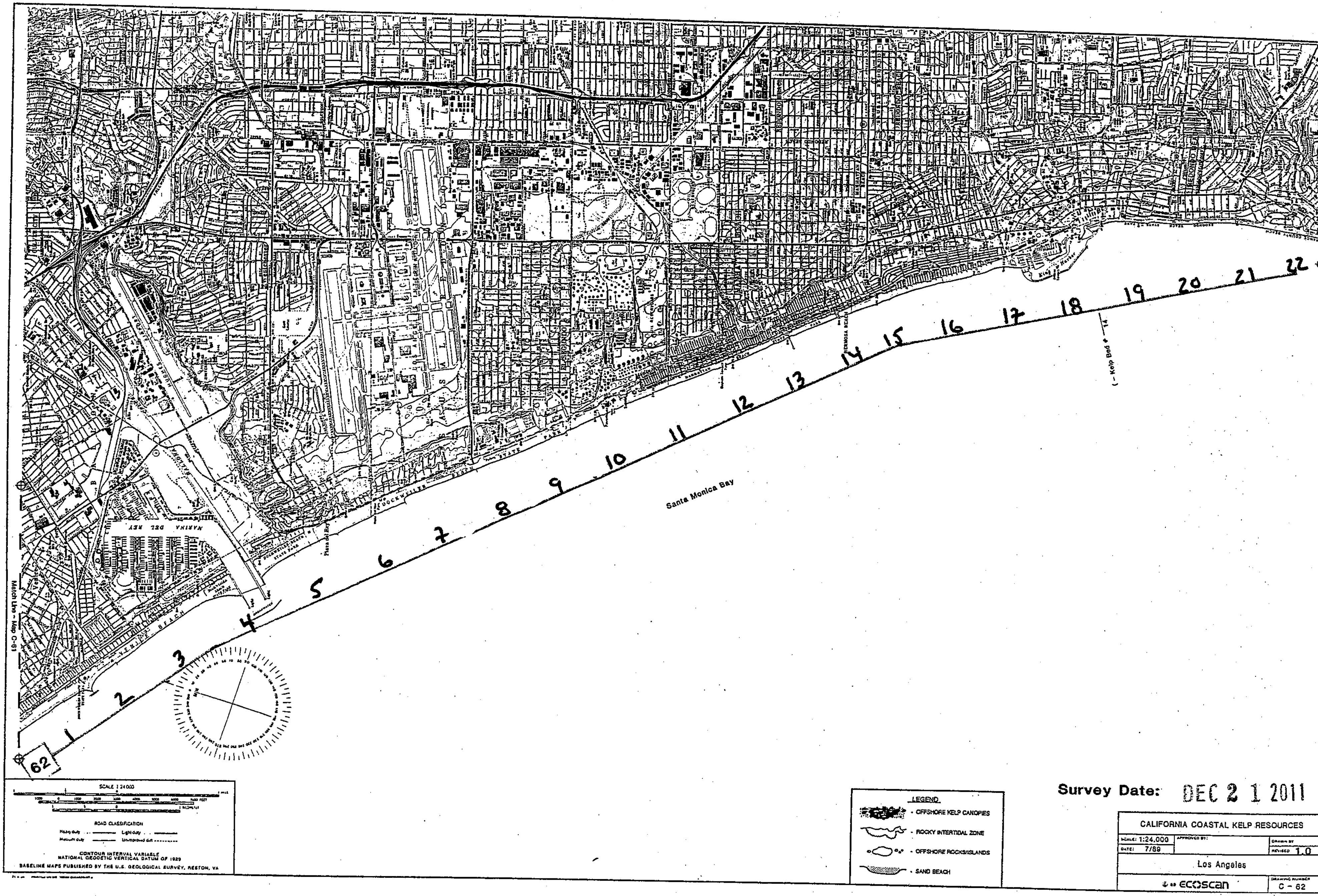
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA

LEGEND

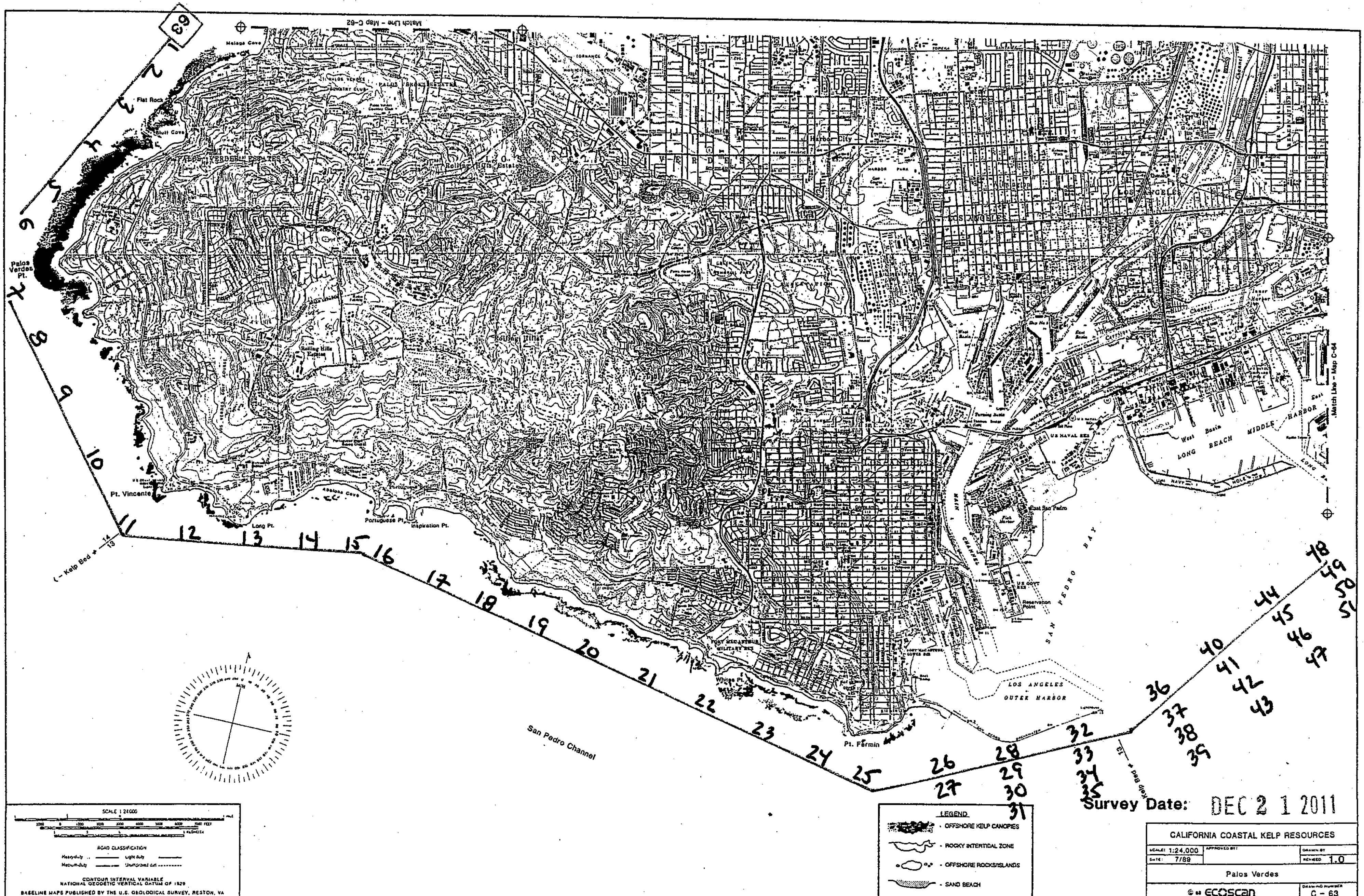
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH

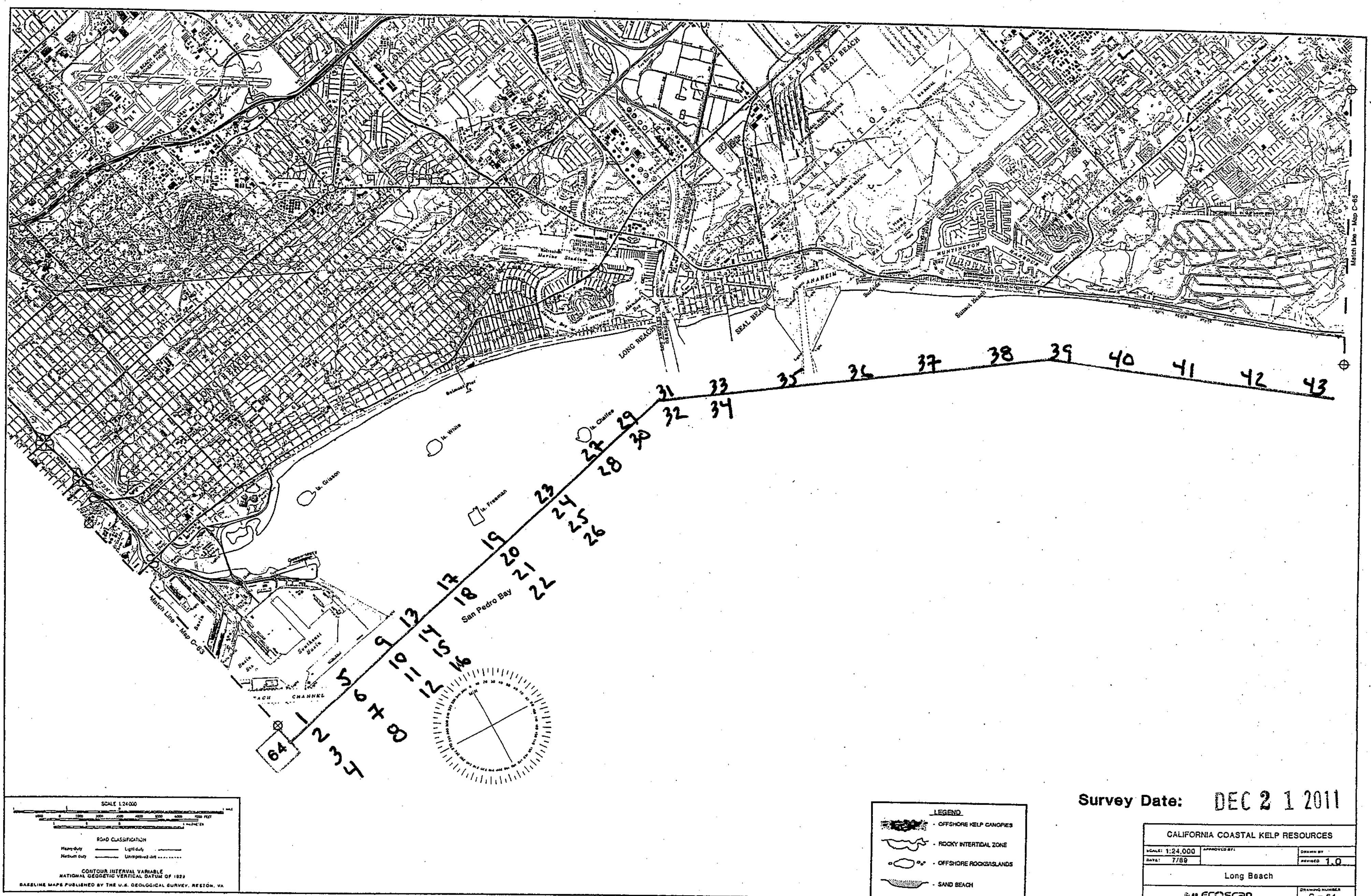
Survey Date: DEC 2 1 2011

CALIFORNIA COASTAL KELP RESOURCES		
SCALE: 1:24,000 / DATE: 7/89	APPROVED BY:	DRAWN BY: / REVISED: 1.0
Santa Monica		
© 89 ecoscan		DRAWING NUMBER C - 61



Match Line - Map C-63
Match Line - Map C-61
Santa Monica Bay
MARINA DEL REY
Playa del Rey
HERMOSA BEACH
(- Kelp Bed # 14
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
62
SCALE 1:24000
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH
Survey Date: DEC 2 1 2011
CALIFORNIA COASTAL KELP RESOURCES
SCALE: 1:24,000
DATE: 7/89
APPROVED BY:
DRAWN BY
REVISED 1.0
Los Angeles
ECOSCAN
DRAWING NUMBER
C - 62

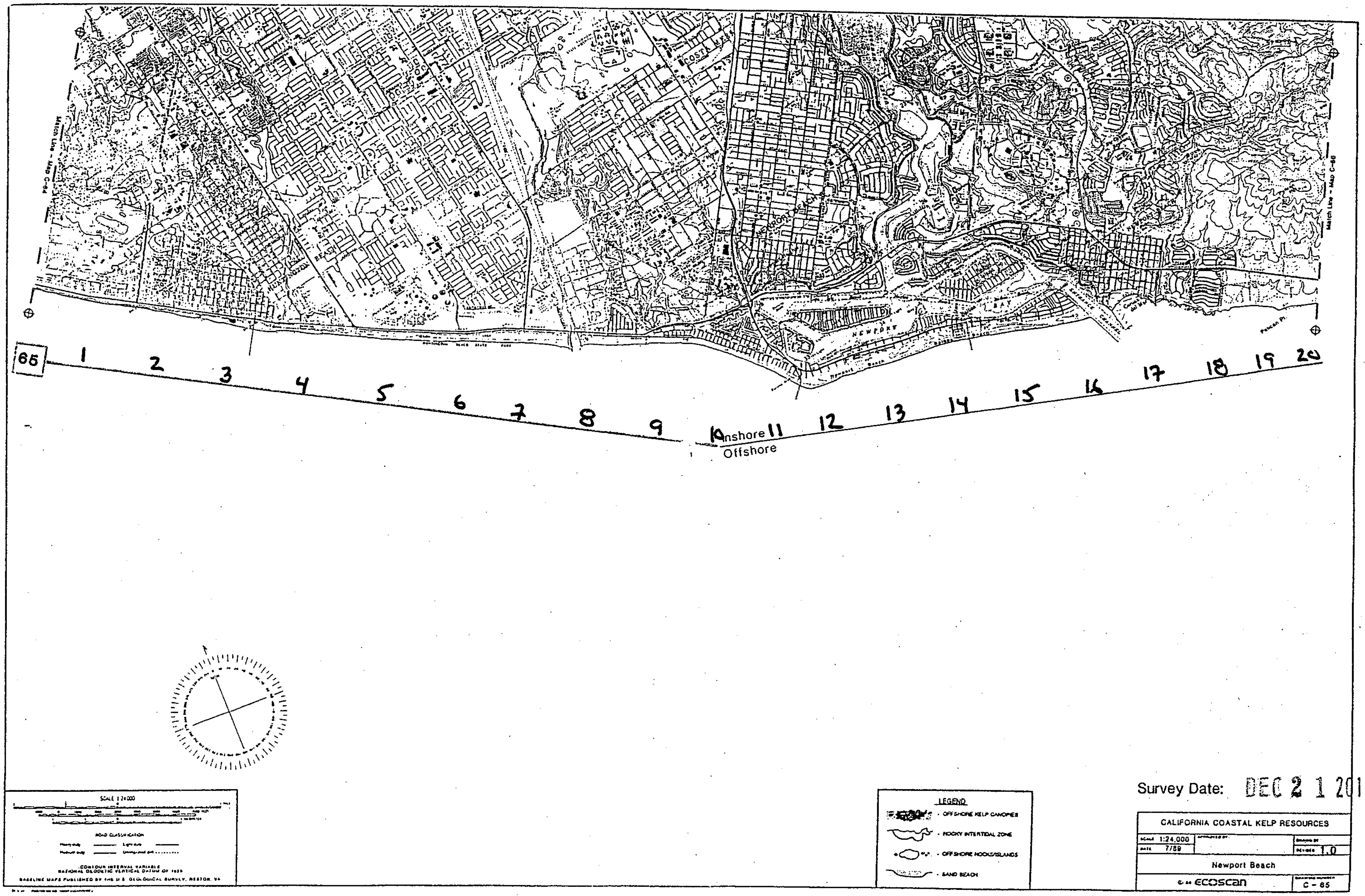

Survey Date: DEC 2 1 2011
CALIFORNIA COASTAL KELP RESOURCES
SCALE: 1:24,000
DATE: 7/89
REVISED 1.0
Palos Verdes
© 88 ECOSCAN
C - 63
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH
SCALE 1:24000
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA
Match Line - Map C-62
Match Line - Map C-64
63
San Pedro Channel
Palos Verdes Pt.
Pt. Vincente
Long Pt.
Portuguese Pt.
Inspiration Pt.
Pt. Fermin
Flat Rock
Malaga Cove
LOS ANGELES OUTER HARBOR
SAN PEDRO BAY
MAIN CHANNEL
LONG BEACH MIDDLE HARBOR
Kelp Bed # 14/13
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 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51



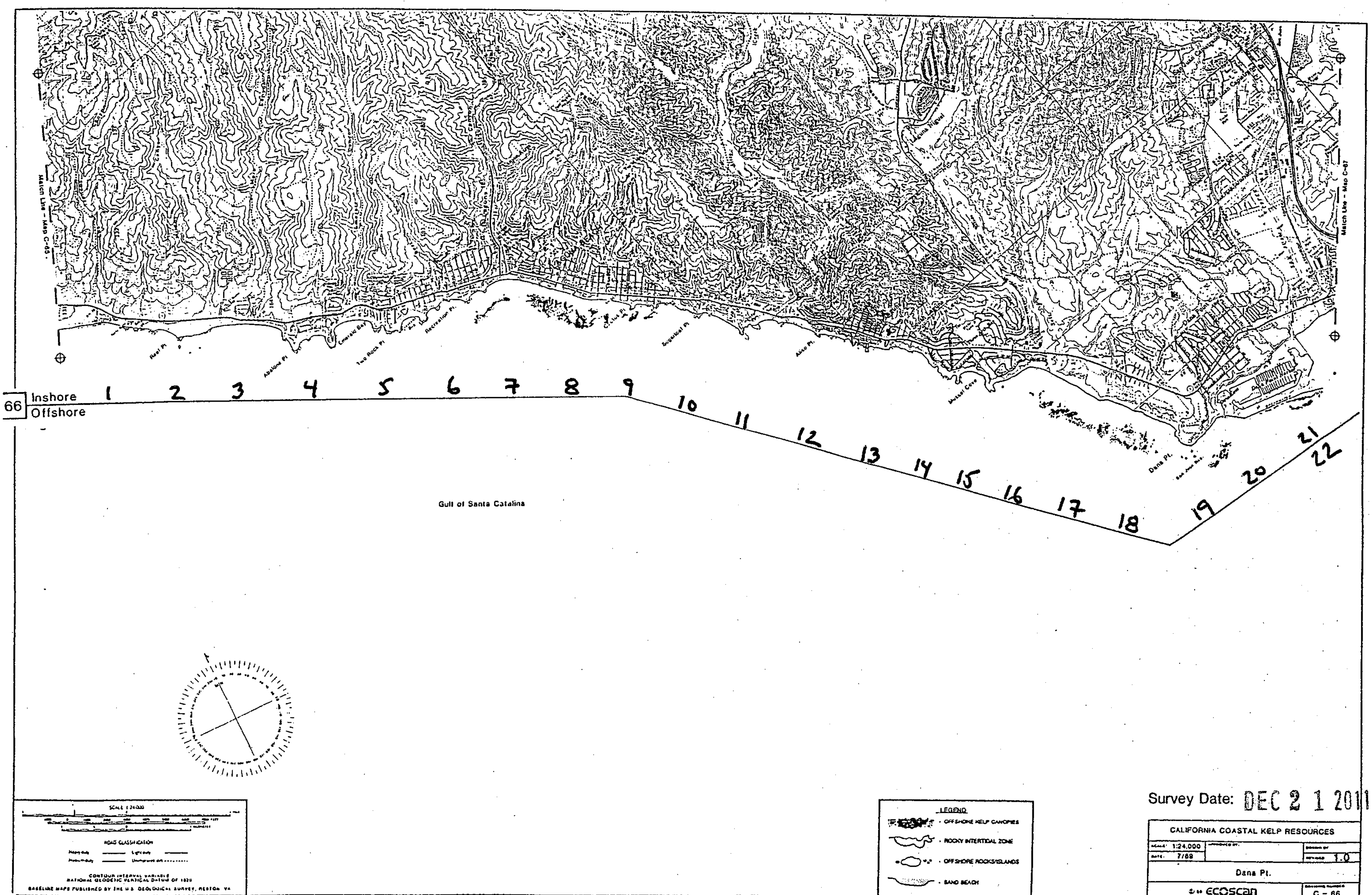
Survey Date: DEC 2 1 2011

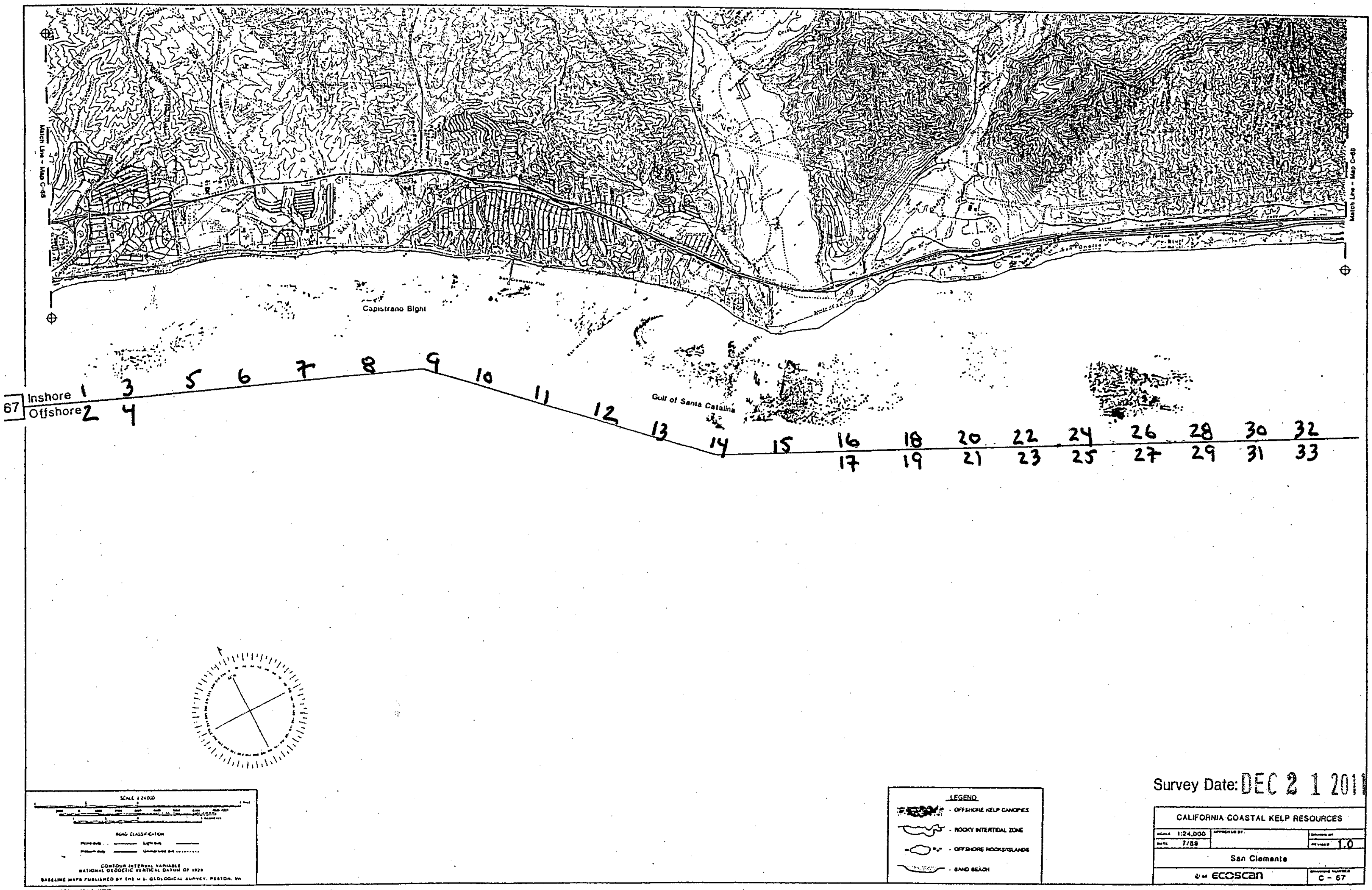
LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE ROCKS/ISLANDS
- SAND BEACH

CALIFORNIA COASTAL KELP RESOURCES		
SCALE: 1:24,000	APPROVED BY:	DRAWN BY:
DATE: 7/89		REVISED: 1.0
Long Beach		
ECOSCAN		DRAWING NUMBER C - 64



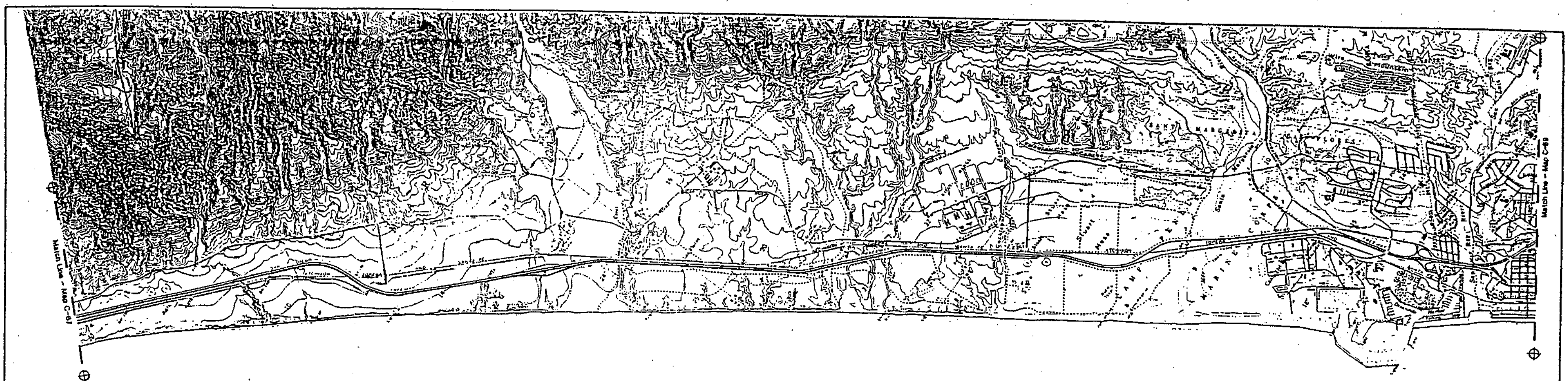
Match Line - Map C-64
Match Line - Map C-66
65
1
2
3
4
5
6
7
8
9
10
Inshore
Offshore
11
12
13
14
15
16
17
18
19
20
NEWPORT
SCALE 1:24000
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 1 2011
CALIFORNIA COASTAL KELP RESOURCES
SCALE 1:24,000
DATE 7/89
REVISION 1.0
Newport Beach
ECOSCAN
C - 65


Match Line - Map C-65
Match Line - Map C-67
Real Pt.
Abalone Pt.
Emerald Bay
Two Rock Pt.
Recreation Pt.
Cactus Pt.
Sugarloaf Pt.
Aliso Pt.
Laguna Niguel
Mussel Cove
Dana Pt.
Gulf of Santa Catalina
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
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 1 2011
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Dana Pt.
ECOSCAN
C - 66



Survey Date: DEC 21 2011

CALIFORNIA COASTAL KELP RESOURCES		
1:24,000		
7/88		1.0
San Clemente		
ECOSCAN		C - 67



68																			
Inshore	1	3	5	7	9	11	13	15	17	19	21	23	25	26	27	28	29	30	31
Offshore	2	4	6	8	10	12	14	16	18	20	22	24							

SCALE 1:24 000

ROAD CLASSIFICATION

CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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

LEGEND

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

Survey Date: DEC 2 1 2011

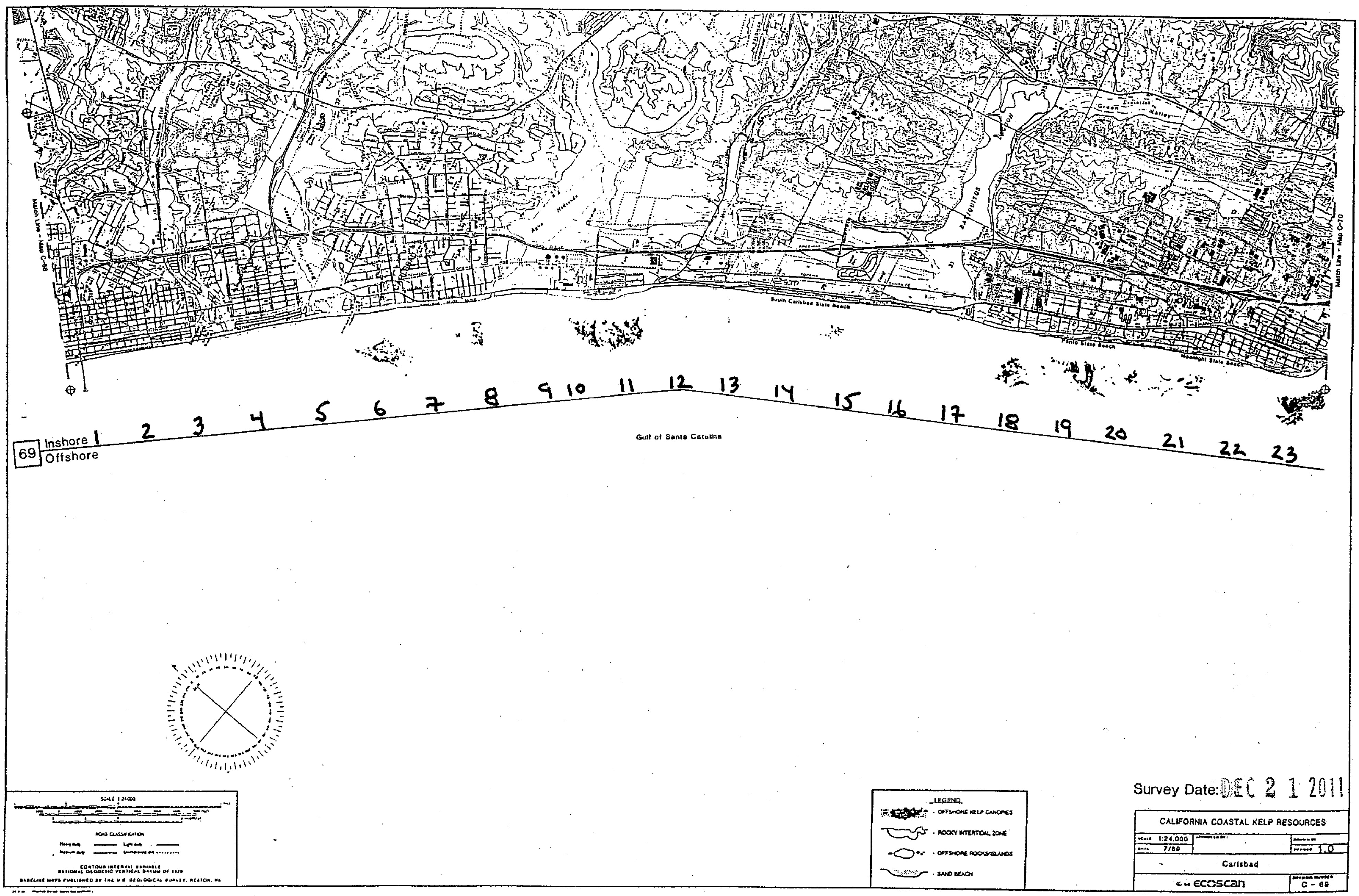
CALIFORNIA COASTAL KELP RESOURCES

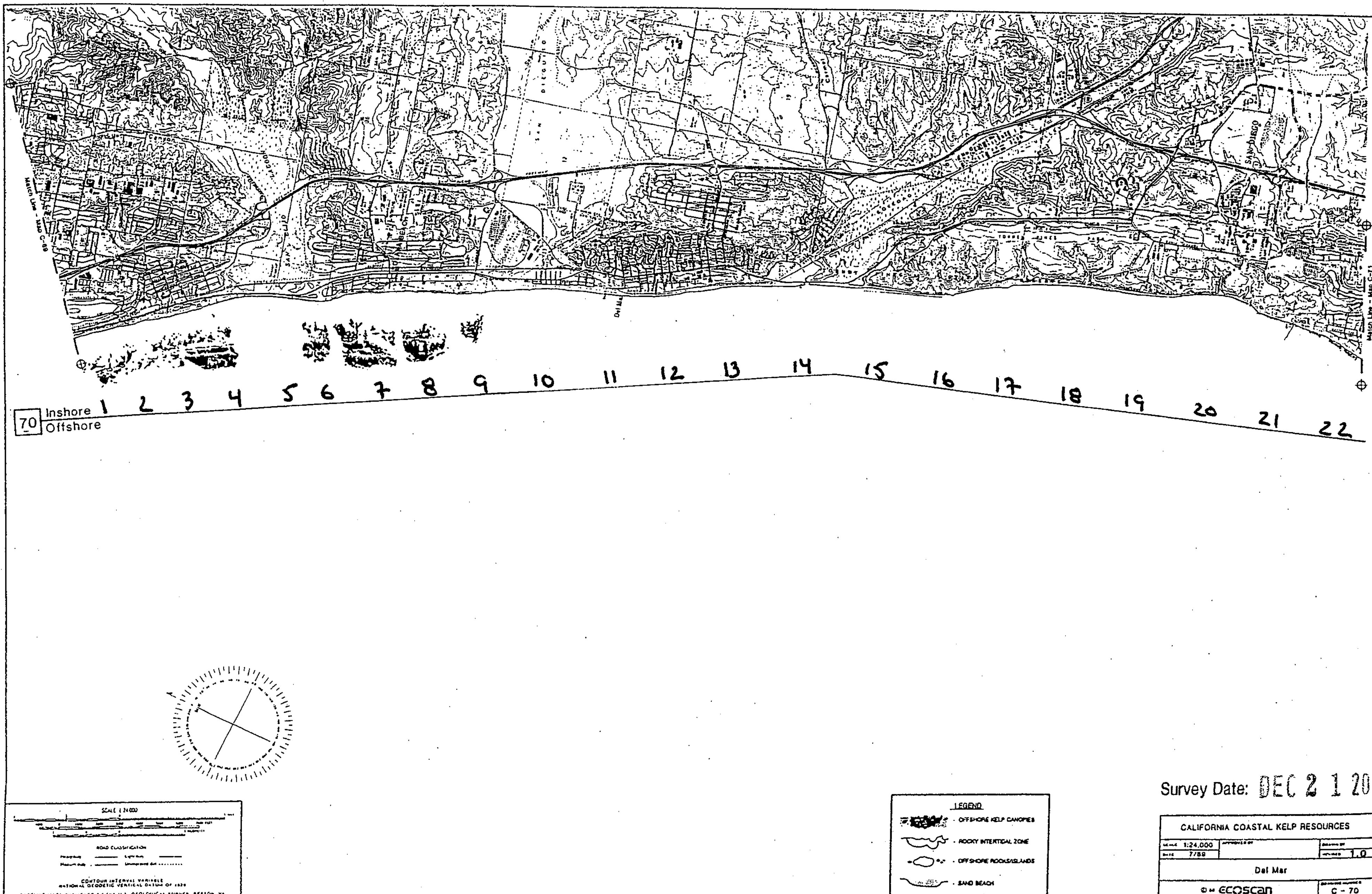
Scale 1:24,000
Date 7/89
1.0

Camp Pendelton

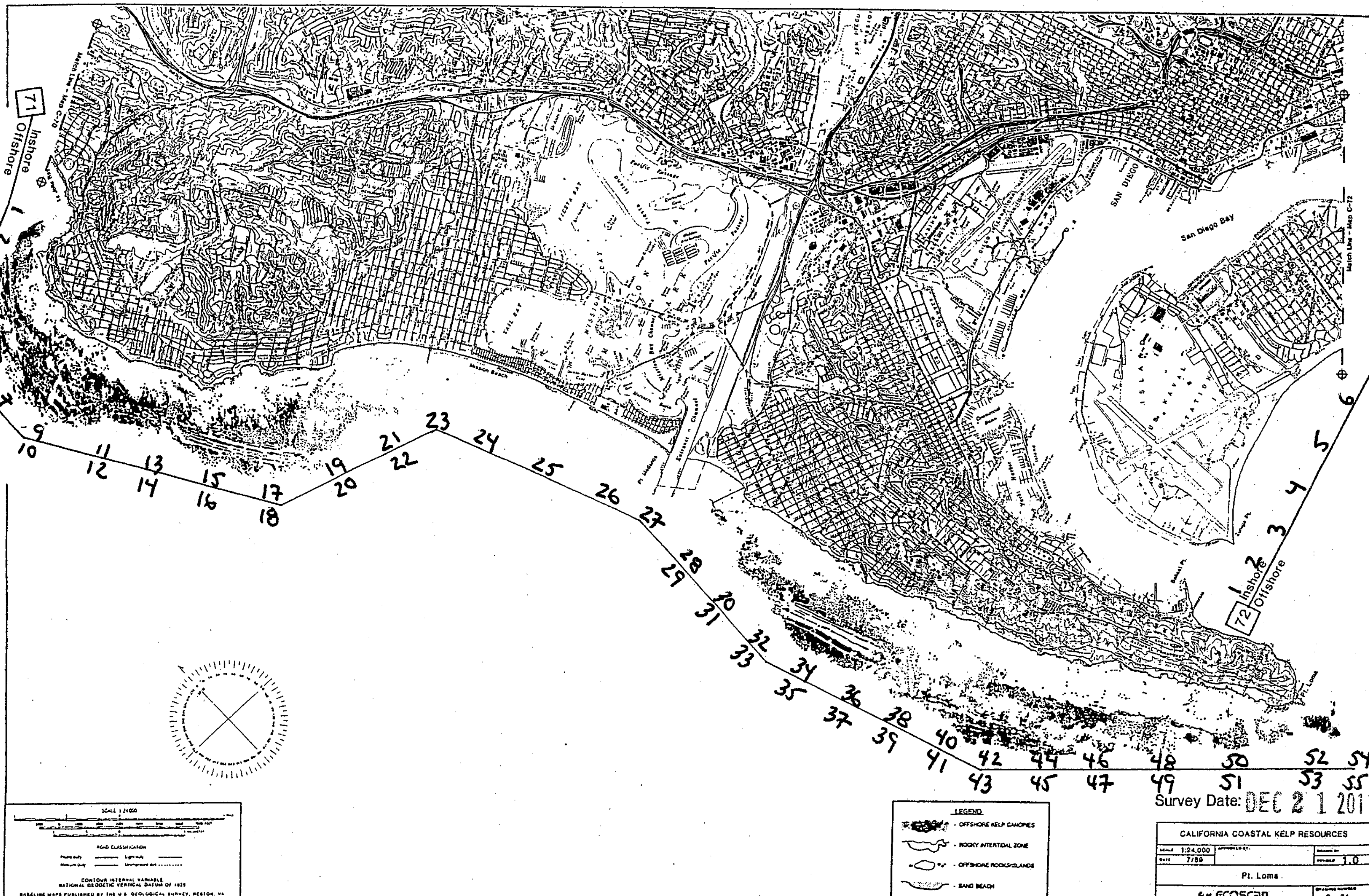
ECOSCAN

C - 88

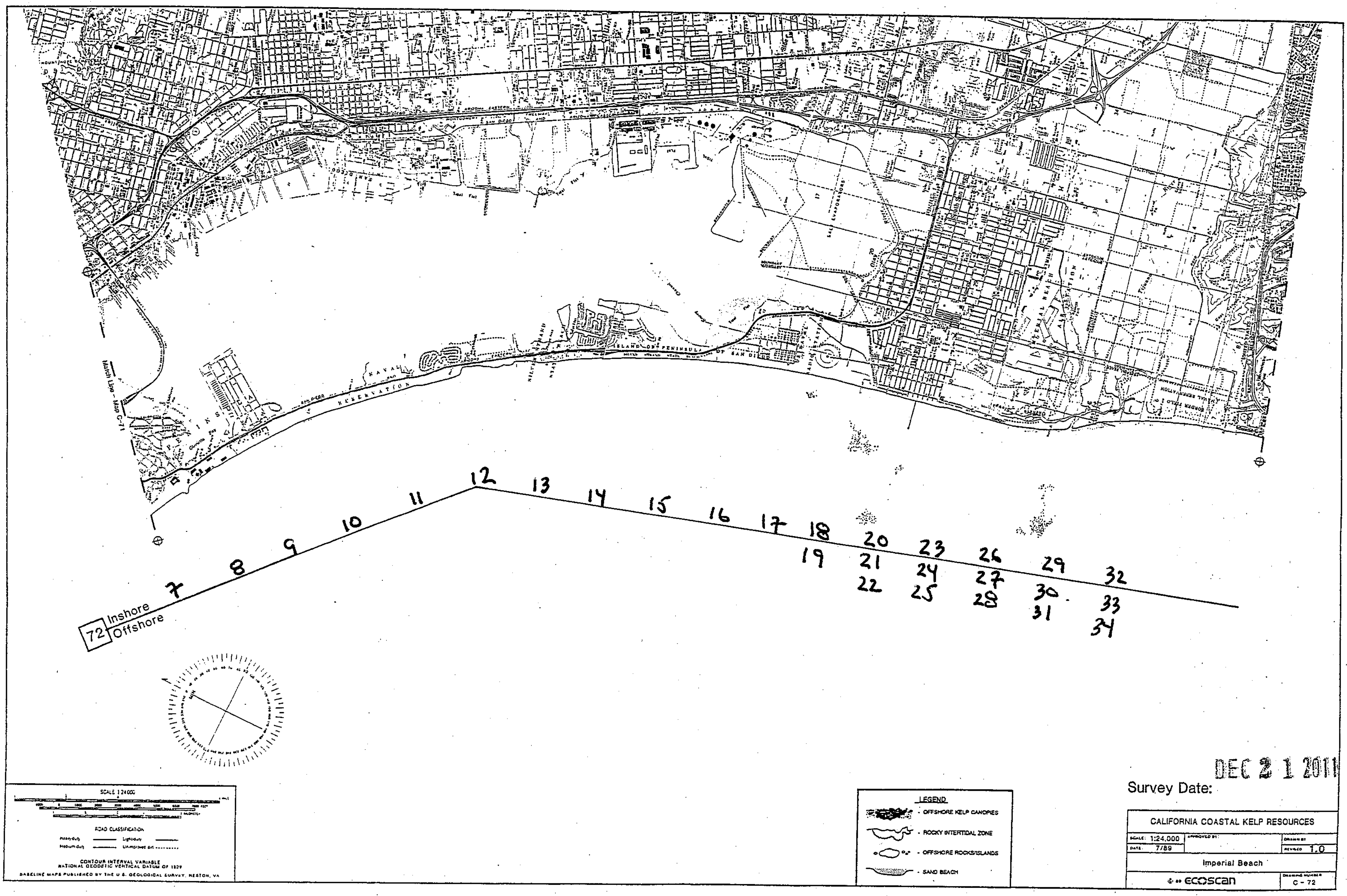

Match Line - Map C-68
Match Line - Map C-70
Batiquitos Lagoon
South Carlsbad State Beach
Ponto State Beach
Moonlight State Beach
Green Valley
Gulf of Santa Catalina
69
Inshore
Offshore
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
SCALE 1:24000
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 1 2011
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Carlsbad
ECOSCAN
C - 69



Match Line - Map C-69
Match Line - Map C-71
Del Mar
SAN DIEGO
70 Inshore
Offshore
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
SCALE 1:24 000
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
Survey Date: DEC 2 1 201
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
7/89
1.0
Del Mar
ECOSCAN
C - 70



71 Inshore Offshore
72 Inshore Offshore
San Diego Bay
SAN DIEGO
Mission Beach
Pt. Loma
Survey Date: DEC 21 2011
CALIFORNIA COASTAL KELP RESOURCES
SCALE 1:24,000
DATE 7/89
REVISED 1.0
Pt. Loma
ECOSCAN
C - 71
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


Match Line - Map C-71
72 Inshore
Offshore
7
8
9
10
11
12
13
14
15
16
17
18
19
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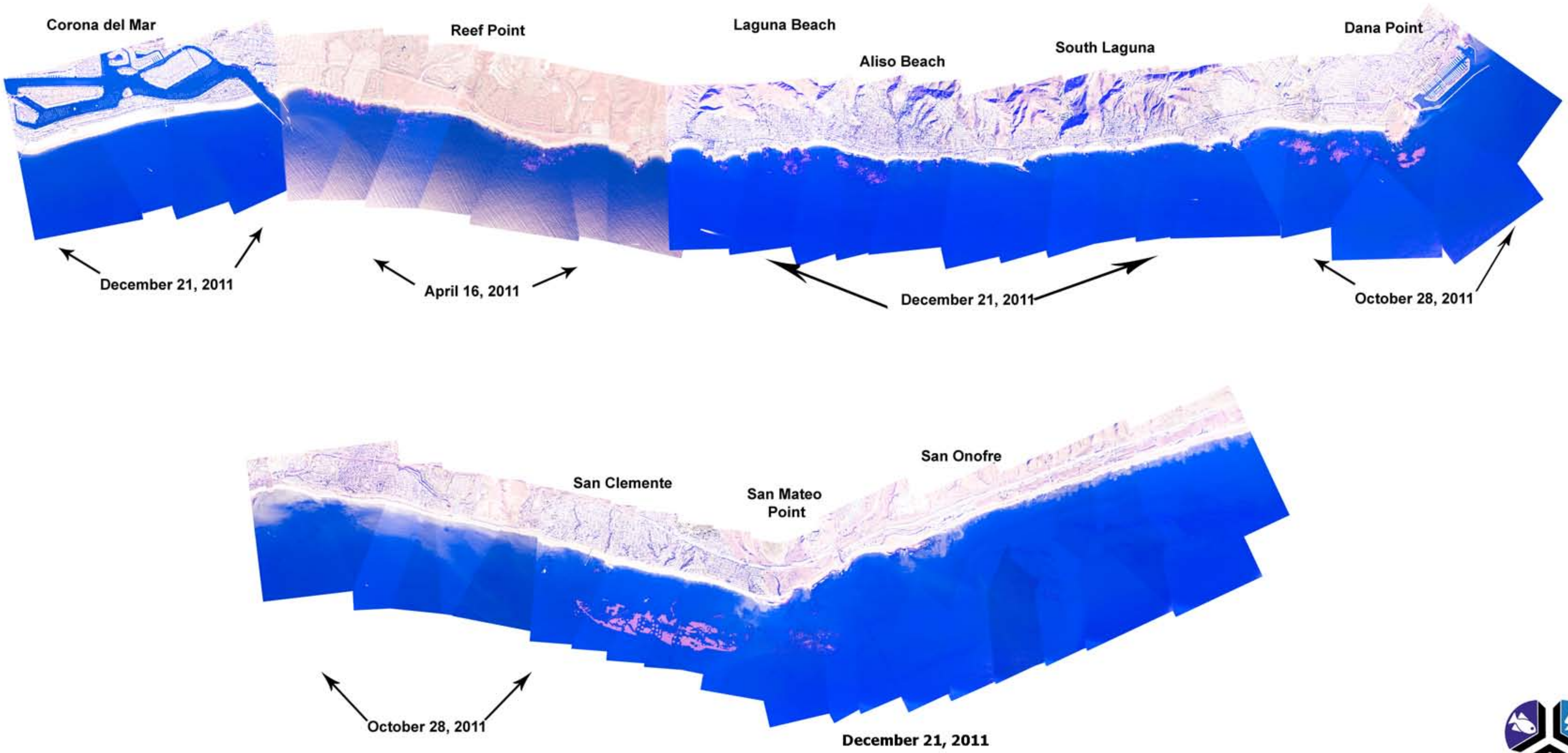
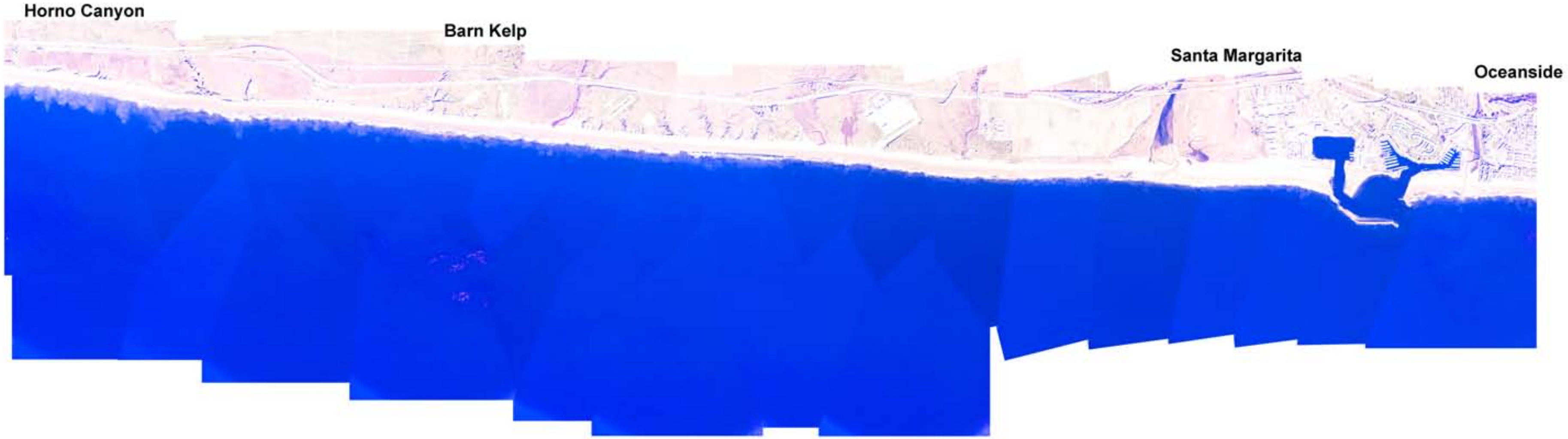
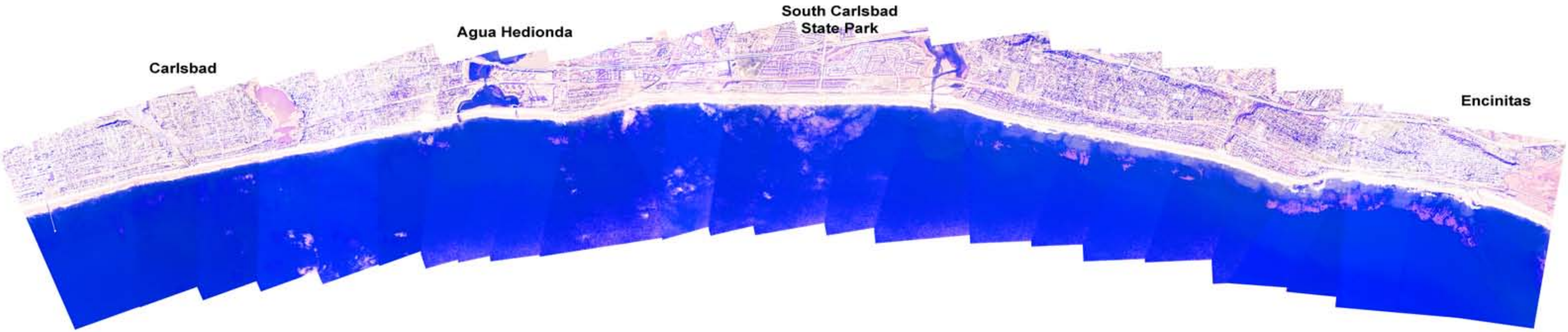
21
22
23
24
25
26
27
28
29
30
31
32
33
34
SCALE 1:24000
ROAD CLASSIFICATION
CONTOUR INTERVAL VARIABLE
NATIONAL GEODETIC VERTICAL DATUM OF 1929
BASELINE MAPS PUBLISHED BY THE U.S. GEOLOGICAL SURVEY, RESTON, VA
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
DEC 2 1 2011
Survey Date:
CALIFORNIA COASTAL KELP RESOURCES
SCALE: 1:24,000
DATE: 7/89
REVISED 1.0
Imperial Beach
ECOSCAN
C - 72

APPENDIX D

Kelp Canopy Aerial Photographs

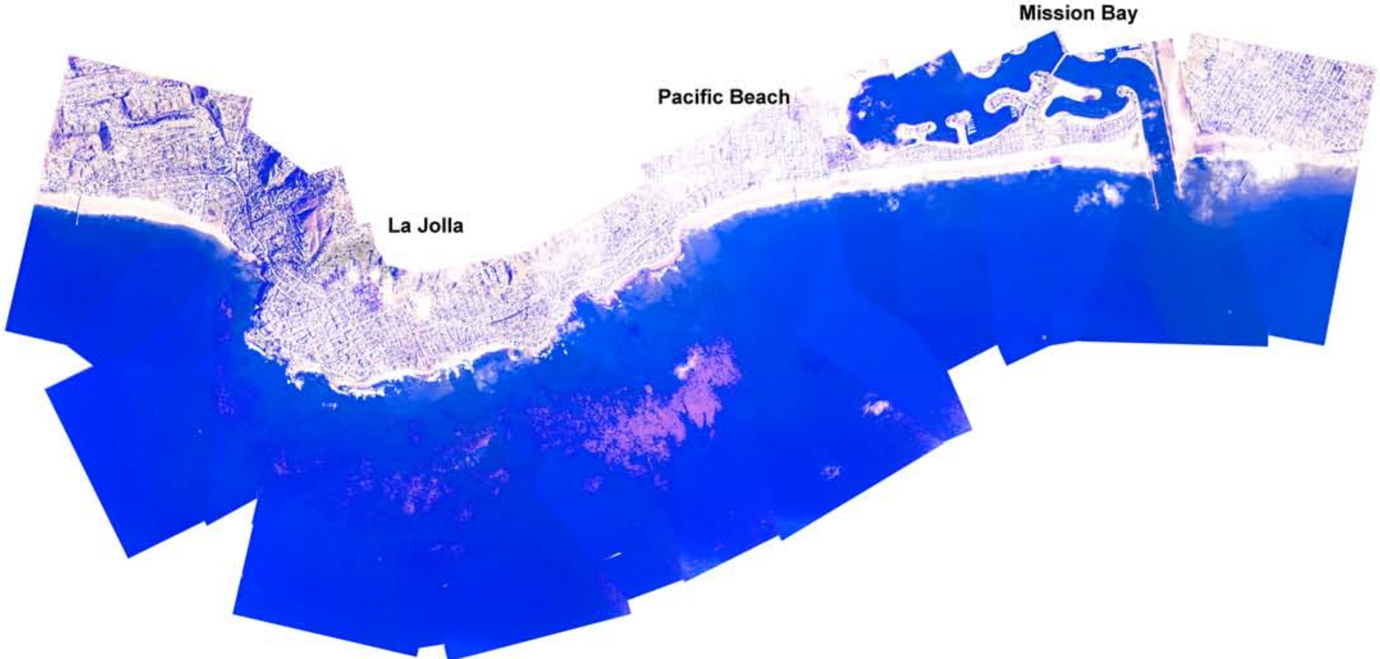

Corona del Mar
Reef Point
Laguna Beach
Aliso Beach
South Laguna
Dana Point
December 21, 2011
April 16, 2011
December 21, 2011
October 28, 2011
San Clemente
San Mateo
Point
San Onofre
October 28, 2011
December 21, 2011
MBC





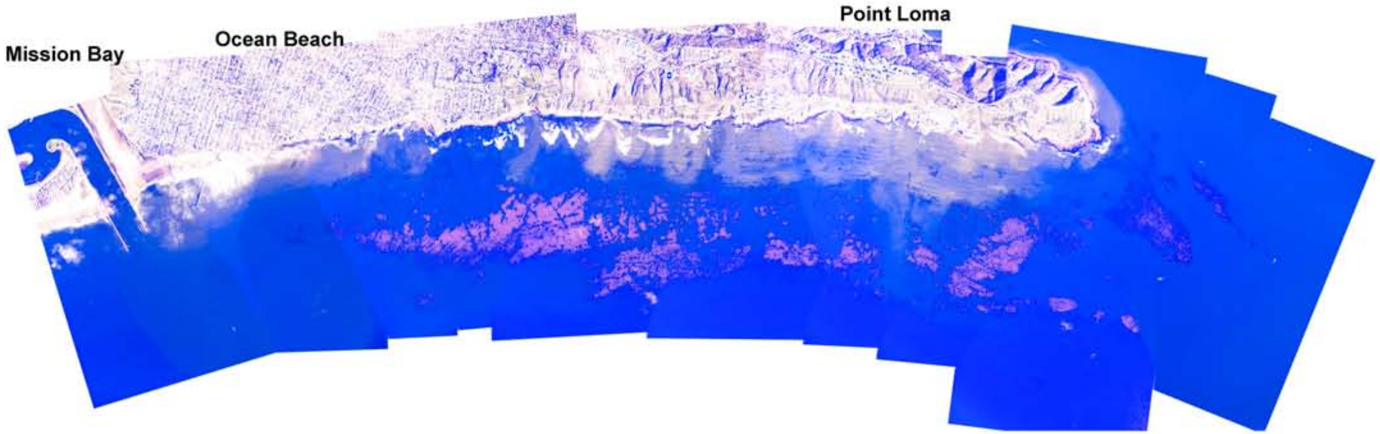
December 21, 2011

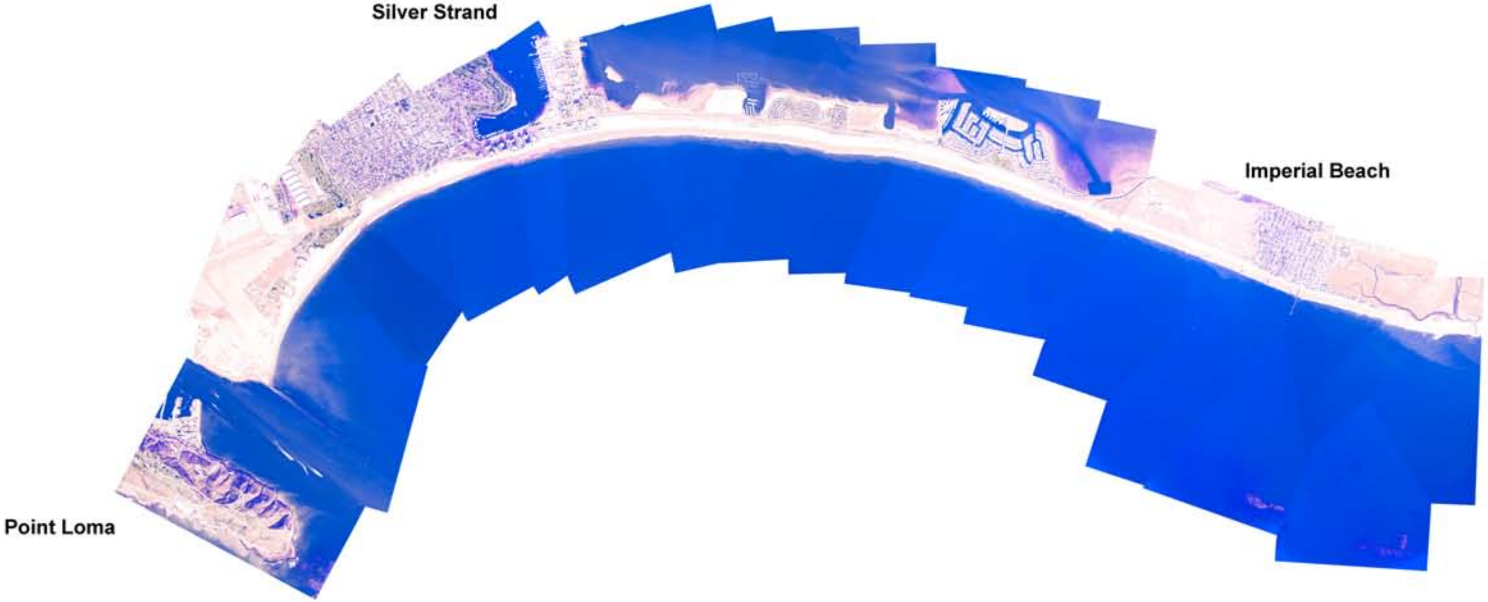
MBC



December 21, 2011

MBC





December 21, 2011