STATUS OF THE KELP BEDS IN 2014

July 27, 2015

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

Prepared for:

Central Region Kelp Survey Consortium and Region Nine Kelp Survey Consortium

Prepared by:

MBC *Applied Environmental Sciences*
Costa Mesa, California

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EXECUTIVE SUMMARY

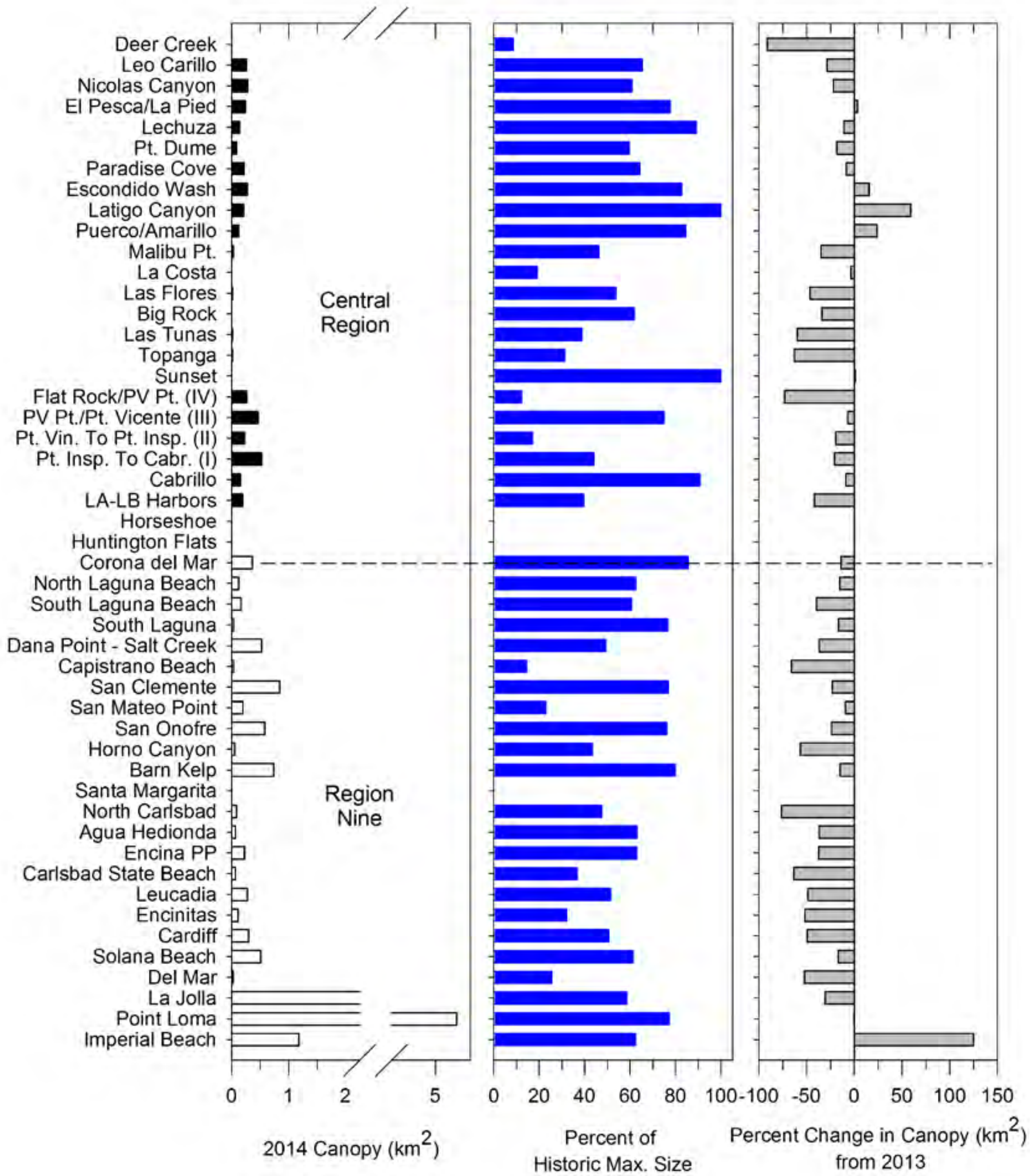
Giant kelp beds have been mapped quarterly off Ventura, Los Angeles, Orange, and San Diego counties for both the Central Region (CRKSC) and Region Nine Kelp Survey Consortiums (RNKSC). The CRKSC was formed in 2003 as a result of regulations from the Los Angeles Regional Water Quality Control Board (LARWQCB).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

Aerial imaging surveys of the giant kelp beds were conducted by MBC *Applied Environmental Sciences* (MBC) on 14 April, 27 June (and 6 July), 10 September, and 22 December 2014. Digital color and color infrared photos were taken of the entire Central Region and Region Nine coastline during each survey. However, the second quarterly overflight was interrupted by fog, so it was conducted on two separate days. These photos were then processed and the kelp depicted on each photo was transferred to base maps to facilitate intra-annual comparisons and for ease of analysis (Appendix A).

Total canopy size within the 50 kelp beds monitored as part of the CRKSC and RNKSC programs remained above average in 2014, but decreased 19% from the previous year. Total canopy coverage for this survey year was 18.3 km^2, with 4.3 km^2 in the Central Region and 14.0 km^2 in Region Nine. However, local coverage decreased by 24% in the Central Region, and by 18% in Region Nine, since 2013. There was no evidence to suggest that any of the two regions' various dischargers had any perceptible influence on the persistence of the giant kelp beds.

Central Region Results. In the Central Region, the maximum total kelp canopy decreased from 5.614 km^2 in 2013 to 4.283 km^2 in 2014. The number of kelp beds displaying canopy has remained the same in the Central Region (at 24 of 26 historic kelp beds). The total amount of kelp peaked in 2009 with 6.406 km^2 of canopy coverage, an amount greater than during any past CRKSC survey or of any surveys since 1989.

Most of the beds in the Central Region lost canopy in 2014. However, three beds upcoast from Malibu Point—Escondido Wash, Latigo Canyon, and Puerco/Amarillo—increased in size since 2013, while all four of the Palos Verdes beds also decreased. Most of the beds in the Central Region reached their maximum extent in summer (during June). However, while most of the kelp beds waned during the last half of the year, most of the beds at Palos Verdes still displayed considerable canopy in the December survey even after being exposed to several months of above-average temperatures.



Central Region kelp canopy coverage in 2014 (km^2; black) and Region Nine kelp canopy coverage in 2014 (white); percent of maximum size at Region Nine since 1983 and Central Region since 2003 (blue); and percent canopy coverage change since 2013 (grey).

Region Nine Results. In Region Nine, the maximum measured kelp canopy decreased from a total of 17.064 km^2 in 2013 to 14.053 km^2 in 2014. Only one bed increased in size in 2014—Imperial Beach by 125%. The much longer history of consecutive monitoring (47 years) in Region Nine (compared to that of the Central Region—11 years) encompasses several very favorable periods for kelp growth. It is also apparent that the La Jolla and Point Loma kelp beds dominate and account for a large percentage of the Region Nine canopy coverage. In 2014, these two beds accounted for 56% of canopy area from Newport Beach to the Mexican border.

The Region Nine kelp beds reached their maximum extent in spring and summer (April and July) overflights. Among the kelp beds that decreased in size last year, the average loss of canopy was -35%. The Imperial Beach kelp bed grew for the fourth straight year, and more than doubled in size since 2013. It was the third largest kelp bed in Region Nine last year.

Environmental Variables. Sea surface temperatures (SSTs) during the first three months of 2014 were above average throughout southern California. Beginning in late March, there were several influxes of cold water between Point Dume and Point Loma. The upwelling index (from 33°N latitude, 119°W longitude) indicated strong upwelling from May through July, but monthly upwelling was below average (compared to the average since 1946) during 10 of 12 months in 2014. The SSTs throughout the region were mostly above average from May through December. Strong cold-water pulses were evident in both regions from April through September. One of the most notable events that occurred in 2014 was the region-wide drop in temperature in late March and April. However, SSTs warmed by June and were relatively warm throughout the rest of 2014. Warmer-than-average SSTs in 2014 coincided with "The Blob", a large mass of warm water that formed off the Pacific Coast and affected coastal waters from the Bering Sea to Baja California.

The calculated Nutrient Quotient values were below average throughout southern California 2013 and 2014. Nutrient Quotient values are based on monthly mean temperatures, and may not adequately capture multiple, brief periods of cold-water influx. At Scripps Pier, the number of days with low water temperatures (i.e., <13–14°C) has been below average the last three years, and the number of days >16°C has been above average, suggesting a shift to warmer temperatures. At Point Dume, the number of days <13–14°C has been below average the last two years, and the number of days >16–20°C has been above average the last two years, also indicative of warmer temperatures. At Newport, the number of days with relatively warm temperatures (>16–18°C) has increased the last two years.

The effects of other environmental variables (rainfall/runoff, algal blooms, and large waves) appeared to have little effect on southern California's kelp beds in 2014. Rainfall was below average in southern California (for the fourth straight year), so effects from runoff were negligible. There were no media reports of red tide in the region, so effects due to reduced visibility, if any, were limited. The wave climate in 2014 was normal, with the largest waves arriving from the west in March and from the south-southeast in August. Wave heights exceeded three meters at all stations during a few storms, and exceeded four meters during the storm in early March. The large swell in late-August lasted for several days, and damaged the breakwaters at Los Angeles and Long Beach Harbors. Some kelp beds in southern California were likely affected; however, the strongest waves (from south-southeast) affected areas without kelp beds (i.e., San Pedro to Newport Beach). Most of the beds shrank between the June/July and September overflights, but beds often shrink in summer and fall, so the proportional effects of strong waves and prolonged periods of high SSTs are unknown. Even though the large swells could have damaged some of the kelp beds, the damage was not sufficient enough to deter continued growth during spring 2014 (and into 2015).

Conclusions. Most kelp canopies shrank in 2014, although a few beds increased in size. There was no evidence of any adverse effects on the giant kelp resources from any of the region's dischargers. Predictions by the National Oceanic and Atmospheric Administration's Climate Prediction Center for a prolonged El Niño could have negative effects on kelp growth based on results from past kelp surveys and evidence presented in those reports. However, total coverage in 2014 was still above average for the region.

INTRODUCTION

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

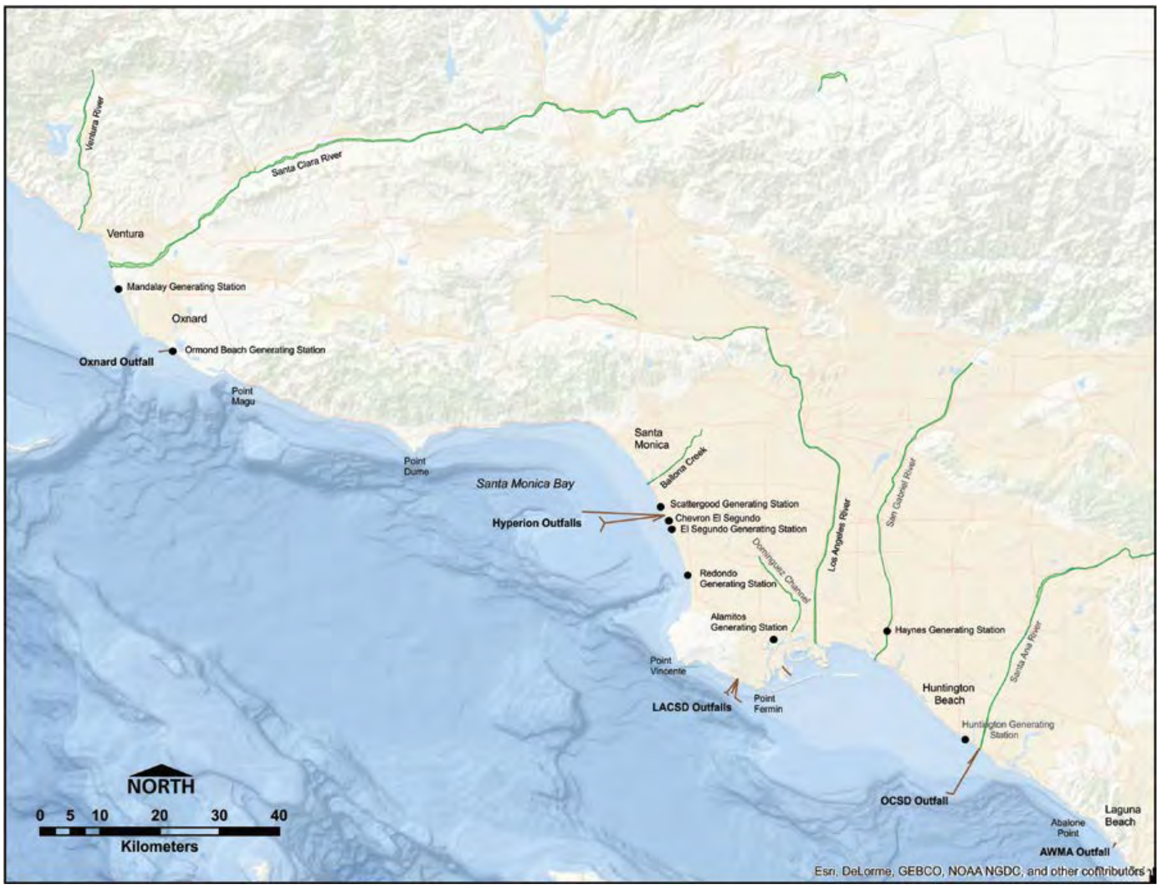


Figure 1. Ocean discharges located within the Central Region kelp survey area.

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

LIFE HISTORY OF GIANT KELP

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

Giant kelp may form beds wherever suitable substrate occurs, typically on rocky, subtidal reefs (North 1971). Such substrate must be free of continuous sediment intrusion. Giant kelp beds can form in sandy-bottom habitats protected from direct swells where individuals will attach to worm tubes; this occurs along portions of the Santa Barbara coastline (Bedford 2001). Like terrestrial plants, algae undergo photosynthesis and therefore require light energy to generate sugars. For this reason, light availability at depth is an important limiting factor to giant kelp growth. Greater water clarity normally occurs at the offshore islands, and as a result, giant kelp is commonly found growing there in depths exceeding 30 m. Along the mainland coast, high biological productivity, terrestrial inputs and nearshore mixing result in greater turbidity and hence lower light levels. Consequently, giant kelp generally does not commonly grow deeper than 20 m along the coastal shelf, although exceptional conditions off San Diego produce impressively large beds that can grow vigorously beyond 30 m.

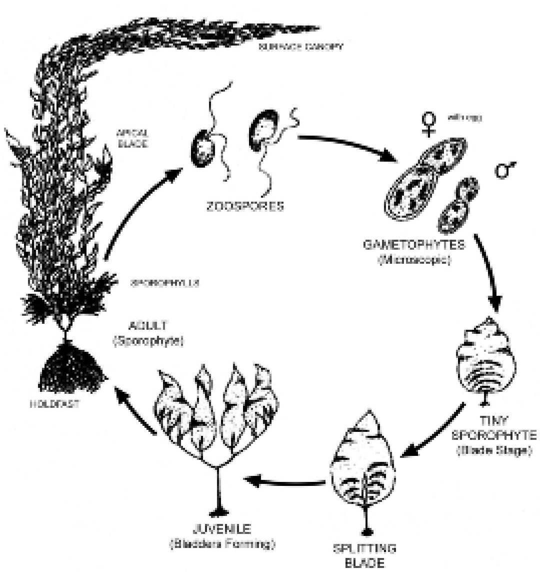


Figure 3. Kelp life cycle.

Giant kelp has a complex life cycle and undergoes a heteromorphic alternation of generations, where the phenotypic expression of each generation does not resemble the generation before or after it (Figure 3). The stage of giant kelp that is most familiar is the adult canopy-forming diploid sporophyte generation. Sporophyll blades at the base of an adult giant kelp release zoospores, especially in the presence of cold, nutrient-rich waters. These zoospores disperse into the water column and generally settle a short distance from the parent sporophyte (Reed et al. 1988). Within three weeks, the zoospores mature into microscopic male and female gametophytes that in turn produce sperm and eggs. This second generation does not resemble the sporophyte. The life cycle is completed when fertilization of the gametophyte egg develops into the adult sporophyte stage. Successful completion of the life cycle relies on the persistence of favorable conditions throughout the process.

Giant kelp grows in groups called forests because erect bundles of fronds (stipes and blades) resemble tree trunks, and spreading canopies at the sea surface represent the stems and leaves (Dawson and Foster 1982). *Macrocysti*s anchors to rocks (or occasionally in sand) by a holdfast, and new fronds, comprised of stipes and attached blades, grow up to the sea surface at rapid rates. Giant kelp is known as a biological facilitator (Bruno and Bertness 2001), where its three-dimensional structure and the complexity of its holdfast provides substrate, refuge, reduction of physical stress, and a food source for many fishes (Carr 1989) and invertebrates (Duggins et al. 1990). Stands of giant kelp can also affect flow characteristics in the nearshore zone, and enhance recruitment (Duggins et al. 1990), thus increasing animal biomass. For these reasons, giant kelp is also of great importance to sport and commercial fisheries.

FACTORS AFFECTING GIANT KELP GROWTH

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

Light. Giant kelp needs adequate light to photosynthesize. Turbidity resulting from natural (e.g., phytoplankton blooms, sediment resuspension, etc.) or anthropogenic sources (construction land use runoff) reduces light penetration and can affect photosynthesis. Phytoplankton blooms are typical in the spring and fall due to an increase in nutrients to inshore waters from upwelling, but blooms of phytoplankton can occlude enough light that they negatively affect kelp health (MBC 2007). Phytoplankton blooms were probably responsible for the large, region-wide decrease in canopy coverage in 2005 and 2006 (MBC 2007). Shading effects on kelp recruitment were well documented by Dean et al. (1989). Consecutive years of large giant kelp canopy can result in recruitment failure due to shading, and these are typically manifested in reduced surface canopy years later as the older plants reach senescence.

Sedimentation. Several kelp forests have been affected by sedimentation, but the most notable are the Palos Verdes and Barn kelp forests. Palos Verdes kelp suffered extensive damage related to wastewater discharge prior to effluent improvements initiated in the 1970s, as well as from landslides. Historically, treated wastewater discharge included fine particulate matter that reduced light penetration while it was suspended, and also buried rocky reef habitat when it settled (Hampton et al. 2002). Additional giant kelp habitat was lost due to the Portuguese Bend landslide beginning in 1956 (Kayen et al. 2002; Pondella et al. 2012). Sedimentation impacts to Barn kelp are less demonstrative, but the coincidental timing of nearby landscape modifications, storm wave activity, and the disappearance and reappearance of the once-persistent kelp forest is highly suggestive. Kuhn and Shepard (1984) detail the extensive landscape modifications made in the Horno Canyon area in the

1970s that resulted in substantially accelerated erosion. Bence et al. (1989) reaffirmed the increased sedimentation in the area after elevated rainfall during the 1978–1980 rainy seasons. The surface canopy at Barn kelp disappeared in 1980 following these landscape modifications and did not reappear until 1989 after a large storm in January 1988 resulted in anomalously high subtidal erosion (Dayton and Tegner 1989). While insufficient data exists to empirically test this theory, the timing of these events is striking and highly indicative of sedimentation effects at Barn kelp.

Nutrients. In addition to light, kelp also requires nitrates and other nutrients in solution to support adequate growth (Jackson 1977; Haines and Wheeler 1978; Dayton et al. 1999). Unlike the waters of central and northern California, the southern California waters are typically depleted of nutrients such as nitrates (Parnell et al. 2010). 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 and colder waters. Typically, the concentration of nitrates increases with depth (Sverdrup et al. 1942). However, shallow waters where kelp commonly occurs tend to have higher temperatures (due to solar insolation) and corresponding reduced nutrient levels. This is due to competition by phytoplankton for nutrients in surface waters where light penetration is good. This presents a physiological challenge for giant kelp plants, which must compete for nutrients and light. In typical, low-nutrient conditions generally encountered during the summer, giant kelp will persist only if it can adequately translocate nitrates from below the thermocline through its tissues (Jackson 1977). If the thermocline is depressed (along with nutrients) below the level where kelp is found for an extended period of time, kelp may not be able to survive. For this reason, kelp thrives best during periods of upwelling, where deeper, nutrient-rich waters rise from depths where light levels are too low to permit nutrient stripping by phytoplankton.

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

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

Because of the strong negative correlation between temperature and kelp growth, episodic El Niño events can have a severe negative impact on the health of kelp beds in the SCB. Strong El Niño events substantially reduced southern California's kelp coverage to near zero in 1983–1984 and 1998 (Table 2). Various studies have described an inverse temperature/nutrient relationship indicating that water temperatures above 15 to 17°C (59–64°F) generally have very low nutrient content (Haines and Wheeler 1978; Gerard 1982; North and Jones 1991; Dayton et al. 1999; Kamykowski and Zentara 1986; Zimmerman and Kremer 1986; Lucas et al. 2011; and Konotchick et al. 2012). North and Jones (1991) combined the results of the earlier studies to make broader interpretations of the availability of nutrients based on surface seawater temperatures at discrete locations. They found that with roughly one degree centigrade (1.9°F) drop in temperature, the availability of nitrates essentially doubled. Therefore, a temperature of 12°C (54°F) would theoretically have 14 times more nutrients available than at 16–17°C (62–64°F).

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

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

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

Storms. Storms can hinder or stimulate kelp growth, depending upon how large they are and how much energy they contain. Waves cause a back and forth motion in kelp; large swells increase the severity of this motion. The heightened drag force on the kelp as a result of large swells can break fronds, and even break the holdfast free from its anchorage. As the fronds of giant kelp often entangle with other nearby giant kelp, the added drag of other loose giant kelp can rip a more firmly attached neighbor free from its holdfast. The resultant mass of entangled, loose giant kelp can drift through a kelp bed ripping out hundreds or thousands of giant kelp plants, which can wash ashore or become a floating kelp paddy offshore (Dayton and Tegner 1984; Ebeling et al. 1985). Conversely, high wave energy can abrade multi-layered invertebrate coverage (thereby eliminating competition for space) and expose bedrock for colonization by giant kelp (North and MBC 2001).

Of particular concern are storms that produce swell heights that exceed four meters and that originate out of the west or southwest rather than from the Gulf of Alaska (GOA). The Northeast Pacific wave climate changed in 1976–1977 to one where waves out of the west or southwest, similar to those occurring during El Niño events, occurred more frequently (Adams et al. 2008; Seymour 2011). Prior to 1976, the wave climate was dominated by energy generated in the GOA. The SCB coastline was largely protected from GOA-sourced waves via the island shadow effect (Pawka et al. 1984; Seymour et al. 1989) (Figure 4).

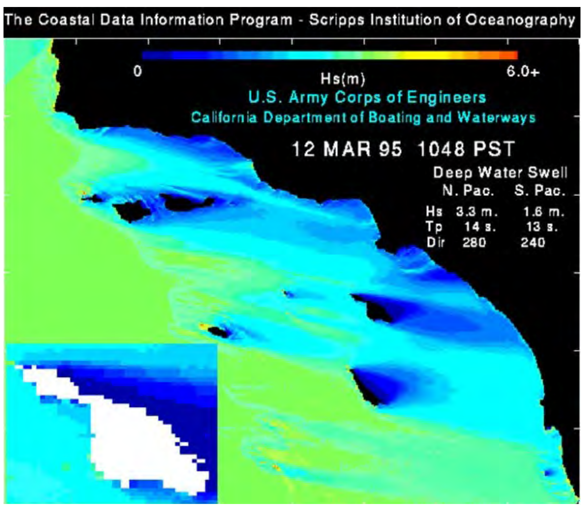


Figure 4. Depiction of the shadow effect (blue) from offshore islands providing protection to mainland kelp beds.

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

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

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

Using several oceanographic models and looking at a variety of variables, a multivariate ENSO Index (MEI) that classifies cold water and warm water periods since the early 1870s was developed by NOAA (NOAA 2015; Figure 5). Based on this index, it is clear there was a transition in 2010 from a relatively warm period to a relatively cool period. This ENSO-negative period persisted for about two years, and in 2012, the standardized departure was positive for several months, before returning to negative in 2013. It transitioned to positive in April 2014, and remained positive through the remainder of the year.

As ENSOs have been recurring events for thousands of years, it was assumed in the long term that their effects have been neutral in regards to long-term maintenance of the kelp bed resources. However, a glance at the last approximately 50 years of the multivariate ENSO Index indicates that the 30 years between 1977 and 2007 were characterized by frequent warm periods (Figure 5). There were only two significant cold periods during the entire time period, whereas the previous 30 years were characterized by mostly cold-water events. Looking even further back from about 1872 to approximately 1918, it is clear that cold-water events lasted longer and probably had a very favorable impact on the kelp beds of that era. The last five years have been characterized by three warm-water periods (spring 2009–spring 2010, summer 2012–winter 2012, and spring 2014–spring 2015), a protracted cool-water period (summer 2010–spring 2012), and a period of near neutral MEI values (spring 2013–spring 2014).

PDO. A regime shift reportedly occurred in the California Current circa 1999 (Petersen and Schwing 2003), but this has not yet manifested as altered conditions in the SCB as all available metrics continue to indicate conditions consistent with the 1976–1977 shift (McGowan et al. 2003; Bograd and Lynn 2003; Pondella et al. 2012). Initial understanding of the 1976–1977 shift centered on increased sea surface temperature (SST), but salinity also declined as the mixed layer deepened with a deeper thermocline (McGowan et al. 1998; Bograd and Lynn 2003; McGowan et al. 2003).The Pacific Decadal Oscillation (PDO) and the Inter Decadal Oscillation (IDO) appear as potential long-term climate changes from a colder to warmer regime, or the reverse (Mantua et al. 1997; Power et al. 1999; Fiedler 2002; Verdon et al. 2004). Both the negative and positive PDO phases are well within the range observed for the 111 years included in the PDO series. Many of these phases did not result in a corresponding giant kelp canopy area change that would be predicted by a direct PDO to kelp growth relationship.

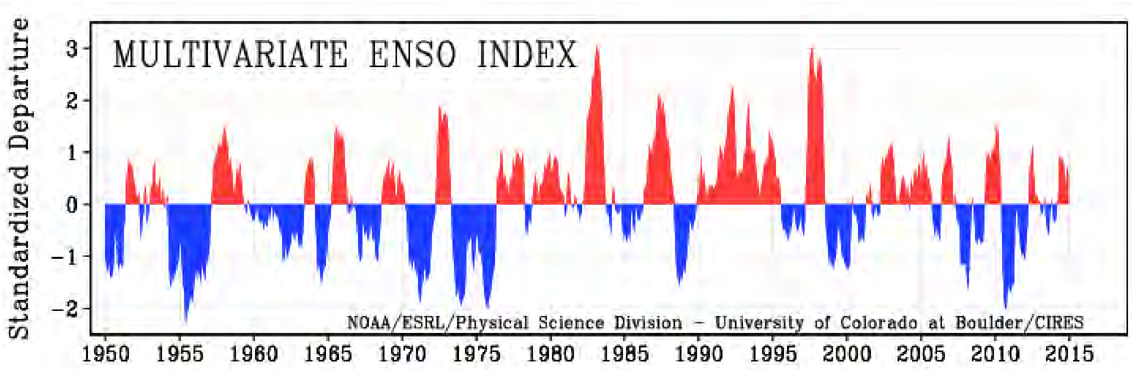


Figure 5. Multivariate ENSO Index from 1950 through 2014. Source: NOAA (2015).

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

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. However, anthropogenic effects on kelp beds have been documented, most notably the pollution-related loss of kelp beds offshore of Palos Verdes (from the late 1950s through much of the 1970s) and Point Loma (in the early 1990s) (SWQCB 1964; North 1968; Meistrell and Montagne 1983; Foster and Schiel 2010). The probable cause of the loss of kelp at the Point Loma outfall was not related to the wastewater, but probably the accompanying turbidity from particulates in the discharge (City of San Diego 1992a, b; North 2001). Other factors have included unchecked runoff from coastal construction, such as what appeared to have occurred during construction of Interstate 5 in the late 1960s (loss of Barn kelp for several years); construction of homes at Salt Creek in the late 1970s that resulted in the loss of the large Dana Point/Salt Creek kelp bed (North and MBC 2001); the loss of the Huntington Flats kelp bed in the early 1930s; and the loss of the Horseshoe kelp bed offshore of San Pedro Harbor in the late 1930s, probably a result of turbidity due to an increasing population and dumping of sediment from dredging of the Los Angeles and Long Beach Harbors. The loss of the Huntington Flats kelp bed was probably a result of increased turbidity due to the construction of Anaheim Bay, Alamitos Bay, and the Long Beach breakwaters (North and MBC 2001).

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

Upon Parnell's review of water density data (collected since the 1950s incidental to fisheries management cruises by the California Cooperative Oceanic Fisheries Investigations) and pier temperature data from Scripps Institution of Oceanography (SIO), there is now evidence that nutrients were replete in the SCB for decades prior to the 1976–1977 regime or climate shift and in contrast have been more or less depleted since. The dramatic increases and decreases in kelp bed canopies observed during El Niño and La Niña events after the regime shift in the latter part of the 20th century were the result of a period of depleted nutrients; kelp bed responses to ENSOs were much more subdued during the period of sufficient nutrients prior to the regime shift (Parnell et al. 2010). Prior to the 1976–1977 regime shift, density of seawater on the inner shelf was above the threshold that best predicts giant kelp density (δ_t = 25.1) much more frequently than after. After the 1976–1977 regime shift, seasonal patterns of change in δ_t indicate that nutrient concentrations during spring and summer became much less favorable. Nutrient concentrations appear to have transitioned from a background of conditions with sufficient nutrients interrupted by large El Niño events (1940–1942 and 1957–1959), to one below the density threshold (δ_t = 25.1) except for brief periods, most of which occurred during La Niñas (i.e., 1985, 1988–1989, and 1999) (Parnell et al. 2010). Climate shifts can come in the form of a gradual drift, smooth oscillations, or step-like changes as noted in the 1976–1977 and the later 1988–1989 regime shifts (Miller et al. 1994; Miller and Schneider 2000). These far-reaching changes are usually decades in duration and can have profound effects on abundance and biodiversity of marine communities (Bakun 2004; Noakes and Beamish 2009).

Sediment Regimes. Changes in sediment regimes have also contributed to the disappearance of several kelp beds since the 1911 surveys by Crandall (1912). Large kelp beds once thrived offshore of Point Dume, Sunset Beach (offshore of Santa Monica), Crystal Cove, Horno Canyon, Santa Margarita, and near the Mexican Border. Because there are no known human-induced causes for the loss of kelp at these areas, these beds likely disappeared due to inundation of low-lying reefs by shifting sediments (or kelp was growing on the sand at some of these locations). Subtidal observations on the seafloor at Sunset Beach, Crystal Cove, Santa Margarita, and the Mexican Border indicate the lack of suitable hard substrate that has limited the re-establishment of these kelp beds (M. Curtis, 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 (H. Elwany, pers. comm.).

HISTORICAL KELP SURVEYS 1911–2013

Information on the first surveys of giant kelp along the coast of southern California is summarized in Appendix B. Estimated canopy coverages of each kelp bed are presented in Tables 1 and 2.

Table 1. Historical canopy coverage in km² of the Ventura, Los Angeles, and Orange County kelp beds to Laguna Beach, from 2003 through 2014. Areal estimates were derived from infrared aerial photographs.

	Canopy Area (km²)											
Kelp Bed	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1 Deer Creek	0.089	0.107	0.053	0.026	0.046	0.074	0.105	0.062	0.055	0.041	0.104	0.103
2 Leo Carillo	0.318	0.399	0.171	0.150	0.145	0.207	0.255	0.232	0.226	0.337	0.366	0.261
3 Nicolas Canyon	0.308	0.362	0.195	0.038	0.473	0.268	0.433	0.291	0.130	0.240	0.369	0.288
4 El Pesc/La Piedra	0.243	0.314	0.141	0.063	0.255	0.173	0.238	0.164	0.136	0.173	0.236	0.244
5 Lechuza	0.105	0.104	0.041	0.022	0.106	0.075	0.105	0.096	0.096	0.066	0.154	0.137
Total 1-5 (F&W 17)	1.063	1.286	0.600	0.298	1.025	0.797	1.136	0.844	0.642	0.857	1.229	1.034
6 Pt. Dume	0.012	0.029	0.028	0.053	0.065	0.070	0.104	0.094	0.078	0.154	0.113	0.092
7 Paradise Cove	0.162	0.258	0.035	0.036	0.100	0.223	0.244	0.259	0.109	0.346	0.244	0.223
8 Escondido Wash	0.214	0.250	0.078	-	0.339	0.278	0.321	0.267	0.104	0.248	0.243	0.281
9 Latigo Canyon	0.125	0.161	0.032	0.007	0.186	0.124	0.195	0.142	0.070	0.202	0.133	0.212
10 Puerco/Amarillo	0.074	0.051	0.039	0.055	0.095	0.064	0.115	0.126	0.069	0.153	0.105	0.130
11 Malibu Pt.	0.011	0.013	0.008	0.008	0.016	0.011	0.012	0.066	0.074	0.084	0.060	0.039
Total 6-11 (F&W 16)	0.598	0.762	0.220	0.158	0.801	0.769	0.991	0.954	0.504	1.189	0.897	0.976
12 La Costa	0.001	0.002	-	-	-	-	0.001	0.001	-	0.003	0.003	0.001
13 Las Flores	0.009	0.023	0.004	-	0.005	0.001	0.005	0.005	0.008	0.025	0.022	0.016
14 Big Rock	0.005	0.014	0.002	0.001	0.004	0.002	0.005	0.006	0.007	0.018	0.017	0.011
15 Las Tunas	0.003	0.018	0.004	-	0.008	0.005	0.019	0.015	0.007	0.030	0.029	0.012
16 Topanga	0.0002	0.002	0.0001	-	-	0.001	0.002	0.052	0.041	0.048	0.044	0.016
17 Sunset	-	-	-	-	-	-	0.004	0.008	0.007	0.008	0.010	0.010
Total 12-17 (F&W 15)	0.017	0.059	0.010	0.001	0.017	0.009	0.035	0.087	0.069	0.131	0.123	0.064
18 Malaga Cove-PV Pt. (IV)	0.196	0.245	0.204	0.859	1.151	1.839	2.122	1.136	1.139	1.337	0.974	0.264
19 PV Pt-PT. Vic (III)	0.045	0.040	0.056	0.135	0.074	0.300	0.570	0.624	0.452	0.488	0.502	0.468
Total 18-19 (F&W 14)	0.241	0.285	0.260	0.993	1.225	2.140	2.692	1.760	1.591	1.825	1.476	0.732
20 Pt Vic to Pt Insp (II)	0.059	0.023	0.034	0.082	0.034	0.108	0.163	0.222	0.238	0.295	0.279	0.224
21 Pt Insp to Cabr (I)	1.063	0.211	0.702	0.951	0.703	0.608	0.980	0.389	0.465	0.384	0.672	0.533
22 Cabrillo	0.062	0.070	0.102	0.161	0.100	0.060	0.163	0.124	0.103	0.095	0.174	0.158
Total 20-22 (F&W 13)	1.184	0.304	0.838	1.194	0.837	0.776	1.306	0.734	0.805	0.774	1.124	0.915
Total 18-22 PV	1.425	0.589	1.098	2.187	2.062	2.916	3.998	2.494	2.396	2.599	2.600	1.647
23 POLA-POLB Harbor	ND	ND	0.147	0.494	0.118	0.213	0.151	0.277	0.397	0.495	0.337	0.196
24 Horseshoe	-	-	-	-	-	-	-	-	-	-	-	-
25 Huntington Flats	-	-	-	-	-	-	-	-	-	-	-	-
26 Newport-Irvine Coast	0.002	0.002	0.000	0.023	0.054	0.089	0.095	0.161	0.419	0.395	0.428	0.366
Total 23-26 (F&W 10)	0.002	0.002	0.147	0.517	0.172	0.302	0.246	0.438	0.816	0.890	0.765	0.561
TOTAL	3.105	2.698	2.075	3.161	4.076	4.793	6.406	4.817	4.427	5.665	5.614	4.283

ND = No Data; "-" = 0

Sources:Veisze et al. (2004); MBC (2004a-2012a, 2013, 2014).

Table 2. Canopy coverages in km² of the southern Orange County and San Diego County kelp beds from 2003 through 2014. Areal estimates were derived from infrared aerial photographs.

Kelp Bed	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
N Laguna Beach	0.0004	-	-	-	-	0.002	0.005	0.093	0.147	0.192	0.142	0.120
S Laguna Beach	0.0002	0.008	-	-	0.001	0.025	0.058	0.098	0.221	0.214	0.273	0.165
South Laguna	0.004	0.009	0.003	-	0.004	0.023	0.017	0.023	0.018	0.017	0.038	0.031
Dana Pt/Salt Crk	0.303	0.278	0.123	-	0.302	1.068	0.892	0.839	0.442	0.607	0.835	0.528
Capistrano Beach	0.069	0.008	-	0.011	0.002	0.071	0.071	0.124	0.010	0.056	0.099	0.034
Total F&W 9	0.376	0.303	0.126	0.011	0.309	1.189	1.043	1.178	0.838	1.086	1.385	0.879
San Clemente	0.352	0.182	0.178	0.014	0.016	0.203	0.210	0.710	0.795	0.874	1.097	0.843
San Mateo Point	0.242	0.123	0.258	0.016	0.201	0.487	0.545	0.583	0.203	0.216	0.219	0.199
San Onofre	0.162	0.109	0.065	-	0.320	0.476	0.419	0.458	0.127	0.191	0.767	0.584
Total F&W 8	0.755	0.414	0.501	0.030	0.536	1.166	1.174	1.750	1.124	1.281	2.083	1.627
Horno Canyon	0.001	-	-	-	0.015	0.083	0.018	0.081	-	0.008	0.125	0.055
Barn Kelp	0.492	0.075	0.064	-	0.466	0.858	0.926	0.500	0.095	0.442	0.868	0.741
Santa Margarita	-	-	-	-	-	-	-	-	-	-	0.080	-
Total F&W 7	0.494	0.075	0.064	-	0.481	0.941	0.944	0.581	0.095	0.450	1.073	0.795
North Carlsbad	0.017	0.003	0.013	-	0.026	0.108	0.135	0.078	0.017	0.052	0.125	0.086
Agua Hedionda	0.002	0.001	0.008	-	0.016	0.080	0.092	0.031	0.022	0.046	0.102	0.065
Encina Power Plant	0.178	0.067	0.001	-	0.081	0.306	0.215	0.176	0.084	0.216	0.352	0.221
Carlsbad St. Bch	0.002	0.0001	-	-	0.064	0.121	0.127	0.069	0.024	0.058	0.178	0.065
Total F&W 6	0.199	0.070	0.023	-	0.187	0.615	0.569	0.354	0.147	0.372	0.757	0.437
Leucadia	0.185	0.048	0.001	0.016	0.233	0.421	0.429	0.215	0.119	0.232	0.541	0.279
Encinitas	0.050	0.016	-	0.002	0.205	0.346	0.205	0.128	0.124	0.260	0.231	0.112
Cardiff	0.202	0.045	-	0.004	0.286	0.484	0.520	0.213	0.395	0.459	0.590	0.299
Solana Beach	0.245	0.022	0.093	0.0003	0.457	0.823	0.505	0.328	0.504	0.442	0.606	0.504
Del Mar	0.030	-	-	-	0.037	0.057	0.044	0.038	0.074	0.024	0.056	0.027
Torrey Pines	-	-	-	0.010	-	0.001	0.0004	0.003	0.031	0.034	0.081	-
Total F&W 5	0.712	0.131	0.094	0.032	1.218	2.133	1.703	0.925	1.247	1.452	2.106	1.221
La Jolla F & W 4	3.444	1.029	0.873	0.117	2.750	4.145	2.274	2.776	2.565	1.569	4.006	2.790
Point Loma F & W 3&2	4.509	1.924	2.152	1.767	3.616	6.623	4.909	3.977	4.212	5.340	5.127	5.121
Imperial Beach F & W 1	0.083	0.191	0.400	0.400	1.493	1.895	0.861	0.004	0.152	0.333	0.526	1.183
TOTAL	10.572	4.136	4.233	2.358	10.591	18.706	13.476	11.545	10.379	11.882	17.064	14.053

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

Sources: MBC 1994-2003; 2004b-2012b, 2013, 2014.

DESCRIPTION OF THE CENTRAL REGION KELP BEDS

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

California during World War II and into the late 1960s. One other historic kelp bed (Newport/Irvine Coast) reappeared (following restoration efforts) after absences of one to several decades resulting from a series of El Niño events in the 1980s and 1990s.

The continued absence of three of these 26 beds may be the result of the loss of suitable substrate. Horseshoe kelp likely was buried during excavations of the Ports of Los Angeles and Long Beach from the 1920s to the 1950s and dumping of the sediment at that location (Schott 1976), and the burial of suitable substrate by natural sedimentation processes at Sunset kelp (which occurred at several other historic kelp bed sites removed from population centers). However, it is possible that the Sunset kelp beds may have grown on sand. The loss of the Huntington Flats kelp bed was probably the result of increased turbidity due to the extension of the Long Beach breakwater, and the dredging of Alamitos Bay and Sunset-Huntington Harbors. The CRKSC surveys began following a strong La Niña event in 1999. All three missing beds had substantial canopies prior to 1950.

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

Administrative kelp bed areas in California waters are numbered, defined by compass bearings from known landmarks, and have associated harvesting commercial regulations in the California Department of Fish and Wildlife Code. The California Fish and Game Commission designated 87 geographical kelp beds along the California coast and Channel Islands. Each of the 87 kelp beds fall within specific designations that were designed for optimal harvest while ensuring sustainable management of the resource and the species that depend upon kelp (Figure 6). The administrative kelp beds are designated as closed, leasable, leased (from the state), or open. Closed beds may not be harvested. Leased beds provide the exclusive privilege of harvesting to the lessee, and open beds may be harvested by anyone with a kelp harvesting license. In 2014, only one administrative kelp bed was leased in the CRKSC and RNKSC areas: Bed Number 3 at Point Loma. However, mechanical kelp harvesting has been proposed in Beds 17 (between Mugu Lagoon and Point Dume) and 18 (off Oxnard) (Mastrup 2015).

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

Many of the kelp studies between 1911 and 1989 consolidated all local kelp beds into the Fish and Wildlife Kelp Bed designations, making it difficult to discern patterns of specific sub-areas within the much larger Fish and Wildlife lease areas. For example, Fish and Wildlife Kelp Bed (lease area) No. 17 encompasses over 10 kilometers of coastline. Therefore, natural breaks in the beds were determined (as noted by either Crandall's 1911 survey or Ecoscan's 1989 survey) and assigned names that describe the location based on nearby canyon names, prominent features, or other local names in use. Descriptions of each Fish and Wildlife Kelp Beds are provided in previous Central Region Kelp Survey Consortium Report (e.g., MBC 2014).

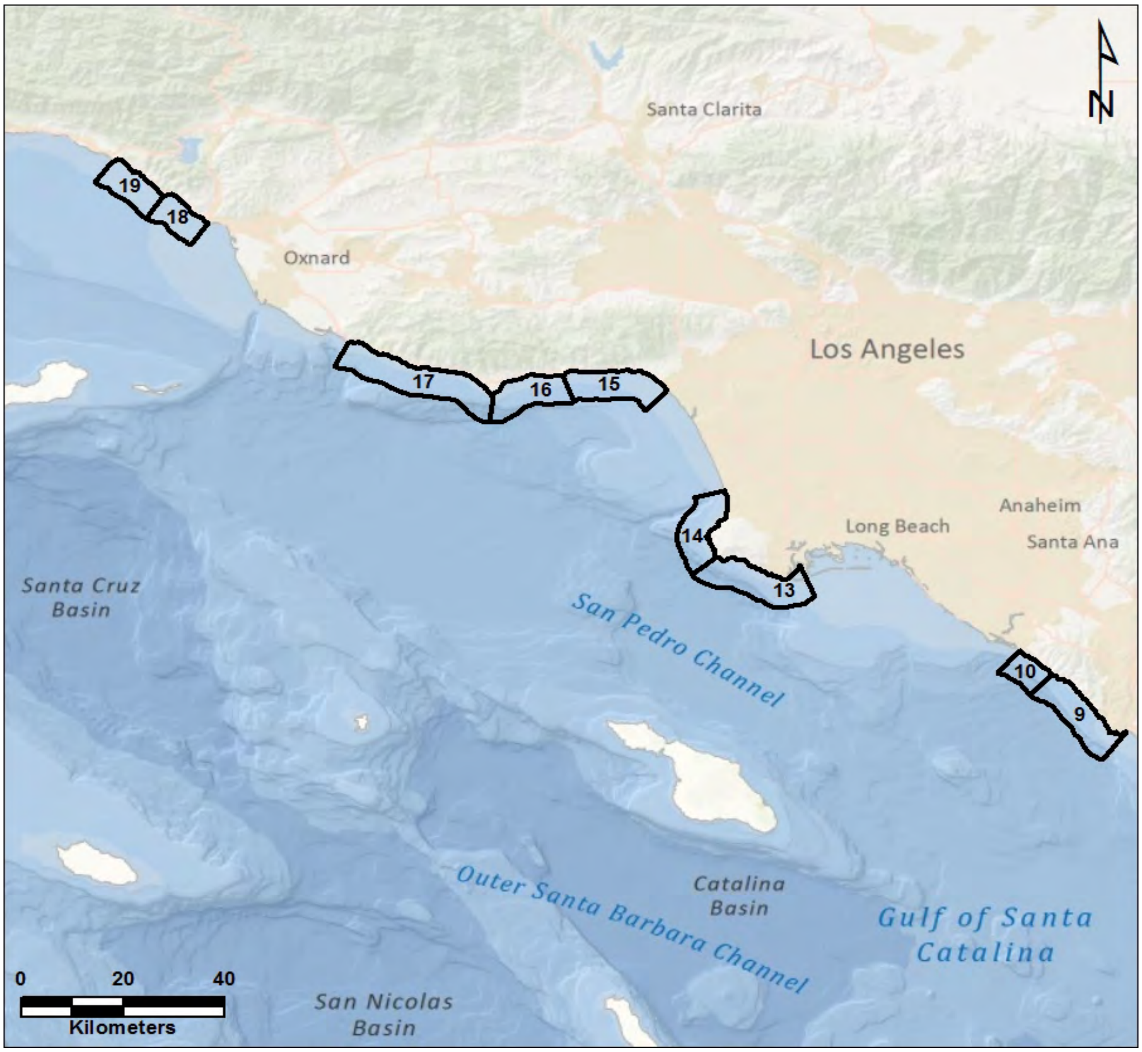


Figure 6. Administrative kelp bed leases in the Central Region study area. Beds 18 and 19 are upcoast from the CRKSC study area.

DESCRIPTION OF THE REGION NINE KELP BEDS

The Region Nine kelp survey area, between Abalone Point in Laguna Beach (Orange County) and the Mexican Border, the CDF&W recognizes just 10 administrative kelp bed lease areas (Figure 7). In this same area, MBC has identified 24 kelp beds: 22 that are persistent and two other beds that appear ephemerally (Santa Margarita and Torrey Pines), as well as four other areas of interest (marinas and small boat harbors) (MBC 1994–2003, 2004b–2012b, 2013-2014). The Consortium's monitoring began following a strong El Niño in 1982–1983, and this was followed by a very strong La Niña cold-water event in 1989–1990. Due in part to the impetus provided by this La Niña, all 24 of the kelp beds that have supported kelp in the last half of the 20th century were displaying canopy in 1991. Descriptions of each Fish and Wildlife Kelp Bed are provided in previous Region Nine Kelp Survey Consortium Reports.

Region Nine supports the largest kelp beds in southern California: from north to south, the La Jolla, Point Loma, and Imperial Beach kelp beds. Rocky substrate is prevalent offshore of La Jolla, and it supports giant kelp beds to a depth of at least 27 m. Sand predominates from Pacific Beach downcoast past Mission Bay, and there is very little hard substrate. South of Mission Bay, rocky substrate emerges and giant kelp can be found out to at least 30 m during favorable years. The Point Loma kelp bed extends along the length of the peninsula. At the entrance to San Diego Bay, sand is the dominant substrate, and this habitat continues south to the Imperial Beach Pier. There is a group of low-lying, mostly cobble reefs from just offshore of the Imperial Beach Pier down to the Baja California border.

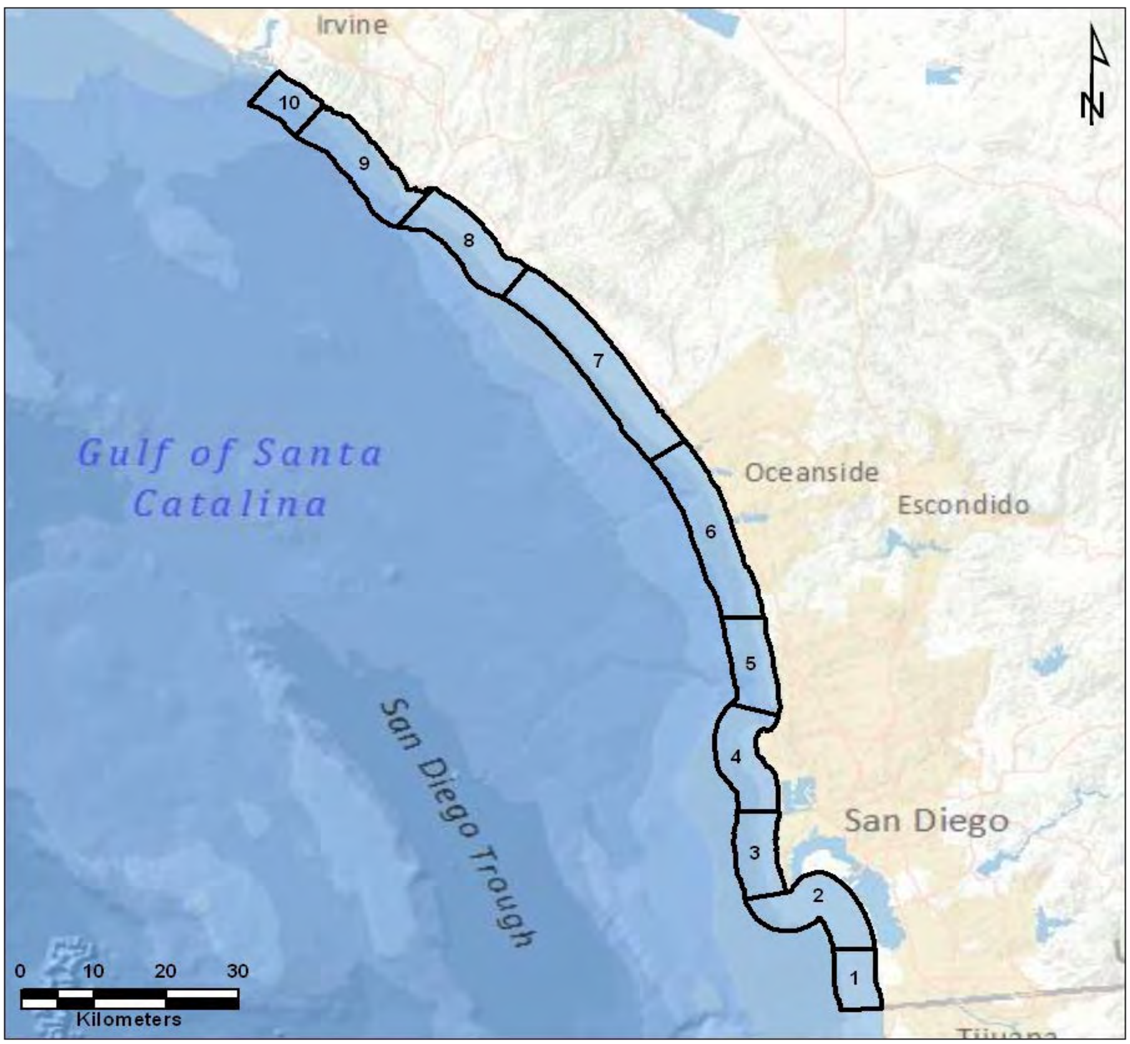


Figure 7. Administrative kelp bed lease areas in the Region Nine study area.

MATERIALS AND METHODS

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

- Water temperature data from automated stations at Santa Monica Pier, Newport Pier, and Scripps Pier. At these locations, automated samplers measure conductivity, temperature, and fluorometry every one to four minutes. Samplers are mounted at a depth of 2 m MLLW at Santa Monica and Newport Piers, and at 5 m MLLW at Scripps Pier. These data are made available in real time via the Southern California Coastal Ocean Observation System (SCCOOS) website (www. SCCOOS.org).

- Water temperature data were also provided by Los Angeles County Sanitation Districts from monitoring stations offshore Palos Verdes Peninsula (Stations PVS and PVN). Both stations are located at a depth of 23 m, with sensors at the surface and a depth of 11 m MLLW.

- Water temperature data from the National Data Buoy Center (NDBC) Point Loma South and Point Dume data buoys that record water temperature, wave height, period, and direction every 30 minutes from approximately one meter below the waterline, and are available in real time via the NDBC website (www.ndbc.noaa.gov).

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

- Nutrient and Harmful Algal Bloom (HAB) data are made available in real time at several locations via the SCCOOS website (www. SCCOOS.org).

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

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

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

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

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

All digital photographs from one of the four surveys that showed the greatest areal coverage were digitally assembled into a composite photo-mosaic that provided a regional view of whole kelp bed areas. If all of the kelp beds displayed the most canopy during a single survey, then the photographs from that survey would be used in the photo-mosaics. However, this rarely occurs. Data from one or two surveys are usually used to make the mosaics in order to provide a realistic estimate of the maximum canopy cover at any time (within about three months) during the year. The Photoshop mosaics were then transferred to GIS (ArcGIS 10.1) to geo-reference them, and to place them into specific Fish and Wildlife geo-spatial shape files. Each mosaic was geo-referenced to match at least three prominent features on the map and converted to Universal Transverse Mercator (UTM) or other acceptable coordinate system, and ultimately converted to a geo-referenced JPEG file. Surface canopy areas were calculated using the image classification function, an extension to the GIS program (SpatialEcology.com). The kelp beds from the photos were then layered on standard base maps to facilitate inter-annual comparisons.

Vessel Surveys. Once per survey year, typically between October and December, a vessel survey is conducted of all of the Region Nine kelp beds. The vessel survey for the 2014 survey year was conducted from Imperial Beach to Oceanside on 19 December 2014 and from Oceanside to Newport Harbor on 9 January 2015. During each survey, biologists locate the main canopies visually (or during poor years by latitude and longitude coordinates of the last remaining canopy) and determine the depth of the inshore and offshore edge of the kelp beds. Once located, there is a focused examination of the kelp health that includes:

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

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

RESULTS

WATER TEMPERATURES AND NUTRIENTS

Temperatures at the sea surface (SST) are a useful surrogate for nutrient availability. Additionally; there appears to be convincing evidence that seawater density can also be used as a surrogate, and in some cases predict nutrient availability better than temperature; however, long-term measurements of density on smaller scales than the SCB are not readily available. In contrast, nearshore temperature measurements have been ongoing for decades, resulting in a readily accessible data set that can be used to evaluate approximate nutrient availability. Two temperature/nutrient indices—one for each region—are presented in Figures 8 and 9. Based on the monthly Nutrient Quotient Index (NQ) described by North and MBC (2001), the average, early-morning SST at each station was correlated with the amount of nitrate that is theoretically available for uptake by kelp (in micrograms-per-gram per-hour) (Haines and Wheeler 1978; Gerard 1982).

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

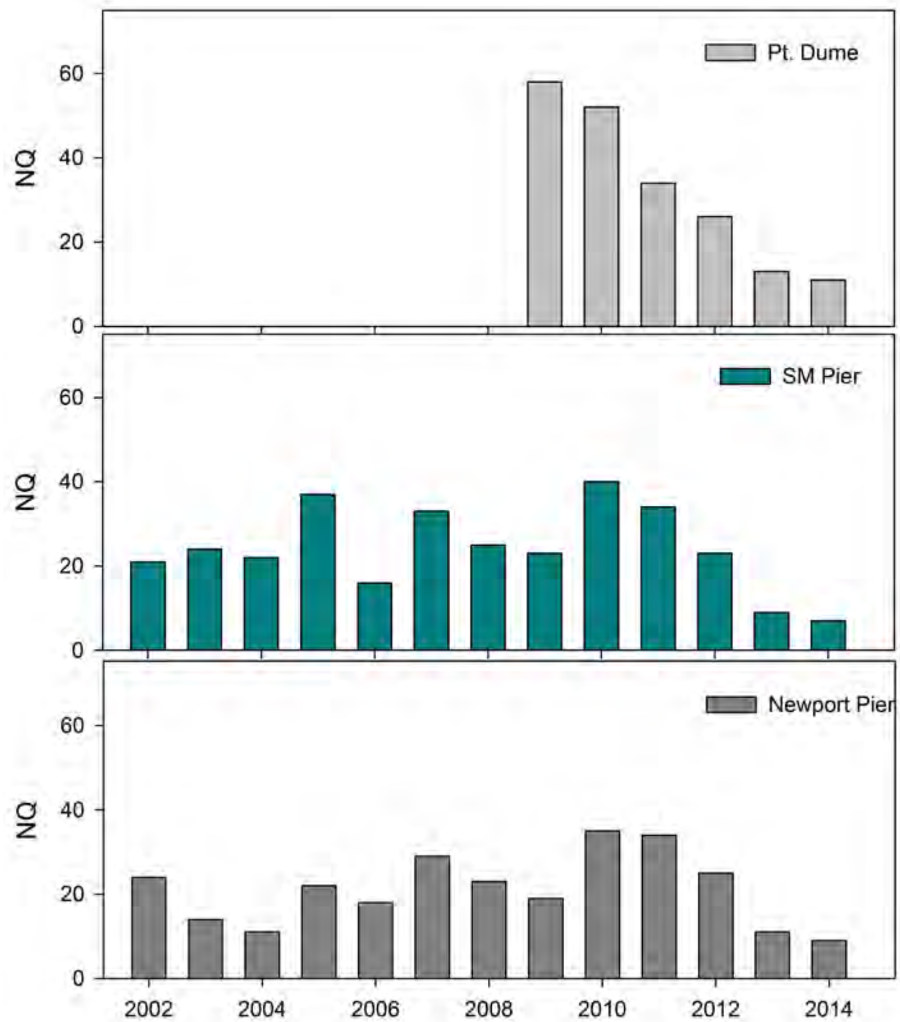


Figure 8. Nutrient Quotient (NQ) values in the Central Region, 2002–2014. “SM Pier” is the Santa Monica Pier. NQ I values are calculated from SSTs collected from these locations: Point Dume (Pt Dume), Santa Monica Pier (SM Pier), and Newport Beach (Newport Pier).

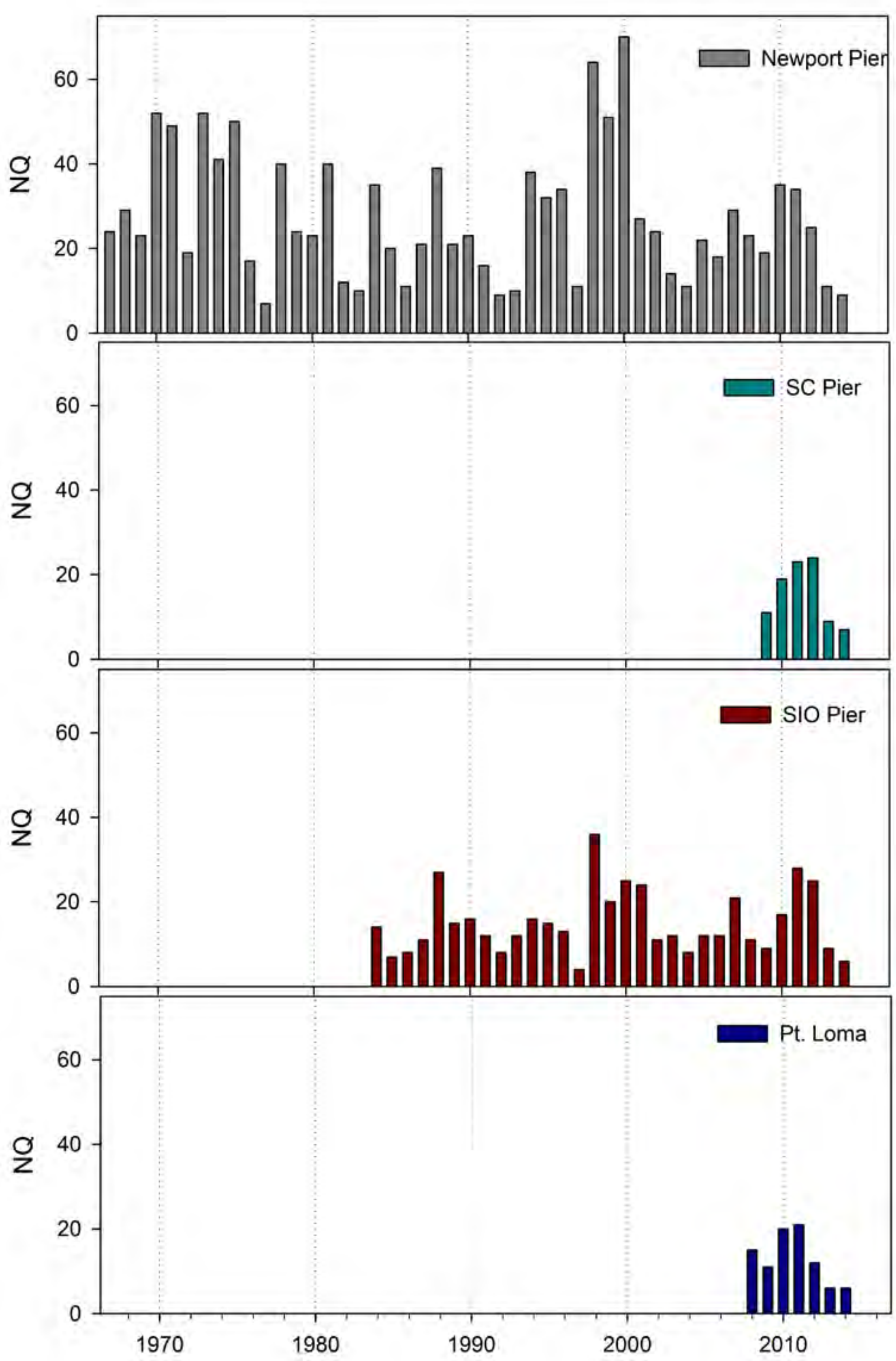


Figure 9. Nutrient Quotient (NQ) values in Region Nine, 1967–2014. "SC Pier" is the San Clemente Pier, and "SIO Pier" is the Scripps Inst. Oceanography Pier. NQ values are calculated from SSTs collect at these locations: Newport Beach (Newport Pier), San Clemente Pier (SC Pier), Scripps Inst. Oceanography Pier, La Jolla (SIO Pier) and Point Loma South CDIP Buoy (Pt Loma).

The variability of SSTs in 2014 tracked closely between Point Dume in the north, Newport in between, and SIO in the south (Figures 10–11). In general, temperatures were warmer than normal from January through mid-March, decreased in late-March, and then increased to above normal in May (and were mostly higher than average from May through December). There were multiple periods of cold-water influx (likely from upwelling) from late March through August. Upwelling was most pronounced at the SIO and Newport Piers during this period, and less so at San Clemente and Point Dume. Region-wide upwelling was calculated to be above normal during only two months in 2014: February and September (Figure 12).

The summer and fall of 2014 (and the first three months of 2015) were warmer than normal, with SSTs throughout southern California above average from October 2014 through March 2015. Temperatures at Point Dume, the northern-most temperature monitoring location, were only below average during 12 days in 2014. Steep declines in temperature occurred in spring and summer, but SSTs stayed above average from October through December. The NQ values at Point Dume are typically the highest in the Central Region (Figure 8). In 2014–2015, the Nutrient Quotient was less than one-half of the 2012–2013 NQ value, and less than one quarter of the 2010–2011 NQ value.

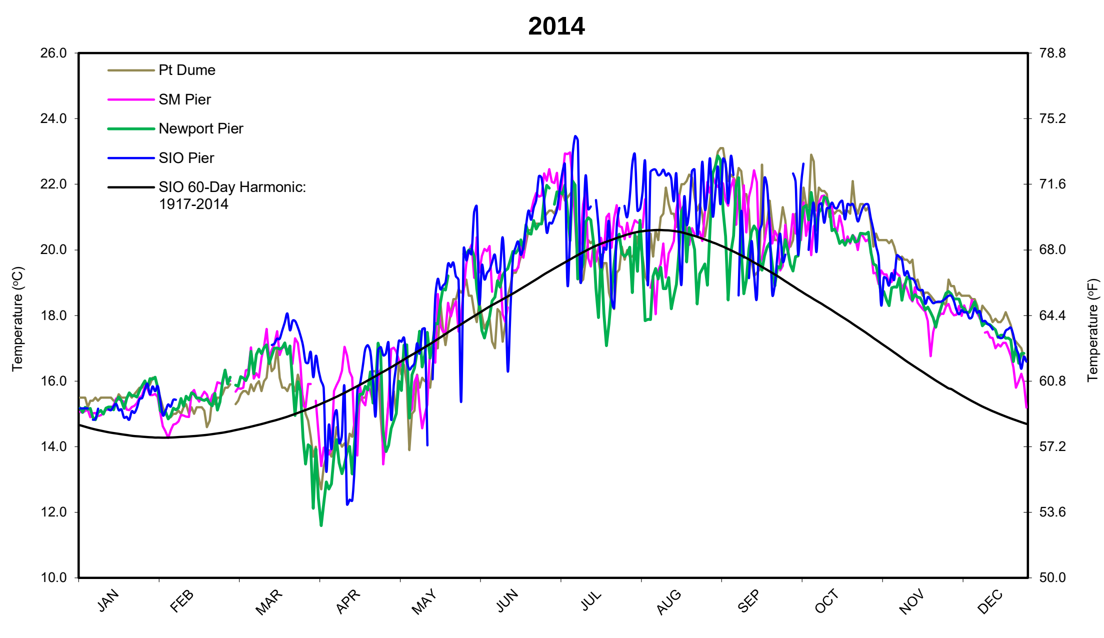


Figure 10. Sea surface temperatures (SST) at Point Dume, Santa Monica (SM) Pier, Newport Pier, and Scripps (SIO) Pier for 2014 compared to long-term harmonic mean from SIO Pier.

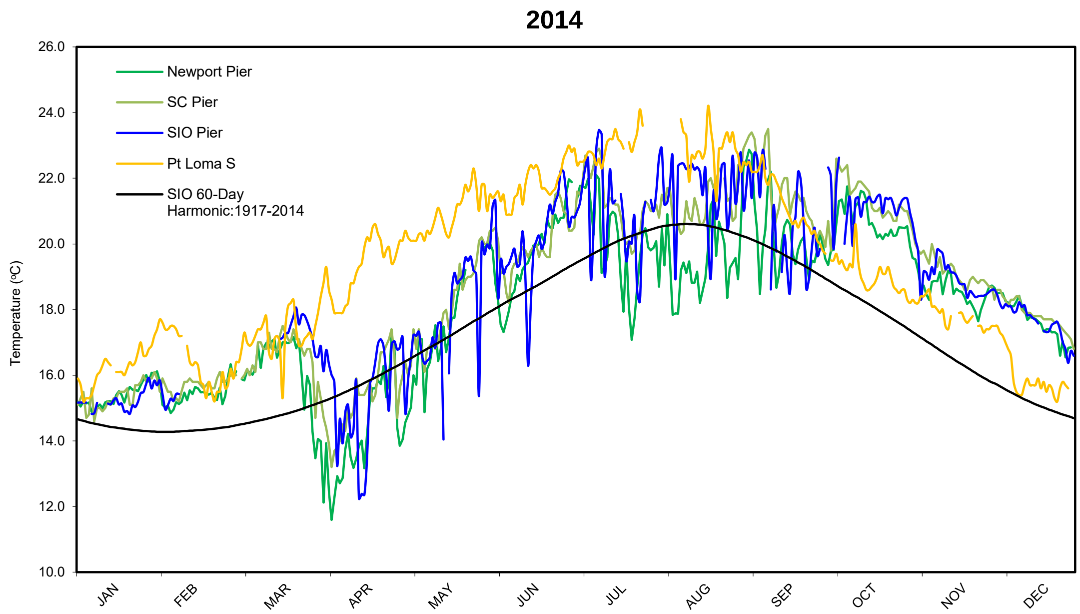
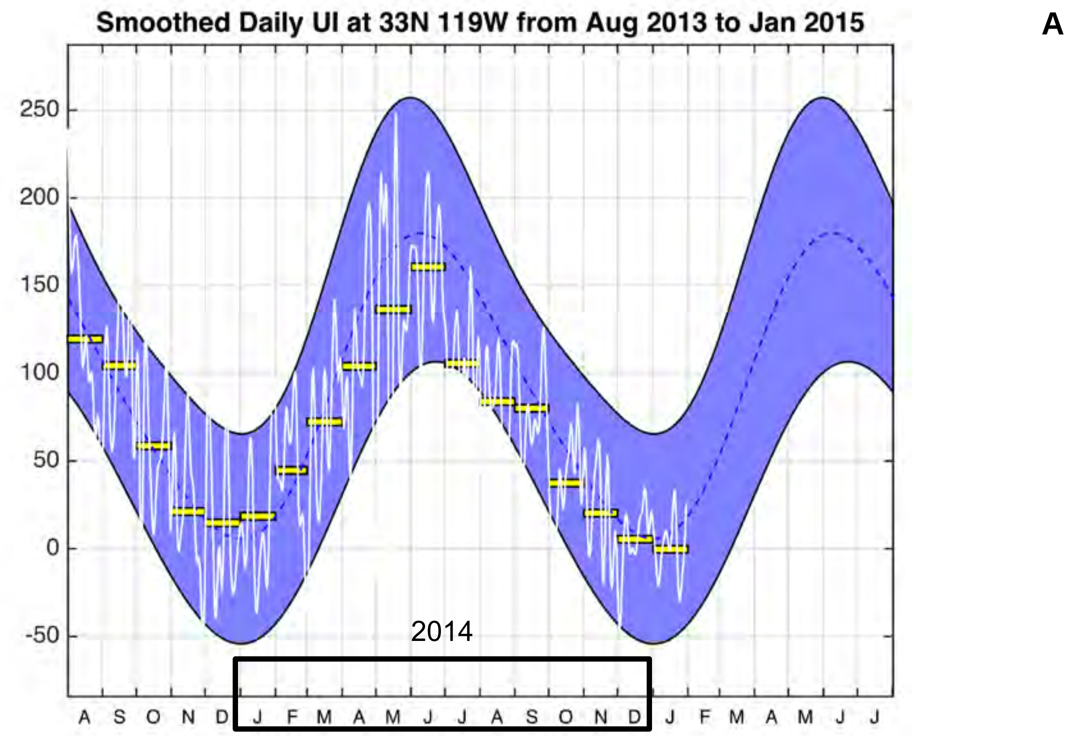


Figure 11. Sea surface temperatures (SST) at Newport Pier, San Clemente (SC) Pier, Scripps (SIO) Pier, and Point Loma South for 2014 compared to long-term harmonic mean from SIO Pier.

Temperatures at Santa Monica Pier in 2014 followed the same pattern, with below-average temperatures recorded during only 28 days (Figure 10). The NQ at Santa Monica Pier in 2013–14 (9) was 61% lower than in 2012–2013 (23), and much lower than the average NQ (26) for the last 13 years (Figure 8). Two stations farther south were located off the Palos Verdes peninsula: Station PVN was in the northern section near Lunada Bay, and Station PVS was in the southern end at Royal Palms (Appendix C). Both stations are at a depth of 23 m. Surface temperatures tracked closely at these two stations, although the NQs of 7 and 12, respectively, were only slightly higher than the NQs from 2013–2014, which were the lowest on record. (The extremely low values at PVN and PVS could have been due to gaps in data records.) There was a larger temperature differential between the surface and a depth of 11 m at Station PVN than at Station PVS.

At the juncture of the Central Region and Region Nine, SSTs at Newport Pier were generally above average from January through late-March, below average from late-March to mid-May, and near average or above average for the remainder of 2014 (Figures 10 and 11). Below-average temperatures were recorded during 48 days in 2014, and the 2014–2015 NQ of 9 was the lowest recorded since 1992–1993 (Figure 9). There were steep drops and wide fluctuations in temperature at Newport Pier from late-March through September. Newport Pier is located near the mouth of Newport Canyon, and strong upwelling usually occurs in distinct pulses at this station. The Newport Coast (based on the SSTs) was characterized by conditions supportive of upwelling during June, July, and August, although temperatures through the remainder of the year were higher than normal.



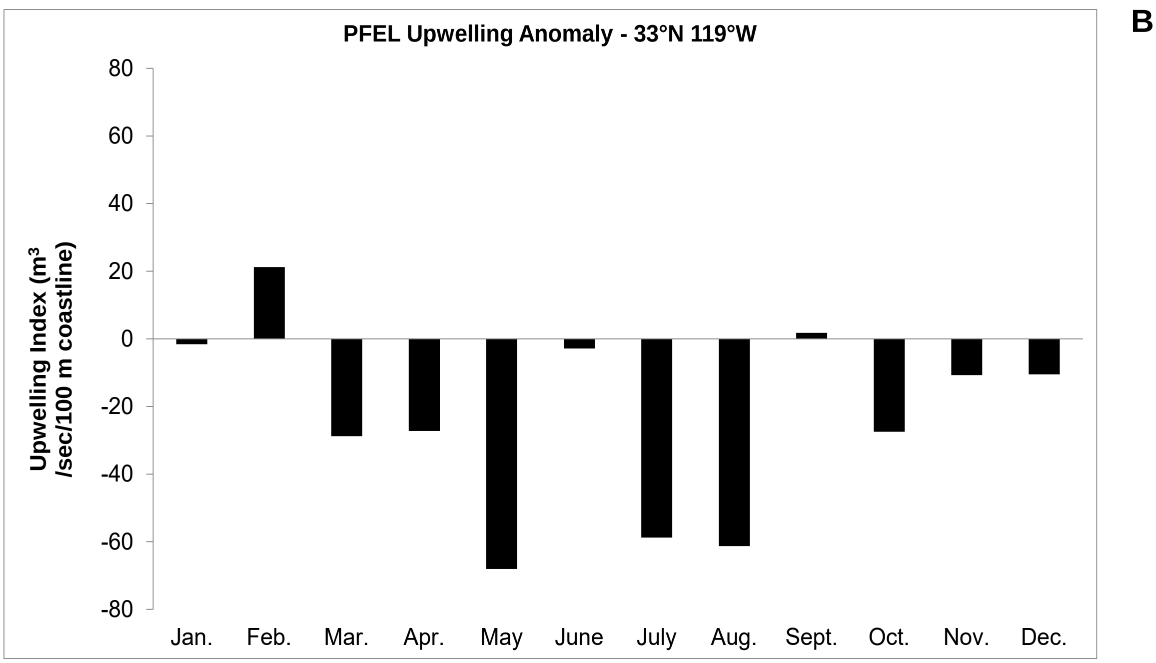


Figure 12. A) Daily Upwelling Index (UI) at 33°N 119°W. The dashed curve is a smoothed biharmonic fit to the daily UI from 1967–1991. The purple area represents one standard error, and the yellow bars are monthly means. Units are cubic meters per second per 100 meters of coastline. **B) UI anomaly (2014 compared to the monthly mean from 1946–2013).** Source: (NOAA PFEG 2015).

The SSTs at San Clemente Pier, in the mid-section of Region Nine, were similar to those at Newport Pier, except the periods of cold-water influx from April through August were less pronounced (Figure 11). The SSTs at Scripps Pier were the most variable of those in Region Nine in 2014, with marked upwelling events throughout spring and summer. The southern portion of Region Nine was tracked by the Point Loma South buoy. Similar to 2012, variability in Point Loma SSTs was muted in comparison to that at the SIO and Newport Piers. However, the Point Loma South buoy is farther offshore than the other stations, and is moored at a water depth of 1,100 m.

The long-term average NQ values at SIO Pier (15.2), Point Loma South (14.2), and San Clemente Pier (16.8) are relatively low compared to those at Newport Pier (27.8) and Santa Monica Pier (27.5), and suggest the kelp beds from San Clemente to San Diego have had comparatively low nutrient availability (Figure 9). The NQ values in Region Nine were above average at all stations (except Point Loma) in 2012–2013, and below average at all stations in 2013 and 2014. The long-term average NQ at Newport Pier (1967–present) is substantially higher than at the other stations, and highlights the variability of nutrient supply in southern California. The nitrate climate shifted from waters with sufficient nitrate prior to the 1976–1977 regime shift to depleted conditions afterward (Parnell et al. 2010). The response of giant kelp beds to nutrient replete years before the regime shift was dampened compared to their response afterward. The sensitivity of kelp canopies to nutrient limitation appears to have increased after 1977, and this intensification of physical control after 1977 is evident in the strong correlation of seawater density (δ_t) and density of giant kelp (Parnell et al. 2010).

The NQ index recorded during the 1997–1998 El Niño is a good example, because it indicated a particularly bad year for kelp beds in the SCB. During that season, NQ values ranged from 3 to 11. In contrast, during 1988–1989 (a year in which kelp beds reached their maximum extents in several decades) NQ values ranged from 27 to 39 (Figure 9). The NQ values at all stations in both regions were above average in 2012–2013, but below average in 2013 and 2014. Values in 2014 ranged narrowly from 6 to 12. The variability in SSTs and nutrients is driven by prevailing flow characteristics and bathymetric features that result in periodic upwelling along the rocky shores of the coastline, particularly from Deer Creek to Point Dume and along the Palos Verdes Peninsula, Dana Point, and La Jolla-Point Loma kelp beds.

INDICES

The MEI and the PDO changed phase about the same time: the MEI transitioned from negative to positive in April 2014, and the PDO went positive in January 2014 (Figure 13). The NPGO changed from positive to negative in October 2013, and has stayed negative for most of the time since then. All three indices changed phase at some point during the winter of 2013/2014. The MEI changed to positive, signaling the pending arrival of an equatorial El Niño. The PDO transition indicates warmer temperatures in the North Pacific, while the NPGO transition is indicative of lower productivity along the coast (Leising et al. 2014).

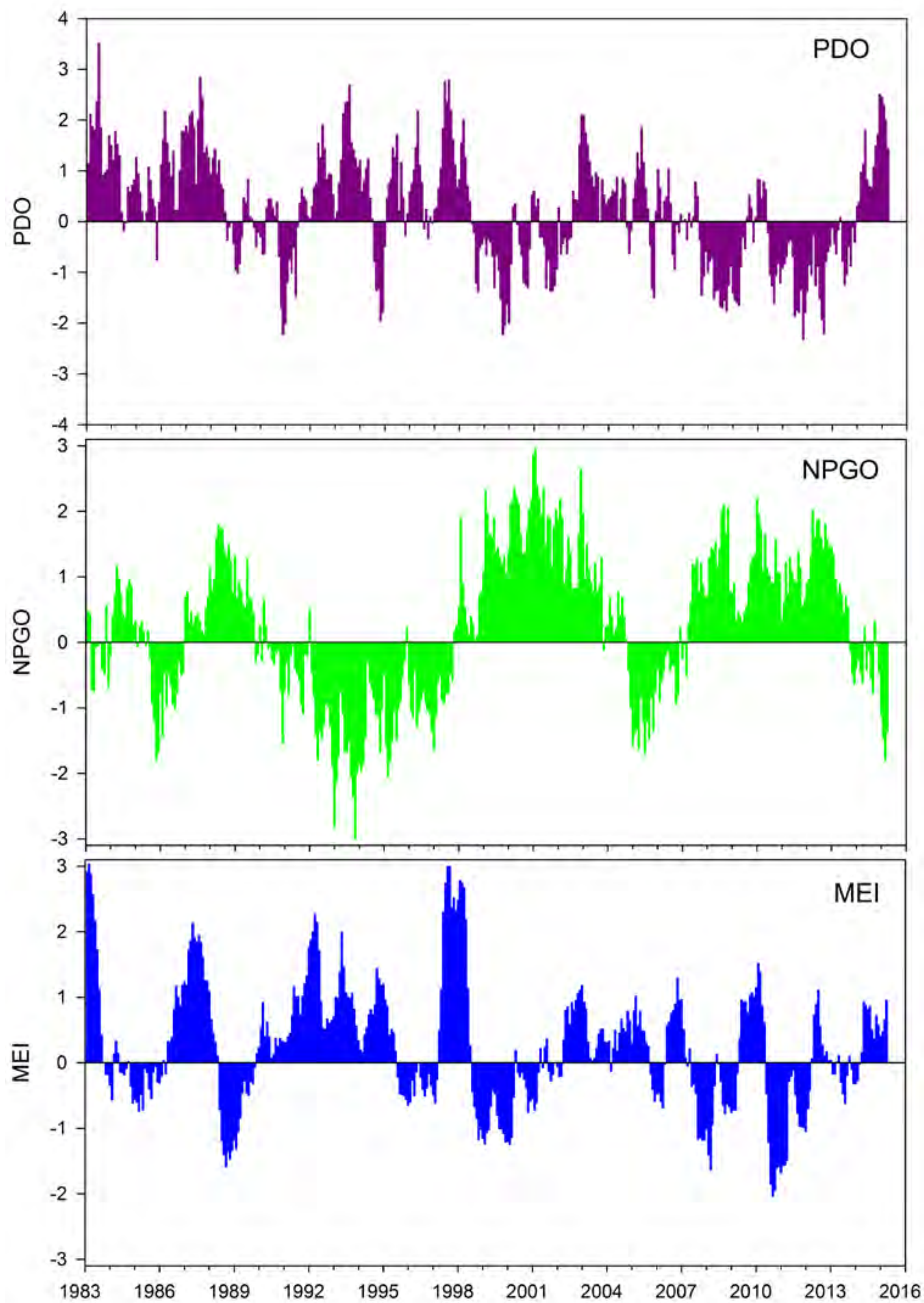
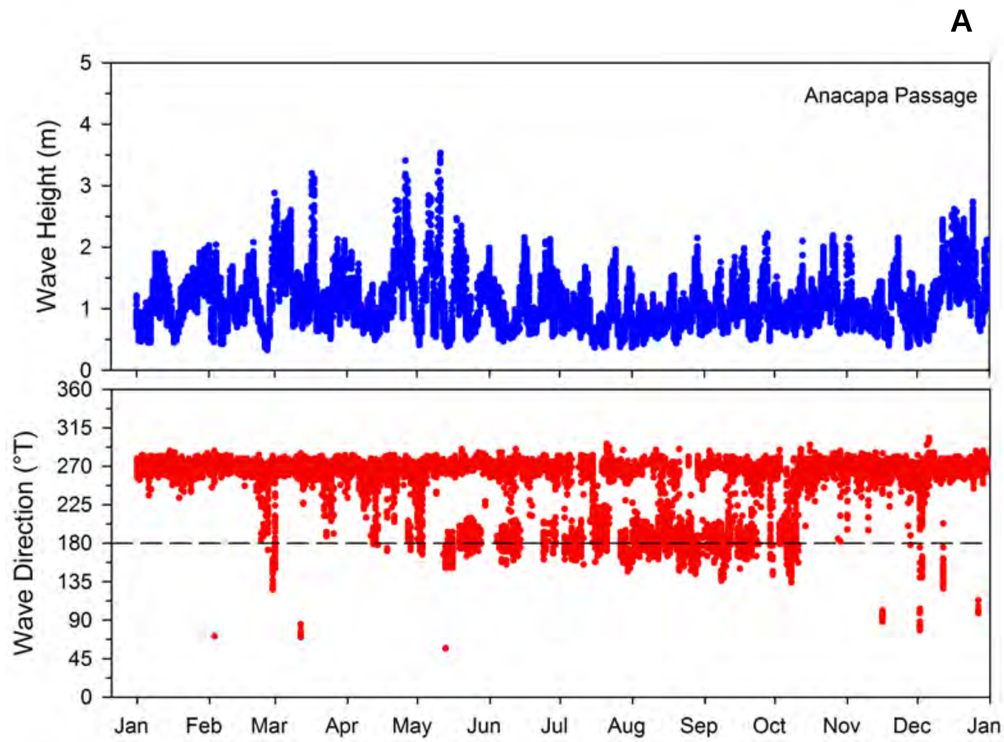


Figure 13. The PDO, NPGO, and MEI from 1983–2015.

WAVE HEIGHTS

Typical swell sizes and directions were observed through most of 2014, and at the northern portion of the range near Port Hueneme (Anacapa Passage), waves approached from the west to southwest about 80% of the time (Figure 14). Off San Pedro, waves originated out of the west about 60% of the time, the southwest 20% of the time, and the south about 20% of the time (Figure 14). Offshore of Point Loma, at the southern end of the SCB, waves were also mostly from the south and west, but there was also a small fraction from the west-northwest (Figure 15).

High-energy waves that negatively impact the kelp beds usually are low-frequency, high-amplitude waves approaching from the west. Significant wave heights (H_s) at Anacapa Passage (CDIP Buoy 111 off Ventura) exceeded three meters March, April and May 2014 (Figure 14). At the San Pedro Bay Buoy (092), H_s exceeded three meters in March, April, and August. Waves in early March exceeded 4.5 m at this location, coinciding with a storm that brought more than one inch of rain to the region. At Oceanside (CDIP Buoy 045), waves were more subdued, with wave heights exceeding three meters only a few times in spring (Figure 15). Off Point Loma (CDIP Buoy 191) high-amplitude waves exceeded three meters in March, April, May, and December, and wave heights of nearly five meters were recorded during the storm in early March (Figures 15 and 16). In addition, a large south swell moved through the area in late-August (Figure 17). Large swells become breaking waves as they approach shallow coastal waters and potentially can rip loose kelp holdfasts and cause the loss of entire kelp beds.



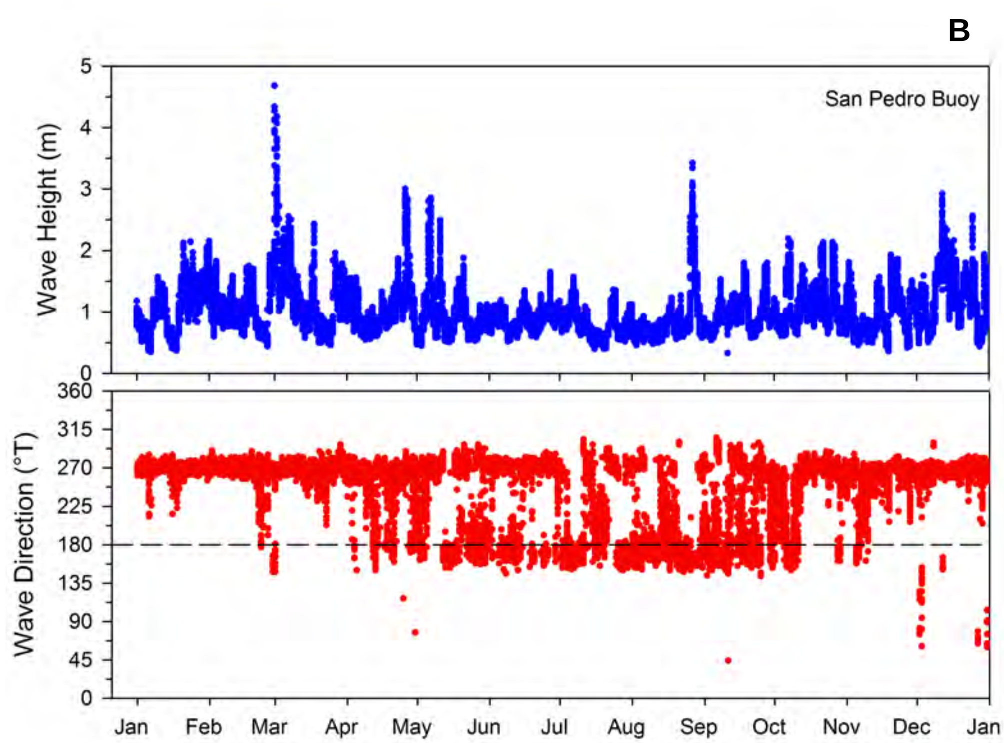


Figure 14. Wave height (blue) and direction (red) at A) Anacapa Passage Buoy and B) San Pedro Buoy from January 2014 through December 2014. Data from CDIP (2015).

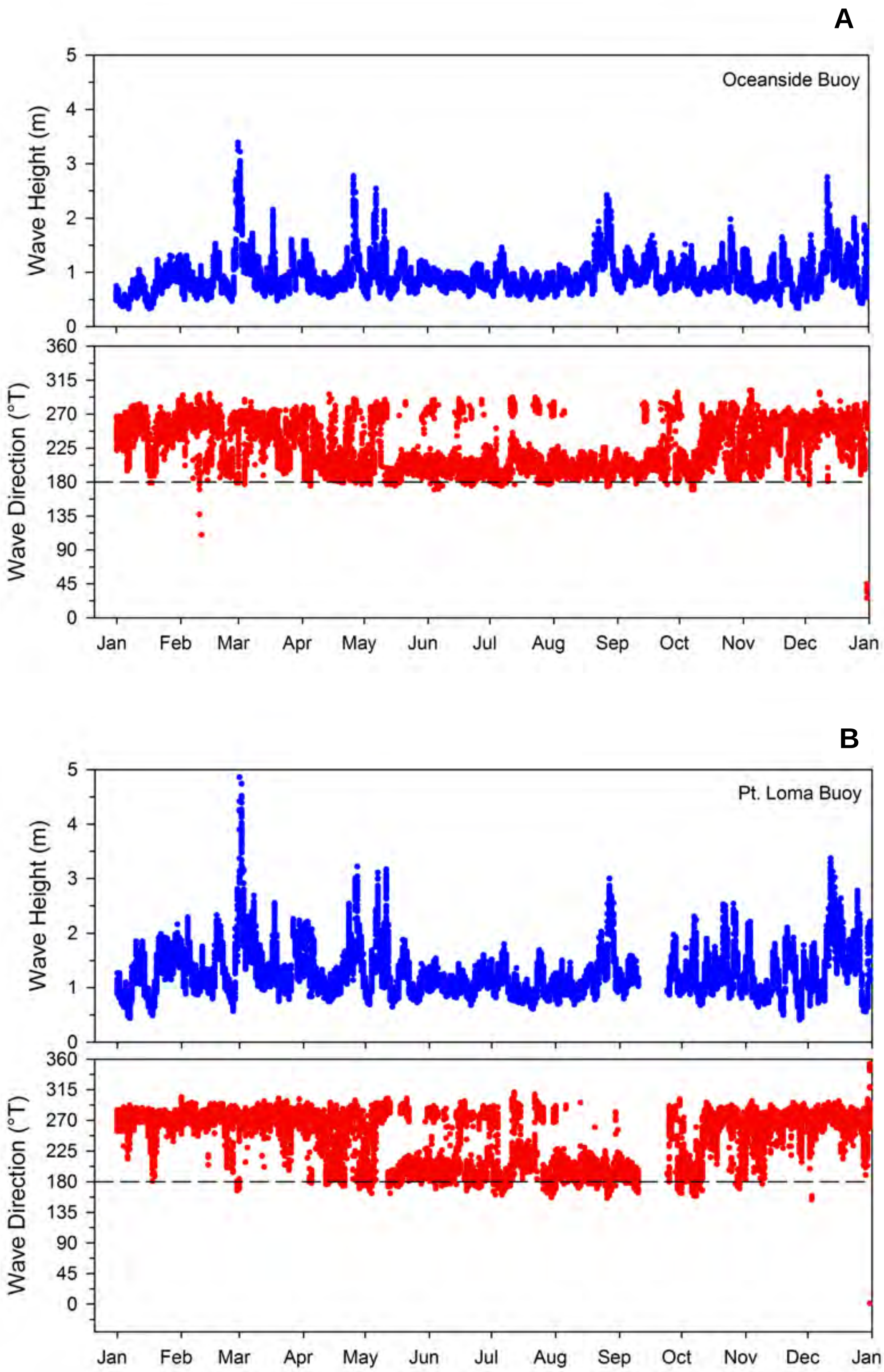


Figure 15. Wave height (blue) and direction (red) at A) Oceanside Buoy and B) Point Loma Buoy (bottom) from January 2014 through December 2014. Data from CDIP (2015).

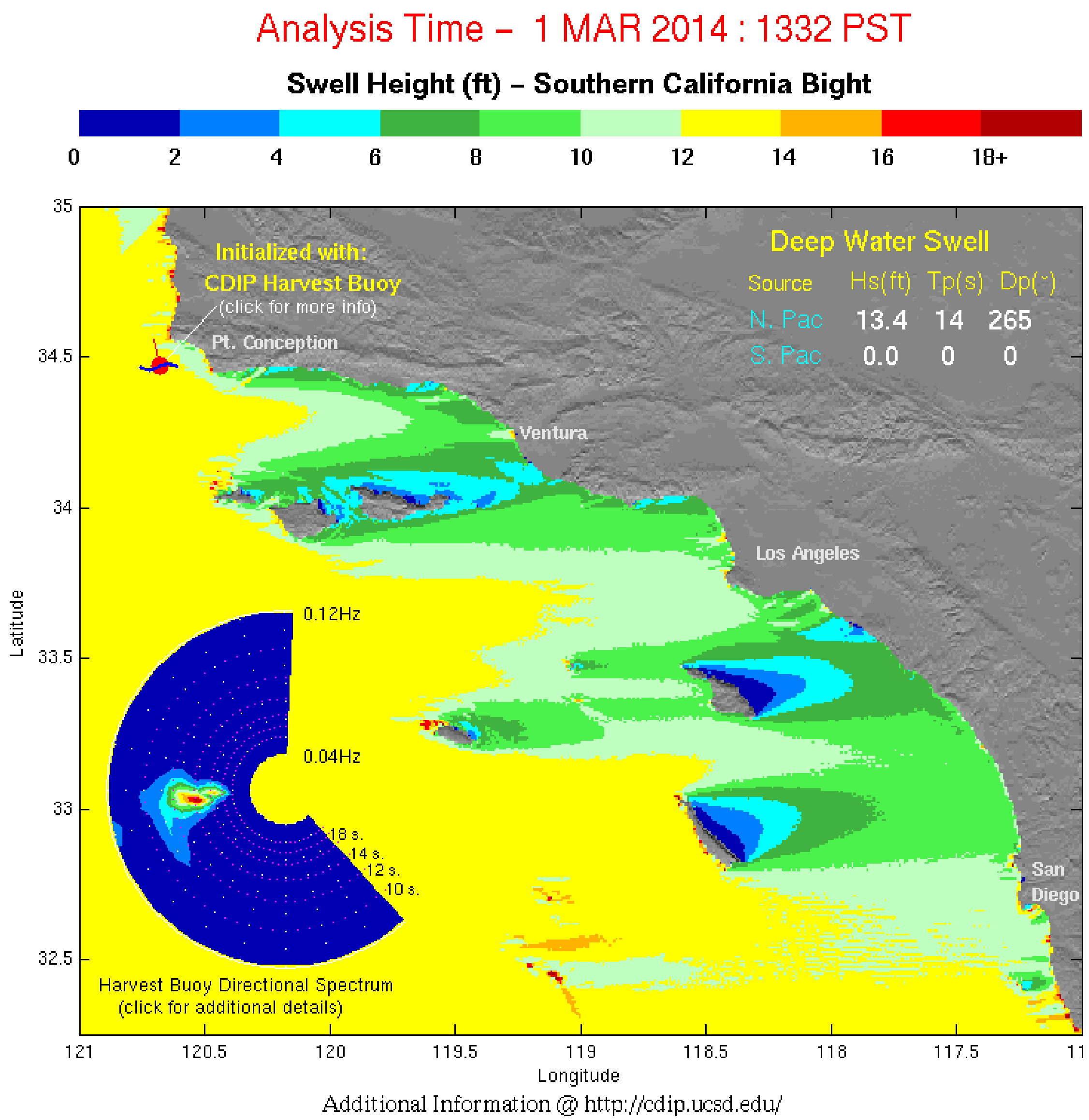


Figure 16. Swell height and direction in the SCB, 1 March 2014. Source: CDIP (2015).

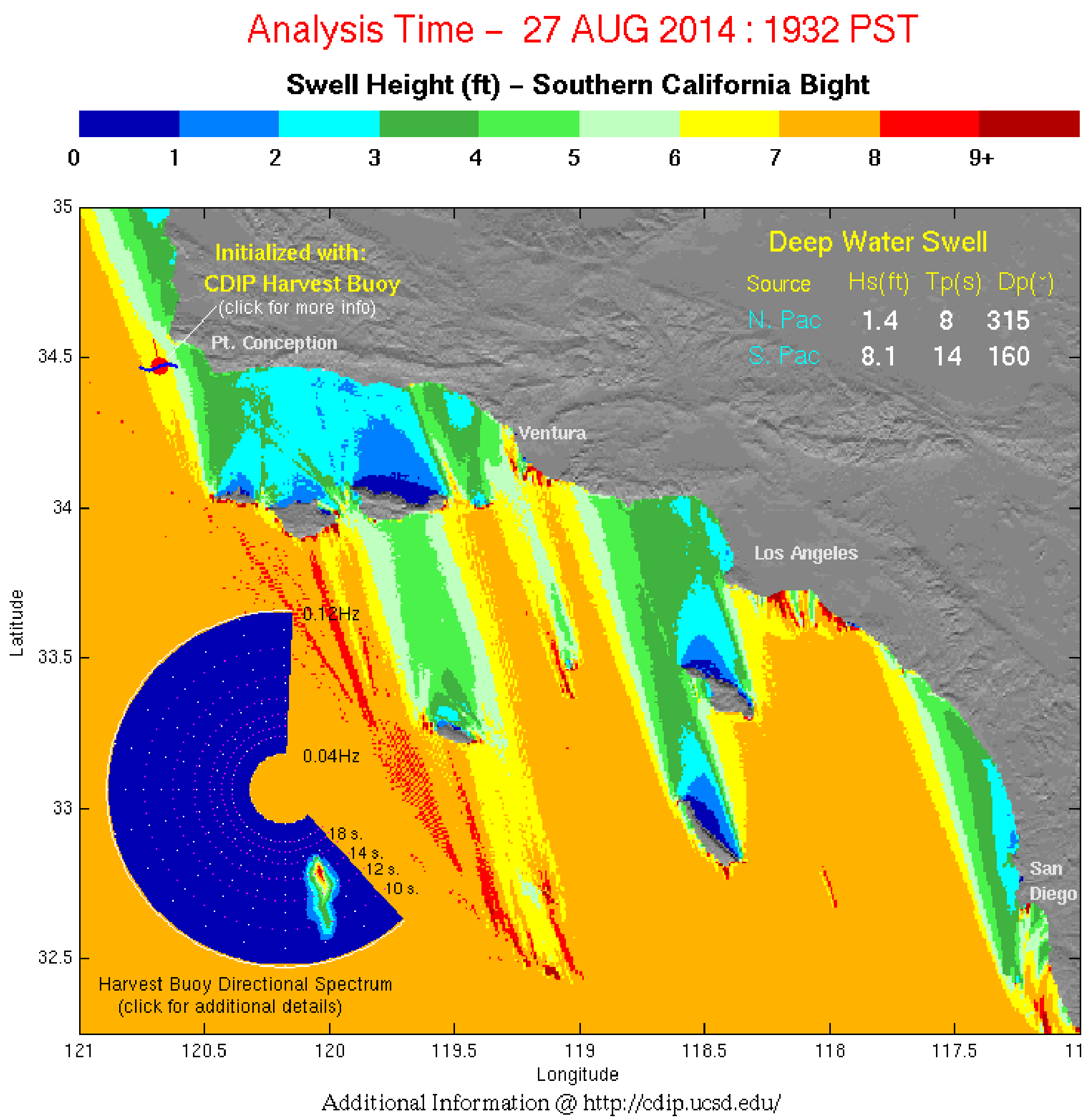


Figure 17. Swell height and direction in the SCB, 27 August 2014. Source: CDIP (2015).

RAINFALL AND NUTRIENTS

Periods of sustained high turbidity in southern California waters often result from high rainfall; however, rainfall was well below average for the fourth straight year (Figure 18). Even though rainfall was three to four times higher than in 2013, annual totals were still well below average. Therefore, turbidity from storm runoff did not likely play an important role in kelp health in 2014. The majority of the rain fell February, March, and December, although small amounts of rain were recorded during other months.

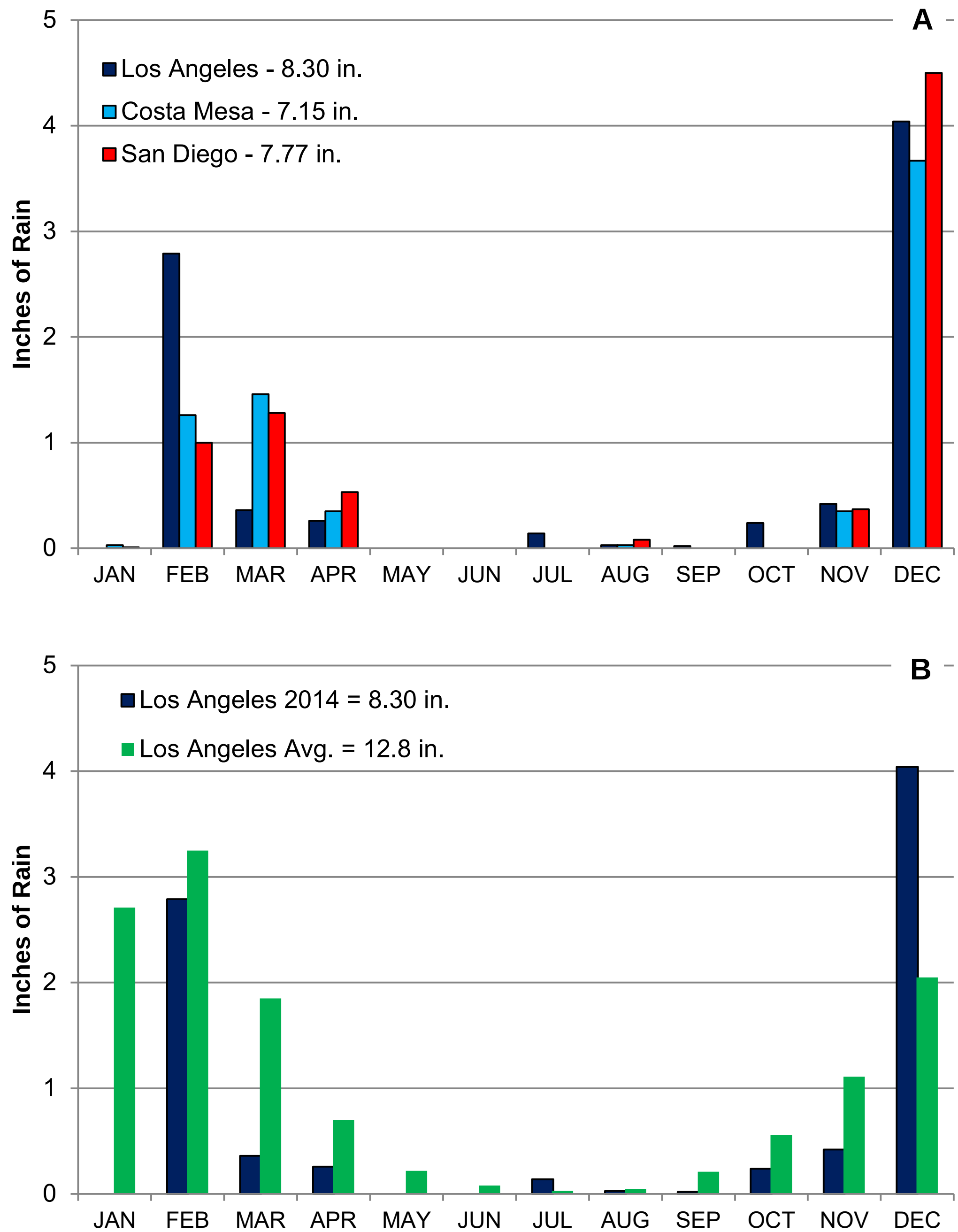


Figure 18. A) Monthly rainfall recorded for Los Angeles International Airport (Los Angeles), Costa Mesa, and Lindbergh Field (San Diego) in 2014. B) Monthly average (1980-2010) and 2014 actual rainfall at LAX. Source: NOAA CNRFC (2015).

At Santa Monica Pier, highest nitrate levels were recorded in late summer and fall, whereas at Scripps Pier, highest nitrate concentrations were recorded earlier in the year (Figures 19 and 20; SCCOOS 2015). About two-thirds of the nitrate concentrations at Santa Monica Pier exceeded the growth threshold for giant kelp (1 μmol nitrate per liter; Zimmerman and Kremer 1984); only 1 of the 31 concentrations at Scripps Pier were higher than the growth threshold. Concentrations of the phytoplankton *Pseudo-nitzschia* and *Prorocentrum* peaked in spring and summer at both locations.

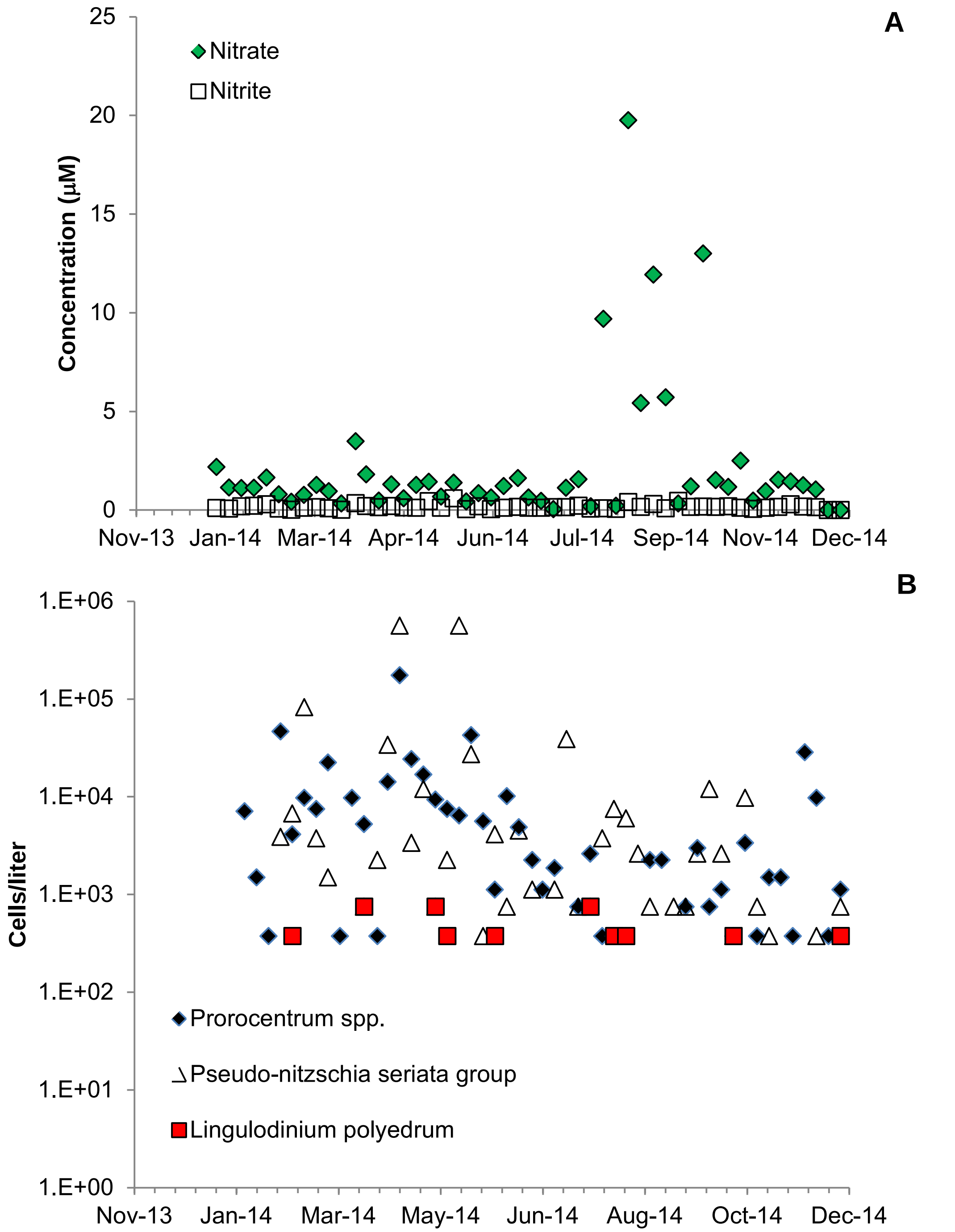


Figure 19. A) Concentrations of nitrate and nitrite, Santa Monica Pier. B) Concentrations of HAB species, Santa Monica Pier, 2014. Source: SCCOOS (2015).

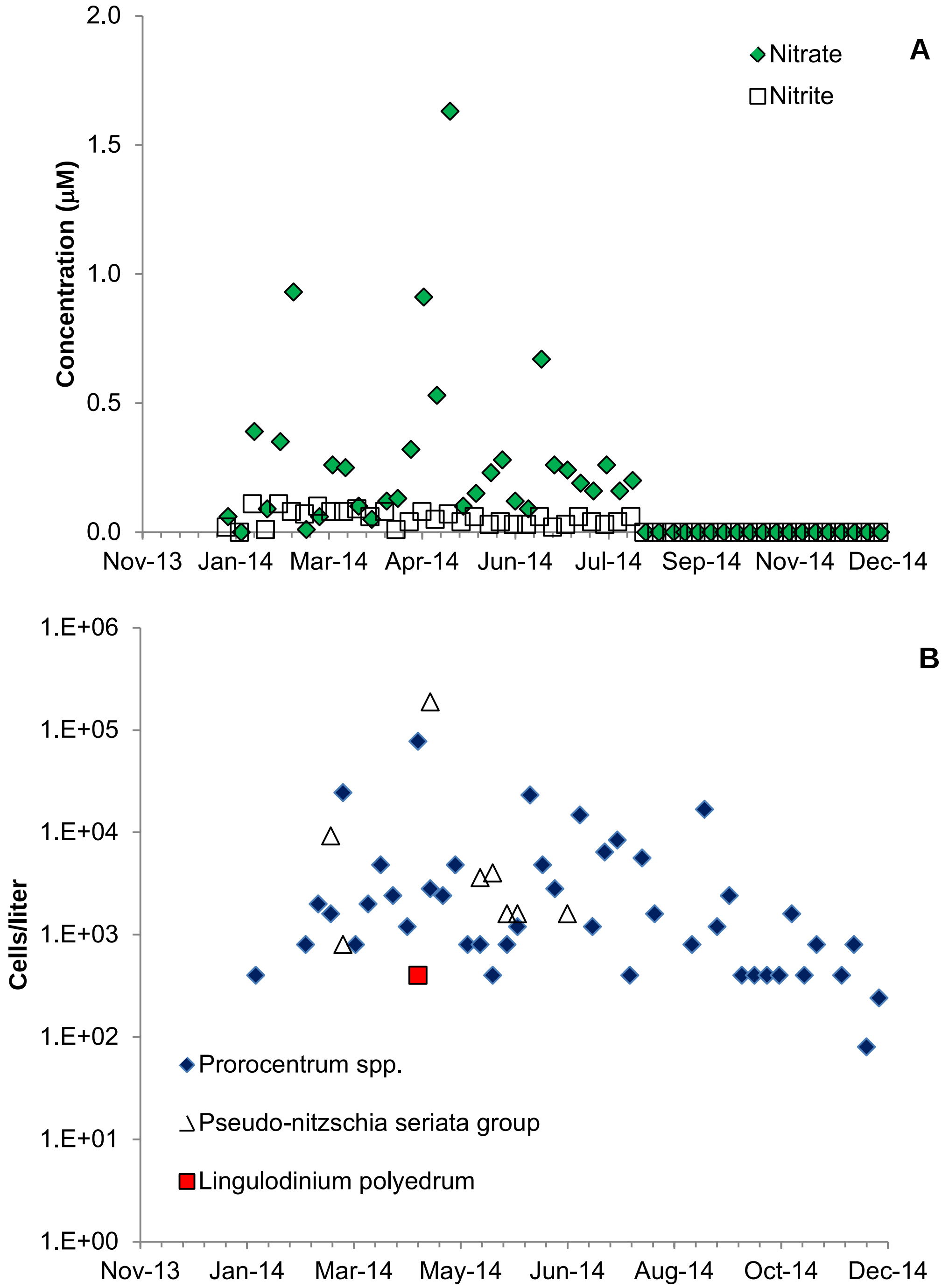


Figure 20. A) Concentrations of nitrate and nitrite, Scripps Pier. B) Concentrations of HAB species, Scripps Pier, 2014. Source: SCCOOS (2015).

Periods of increased phytoplankton concentrations (exceeding 10^4 cells/liter) were recorded in Santa Monica Bay in spring 2014 and off SIO Pier in spring and summer 2014 (Figures 19 and 20). No widespread red tide (plankton bloom) was recorded during the year at either location. Concentrations at over 350,000 cells per liter (R. Shipe, pers. comm.) can effectively exclude light from all but the shallowest depths. This limits photosynthetic activity at depth and was may have been 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).

2014 QUARTERLY OVERFLIGHT SUMMARY

Aerial surveys were flown on 7 April, 27 June/6 July, 10 September, and 22 December 2014. One survey was completed for the 2015 survey year on 9 April. Reasonable attempts were made to conduct one aerial overflight within each of the four quarters in the year (Table 3). The overflight on 27 June covered Ventura to Newport Beach, but fog precluded continuation farther south. That section of Region Nine was surveyed on 6 July. The timing of maximum canopy coverage varied by region and kelp bed. Most of the beds in the Central Region displayed maximum canopies during the June overflight (Table 4). Most of the beds in Region Nine displayed the most canopy coverage during the July overflight, even though the beds from Newport Beach to Barn kelp peaked during the April survey (Table 5). The Lower Point Loma and Imperial Beach kelp beds appeared slightly larger in September than in July; however, the images from the July overflight were processed to maintain consistency with the Upper Point Loma kelp bed and the southern half of the RNKSC.

Table 3. Status of planned aerial overflights 2014.

Target Date	Actual Date	Comments
1st Quarter – March 2014	7 April 2014	Favorable conditions.
2nd Quarter – June 2014	27 June 2014	Fog prevented survey from Newport Beach to Imperial Beach.
	6 July 2014	Completion of 2nd Quarter survey (Newport Beach to Imperial Beach).
3rd Quarter – Sept. 2014	10 Sept. 2014	Favorable conditions.
4th Quarter – Dec. 2014	22 Dec. 2014	Clouds/fog at Palos Verdes I (PV I).

2014 VESSEL SURVEY SUMMARY

Boat surveys were conducted periodically throughout the year from Newport Beach to Barn kelp (during ongoing physical and biological surveys), on 19 December 2014 from Oceanside to Imperial Beach, and on 9 January 2015 from Newport Beach to Oceanside, to document the apparent health and extent of the kelp canopies. Results from these surveys are presented in the individual summaries of each kelp bed.

2014 KELP CANOPY SUMMARY

Central Region. The following changes since 2013 were documented in the 26 CRKSC kelp beds in 2014:

- 4 kelp beds increased in size
- 1 kelp bed remained the same
- 19 kelp beds decreased in size
- 2 kelp beds were not present (and have been absent for decades)

Overall, the maximum measured kelp canopy decreased by 24% from 2013 (from 5.614 km^2 to 4.283 km^2) (Table 1).

Region Nine. The following changes since 2013 were documented in the 24 RNKSC kelp beds in 2014:

- 1 kelp bed increased in size
- 1 kelp bed remained the same
- 24 kelp beds decreased in size

Overall, the maximum measured kelp canopy decreased by 18% from 2013 (from 17.064 km^2 to 14.053 km^2) (Table 2). Only the Imperial Beach kelp bed increased in size (by 0.66 km^2). Graphical depictions of each bed are presented in Appendix A, and a mosaic of the kelp canopies along the coastline is presented in Appendix E.

Table 4. Rankings assigned to the 2014 aerial photograph surveys of the Ventura, Los Angeles, and Orange County kelp beds. The basis for a ranking was the status of a canopy during surveys from recent years, excluding periods of El Niño or La Niña conditions or following exceptional storms.

	2014 Surveys			
Kelp Beds	**7 April**	**27 June/6 July**	**10 Sept.**	**22 Dec.**
Ventura Harbor *	-	**-**	-	-
Channel Islands *	-	**-**	-	-
Port Hueneme *	-	**-**	-	-
Deer Creek	2.5	**4.0**	2.0	2.5
Leo Carillo	2.5	**4.0**	1.0	1.0
Nicolas Canyon	2.5	**4.0**	1.0	1.0
El Pescador/La Piedra	2.0	**3.0**	1.0	1.0
Lechuza Kelp	2.0	**4.0**	1.0	0.5
Point Dume	1.0	**3.0**	1.0	0.5
Paradise Cove	1.0	**3.0**	1.0	0.5
Escondido Wash	2.5	**3.0**	1.0	0.5
Latigo canyon	3.0	**3.0**	1.0	0.5
Puerco/Amarillo	2.0	**3.0**	1.0	0.5
Malibu Pt.	1.0	**3.0**	-	-
La Costa	1.0	**1.0**	-	-
Las Flores	2.0	**3.0**	-	-
Big Rock	1.0	**3.0**	-	-
Las Tunas	1.0	**2.5**	-	0.5
Topanga	1.0	**3.0**	-	0.5
Sunset	1.0	**-**	-	-
Marina Del Rey *	-	**-**	-	-
Hyperion Pipeline *	-	**-**	-	-
Redondo Breakwater *	-	**-**	-	-
Malaga Cove - PV Point (IV)	1.0	**1.0**	1.0	2.0
PV Point - Point Vicente (III)	1.0	**3.0**	3.0	3.0
Point Vicente - Inspiration Point (II)	1.0	**4.0**	2.0	3.0
Inspiration Point - Point Fermin (I)	1.0	**2.0**	1.0	NI
Cabrillo	1.0	**2.5**	1.0	2.0
LB/LA Harbor and Breakwaters	1.0	**2.5**	1.0	1.0
Horseshoe Kelp	-	**-**	-	-
Huntington Flats	-	**-**	-	-
Newport Harbor *	**1.0**	-	-	-
Corona Del Mar	**2.5**	2.5	1.0	0.5
North Laguna Beach	**2.5**	2.0	1.0	1.0

" - " = no canopy present; * = not part of the monitored beds; NI = no image due to clouds or fog.

Ranking values: 0.5 = trace or very small amount of kelp present; 1 = well below average; 2 = below average; 2.5 = average; 3 = above average; and 4 = well above average. Bold indicates survey used for canopy analysis.

Table 5. Rankings assigned to the 2014 aerial photograph surveys of the Orange and San Diego County kelp beds. The basis for a ranking was the status of a canopy during surveys from recent years, excluding periods of El Niño or La Niña conditions or following exceptional storms.

	2014 Surveys			
Kelp Bed	**7 April**	**27 June/6 July**	**10 Sept.**	**22 Dec. 15**
Newport Harbor *	**1.0**	-	-	-
Corona del Mar	**2.5**	2.5	1.0	0.5
No. Laguna Beach	**2.5**	2.0	1.0	1.0
So. Laguna Beach	**2.5**	1.0	0.5	-
South Laguna	**2.0**	1.0	1.0	0.5
Salt Creek-Dana Point	**2.5**	1.0	1.0	1.0
Dana Marina *	**-**	-	-	-
Capistrano Beach	**1.0**	NI	1.0	-
San Clemente	**3.0**	3.0	2.5	2.5
San Mateo Point	**3.0**	2.0	1.0	2.5
San Onofre	**2.5**	2.5	2.0	2.0
Pendleton Reefs *	**-**	-	-	-
Horno Canyon	**1.0**	2.0	-	-
Barn Kelp	**3.0**	2.5	-	1.0
Santa Margarita	-	**-**	-	-
Oceanside Harbor *	-	**-**	-	-
North Carlsbad	2.0	**2.0**	2.0	1.0
Agua Hedionda	1.0	**3.0**	1.0	2.0
Encina Power Plant	3.0	**3.0**	2.0	2.5
Carlsbad State Beach	2.0	**2.0**	1.0	1.0
North Leucadia	2.5	**2.0**	2.0	2.0
Central Leucadia	2.0	**2.0**	2.0	2.0
South Leucadia	2.0	**2.0**	2.0	2.0
Encinitas	2.0	**2.0**	1.0	2.0
Cardiff	3.0	**2.0**	1.0	2.0
Solana Beach	3.0	**3.0**	2.5	2.5
Del Mar	2.0	**2.0**	-	-
Torrey Pines Park	-	**-**	-	-
La Jolla Upper	3.0	**4.0**	3.0	0.5
La Jolla Lower	2.0	**3.0**	2.0	0.5
Point Loma Upper	3.0	**4.0**	4.0	2.0
Point Loma Lower	3.0	**3.0**	3.5	2.0
Imperial Beach	2.0	**2.5**	3.0	2.0

" - " = no canopy present; * = not part of the monitored beds; NI = no image due to clouds or fog.

Ranking values: 0.5 = trace or very small amount of kelp present; 1 = well below average; 2 = below average; 2.5 = average; 3 = above average; and 4 = well above average. Bold indicates maximum canopy size for the year.

STATUS OF THE 50 KELP BEDS IN CENTRAL REGION AND REGION NINE IN 2014

The following is a synopsis of the status of each individual bed during the 2014 survey year based upon the quarterly surveys.

CENTRAL REGION KELP SURVEYS

The kelp bed coverage of the Central Region has been above the long-term average since 1967 (4.096 km^2) for seven of the past eight years (Figure 21).

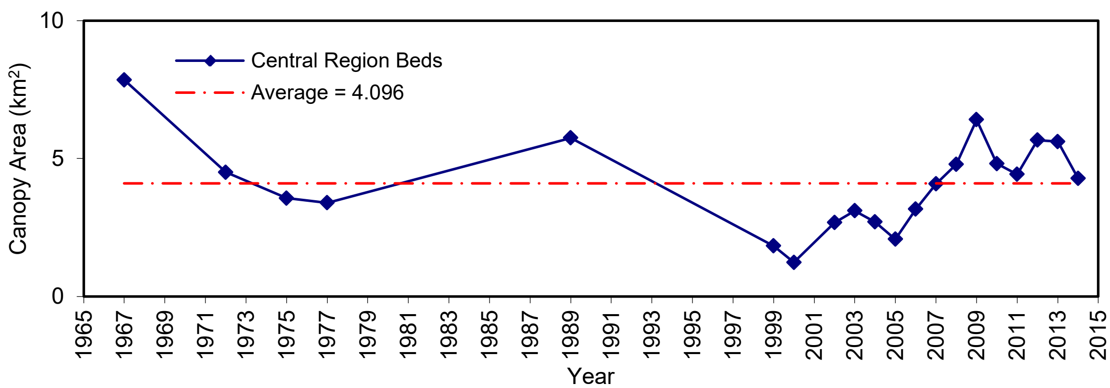


Figure 21. Combined canopy coverages at all kelp beds in Central Region from Ventura to Newport/Irvine Coast.

Ventura Harbor, Channel Islands Harbor to Point Mugu. A small amount of giant kelp was noted growing along the breakwaters of Ventura Harbor (0.009 km^2), Channel Islands Harbor (0.007 km^2), and at Port Hueneme (0.011 km^2) in 2014. No kelp was noted offshore of the Mandalay and Ormond Beach Generating Stations, and no kelp was noted downcoast of Port Hueneme until Deer Creek. These results are consistent with those from 2013.

POINT MUGU TO POINT DUME

Deer Creek. The Deer Creek kelp bed changed little between 2013 (0.104 km^2) and 2014 (0.103 km^2). The Deer Creek canopy was compared to the average bed area per year (ABAPY) of the northern and central portions of the Central Region to determine whether it was responding synoptically with the beds from the same area. The ABAPY was calculated by summing the annual canopy estimates for the relevant beds during each year, and dividing the total by the number of beds included. The ABAPY for the Northern and Central Los Angeles County area included all beds in the CRKSC upcoast from Palos Verdes. Kelp beds in the Palos Verdes region were treated separately as they are typically larger beds and react differently from the other beds of the Central Region. The ABAPY decreased 8% from 2013 (0.132 km^2) to 2014 (0.122 km^2) (Figure 22).

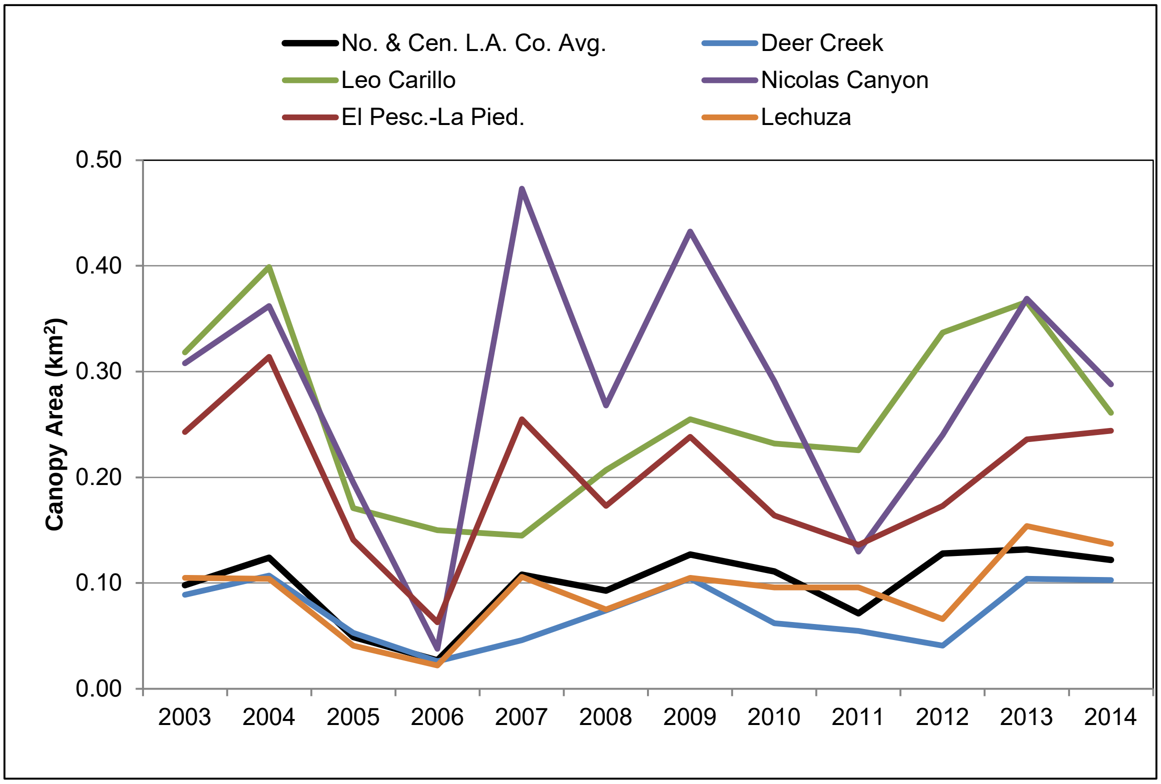


Figure 22. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the five northern-most kelp beds for the years shown.

Leo Carillo. Leo Carillo kelp bed decreased by 29% in 2014 (from 0.366 km^2 to 0.261 km^2). With the exception of 2007 and 2008, Leo Carillo kelp has reacted synoptically with the kelp beds in the region (Figure 22). The decrease of the Leo Carillo kelp bed in 2014 was slightly larger than the decrease of the ABAPY (8%).

Nicolas Canyon. The Nicolas Canyon kelp bed decreased by 22% in 2014 (from 0.369 km^2 to 0.288 km^2). The decrease of the Nicolas Canyon kelp bed in 2014, however, was larger than the decrease of the ABAPY (8%) (Figure 22).

El Pescador/La Piedra. The El Pescador/La Piedra kelp bed was one of four kelp beds in the Central Region that increased in size in 2014 (Figure 22). The area of the bed increased by 3% since 2013 (from 0.236 km^2 to 0.244 km^2). The changes in size at the El Pescador/La Piedra kelp bed have typically mirrored those of the regional beds, although the bed increased slightly in 2014 while most beds decreased.

Lechuza. In 2013, Lechuza kelp bed reached its largest extent (0.154 km^2), exceeding that recorded in the last century. However, in 2014 the area of the bed decreased by 11% (to 0.137 km^2) (Figure 22). The Lechuza kelp bed size and its responses have been nearly identical to those of the average bed in the region until 2012 when it unexpectedly decreased while most beds in the region increased. Even though the ABAPY was similar in 2013 and 2012, the size of the Lechuza kelp bed more than doubled. Despite the decrease in size in 2014, the area of the bed in 2014 was still the second largest recorded since 2003.

POINT DUME TO MALIBU POINT

Point Dume. In 2012, Point Dume kelp bed increased to a 10-year maximum size (0.154 km^2), although it decreased by 27% in 2013, and by another 19% in 2014 (to 0.092 km^2). The canopy size of the Point Dume kelp bed has typically fluctuated in sync with the ABAPY since 2006 (Figure 23).

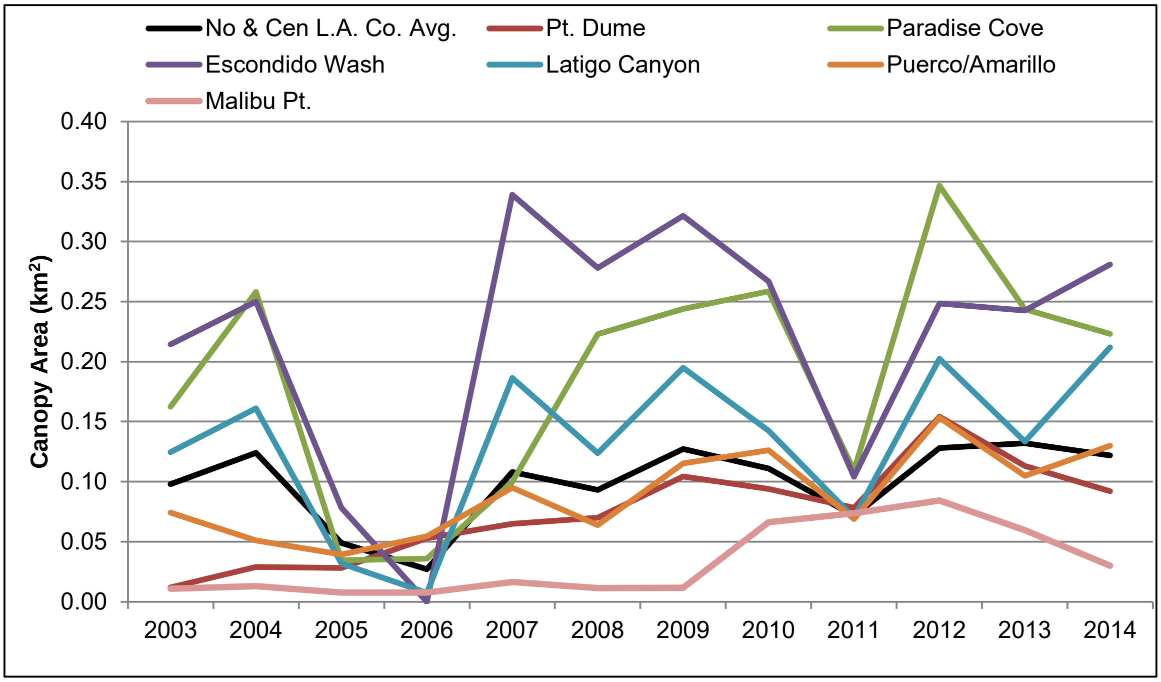


Figure 23. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the six kelp beds between Point Dume and Malibu Point for the years shown.

Paradise Cove. The Paradise Cove kelp bed has been larger than average during most of the last decade, and has usually responded in relative concert with the ABAPY. The bed reached its maximum size in 2012 (0.346 km^2), but decreased 30% in 2013 and 9% in 2014 (to 0.223 km^2) (Figure 23). Despite the decrease in size, Paradise Cove kelp bed is still considered larger than average.

Escondido Wash. The Escondido Wash kelp bed decreased by 22% in 2013, but increased 16% in 2014 (from 0.243 km^2 to 0.281 km^2) (Figure 23). This bed is typically larger than the ABAPY, and its fluctuations in size generally mirror those of the ABAPY, but in 2014 the two trended in opposite directions.

Latigo Canyon. In 2012, the Latigo Canyon kelp bed grew considerably and attained its largest size (0.202 km^2) since the CRKSC monitoring began. The canopy at Latigo Canyon decreased by about one-third in 2013. However, in 2014 it grew to its largest size on record (0.212 km^2) (Figure 23). The Latigo Canyon kelp bed is usually near the ABAPY for the region, and has tracked closely during most of the 12 years of monitoring.

Puerco/Amarillo. Like many other beds in this part of the Central Region, the Puerco/Amarillo kelp bed was larger in December 2012 (0.153 km^2) than during any previous CRKSC survey. In 2013, canopy coverage at Puerco/Amarillo decreased by 31%. However, in 2014 it grew by 29% to 0.130 km^2 (Figure 23). This bed typically trended with the ABAPY after 2007, although it responded differently than the ABAPY in 2013 and 2014.

Malibu Point. The canopy size at Malibu Point was 0.084 km^2 in 2012, the largest extent of kelp since CRKSC surveys began. However, the Malibu Point kelp bed decreased in size by 29% in 2013, and by another 35% in 2014 (to 0.039 km^2). The size of this kelp bed was smaller than the ABAPY during most years, and it has not correlated well with the ABAPY.

MALIBU POINT TO SANTA MONICA PIER

La Costa. In 2011, the La Costa kelp bed was not present in the June or October surveys, but reappeared as a very small bed (0.003 km^2) in December, the largest in 10 years of monitoring. In May 2013, canopy size was unchanged since 2012. However, in 2014 the bed shrank to just 0.001 km^2, consistent with its average size since 2003. Due to its relatively small size, the kelp bed at La Costa has not reacted in any discernable pattern since 2003 (Figure 24).

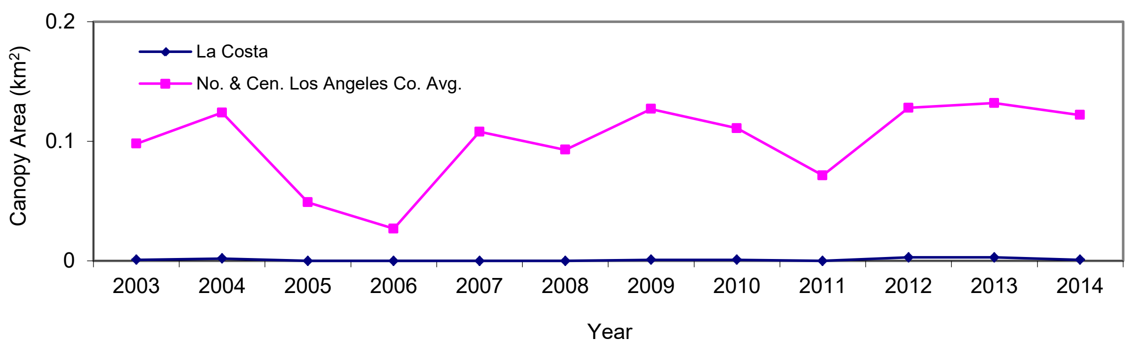


Figure 24. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the kelp bed off La Costa for the years shown.

Las Flores. The Las Flores kelp bed reached its maximum size in December 2012, and at 0.025 km^2, it was slightly larger than in 2004. Canopy size decreased by 12% in 2013, and another 28% in 2014 (to 0.016 km^2) (Figure 25). However, it was still larger than average in 2014. The Las Flores kelp bed has generally not mirrored the ABAPY (due in part to its relatively small size) except for growth spikes in 2004 and 2012.

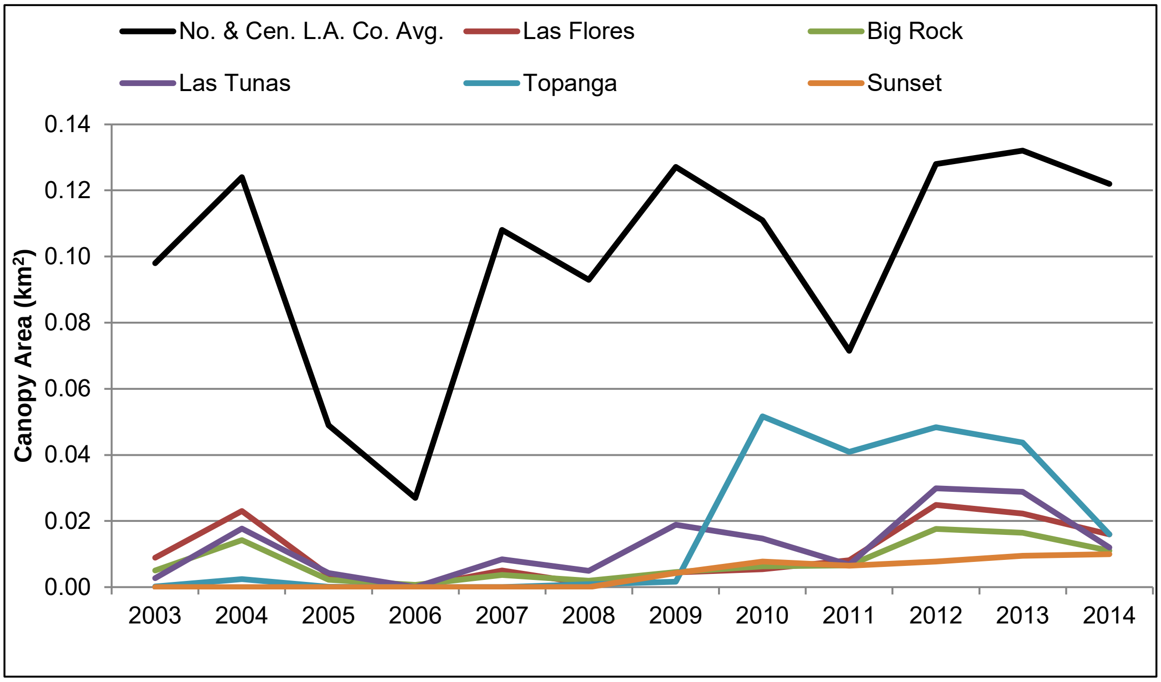


Figure 25. Comparisons between the average Northern and Central Los Angeles County ABAPY and the canopy coverages of the five kelp beds from Las Flores to Sunset for the years shown.

Big Rock. In December 2012, Big Rock kelp bed reached its largest size (0.018 km^2) since the inception of the CRKSC program. Canopy size decreased to 0.017 km^2 in 2013, and to 0.011 km^2 in 2014. The kelp bed at Big Rock has generally not mirrored the ABAPY (due in part to its relatively small size) except for growth spikes in 2004 and 2012 (Figure 25).

Las Tunas. Las Tunas kelp bed canopy size reached 0.030 km^2 in December 2012. The Las Tunas kelp bed size decreased by 3% in 2013 and by 58% (to 0.012 km^2) in 2014. Las Tunas is a very small bed, and well below the ABAPY for the region, but has generally responded in the same direction of the ABAPY during most years (Figure 25).

Topanga. Topanga kelp bed reached its maximum size 2010 at 0.052 km^2. However, it has decreased in size three of the past four years. In the last year, the bed shrank by 63% (from 0.044 to 0.016 km^2). Topanga is a relatively small bed, and well below the ABAPY for the region, and therefore its extent has generally not mirrored the ABAPY (Figure 25).

Sunset. Sunset kelp bed has not been observed in any of the CRKSC surveys through 2012, but a small amount of kelp was noted on the submerged breakwater offshore of Santa Monica at the southern end of the bed from 2009 through 2014. The bed size was essentially the same in 2013 and 2014 (0.010 km^2) (Figure 25).

SANTA MONICA PIER TO REDONDO BEACH BREAKWATER

Santa Monica Pier to Redondo Beach Breakwater. Although no kelp was noted in 2003 or 2004 from the Santa Monica Pier to Marina del Rey Harbor, a small amount of kelp was noted along the breakwaters at Marina del Rey Harbor and King Harbor in April 2005 and at slightly higher concentrations in December 2006. No kelp was seen between the two harbors along the Hyperion Treatment Plant outfall pipeline, offshore the Scattergood and El Segundo Generating Stations, Chevron Oil Refinery, Manhattan or Hermosa Beach, or the

Redondo Beach Generating Station in 2014. Since at least 2005, kelp has been visible at both the Marina del Rey and King Harbor breakwaters during some portion of the year.

Redondo Beach Breakwater to Malaga Cove, Torrance. This stretch of coastline appears to have been unsuitable for kelp since the Crandall survey of 1911, implying that it continues to be sandy bottom with no substantial hard substrate. In 2014, no kelp was seen between King Harbor and Malaga Cove at the Palos Verdes Peninsula.

MALAGA COVE TO SAN PEDRO BREAKWATERS

The Palos Verdes kelp beds are typically quite large and have been more accessible to researchers than other areas, resulting in many more comprehensive surveys of this region (Table 6). The CRKSC divides the two beds that Fish and Wildlife recognizes into four distinct kelp regions since they have at times responded differently to oceanographic conditions. Maps of the kelp beds at Palos Verdes Peninsula from 1890 (and possibly earlier) indicate that the kelp beds were large even then, but major fluctuations in extent of Palos Verdes kelp beds have occurred at least since 1911, when 9.124 km^2 of kelp was reported (Appendix B). Despite the region-wide decline of kelp beds since 1911, the extent of the decline in the Palos Verdes kelp forest over the first half of the 20^{th} century was unusual.

Appendix B presents representative survey results of 2.676 km^2 of kelp taken on 21 February 2002 since that particular survey provided information on all four sections of the Palos Verdes Peninsula. The varying estimates probably reflect the time of year the surveys were conducted and suggest the February 2002 survey did not represent the annual maximum canopy at Palos Verdes. The total of nearly 4.0 km^2 of kelp by June 2009 was the largest measurement of kelp at Palos Verdes in the 20 years since the 1989 survey total of about 4.5 km^2 of kelp. However, the beds of Palos Verdes decreased in size by 37% between 2013 and 2014.

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

The Bay Foundation mapped and recorded 0.615 km^2 of urchin barrens around the PV-III and PV-II kelp beds in 2010 (Ford et al. 2014). Beginning in 2013, commercial urchin divers started harvesting and smashing sea urchins from Honeymoon Cove in an effort to provide suitable habitat for kelp restoration. Urchin eradication will continue at three additional areas off the Palos Verdes Peninsula through July 2015. Analyses of gonadosomatic indices of urchins, species richness of fishes, and fish biomass, as well as increased density of giant kelp, indicate preliminary positive effects from restoration (Ford et al. 2014). Kelp coverage within the restoration areas (identified in yellow in Appendix A, map page 19) was fairly sparse in 2014, but at Honeymoon Cove it appeared to be slightly denser in 2014 than it was in 2009, the year with the highest canopy coverage in the last 25 years.

Table 6. Historical record of kelp canopy coverage of the Palos Verdes Peninsula.

Year	km^2	Acres	Hectares	Naut. $Mi^{2\ A}$ ($N\ mi^2$)	Sources
2014	1.647	406.98	164.70	0.480	CRKSC IR Survey (4 Surveys)
2013	2.600	642.47	260.00	0.758	CRKSC IR Survey (4 Surveys)
2012	2.599	642.22	259.90	0.758	CRKSC IR Survey (4 Surveys)
2011	2.396	592.06	239.60	0.699	CRKSC IR Survey (4 Surveys)
2010	2.494	616.41	249.45	0.727	CRKSC IR Survey (4 Surveys)
2009	3.998	987.92	399.80	1.17	CRKSC IR Survey (4 Surveys)
2008	2.916	720.56	291.60	0.85	CRKSC IR Survey (3 Surveys)
2007	2.062	509.53	206.20	0.60	CRKSC IR Survey (4 Surveys)
2006	2.187	540.49	218.73	0.64	CRKSC IR Survey (4 Surveys)
2005	1.099	271.57	109.90	0.32	CRKSC IR Survey (4 Surveys)
2004	0.589	145.54	58.90	0.17	CRKSC IR Survey (4 Surveys)
2003	1.425	352.12	142.50	0.42	CRKSC IR Survey (4 Surveys)
2002	2.837	701.00	283.68	0.83	CF&G/Ocean Imaging (2 Surveys)
2000	1.230	303.94	123.00	0.36	W.J. North IR Survey (1 Survey)
1999	1.267	313.00	126.67	0.37	CF&G IR Survey (1 Survey)
1998	0.498	123.00	49.78	0.15	CF&G IR Survey (3 Surveys)
1997	1.048	259.00	104.81	0.31	CF&G IR Survey (2 Surveys)
1996	1.356	335.00	135.57	0.40	CF&G IR Survey (2 Surveys)
1995	1.493	369.00	149.33	0.44	CF&G IR Survey (2 Surveys)
1994	2.703	668.00	270.33	0.79	CF&G IR Survey (2 Surveys)
1993	1.214	300.00	121.41	0.35	CF&G IR Survey (1 Survey)
1992	1.731	427.70	173.08	0.50	CF&G IR Survey (3 Surveys)
1991	2.964	732.50	296.43	0.86	CF&G IR Survey (4 Surveys)
1990	3.641	899.60	364.06	1.06	CF&G IR Survey (4 Surveys)
1989	4.549	1124.20	454.95	1.33	CF&G IR Survey (2 Surveys)
1988	3.379	835.00	337.91	0.99	CF&G IR Survey (4 Surveys)
1987	4.242	1048.30	424.23	1.24	CF&G IR Survey (4 Surveys)
1986	3.097	765.20	309.67	0.90	CF&G IR Survey (4 Surveys)
1985	2.627	649.20	262.72	0.77	CF&G IR Survey (4 Surveys)
1984	2.861	707.00	286.11	0.83	CF&G IR Survey (4 Surveys)
1983	1.963	485.00	196.27	0.57	CF&G IR Survey (4 Surveys)
1982	2.871	709.40	287.08	0.84	CF&G IR Survey (4 Surveys)
1981	2.424	598.90	242.37	0.71	CF&G IR Survey (4 Surveys)
1980	2.397	592.40	239.74	0.70	CF&G IR Survey (4 Surveys)
1979	1.842	455.25	184.23	0.54	CF&G IR Survey (4 Surveys)
1978	1.205	297.80	120.52	0.35	CF&G IR Survey (4 Surveys)
1977	0.365	90.30	36.54	0.11	CF&G IR Survey (4 Surveys)
1976	0.262	64.80	26.22	0.08	CF&G IR Survey (4 Surveys)
1975	0.095	23.50	9.51	0.03	CF&G IR Survey (3 Surveys)
1974	0.015	3.70	1.50	0.00	CF&G IR Survey (2 Surveys)
1967	1.062	262.4	106.2	0.31	SAI (1 Survey)
1959[B]	0.034	8.48	3.43	0.01	SWQCB 1964
1958	0.171	42.38	17.15	0.05	SWQCB 1964
1957	0.446	110.18	44.59	0.13	SWQCB 1964
1955	0.823	203.41	82.32	0.24	SWQCB 1964
1953	1.509	372.92	150.92	0.44	SWQCB 1964
1947	3.601	889.93	360.14	1.05	SWQCB 1964
1945	5.591	1381.51	559.08	1.63	SWQCB 1964
1928	9.912	2449.42	991.25	2.89	SWQCB 1964
1911	9.124	2254.58	912.40	2.66	Crandall 1912

A - Data in nautical mi^2 are from SWQCB (1964);
B - 1959 value as reported by SWQCB (1964) is actually <0.01 N mi^2. This was changed to 0.01 N mi^2 (8.5 acres).

2003-2007 data includes Cabrillo. 1911-1959 values were converted using 1 N mi^2 $(6076.13\ ft)^2 = 36{,}919{,}368\ ft^2$ = 847.55 acres = 342.99 hectares = 3.43 km^2. Values from 1974 to present are maximum coverage for each year in the CF&G or CRKSC aerial surveys.

Palos Verdes IV. The PV IV kelp bed has historically been the largest of the beds on the Palos Verdes Peninsula. In 2014, however, the bed shrank by 73% (to 0.264 km^2). The PV IV kelp bed was typically much larger than the average kelp bed in the region (Figure 26). It is apparent from the ABAPY graph that 2003 through 2005 were poor years for growth throughout the region, particularly at Palos Verdes. It is equally clear from the ABAPY that the PV IV kelp bed responded similarly to other beds in the region, though generally with a sharper upward or downward trend.

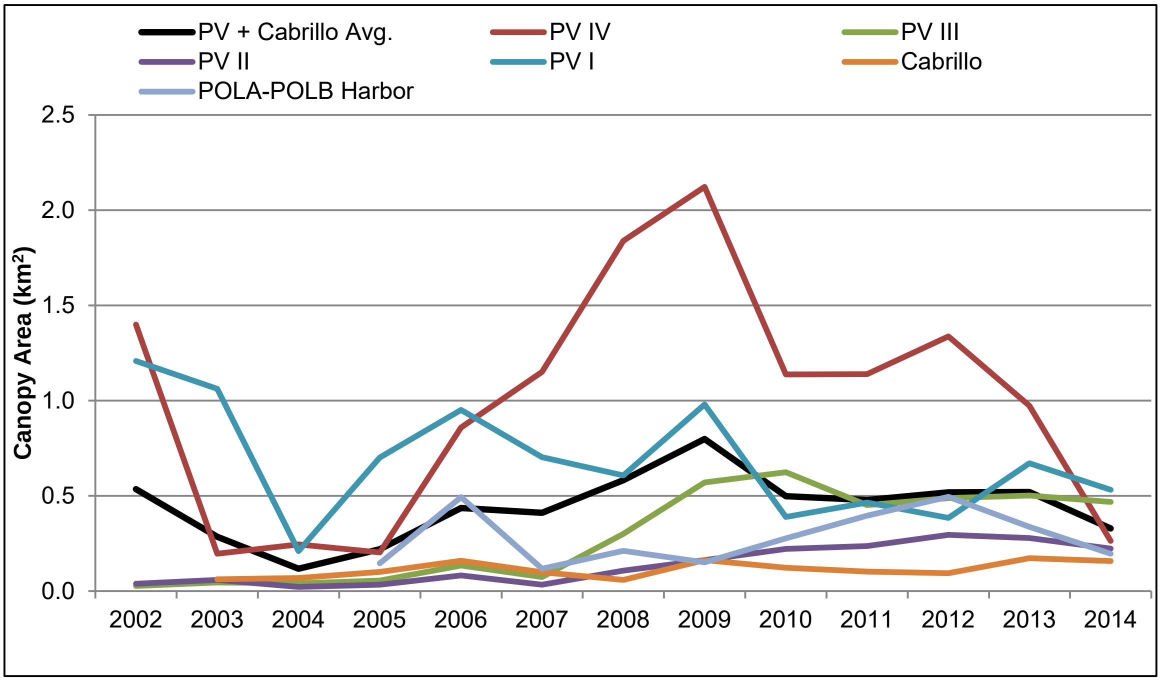


Figure 26. Comparisons between the average Palos Verdes and Cabrillo ABAPY and the canopy coverages of the kelp beds off Palos Verdes for the years shown.

Palos Verdes III. Palos Verdes III (PV III) kelp bed includes the area from Palos Verdes Point to Point Vicente. Since PV III kelp bed is physically connected to PV IV kelp bed, its areal coverage has historically tracked that of PV IV kelp bed, with the exception of periods of area-wide kelp canopy decline when Palos Verdes III kelp bed declined to an even greater extent than PV IV. In 2014, the PV III kelp bed shrank 7% (to 0.468 km^2), but it was much larger than the PV IV bed and much larger than average (Figure 26). Prior to 2010, PV III was well below the ABAPY, but in 2010 and 2014, the kelp bed outperformed the ABAPY. It has generally corresponded to the ABAPY the last several years.

Palos Verdes II. Palos Verdes II (PV II) kelp bed includes the kelp from Point Vicente to Inspiration Point. Unlike the PV III and PV IV beds, canopy size at PV II increased for five consecutive years (2008 through 2012), and in December 2012 it covered 0.295 km^2, the largest total of any CRKSC survey. In September 2013, the bed was 6% smaller than during 2012, and it shrank an additional 20% in 2014 (to 0.224 km^2) (Figure 26). PV II kelp bed was also much smaller than the ABAPY, and patterns of bed size were muted. However, with the exception of continued growth from 2009 through 2010, the bed has generally corresponded with the ABAPY.

Palos Verdes I. Palos Verdes I (PV I) kelp bed includes the area from Inspiration Point to Point Fermin. Unlike the other Palos Verdes kelp beds, PV I increased substantially (75%) in 2013, and the canopy coverage was the highest recorded since 2009 (Figure 26). In 2014, canopy size decreased 21% to 0.533 km^2. However, PV I was the largest bed off the Palos Verdes Peninsula for the first time since 2006. PV I kelp bed was considerably larger than the ABAPY during some years, but it size and growth patterns have corresponded to the ABAPY during most years since 2008 (Figure 26).

Cabrillo. The Cabrillo kelp bed includes the area east of Point Fermin up to and including the western end of the San Pedro Breakwater. In 2013, Cabrillo kelp bed increased in size by 83%, and the measured area was the highest recorded since 2003. The canopy area decreased by 9% in 2014 (to 0.158 km^2), but the bed was still larger than average. The bed is relatively small, but with the exception of a downward decline in opposition to the ABAPY in 2008 and 2012, it has corresponded to the ABAPY (Figure 26).

Los Angeles and Long Beach Harbors (POLA-POLB). Kelp grows along the Ports of Los Angeles and Long Beach breakwaters, on the armored edges of the outer harbors, and it extends in some places into the inner harbors. This kelp was not adequately considered in CRKSC reports before 2005, but has been measured on a yearly basis since. The existence of these beds was known for some time, but the extent was not thought to be great. In response to growing curiosity as to the extent of the kelp in the harbor complex, it was requested that the overflight photographs for the third quarterly survey in 2005 (28 September 2005) include the entire outer harbor complex. Analysis revealed a narrow band of dense kelp (0.147 km^2) on both the inside and outside of the riprap. Only a small portion of the berths in the southern part of the port complex was included in the photographs, and it was suggested that the outer harbor be included in future overflights. Due to reports of kelp existing along a number of the inner breakwaters, the entire harbor was photographed and surveyed by biologists to determine whether the algae in the infrared photographs was giant kelp, feather boa kelp (*Egregia menziesii*), and/or *Sargassum* spp. The visual inspection of the growth along the breakwaters and within the confines of the harbors confirmed that the major portion was giant kelp. The more inclusive survey of the harbor complex in 2006 measured 0.494 km^2 of giant kelp on the inner and outer breakwaters (Table 1).

The canopy area within the Ports peaked in 2012 at 0.495 km^2, but shrank the last two years to 0.196 km^2. With the exception of the three-year period of 2009–2011, the patterns of the POLA-POLB kelp have generally not corresponded to the ABAPY from Palos Verdes and Cabrillo (Figure 26). The coverage of the kelp in the port complex was also smaller than the ABAPY during most years, but the two have been relatively similar in size during the last four years.

SAN PEDRO BREAKWATER LIGHTHOUSE TO LAGUNA BEACH

POLA and POLB

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

Horseshoe Kelp. No giant kelp canopy has formed at the site of Horseshoe kelp in more than 60 years. Subsurface kelp has grown at this location; in 2004, giant kelp was photographed growing at depths of 20–30 m (Wong et al. 2012).

Huntington Flats. No giant kelp canopy was apparent at Huntington Flats in 2014.

Huntington Flats to Newport Harbor. No kelp was observed from Huntington Flats to Newport Harbor, which includes the area offshore of the Huntington Beach Generating Station and Orange County Sanitation District outfalls. However, narrow bands of kelp were visible on the Newport Harbor jetties during the 2014 quarterly surveys.

NEWPORT BEACH TO ABALONE POINT, LAGUNA BEACH

Newport/Irvine Coast - Corona del Mar to Crystal Cove. Downcoast from Newport Harbor, giant kelp grows in a number of small beds (collectively called the Newport/Irvine Coast kelp bed). Canopy coverage during December 2013 was the highest on record, and represented an 8% increase since 2012. In 2014, the canopy area was reduced 15% from the previous year (to 0.366 km^2), but it was still the third largest ever measured along this stretch of coastline. Kelp restoration efforts from 1986 through 2009 revived these beds from their total extirpation in the early 1980s (MBC 2010c). The Newport/Irvine Coast bed followed the ABAPY for other beds of the region until giant kelp was eliminated from Newport/Irvine Coast during the El Niño of 1982–1984, and it did not return until about 1989 (due to restoration efforts). Kelp disappeared from this stretch of coast again in the 1990s, returned due to further restoration efforts in 2003, and has roughly followed the ABAPY since then (Figure 27). During the vessel survey in January 2015, no canopy was visible from Corona del Mar to Crystal Cove, but there was a thin canopy growing to depths of 17 m at Reef Point (just downcoast from Crystal Cove).

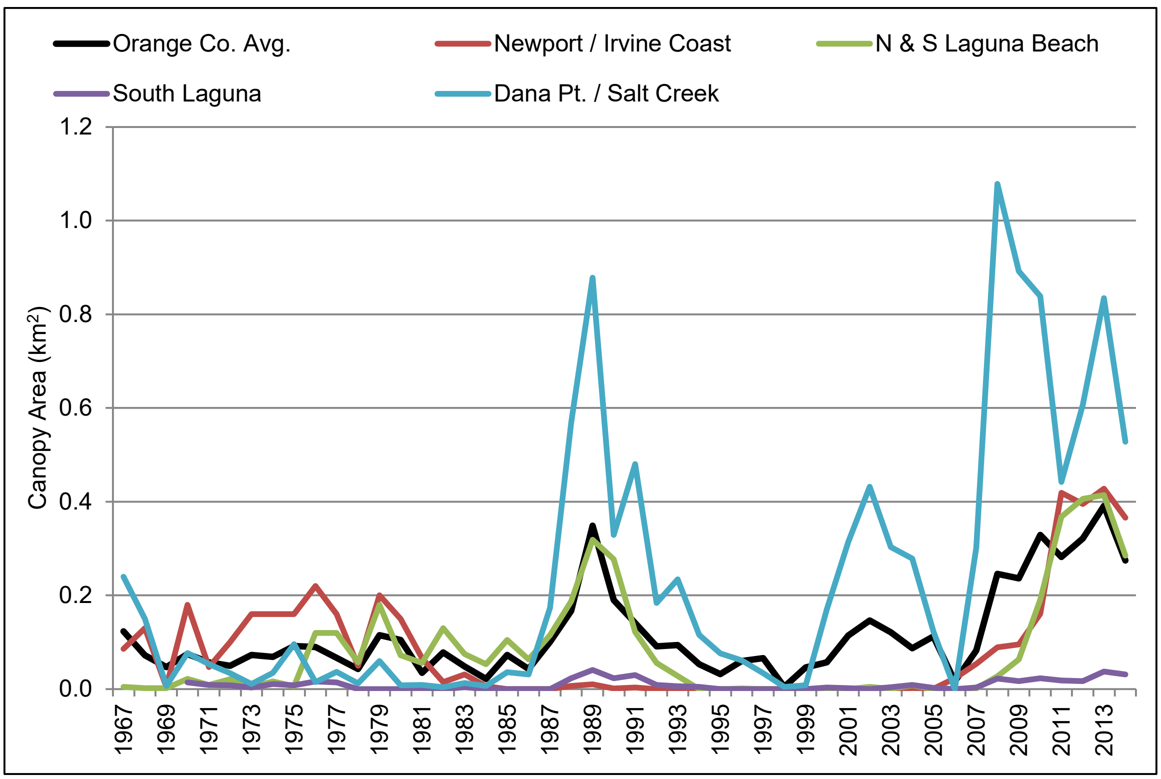


Figure 27. Comparisons between the average Orange County ABAPY and the canopy coverages of the kelp beds from Newport/Irvine Coast to Dana Point/Salt Creek for the years shown.

REGION NINE KELP SURVEYS

The Region Nine program identifies 24 individual kelp beds (although many are comprised of two or more distinct beds) either using local names or geographical references for the name. The combined RNKSC kelp canopy coverage has been well above average (7.140 km^2) during each of the last eight years (Figure 28). Each bed is also compared to the average for the beds in both Orange and San Diego County, excluding the very large beds of La Jolla (LJ) and Point Loma (PL), because these two beds tend to skew the data (Figure 29). Strong upwelling events, such as those associated with La Niña (1989), and warming events such as El Niño (1983–4 and 1998), cause sharp increases and decreases in kelp coverage (Figure 28). Comparison of individual beds to each sub-region further refines the ability to identify underperforming beds and determine possible reasons for anomalous results. It is important to conduct these comparisons because large declines and subsequent recoveries are common occurrences in the historical record (especially if we include all the quarterly surveys). Drastic reductions may simply be short-term fluctuations of little importance to the long-term welfare of the bed. If, however, the decline represents a persistent change or develops into a downward trend, more evaluation may be needed to clarify the cause(s).

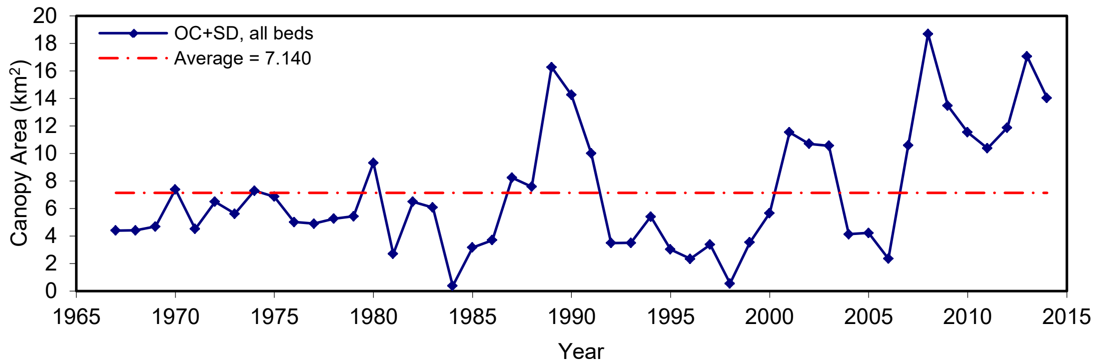


Figure 28. Combined canopy coverages of all kelp beds in Orange and San Diego Counties.

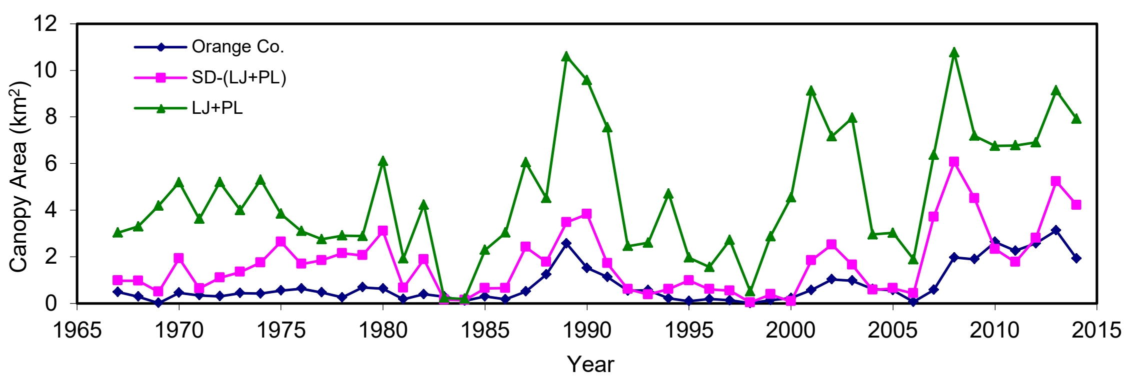


Figure 29. Diagram showings components of the Total Area graph partitioned into the kelp beds of: Orange County; San Diego County less La Jolla and Point Loma (SD-[LJ+PL]); and La Jolla plus Point Loma (LJ+PL).

NORTH LAGUNA BEACH TO CAPISTRANO BEACH

North Laguna Beach/South Laguna Beach. Canopy at North Laguna Beach/South Laguna Beach in 2013 was larger than at any time in a continuous 47-year record. In 2014, coverage decreased by 31% (to 0.285 km^2), but coverage was still more than three times higher than the long-term average. The two Laguna Beach beds followed the patterns of the ABAPY (when canopy was apparent), and survived the El Niño of 1982–1984, but were extirpated in 1994. The Laguna Beach beds remained at zero in our measurements until about 2006 when the beds again reappeared as a result of restoration efforts, and have since followed the mostly positive trend of the ABAPY (Figure 27). During the January 2015 vessel survey, the canopy at North Laguna Beach measured approximately 100 m by 800 m, and extended out to the 17-m isobath. The canopy was thin, and most of the fronds were senescent, pale yellow and measured about two meters long.

South Laguna. In 2013, the South Laguna kelp bed more than doubled in size from 2012, and it reached its largest extent since 1989. In 2014 the South Laguna kelp bed shrank by 17% (to 0.031 km^2), but it was still more than three times larger than average. The South Laguna kelp bed was much smaller than the ABAPY during most years, and canopy size at this site has not correlated well with the ABAPY. However, the bed responded to relatively large stimuli such as the 1989–1990 La Niña, and since 2007 has usually trended in the same direction as the ABAPY (Figure 27). During the January 2015 vessel survey, the canopy at South Laguna was sparse and patchy. Most of the fronds were mature and evenly mixed between dark yellow and light yellow in color. The surface canopy was limited to areas adjacent to wash rocks, but subsurface kelp was visible on the fathometer in shallower areas (to about 6 m).

Dana Point/Salt Creek. The canopy at Dana Point/Salt Creek has fluctuated greatly over the last 47 years. After increasing 38% in 2013, the canopy area decreased 37% in 2014 (to 0.528 km^2). However, canopy size was still more than twice the average size for this bed, and similar to the bed sizes in 2011 and 2012 (Figure 27). The beds at Dana Point/Salt Creek have been much larger than the ABAPY for much of the past decade. Canopy growth/reduction has usually corresponded with the ABAPY, although canopy decreases in 2009 and 2010 were out of synchrony with the Orange County average. The canopy at Dana Point/Salt Creek was large and scattered during the January 2015 vessel survey. The surface canopy extended out to approximately the 20-m isobath, but subsurface kelp extended out to nearly the 23-m isobath. The fronds were between one and three meters long, and most were mature and dark yellow.

Capistrano Beach. In 2014, the Capistrano Beach kelp bed decreased in size by 66% (from 0.099 to 0.034 km^2), which offset most of the 77% increase from the previous year. Canopy size in 2014 represented about 15% of the maximum canopy size observed in 1989. The Capistrano Beach beds (combined with San Clemente beds) have responded in synch with the ABAPY (Figure 30). Kelp was sparse and there was no coherent canopy at Capistrano Beach in January 2015. Kelp was growing in two separate locations (the same locations mapped in 2014). Surface fronds were one to two meters in length and an even mix of young and mature plants. A large area of subsurface kelp was also visible on the fathometer.

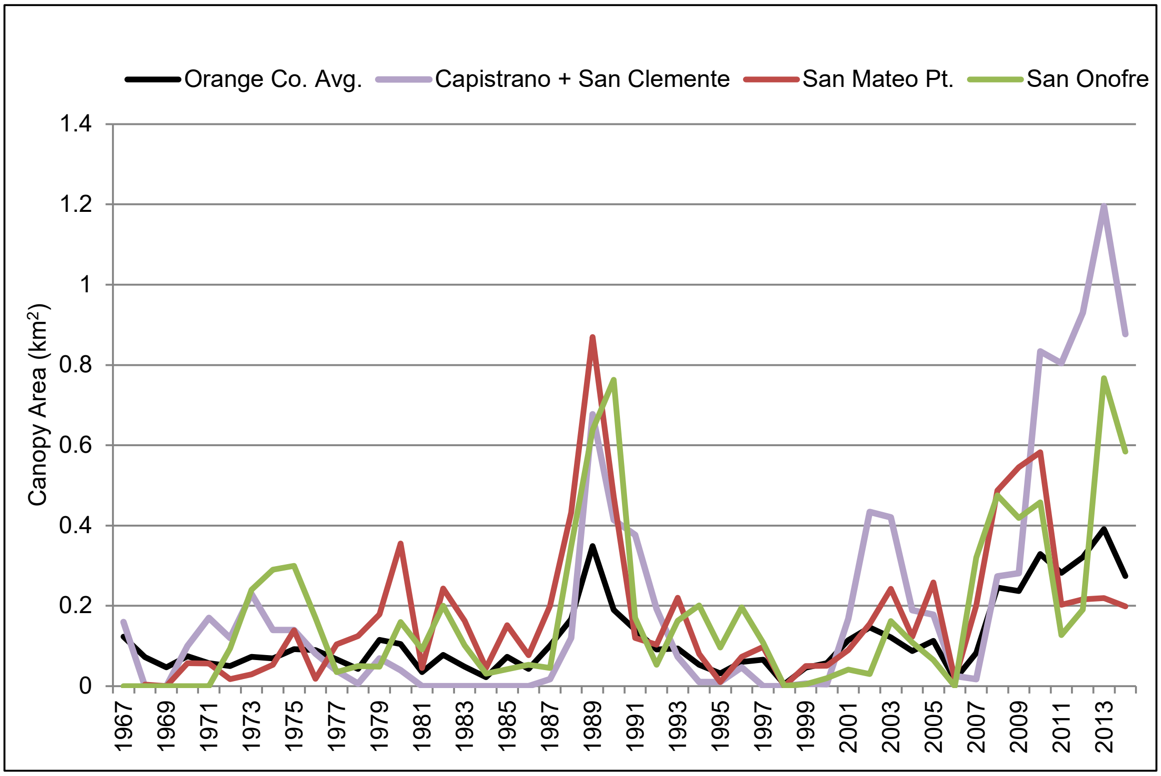


Figure 30. Comparisons between the average Orange County ABAPY and the canopy coverages from Capistrano Beach to San Onofre for the years shown. The Capistrano and San Clemente kelp bed areas are combined to facilitate visualization.

SAN CLEMENTE TO SAN ONOFRE

San Clemente. Beginning in 2002, the kelp beds at San Clemente were enhanced by the placement of approximately 50 small artificial reefs (each measuring 40 m x 40 m) offshore of San Clemente on barren sand at depths of about 12 to 15 m. Kelp immediately recruited to these reefs, and canopies in the shape of small squares were visible during most of the aerial surveys of 2002 and 2003. In early 2008, Southern California Edison (SCE) added additional reef material (covering 0.615 km^2 in total) and kelp recruited to the new reefs in late 2008. After increasing in size for seven consecutive years (from 0.014 km^2 in 2006 to 1.097 km^2 in 2013), the canopy coverage of this reef decreased by 23% in 2014 (Figure 30). The canopy area was still much larger than average, and San Clemente was the fourth largest bed in Region Nine. The San Clemente beds (combined with the Capistrano Beach beds) have responded synchronously with the ABAPY. During the January 2015 vessel survey, there was a cohesive canopy more than one mile long, and tissues were dark yellow. Fronds grew to three meters in length, with about 50% having growing tips. Canopy extended to a depth of about 15 m.

San Mateo Point. The kelp bed off San Mateo Point decreased in size by 9% between 2013 and 2014 (from 0.219 km^2 to 0.199 km^2). Even though the canopy size is still slightly larger than average, the bed is still much smaller than the maximum sizes measured in 1989 (0.870 km^2) and 2010 (0.583 km^2). The average change in canopy size in Region Nine between 2012 and 2013 was a 22% increase; however, the San Mateo bed remained about the same size. Still, the San Mateo kelp bed has closely followed the patterns of the Orange County average (Figure 30). In January 2015, the San Mateo kelp bed consisted entirely of young kelp plants with fronds two to three meters in length. Tissue color was dark yellow, but 90% of the blades were tattered. Extensive kelp was visible below the surface.

San Onofre. Canopy size at San Onofre in 2013 represented a three-fold increase from 2012, and was the largest recorded by the RNKSC. In 2014, the San Onofre kelp bed decreased in size by 24%, but it was still more than three times larger than average. Because of their location in a similar geographically area, San Mateo kelp bed has been used in several scientific studies as a control station for San Onofre kelp, and the two beds usually react similarly (Figure 30). The San Onofre kelp bed has also followed the ABAPY for Orange County and San Diego County (Figures 30 and 31). In January 2015, no canopy was visible during the vessel survey, although there were plants approximately five to six meters tall visible below the surface. One kelp plant extended to the surface; it was dark yellow in color and had apical growing tips.

HORNO CANYON TO SANTA MARGARITA RIVER

Horno Canyon. The Horno Canyon kelp beds are small and have been viable only during very large stimuli—such as the La Niñas of 1989–1990, 2001, and 2007–2008—and during the last three years. In 2013, kelp coverage at Horno Canyon (0.125 km^2) was the highest on record since 1911. The canopy area decreased 56% in 2014, but Horno Canyon kelp was still more than five times larger than average. During the January 2015 vessel survey, one plant was growing at Pendleton Artificial Reef (PAR) at a depth of 14 m, and several more plants were visible below the surface. No canopy was visible at Horno Canyon in January 2015, nor were any plants visible below the surface.

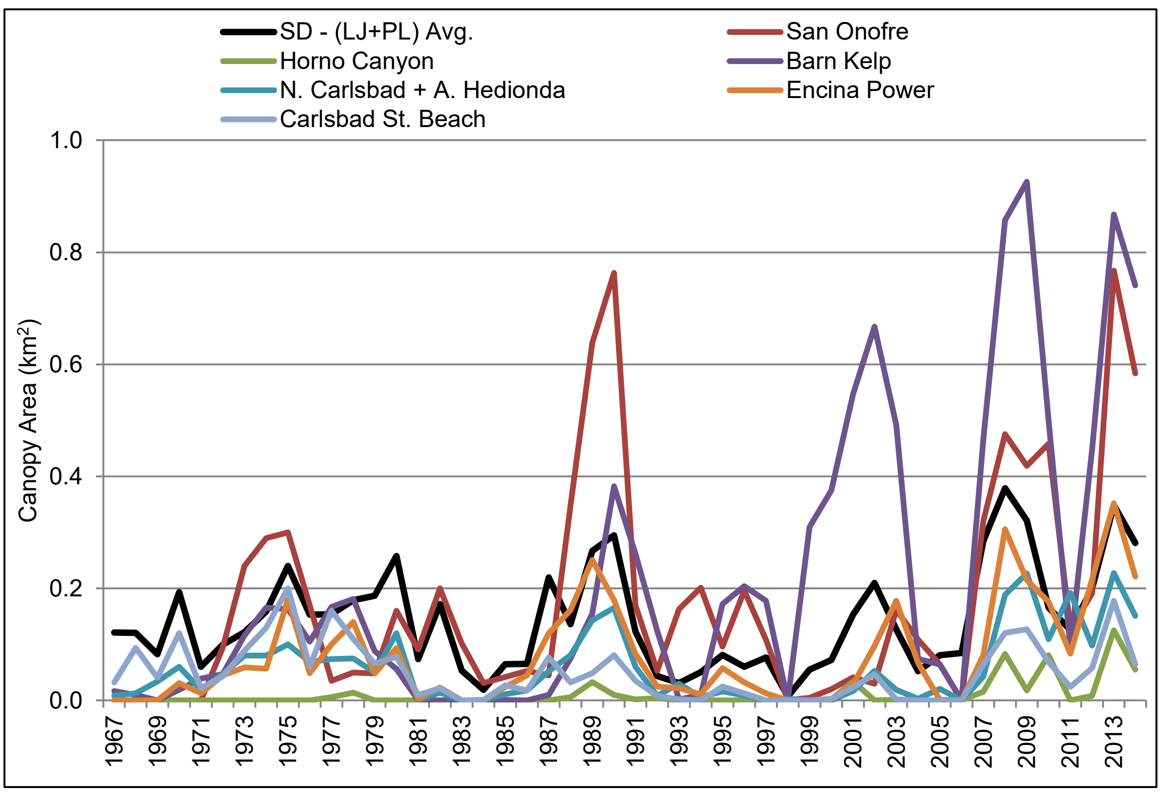


Figure 31. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages from San Onofre to Carlsbad State Beach for the years shown.

Barn Kelp. In 2014, Barn kelp decreased in size by 15%, similar to the change of the average San Diego kelp bed (19%). At 0.741 km^2, Barn kelp was more than three times larger than average, and it was the fifth largest kelp bed in Region Nine. Other than the severe downturn from 1980 to 1987, Barn kelp reacted similarly to the other beds in the San Diego region (Figure 31). Only a thin, scattered canopy was apparent at Barn kelp by January 2015. Almost all of the plants were young, tissues were dark yellow, and fronds were two to five meters in length. About 10% of the plants had apical growing tips. Kelp was visible below the surface growing in a swath approximately 1.8 km wide to a depth of about 14 m.

Santa Margarita. In 1911, Santa Margarita was the site of a substantial kelp bed that covered 0.858 km^2. Kelp disappeared here sometime before regular surveys began in 1967 by Dr. North. No kelp was seen during any of the vessel or aerial surveys until 1991, when a small bed covered an area of 0.049 km^2; it was much smaller in 1992, and disappeared in 1993. No canopy was observed at Santa Margarita for the next two decades, but a small kelp bed was visible during the December 2013 overflight. The size of the bed in 2013 (0.080 km^2) was 63% larger than in 1992. No canopy was observed at this kelp bed in 2014 (or during the January 2015 vessel survey). During the vessel survey in January 2015, kelp was visible growing below the surface from depths of about 6 to 11 m, but the density of kelp plants was low.

NORTH CARLSBAD TO CARLSBAD STATE BEACH

North Carlsbad. The North Carlsbad kelp bed is comprised of several small beds. In 2014, the beds shrank by 32% (to 0.086 km^2). The North Carlsbad and Agua Hedionda kelp beds disappeared or became very small during periods of below-average nutrient availability, but reacted strongly to stimuli such as large La Niña events. The two beds combined followed the ABAPY fairly close, but were out of sync during 2011–2012 (Figure 31). The North Carlsbad bed was large and thick in December 2014, and it extended to a depth of about 12 m. It consisted of mostly (90%) mature kelp plants with healthy apical growing tips.

Agua Hedionda. Similar to the North Carlsbad kelp bed, the Agua Hedionda kelp bed decreased in size by 37% in 2014 (after more than doubling in size the previous year). Canopy area was still the fourth highest in the last 20 years at this site. The North Carlsbad and Agua Hedionda kelp beds disappeared or became very small during periods of below-average nutrient availability, but reacted strongly to stimuli such as large La Niña events. The two beds combined followed the ABAPY fairly close, but were out of sync during 2011–2012 (Figure 31). In December 2014, the bed of Agua Hedionda was thick but patchy, and grew to a depth of 13 m. Most of the plants were mature, and frond lengths reached four meters.

Encina Power Plant. The Encina Power Plant kelp bed reached its maximum size in 2013 (0.352 km^2). It shrank by 37% in 2014, but it was still nearly three times larger than its average size. The Encina Power Plant kelp bed mirrored the other beds in the San Diego region, and its size is similar to the ABAPY (Figure 31). This bed was large and thick in December 2014, and grew to a depth of 20 m. Most of the plants were mature and tissues were dark yellow. However, 90% of the blades were tattered.

Carlsbad State Beach. The Carlsbad State Beach kelp bed made considerable gains in 2013, and increased three-fold to 0.178 km^2. However, like most of the other beds in Region Nine, it shrank in 2014 by 63%. It was still almost 30% larger than average despite the loss of canopy size. This bed grew/shrank similarly to the other beds in the San Diego region through about 1977. It acted in opposition to the ABAPY in 1978–1979, but while muted, corresponded to the ABAPY during the last three decades (Figure 31). The bed off Carlsbad State Beach was approximately 100 m by 300 m in December 2014, and grew between depths of 16 and 22 m. The canopy was thin and patchy, but most of the tissues were dark yellow and most of the apical blades looked good. Fronds measured three to five meters in length.

LEUCADIA TO TORREY PINES

Leucadia. The Leucadia kelp bed is comprised of the North, Central, and South Leucadia kelp beds (because of distinct breaks in the beds). In 2013, Leucadia kelp bed increased to its highest coverage in the last 30 years (0.541 km^2); however, the bed size decreased by 48% in 2014. The North bed (off Batiquitos Lagoon) shrank by 23%, the Central bed shrank by 61%, and the South bed shrank by 88% since 2013. The Leucadia kelp beds have mirrored the other beds in the San Diego region, but the separation between Leucadia and the ABAPY has been muted since 1983 (Figure 32). In December 2014, the beds were patchy and grew to a depth of 20 m (with a few areas metered out to 23 m). The beds grew in deeper water extending from south to north. Most of the plants were mature, tissues were mostly dark yellow, and about 70% of the apical blades looked good. Fronds were four to five meters in length.

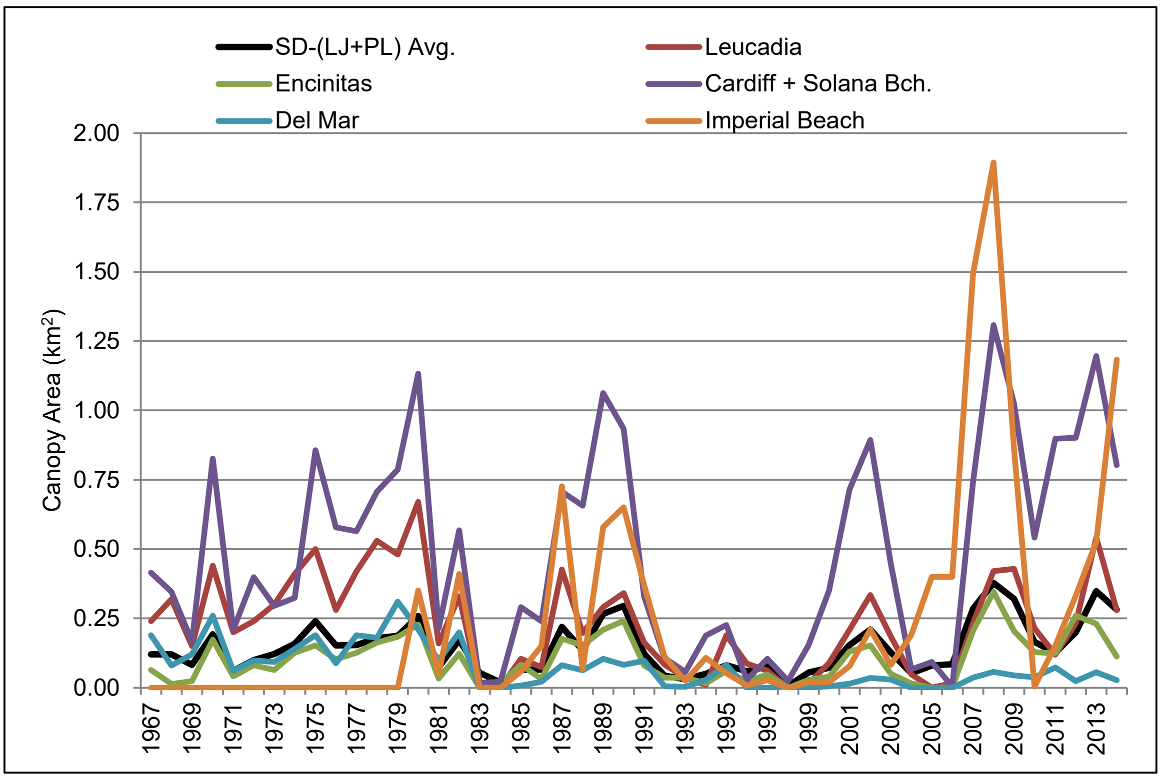


Figure 32. Comparisons between the average SD-(LJ+PL) ABAPY and canopy coverages from Leucadia to Del Mar (and Imperial Beach) for the years shown.

Encinitas. The Encinitas kelp bed shrank by 52% in 2014, but it was still slightly larger than average. The size of this bed has mirrored the other beds in the San Diego region (Figure 32). For unknown reasons, Encinitas kelp shrank slightly in 2013 while most beds in Region Nine grew. However, canopy size of Encinitas kelp bed in 2013 was still the fourth highest recorded in the last 50 years. In December 2014, the kelp bed looked good during the vessel survey.

Cardiff and Solana Beach. The Cardiff and Solana Beach kelp beds shrank in 2014, and the combined coverage of the two was 33% smaller than in 2013. Combined, these two beds are more than three times larger than the ABAPY in the San Diego Region. Changes in Cardiff/Solana Beach kelp bed sizes have mirrored the other beds in the San Diego region, although the magnitude of the changes was generally greater because of the relatively large size of these two beds (Figure 32). The lower Cardiff bed extended to a depth of about 20 m, and the upper Cardiff bed was growing to 22 m in December 2014. Kelp was thick and consisted almost entirely of mature kelp plants. Frond length was five meters. Off Solana Beach, kelp was growing to a depth of 19 m, and was thick in the upper section, but thinner in the lower section. Frond length off Solana Beach was two to four meters.

Del Mar. The Del Mar kelp bed is typically one of the smallest beds in Region Nine, and in 2014 it was the smallest kelp bed displaying canopy. It decreased in size by 52% (from 0.056 km^2 in 2013 to 0.027 km^2 in 2014). The kelp bed off Del Mar was only about one third of its long-term average size, but consistent with its average size during the last 20 years. This kelp bed typically has mirrored the other beds in the San Diego region, although it reacted opposite the ABAPY during 2011–2012. Its size has usually been much smaller than that of the ABAPY since 1983 (Figure 32). In December 2014, the canopy off Del Mar was approximately 50 m by 300 m, and consisted of mostly mature plants with three-meter-long fronds. Subsurface kelp consisted of plants with visible growing tips.

Torrey Pines. Torrey Pines kelp bed appeared in our records as a small trace of kelp during La Niña conditions in 1988 and 1989. It reappeared in 2006 as a measurable canopy (0.010 km^2) with scattered giant kelp about 1.5 km north of Scripps Pier, another concentration about 3.5 km north, and a third concentration of scattered giant kelp was found about 1.5 km north of that position (5 km north of the pier). The canopy disappeared in 2007, but from 2008–2013 small canopies were observed in various locations in the area. In 2013, Torrey Pines kelp bed was measured at its largest extent (0.081 km^2), but no canopy was visible during the quarterly surveys of 2014, nor was any kelp visible on the surface during the December 2014 vessel survey.

LA JOLLA

La Jolla. La Jolla kelp bed is composed of two canopies: northern La Jolla and southern La Jolla. In 2013, La Jolla kelp canopy coverage increased by 159% and covered more than 4 km^2, and in 2014 canopy coverage decreased 30% (to 2.790 km^2) (Figure 33). However, La Jolla kelp bed was still nearly twice as large as its long-term average size, and was the second largest bed in Region Nine. Changes in bed size at La Jolla have usually mirrored those at Point Loma, but this year La Jolla shrank while Point Loma maintained most of its size (Figure 32). This suggests that overall they are affected by the same oceanographic regime, but that small differences in bathymetry and currents can still make profound differences to kelp beds that otherwise appear very closely related.

In December 2014, the northern La Jolla bed was thick and solid, with frond lengths to seven meters. The kelp consisted mostly of mature kelp plants, and about 80% had apical growing tips. The southern La Jolla bed was large, but unlike northern La Jolla was patchy in distribution. Frond length was nine meters, and kelp consisted almost entirely of mature kelp plants. Kelp at northern La Jolla was growing as deep as 26 m, and kelp at southern La Jolla was as deep as 22 m.

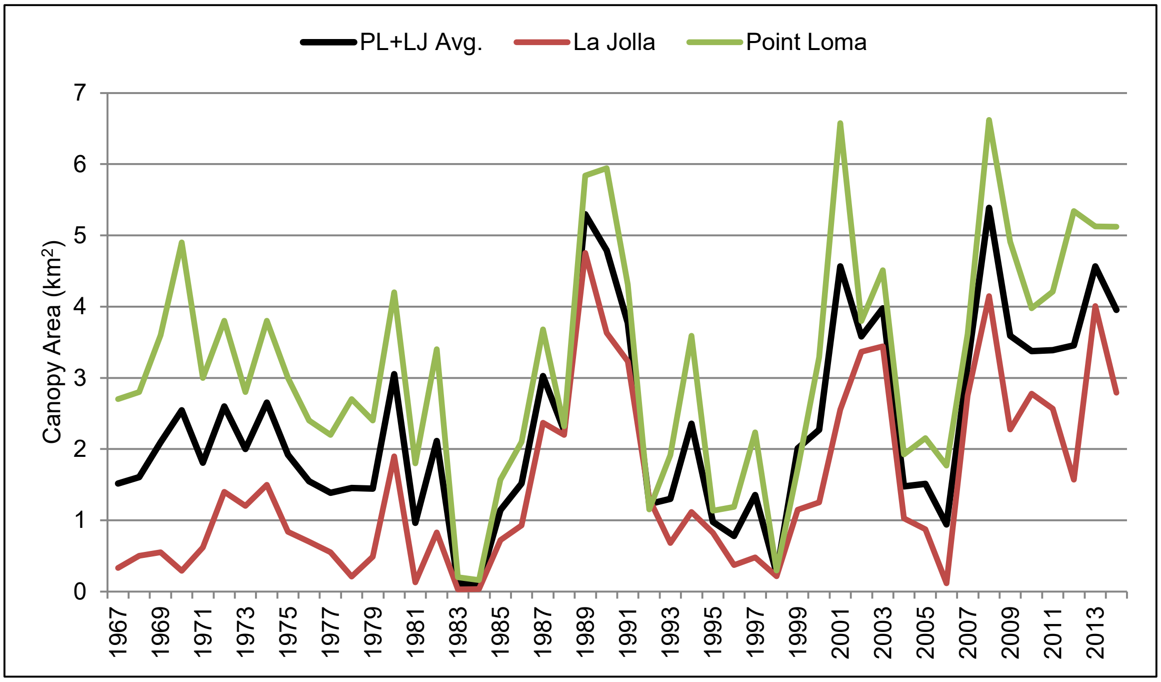


Figure 33. Comparisons between the (LJ+PL)/2 ABAPY and canopy coverages of the La Jolla and Point Loma kelp beds for the years shown.

Konotchick et al. (2012) found that the discrepancies in the persistence of giant kelp in the northern and southern portions of the La Jolla kelp bed were caused by differential, alongshore vertical variations in temperature (and thereby nutrients) and topographically induced internal wave dynamics; instrumentation to elicit these parameters are not typically available in the scale of a regional study. Parnell (2015) analyzed algal patch structure and the importance of seascapes at La Jolla and Point Loma kelp beds. Understory algae grows within the La Jolla kelp forest, and also offshore of the kelp forest (in association with *Pelagophycus*, which grows in waters as deep as 35 m).

POINT LOMA TO IMPERIAL BEACH

Point Loma. The Point Loma kelp bed is composed of many, usually contiguous, kelp canopies ranging from depths of 5 m to over 30 m during years with sufficient nutrients. Similar to La Jolla, the Point Loma kelp bed is divided into upper and lower sections. The canopy at Point Loma has maintained a relatively large size (>5 km^2) and has changed little during the last three years. It is the largest bed in Region Nine (Figure 33). The size of Point Loma kelp changed little (<1%) between 2013 and 2014.

In December 2014, the upper Point Loma bed was thick, and consisted of a combination of mature and young plants. Kelp was growing to a depth of 25 m, and fronds were eight to nine meters long. About one half of the blades were tattered. The lower Point Loma bed was also thick, but it consisted of mostly mature plants (approximately 90%). Tissues were dark yellow, and fronds were two to three meters long, but the blades were tattered. The offshore extent of the lower Point Loma kelp bed was about the 21-m isobath.

IMPERIAL BEACH TO BAJA CALIFORNIA, MEXICO BORDER

Imperial Beach. The Imperial Beach kelp bed canopies have been observed in different locations during years when they were apparent. Svejkovsky (2015) noted "major bed locations shifts and coverage area variability give the appearance in the persistence analysis that this kelp bed rarely persists longer than one year. In actuality the same bed appears to change in location slightly from year to year with some years (1999 and 2003) showing very sparse coverage and others (2008 and 2009) exhibiting much larger canopy area." The Imperial Beach kelp beds have also responded differently than most of the other beds in the region during much of the past two decades, including in 2014. All of the beds in Region Nine either lost or maintained canopy size in 2014, but the bed off Imperial Beach grew considerably (by 125%) (Figure 32). It was the third largest bed in Region Nine, and even though it did not reach its size from 2007–2008, it was still nearly five times larger than average. Except for the period from 1967 to 1979 (when it was missing), the Imperial Beach kelp bed generally followed the ABAPY.

In December 2014, the Imperial Beach kelp bed was large and thick, and consisted of mostly mature plants (approximately 90%). Fronds were two to three meters long, and tissues were dark yellow. In addition to the surface canopy, subsurface kelp was visible on the fathometer in several locations. There were also several small patches of kelp on the surface offshore and downcoast of the primary bed, which extended to a depth of 19 m.

UPDATE TO THE PRESENT

Two aerial surveys for 2015 have been conducted (on 7 April and 20 June). Based on a preliminary review of the data, the following is a summary of the canopy coverage through 20 June 2015.

- Canopy sizes from Deer Creek to Point Dume were above average;
- Many of the smaller kelp beds from Malibu Point to Sunset were not visible;
- PV IV was much larger than its peak coverage in 2014;
- Canopy coverages at PV II and III and Cabrillo were above average in June, and larger than in April;
- Canopy coverages between Newport Harbor and San Clemente increased substantially since April and were about average in June. No kelp canopy was visible between Dana Point and Oceanside in April (although biologists metered subsurface kelp at San Onofre and Barn kelp with a fathometer on a research vessel the same week as the quarterly overflight);
- Kelp beds from San Mateo Point to Oceanside were much smaller than average in June;
- Canopy sizes from Carlsbad to Torrey Pines were mostly above average in June;
- Both the La Jolla and Point Loma kelp beds looked much larger than average in June; and
- Imperial Beach kelp bed was still visible in two separate locations, and its size looked much larger than average in June.

Daily SSTs in the Central Region and Region Nine tracked closely during the first three months of 2015, and were warmer than in 2014 (Figure 34). Surface temperatures dropped below average at Newport Pier and Scripps Pier in April 2015, the first time they were below average since September 2014 at those locations.

In March 2015, NOAA issued an El Niño advisory, signaling the beginning of weak equatorial El Niño conditions. As of June 2015, equatorial SSTs in the upper 300 m increased, suggesting a strengthening of El Niño conditions. The Climate Prediction Center estimates there is an approximately 90% chance that El Niño will continue through winter 2015–2016 in the Northern Hemisphere, and a greater than 80% chance it will last through spring 2016.

At this early stage, it is unclear how the Central Region and Region Nine kelp beds will fare in 2015. At the time of this writing (June 2015), El Niño conditions persist at the equator, with likely strengthening through 2015. In January 2015, thousands of pelagic red crabs (*Pleuroncodes planipes*) washed ashore in Newport Harbor (Daily Pilot 2015), and in May 2015 the same occurred in Pacific Beach (San Diego) (CBS 2015). This species is associated with warm water, and some consider it a harbinger of El Niño (McPeak et al. 1988). If the developing El Niño event is strong enough to affect oceanographic conditions in the SCB, this could lead to deterioration of kelp canopies.

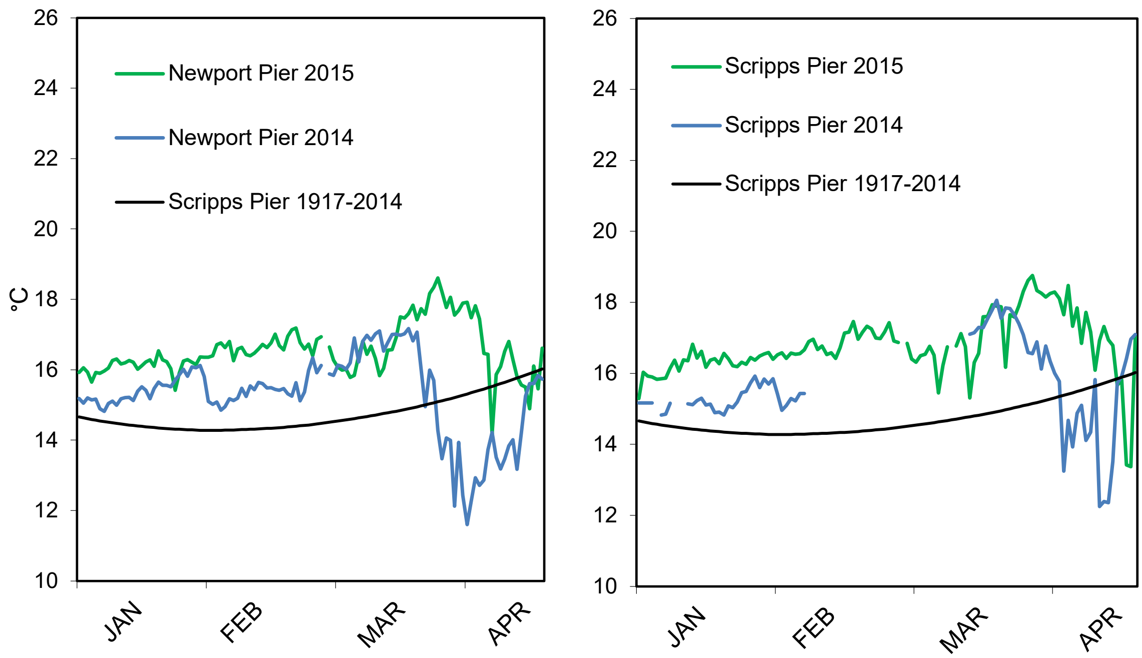


Figure 34. Comparisons between SSTs from January–April 2014 and 2015 at Newport Pier (left) and Scripps Pier (right). 60-day harmonic mean from Scripps Pier (1917-2014) is presented for comparison.

DISCUSSION

Overall Size

Total canopy size within the 50 kelp beds monitored as part of the CRKSC and RNKSC programs was above average in 2014. However, canopy cover off Ventura to San Diego County decreased 19% from 2013.

Spatial Trends

Kelp coverage in the CRKSC decreased by about 24%, and coverage in Region Nine decreased by about 18%. Within each region, there were major spatial differences in gains/losses. Most of the beds in the Central Region lost canopy in 2014; however, three beds between Malibu Point and Point Dume increased last year. The angle of the coastline from Point Dume to Santa Monica Bay is slightly different from that in other areas of Region Nine, and this affects the exposure to waves. Currents and water quality characteristics at Point Dume can vary on small scales. On 9 June 2014, the Regional Ocean Model System calculated temperatures were 2.2°C warmer immediately upcoast of Point Dume than downcoast, and currents were flowing in opposite directions (north-northeast just upcoast from Point Dume, and southwest just downcoast from the Point). The differences in bed performances around Point Dume could be related to these differences in flow regimes and water quality. The upcoast part of the Palos Verdes beds also fared poorly, and decreased in size by about 73%. The other PV beds decreased in size, but not as substantially (7%–21%).

Within Region Nine, only one kelp bed increased in size since last year (Imperial Beach). In contrast to the two larger beds nearest to Imperial Beach—Point Loma (which maintained its size) and La Jolla (which shrank by 30%)—the beds of Imperial Beach expanded by 259%. Reason(s) for this aberrant growth is/are unknown.

Temporal Trends

From Ventura to Newport Beach, kelp beds were at their greatest size during the June 2014 overflight. This coincided with several months (March–May) of cool-water influx (potentially upwelled) in the Central Region. There were similar periods of cold-water intrusions in summer and fall, but most of the daily temperatures were above average. From Newport Beach to Barn kelp, the kelp beds reached their maximum extent in April 2014, and from Oceanside to Baja California most kelp beds peaked in July 2014. The coolest temperatures of the year at Newport Beach and Scripps Pier were recorded in early April 2014.

Oceanographic Processes

Temperatures during the first three months of 2014 were mostly above average, but there were several cold-water influxes from late March through May. Eighty-six percent of the daily SST values at Scripps Pier in 2014 were above the long-term daily means. The upwelling index (from 33°N latitude 119°W longitude) indicated above-average upwelling during only two months—February and September—compared to the 66-year average since 1946. Strongest upwelling occurred in May and June, however. The SSTs throughout the region increased in summer, and upwelling was reduced. Maximum SSTs occurred in June at Scripps Pier, in September at Newport, and in August at Point Dume.

The warmer-than-average temperatures in late 2013 and throughout 2014 coincided with "The Blob", a large mass of warm water that formed off the Pacific Coast and affected coastal waters from the Bering Sea to Baja California. The warm waters likely resulted from (1) lower-than-normal heat loss from the upper ocean to the atmosphere, and (2) weak advection of colder water in the upper ocean. Both of these were attributed to high sea level pressure over the affected areas (Bond et al. 2015). The coastal waters off southern California appeared only slightly warmer than normal in January and April 2014, but by July all of coastal California (and Baja California) was affected, and by fall the waters of the entire West Coast of the United States were much warmer than average (Figure 35). Productivity—assessed here using chlorophyll a—was remarkable in southern California in spring 2014, but muted compared to the rest of the West Coast thereafter (Figure 36).

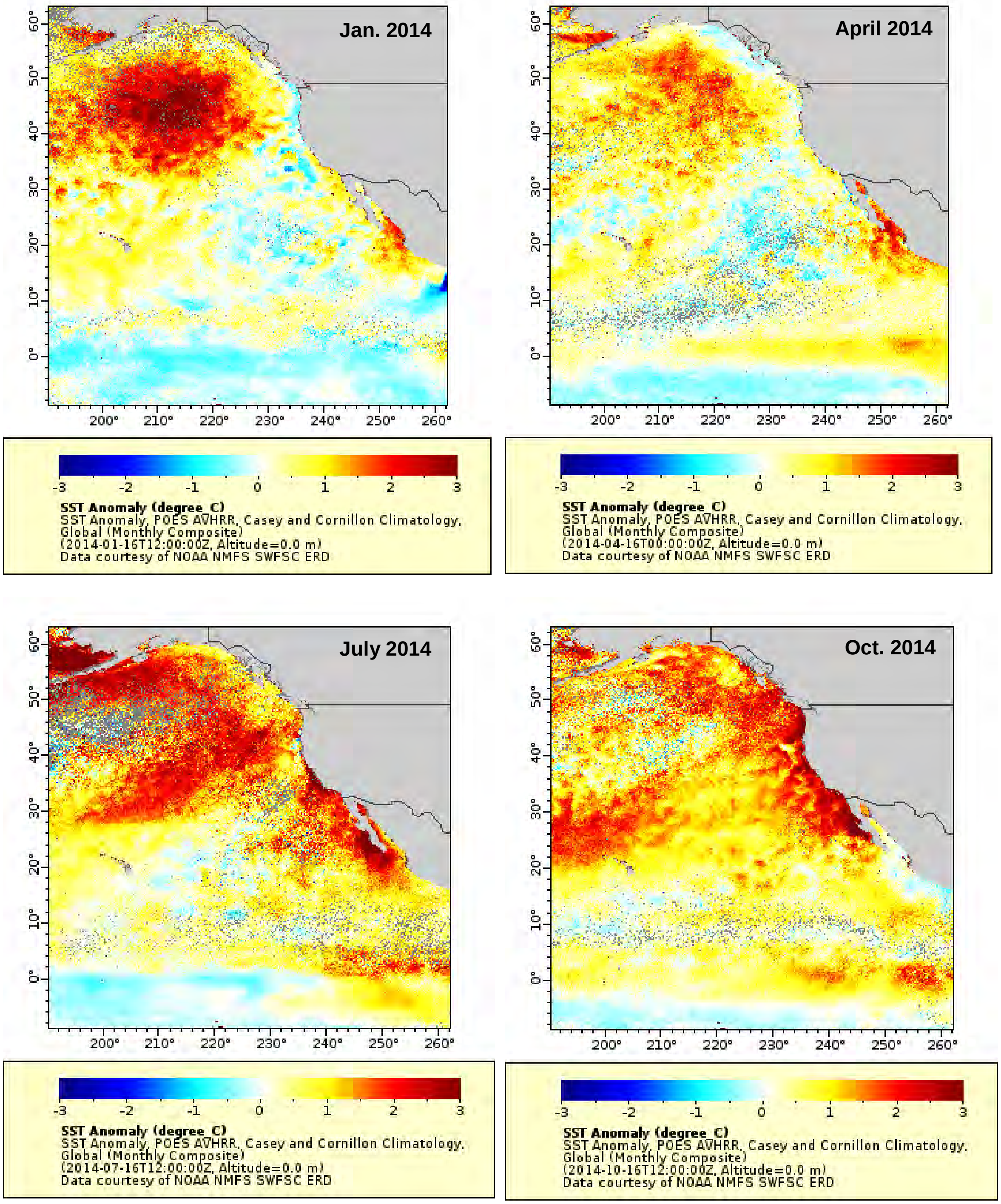


Figure 35. SST anomalies (+/- °C) off the West Coast of North America in January, April, July, and October 2014. Source: NOAA SWFSC ERD (2015).

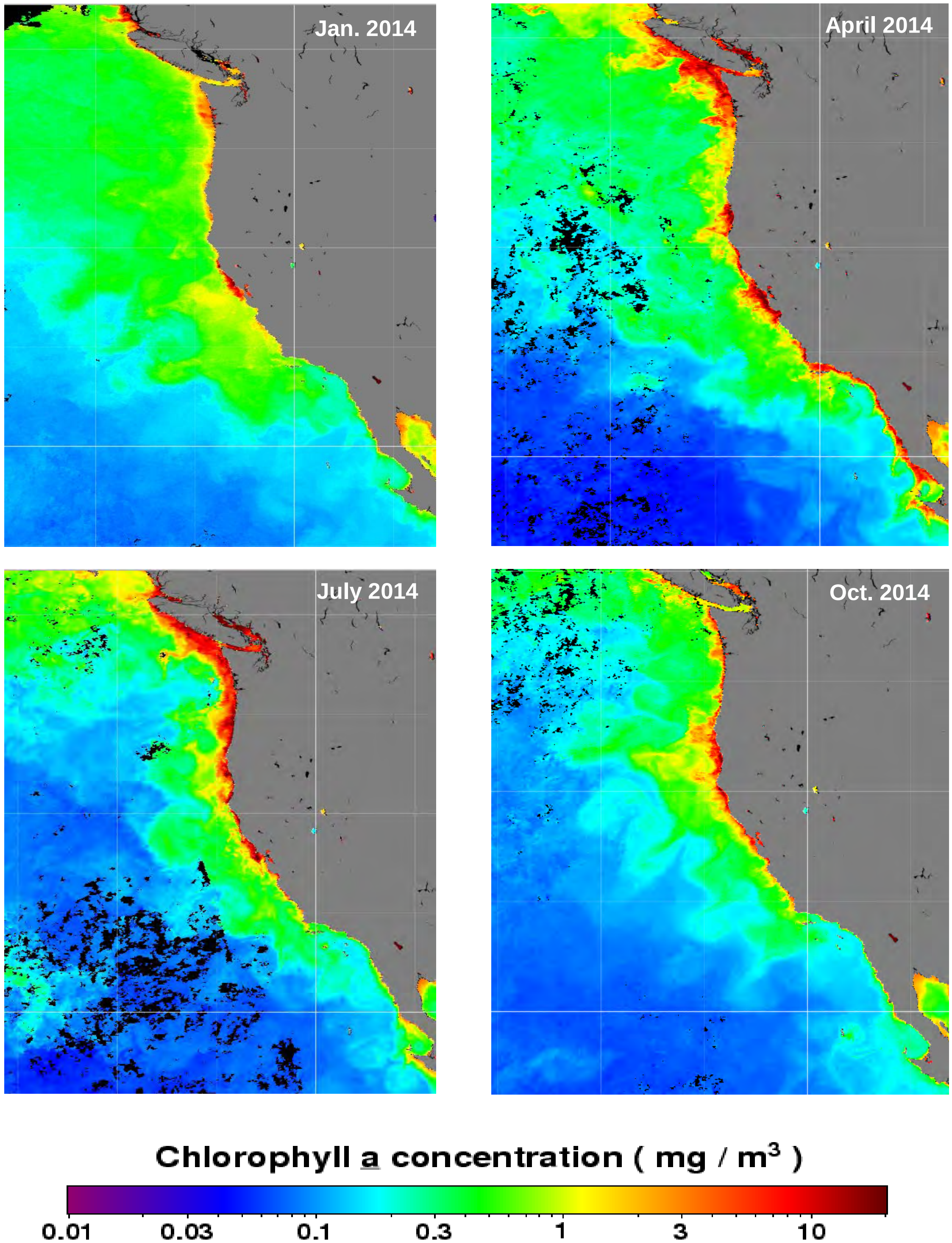


Figure 36. Chlorophyll a concentration off the West Coast of North America in January, April, July, and October 2014. Source: NASA (2015).

During the 2013–2014 nutrient season (beginning in July and ending in June the following year), the NQ values in the Central Region were low, ranging from 7 to 12 (22 to 43 is about average). The NQ values in Region Nine were similarly low (ranging from 6 to 9). The NQ values from Point Dume, Santa Monica Pier, and Newport Pier were the lowest since the CRKSC was formed (2003), and in Region Nine, NQ values were also well below average, but similar to those recorded last year. Three major, basin-scale indicators all changed phase at some point during the winter of 2013/2014: the PDO changed to positive (indicating warmer temperatures in the North Pacific), the NPGO changed to negative (indicative of lower productivity along the coast), and the MEI changed to positive, signaling the pending arrival of an equatorial El Niño. Leising et al. (2014) reported above-average SSTs, near average upwelling, and lower-than-average chlorophyll a values in southern California in 2014.

The NQ values have historically been calculated for each “indexed year”, which spans from July through June of the following year. The logic in this time span is the historical availability of nutrients, which coincided with colder temperatures during winter and spring (i.e., December through May/June) (North and MBC 2001). The NQ values for calendar years from 2010–2014 were calculated for multiple sites in both regions. In the Central Region, NQ values at all locations (except Santa Monica Pier) were lower from 2013–2015 than they were in 2010, 2011, and 2012. In Region Nine, NQ values were the lowest in the last 22 years at Newport Pier, and in the last 17 years at Scripps Pier.

Even though the temperature patterns were fairly similar across southern California, and NQ values were regionally low, some distinct SST patterns have developed over the last few years. At Point Dume, the number of days with SSTs >16–20°C has increased above the 20-year mean since 2011 (Table 7). Likewise the number of days <13–14°C has declined substantially. At Newport Beach, the number of days >16–18°C increased in 2013, and the number of days <14°C decreased. Lastly, at Scripps Pier, the number of days with SST below 13–14°C from 2011–2013 was well above the long-term mean, which could explain the protracted kelp growth. However, the number of days below 13–14°C decreased substantially in 2014. Conversely, the number of days with SSTs above 16–20°C increased substantially in 2014.

Table 7. Number of days above or below specific SSTs at three locations in southern California: 2011, 2012, 2013, 2014, and the 20-year mean. Red cells indicate years above the long-term mean (16–20°C) and blue cells below the long-term mean (13–14°C).

	Mean (1994-2013)	2011	2012	2013	2014
Point Dume					
>20°C	14	0	**58**	**18**	**116**
>18°C	63	**65**	**111**	**132**	**200**
>16°C	150	**163**	**211**	**214**	**248**
<14°C	87	**89**	54	59	10
<13°C	35	29	23	7	1
Newport Pier					
>20°C	32	5	22	31	**81**
>18°C	103	63	**113**	**114**	**189**
>16°C	195	159	195	**221**	**263**
<14°C	61	56	56	**64**	17
<13°C	22	7	17	11	7
SIO Pier					
>20°C	75	13	29	61	**117**
>18°C	142	46	115	136	**201**
>16°C	220	128	190	191	**263**
<14°C	17	**72**	**51**	**53**	6
<13°C	2	**10**	**13**	**8**	**3**

The pattern in mean SST has also differed along the coast. During the last four years, annual mean SSTs at Point Dume exceeded the 20-year mean each year, and they were substantially higher (by 2.6°C) during 2014 (Table 8). Temperatures were also 1–2°C higher than the long-term means at Newport Beach and at SIO Pier in 2014.

Table 8. Comparison of (1) mean temperature from 1994–2013, and (2) annual mean temperature during 2011, 2012, 2013, and 2014 at three location in southern California. Cells in red are higher than the long-term mean, and those in blue are lower.

	Mean SST (°C; 1994-2013)	2011 Annual Mean SST (°C)	2012 Annual Mean SST (°C)	2013 Annual Mean SST (°C)	2014 Annual Mean SST (°C)
Point Dume	**15.6**	15.7	16.8	16.8	18.2
Newport	**16.5**	15.9	16.6	16.7	18.0
SIO Pier	**17.6**	15.7	16.6	17.0	18.8

La Niña conditions persisted in the Pacific Ocean through half of 2010 and most of 2011, and dissipated in early 2012. During this period, most of the kelp beds in the region achieved larger-than-average canopies. Despite a return to ENSO neutral conditions in 2012 and 2013, kelp coverage was higher than average, particularly in Region Nine. In light of recent studies suggesting that all of southern California has been subjected to a marine environment relatively depleted in nutrients since 1977, the respite from El Niño conditions has benefited the kelp beds. However, the MEI transitioned from neutral conditions in 2013 to positive values in April 2014. This coincided with higher-than-average SSTs in the SCB for most of 2014.

Other environmental factors appeared from the data to have had minimal effects on the kelp beds of both regions during 2013. Annual rainfall in 2014 was low (for the fourth year in a row) and effects from runoff (turbidity) were likely negligible. Point Loma was one of three beds in Region Nine to wane in 2013, but it maintained its size in 2014. It is not known if kelp is being harvested from Point Loma kelp bed, but Kelp Bed Number 3 was leased from the state in 2012.

The wave climate was relatively mild in 2014, although there were periods with waves that approached and exceeded four meters, where one would expect to see damage from breaking waves. The largest waves (three to five meters from the west) were measured in early March. Most of the kelp beds reached their maximum size in the months that followed, during the April and June/July overflights. La Jolla kelp grows in shallower water than Point Loma kelp, and is more exposed to extreme wave stress (Parnell 2015). La Jolla kelp shrank more than Point Loma kelp in 2014, but it is unknown if wave stress in early March (prior to the overflights) was a contributor to this. The large swell in late-August lasted for several days, and damaged the breakwaters at Los Angeles and Long Beach Harbors. Some kelp beds in southern California were likely affected; however, the strongest waves (from south-southeast) affected areas without kelp beds (i.e., San Pedro to Newport Beach). However, Palos Verdes and Cabrillo were still exposed to large waves for several days. Most of the beds shrank between the June/July and September overflights, but beds often shrink in summer and fall, so the proportional effects of strong waves and prolonged periods of high SSTs are unknown. Even though the large swells could have damaged some of the kelp beds, the damage was not sufficient enough to deter continued growth during spring 2014 (and into 2015). There were also no widespread algal blooms that persisted long enough to reduce canopy sizes.

CONCLUSION

Kelp bed performance varied by region in 2014. However, most of the beds in both regions decreased in size from 2013. Three kelp beds upcoast from Malibu Point increased in size, and while all four of the Palos Verdes kelp beds shrank, the adjacent bed at Cabrillo increased in size by more than 80%. In Region Nine, only one kelp bed increased in size: Imperial Beach. Despite the region-wide declines, canopy coverage in 2014 was still above average in both regions.

Most areas in the region were subjected to similarly large temperature fluctuations synoptically, and responses by kelp beds differed among areas. Sea surface temperatures have been above average during the last three years, and periods of cold-water intrusions have been shorter than average, particularly at Newport Beach and Point Dume.

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

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PERSONAL COMMUNICATIONS

Curtis, M. 2012. Mike Curtis is a marine biologist working on kelp ecosystems for MBC Applied Environmental Sciences in Costa Mesa, California.

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

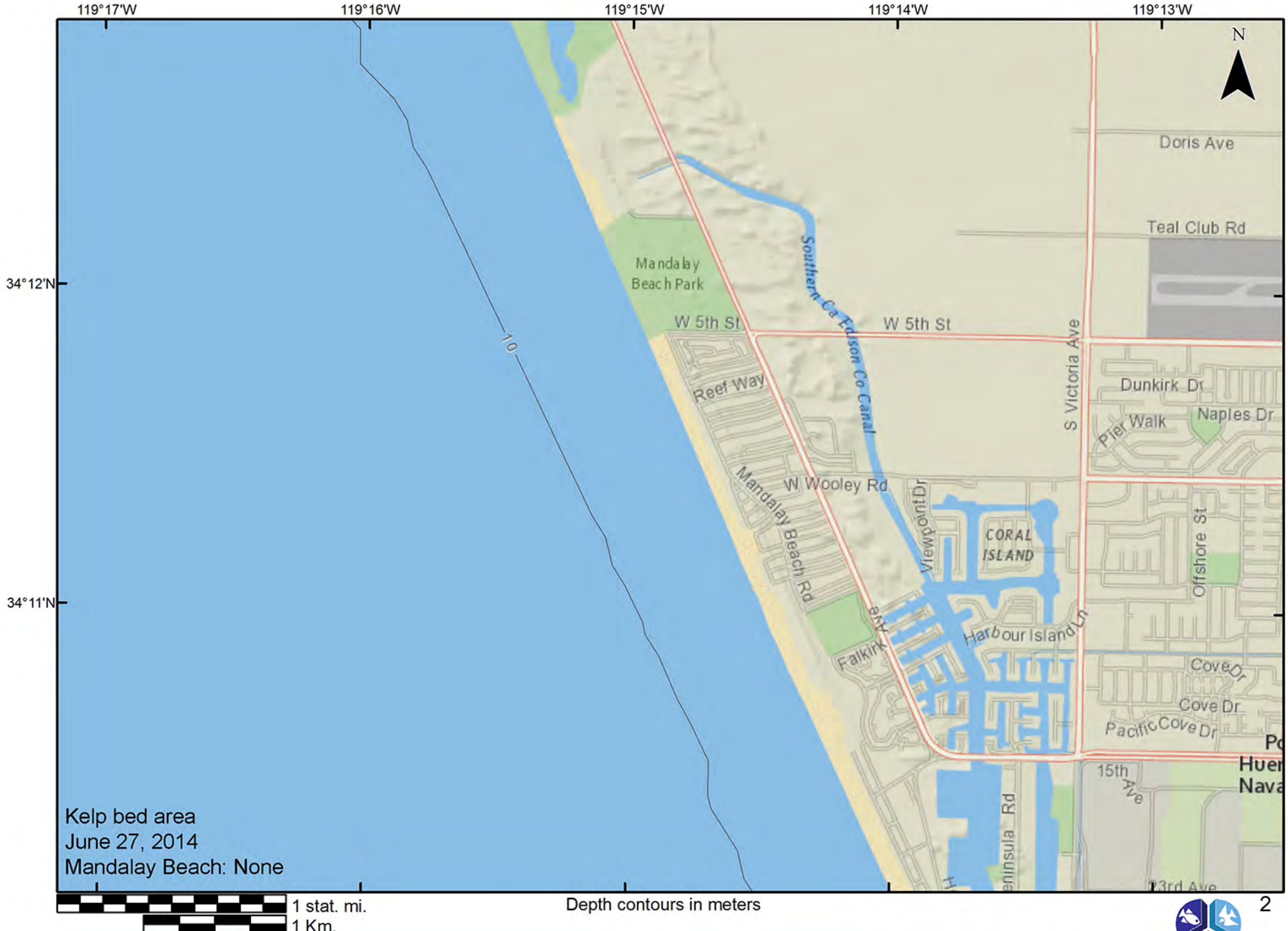
Shipe, R. 2006. Dr. Rebecca Shipe is an Assistant Professor in the Department of Ecology and Evolutionary Biology at the University of California, Los Angeles. Her expertise is phytoplankton ecology and physiology, particularly in southern California coastal zones. Throughout 2005 and 2006, Dr. Shipe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

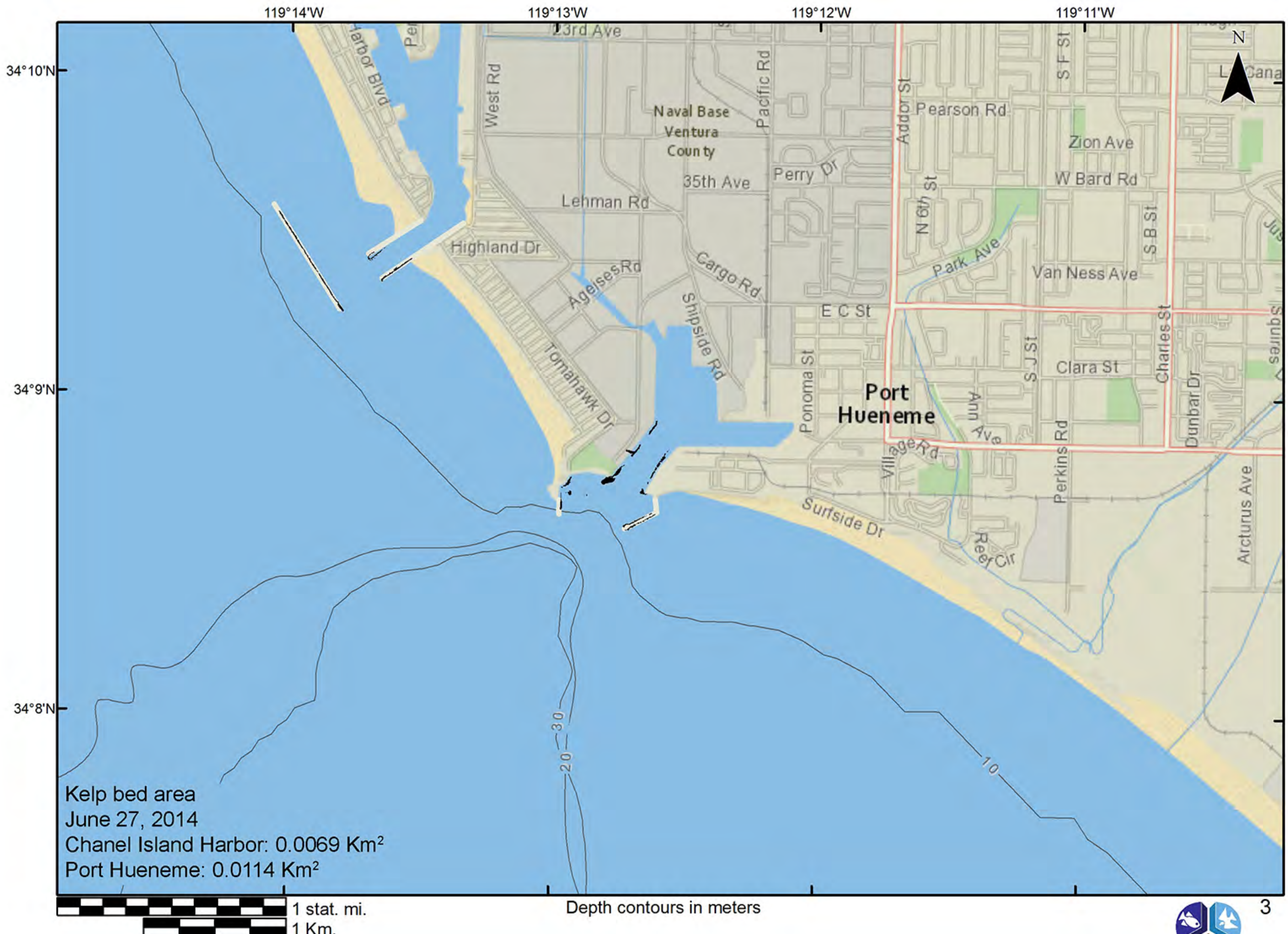
APPENDIX A

Kelp Canopy Maps

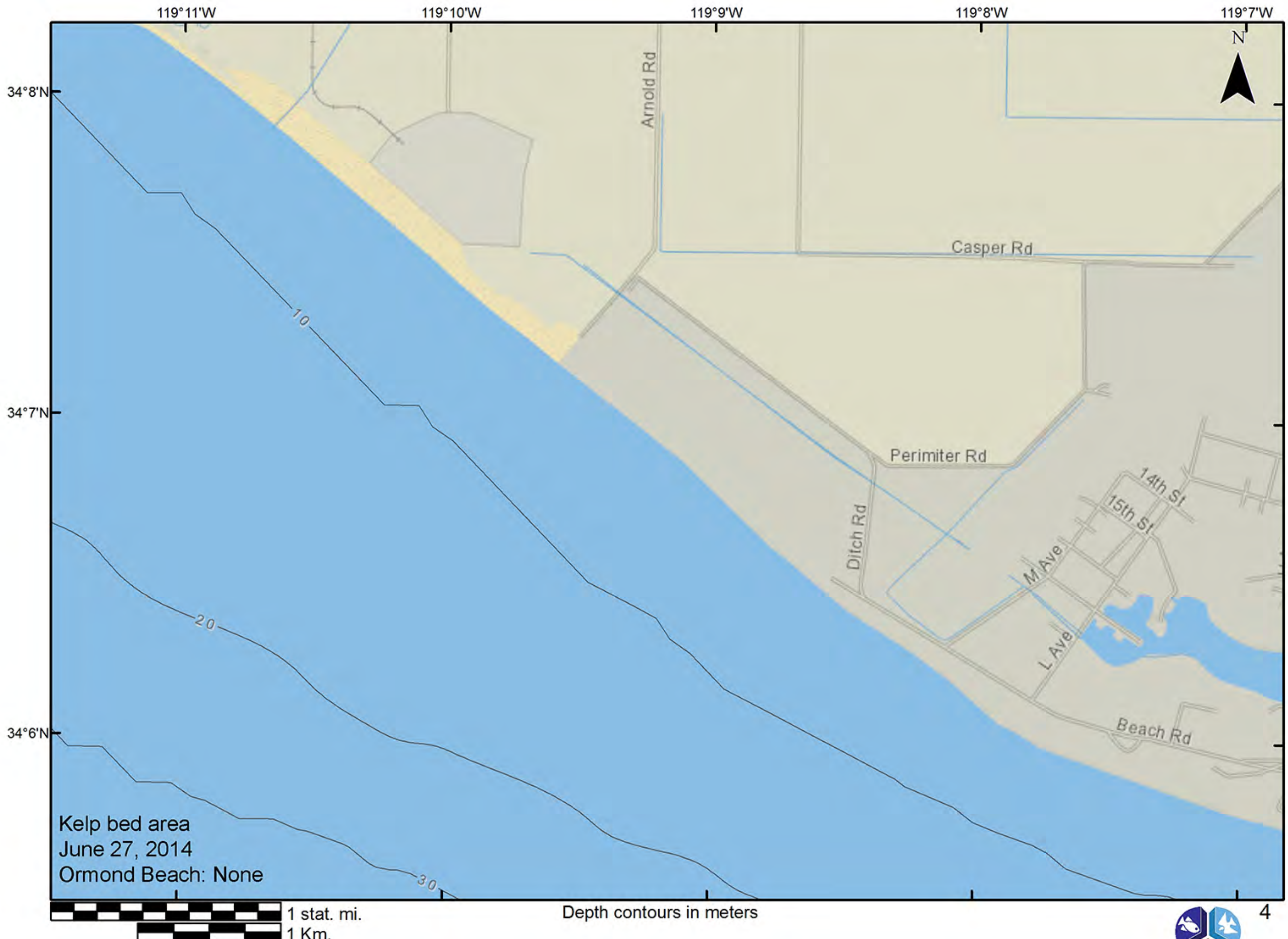
Depth contours in meters

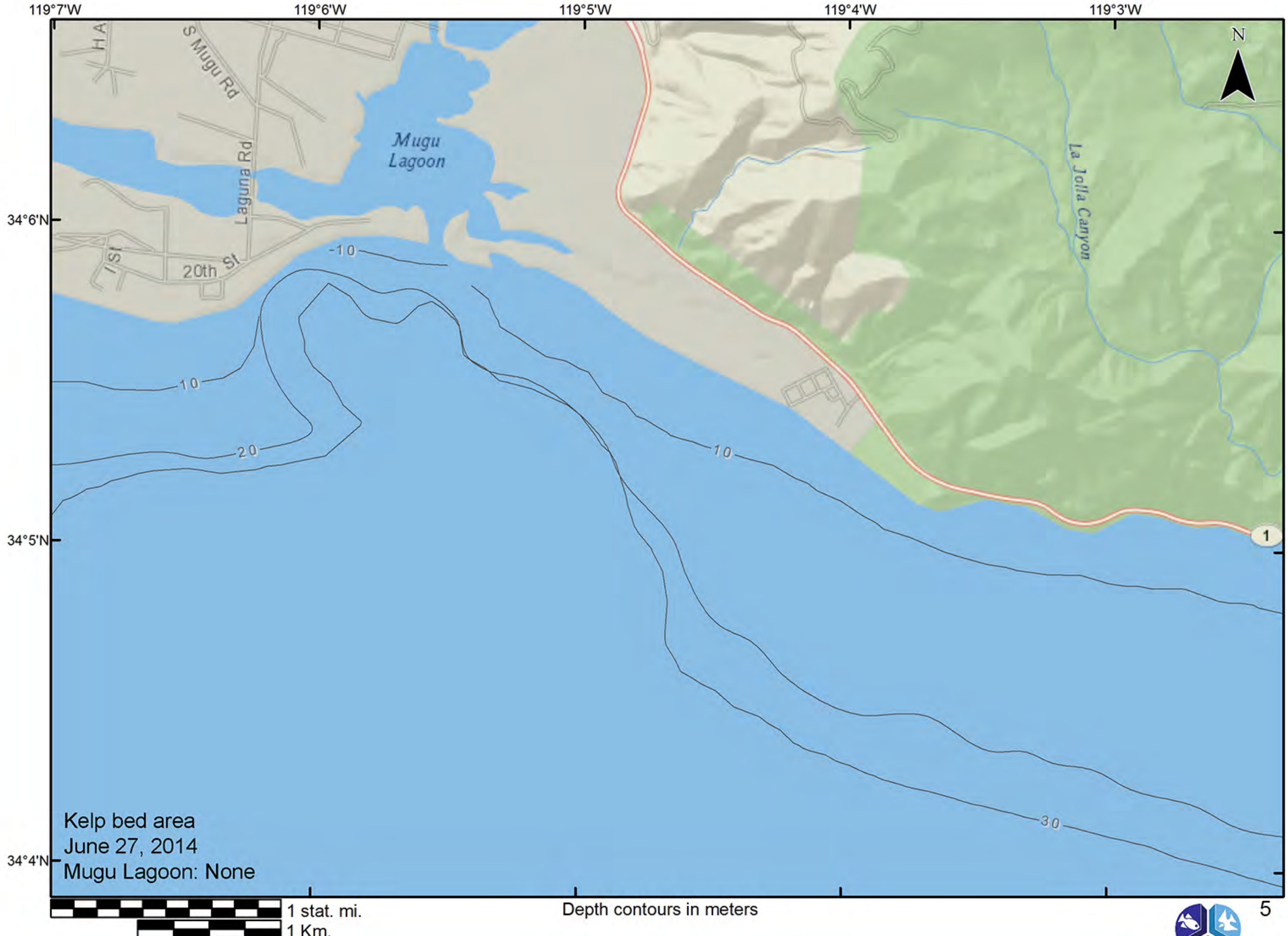
MBC


119°17'W
119°16'W
119°15'W
119°14'W
119°13'W
34°12'N
34°11'N
N
Doris Ave
Teal Club Rd
Mandalay Beach Park
W 5th St
W 5th St
Southern Ca Edison Co Canal
S Victoria Ave
Reef Way
Dunkirk Dr
Naples Dr
Pier Walk
W Wooley Rd
Mandalay Beach Rd
Viewpoint Dr
CORAL ISLAND
Offshore St
Harbour Island Ln
Falkirk Ave
Cove Dr
Cove Dr
Pacific Cove Dr
15th Ave
10
Kelp bed area
June 27, 2014
Mandalay Beach: None
1 stat. mi.
1 Km.
Depth contours in meters
MBC

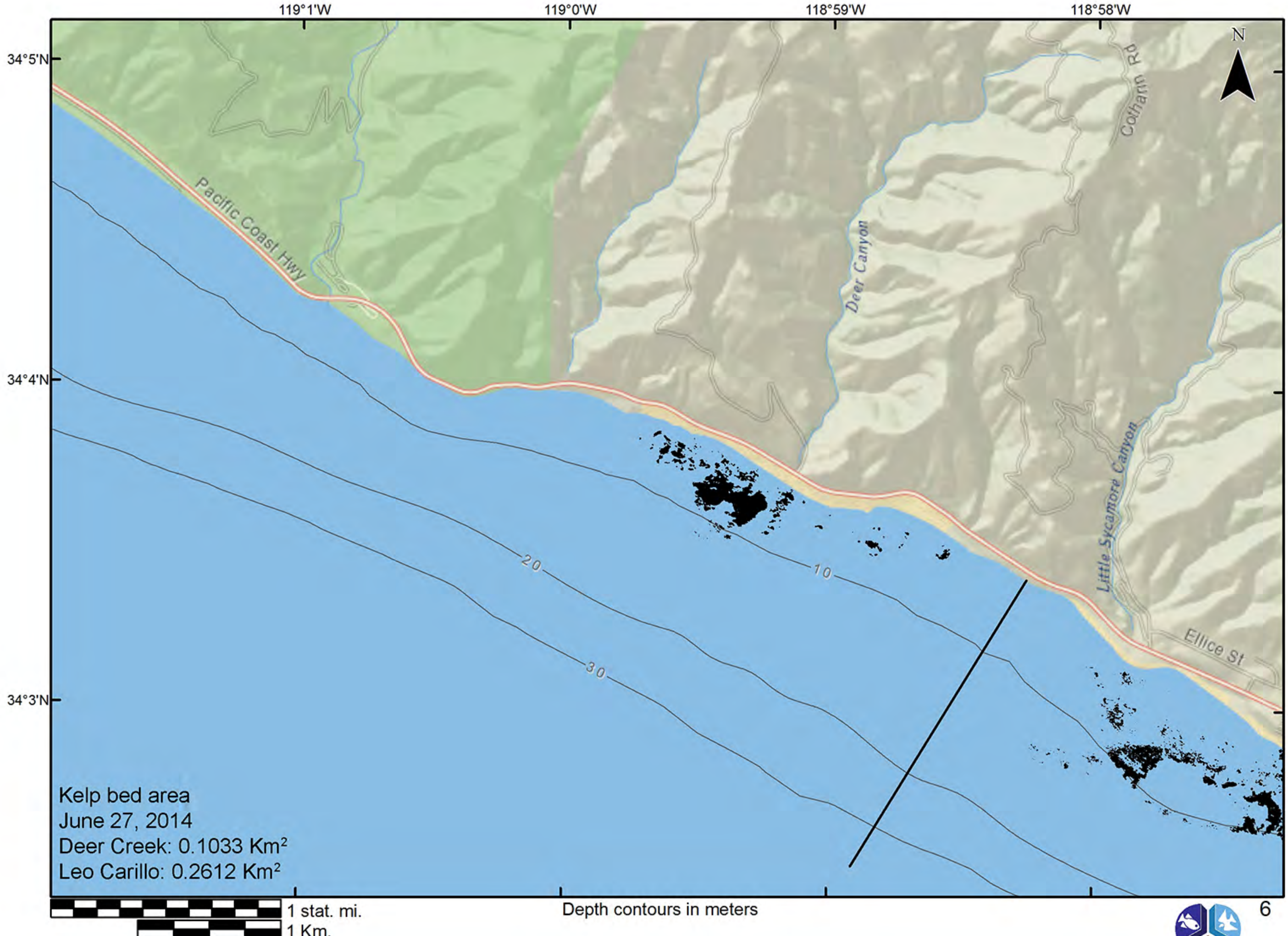


119°14'W
119°13'W
119°12'W
119°11'W
34°10'N
34°9'N
34°8'N
N
Naval Base Ventura County
Port Hueneme
Harbor Blvd
West Rd
23rd Ave
Pacific Rd
Addor St
Pearson Rd
S F St
Zion Ave
35th Ave
Perry Dr
W Bard Rd
Lehman Rd
N 6th St
Highland Dr
Park Ave
S B St
Van Ness Ave
AgeisesRd
Cargo Rd
Shipside Rd
E C St
Charles St
Tomahawk Dr
Ponoma St
S J St
Clara St
Ann Ave
Village Rd
Perkins Rd
Dunbar Dr
Surfside Dr
Reef Cir
Arcturus Ave
30
20
10
Kelp bed area
June 27, 2014
Chanel Island Harbor: 0.0069 Km²
Port Hueneme: 0.0114 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

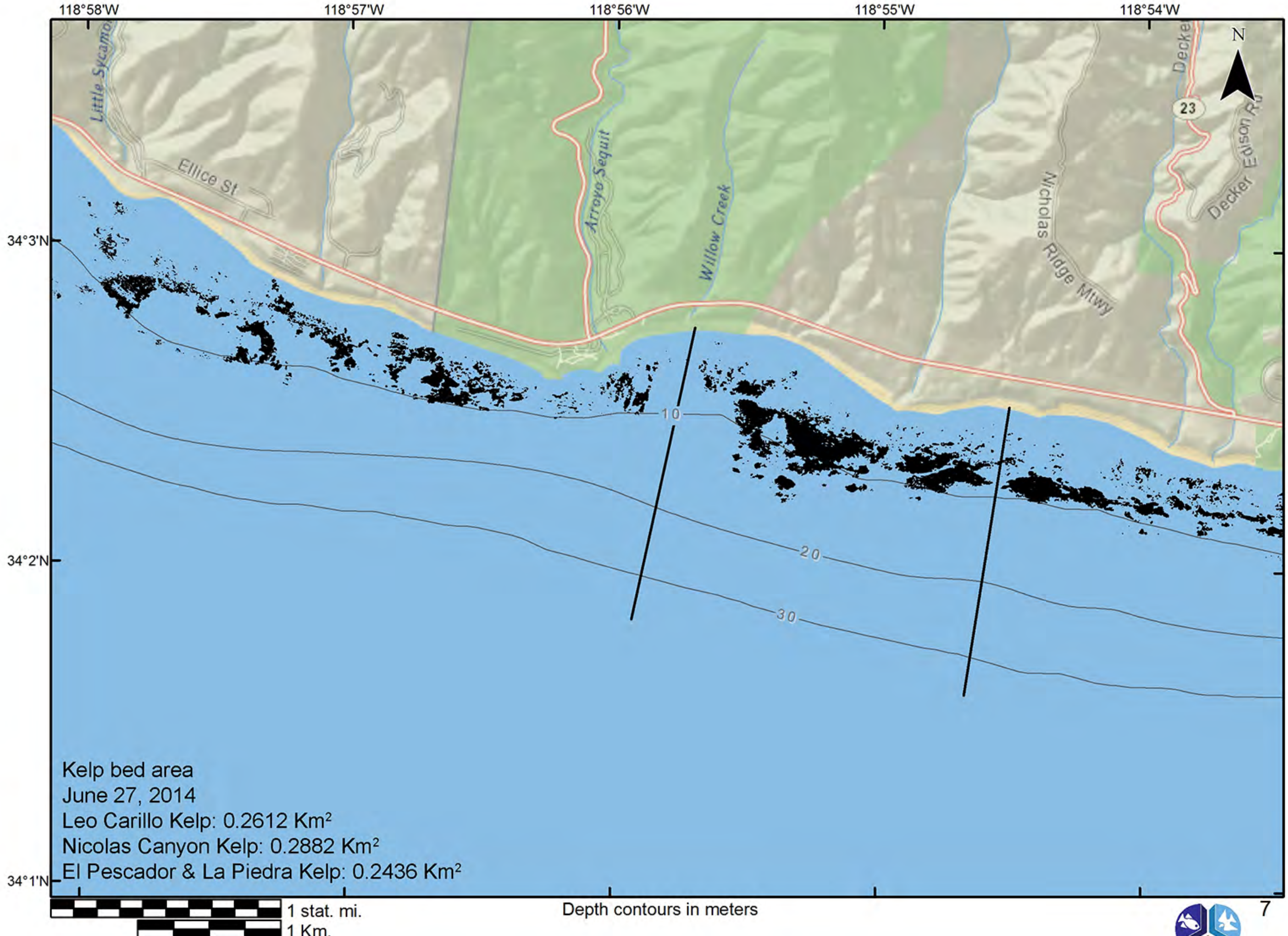

119°11'W
119°10'W
119°9'W
119°8'W
119°7'W
34°8'N
34°7'N
34°6'N
N
Arnold Rd
Casper Rd
Perimiter Rd
Ditch Rd
14th St
15th St
M Ave
L Ave
Beach Rd
10
20
30
Kelp bed area
June 27, 2014
Ormond Beach: None
1 stat. mi.
1 Km.
Depth contours in meters
MBC


119°7'W
119°6'W
119°5'W
119°4'W
119°3'W
34°6'N
34°5'N
34°4'N
N
S Mugu Rd
Laguna Rd
20th St
Mugu Lagoon
La Jolla Canyon
1
-10
10
20
30
Kelp bed area
June 27, 2014
Mugu Lagoon: None
1 stat. mi.
1 Km.
Depth contours in meters

MBC

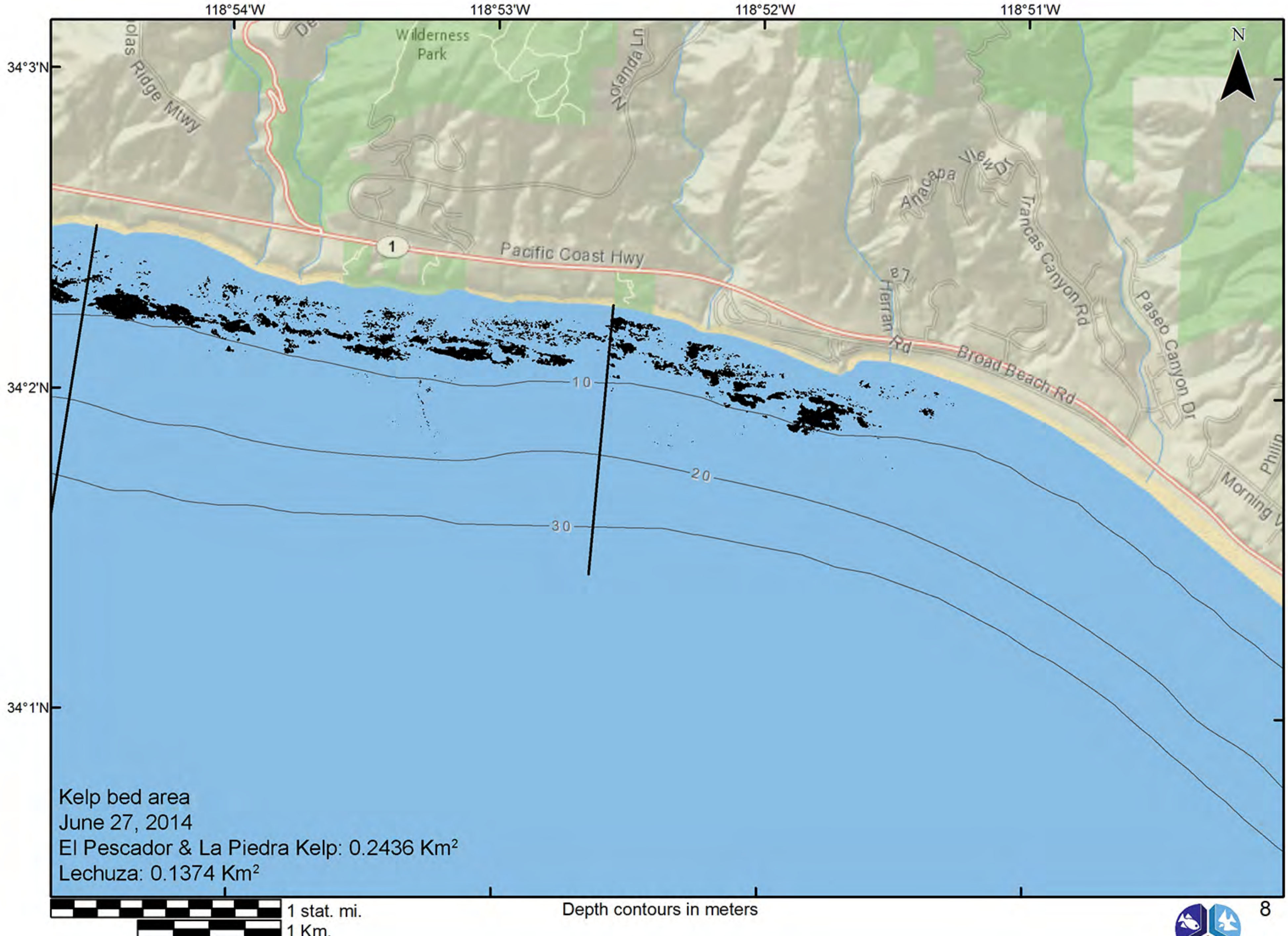


119°1'W
119°0'W
118°59'W
118°58'W
34°5'N
34°4'N
34°3'N
N
Pacific Coast Hwy
Deer Canyon
Cotharin Rd
Little Sycamore Canyon
Ellice St
20
10
30
Kelp bed area
June 27, 2014
Deer Creek: 0.1033 Km²
Leo Carillo: 0.2612 Km²
1 stat. mi.
1 Km.
Depth contours in meters
6



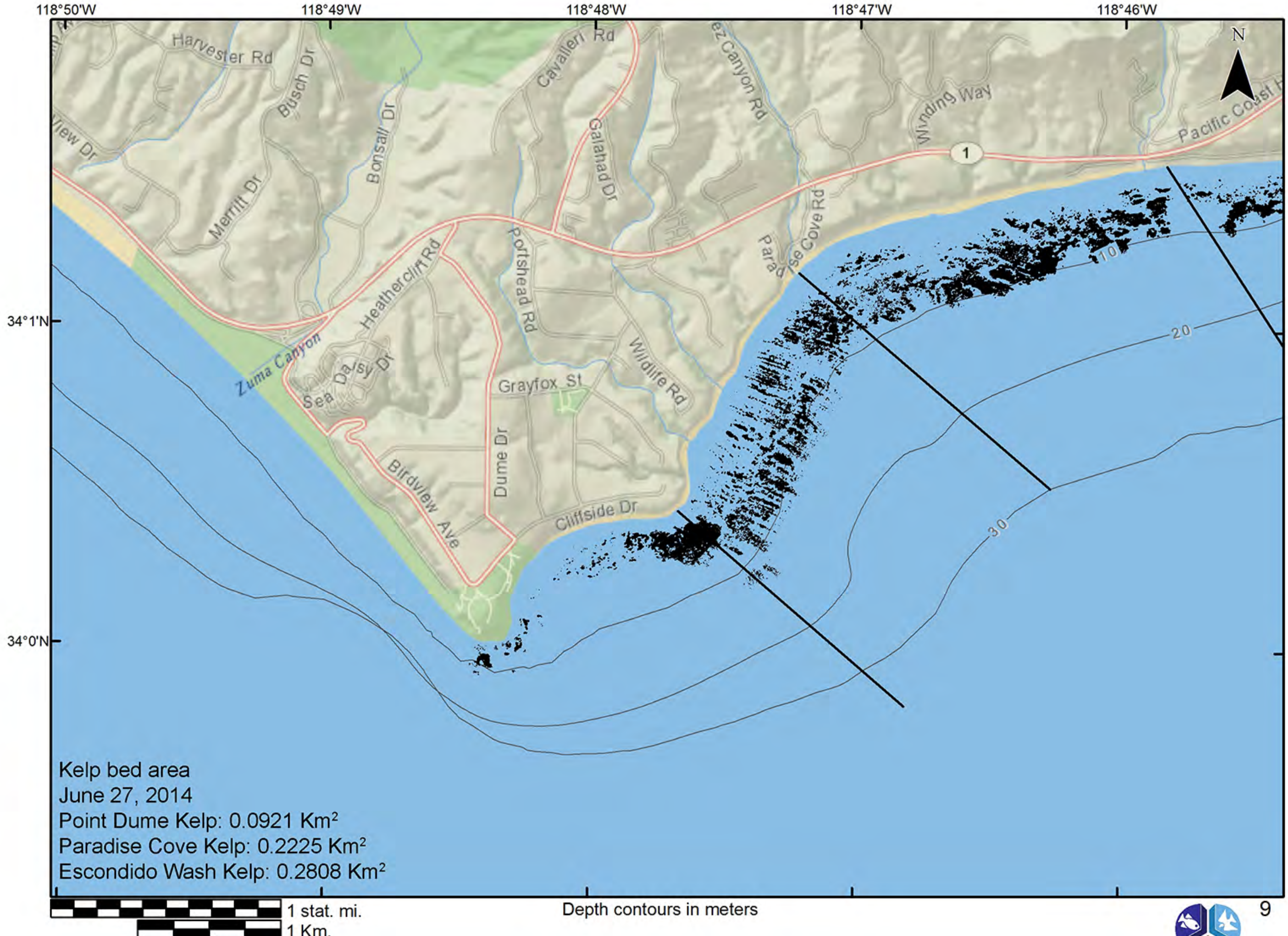
118°58'W
118°57'W
118°56'W
118°55'W
118°54'W
34°3'N
34°2'N
34°1'N
N
Little Sycamore
Ellice St
Arroyo Sequit
Willow Creek
Nicholas Ridge Mtwy
Decker
Decker Edison Rd
23
10
20
30
Kelp bed area
June 27, 2014
Leo Carillo Kelp: 0.2612 Km²
Nicolas Canyon Kelp: 0.2882 Km²
El Pescador & La Piedra Kelp: 0.2436 Km²
1 stat. mi.
1 Km.
Depth contours in meters

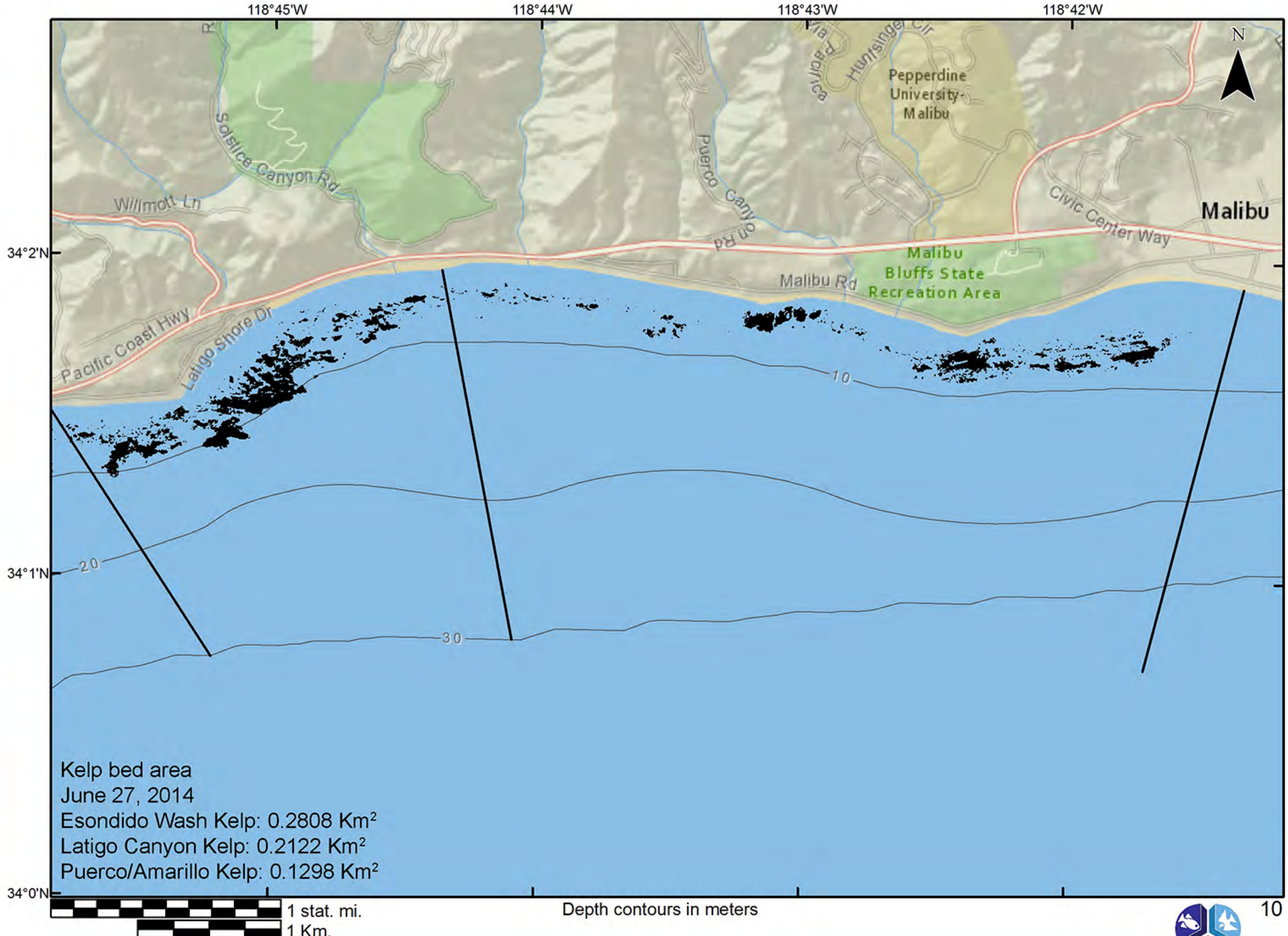
MBC



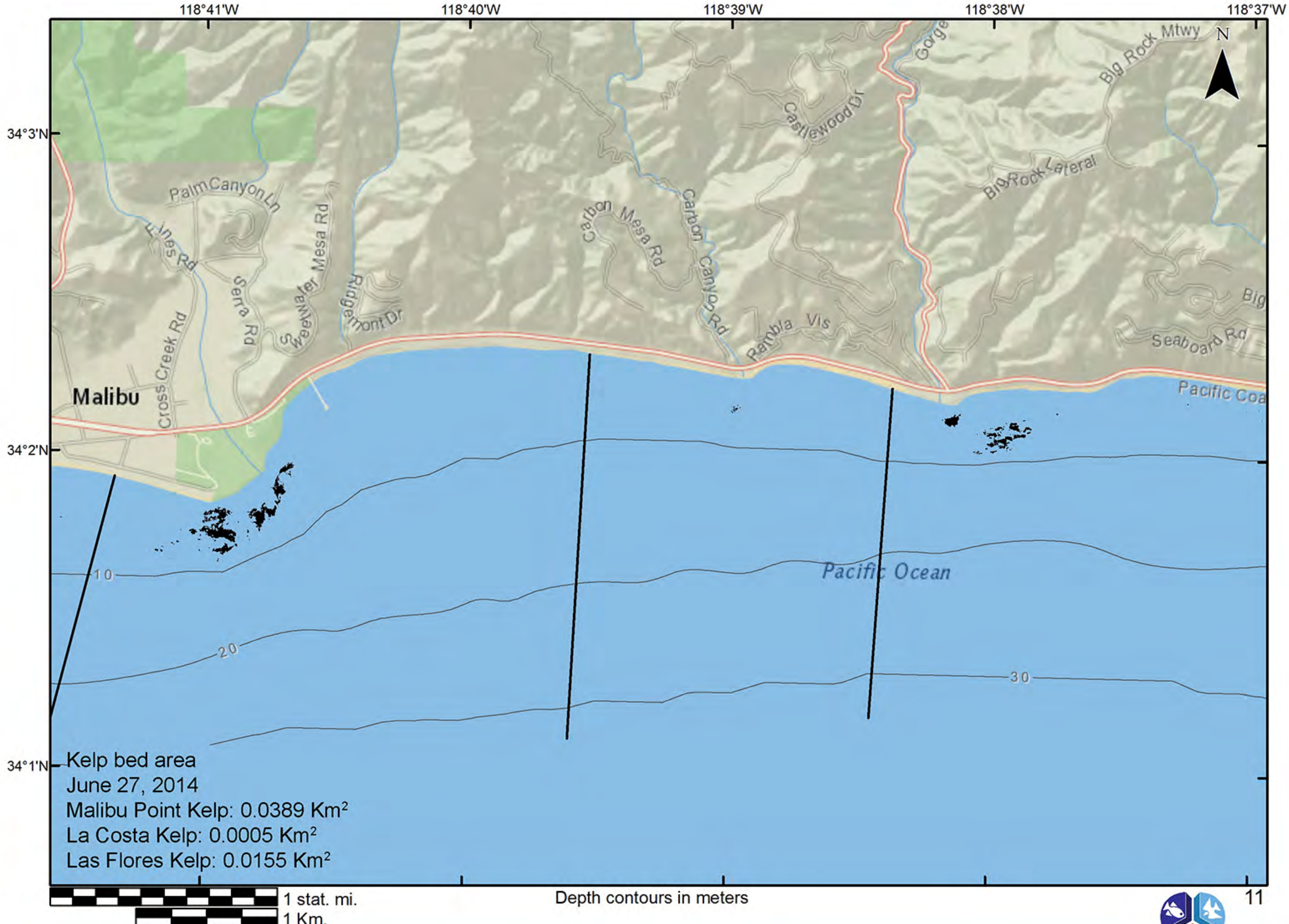
Depth contours in meters

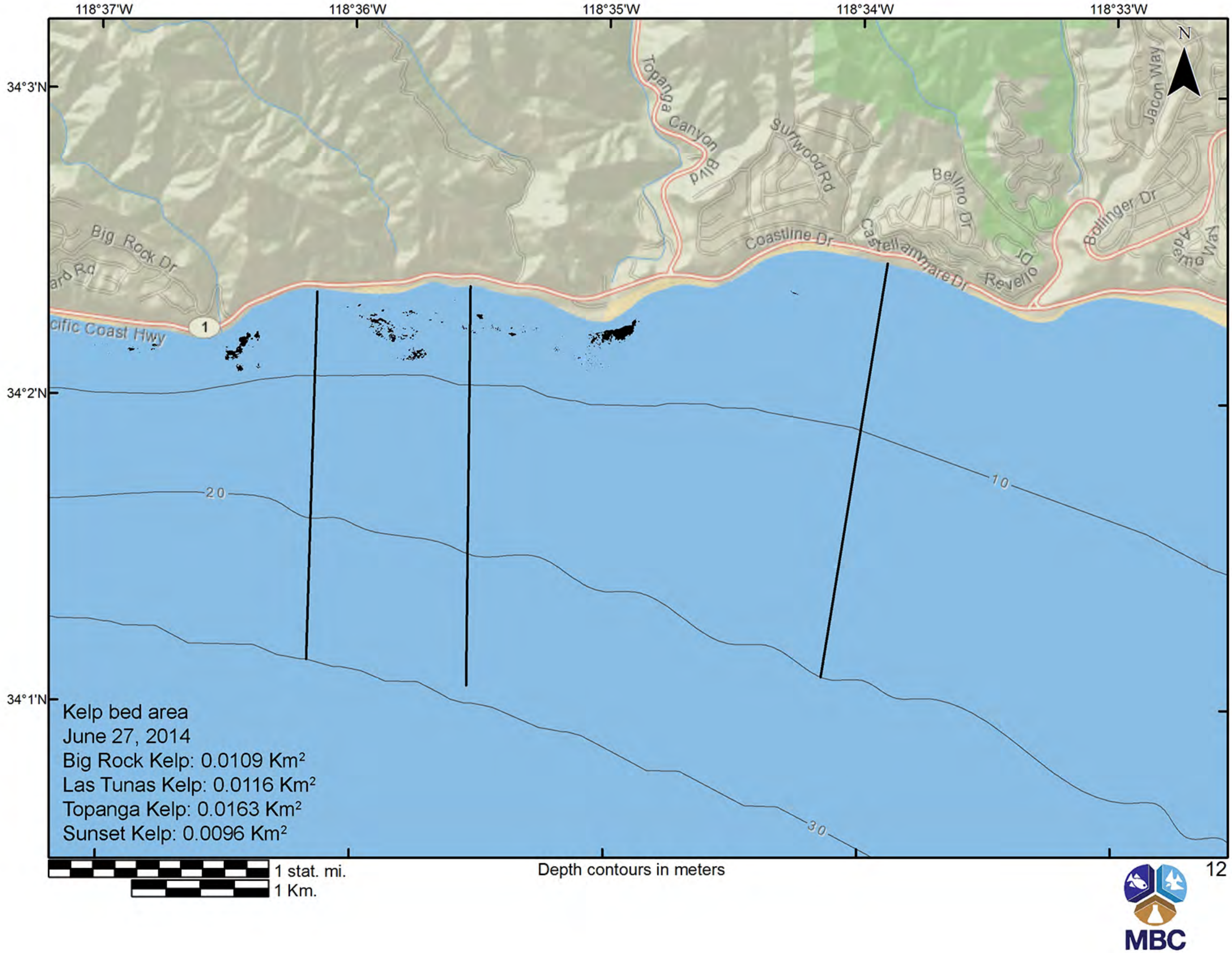
MBC

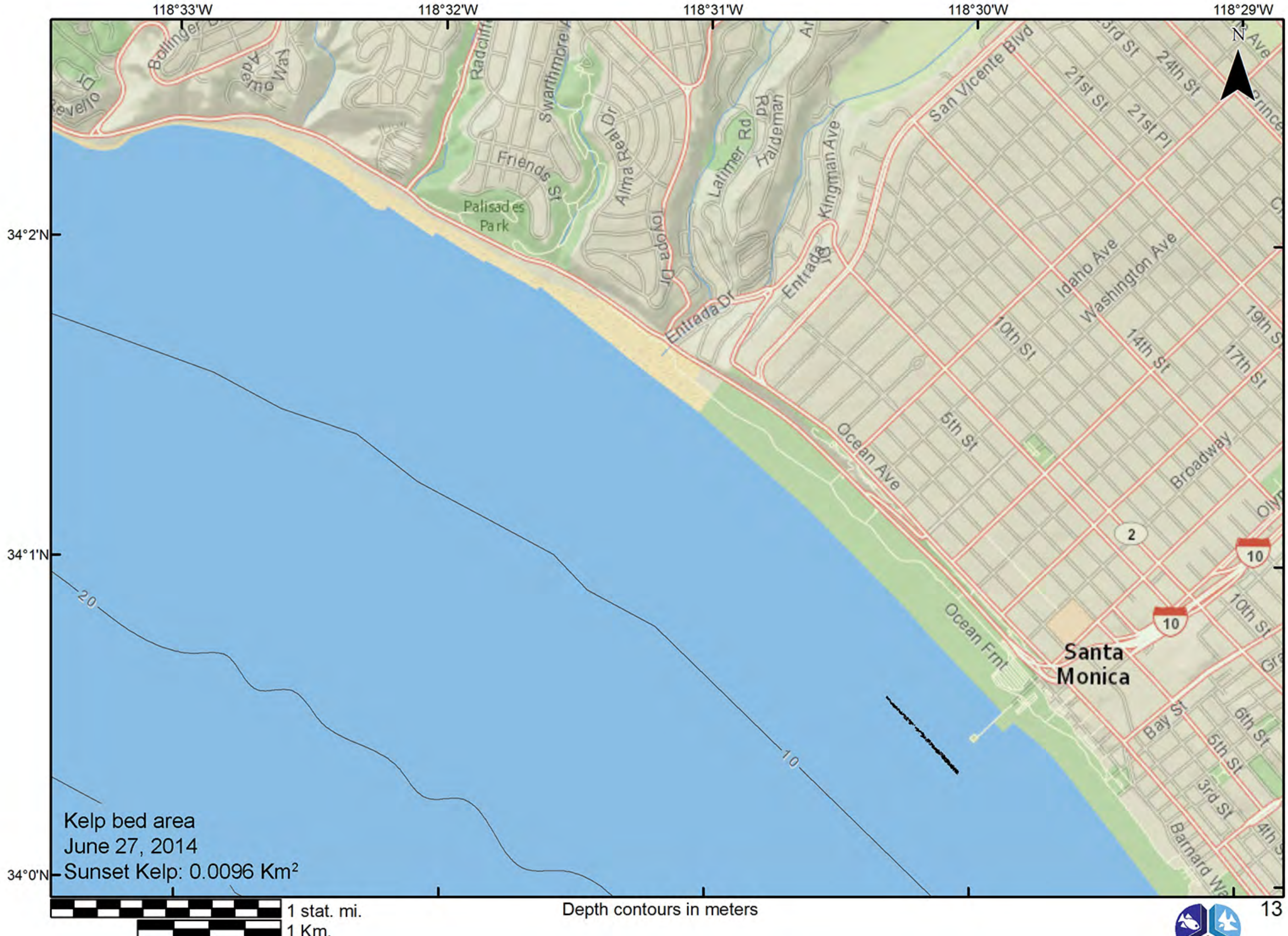

118°50'W
118°49'W
118°48'W
118°47'W
118°46'W
34°1'N
34°0'N
N
Harvester Rd
Busch Dr
Cavalleri Rd
Bonsall Dr
Galahad Dr
Winding Way
Pacific Coast H
1
Merritt Dr
Portshead Rd
Heathercliff Rd
Zuma Canyon
Sea Daisy Dr
Grayfox St
Wildlife Rd
Birdview Ave
Dume Dr
Cliffside Dr
10
20
30
Kelp bed area
June 27, 2014
Point Dume Kelp: 0.0921 Km²
Paradise Cove Kelp: 0.2225 Km²
Escondido Wash Kelp: 0.2808 Km²
1 stat. mi.
1 Km.
Depth contours in meters

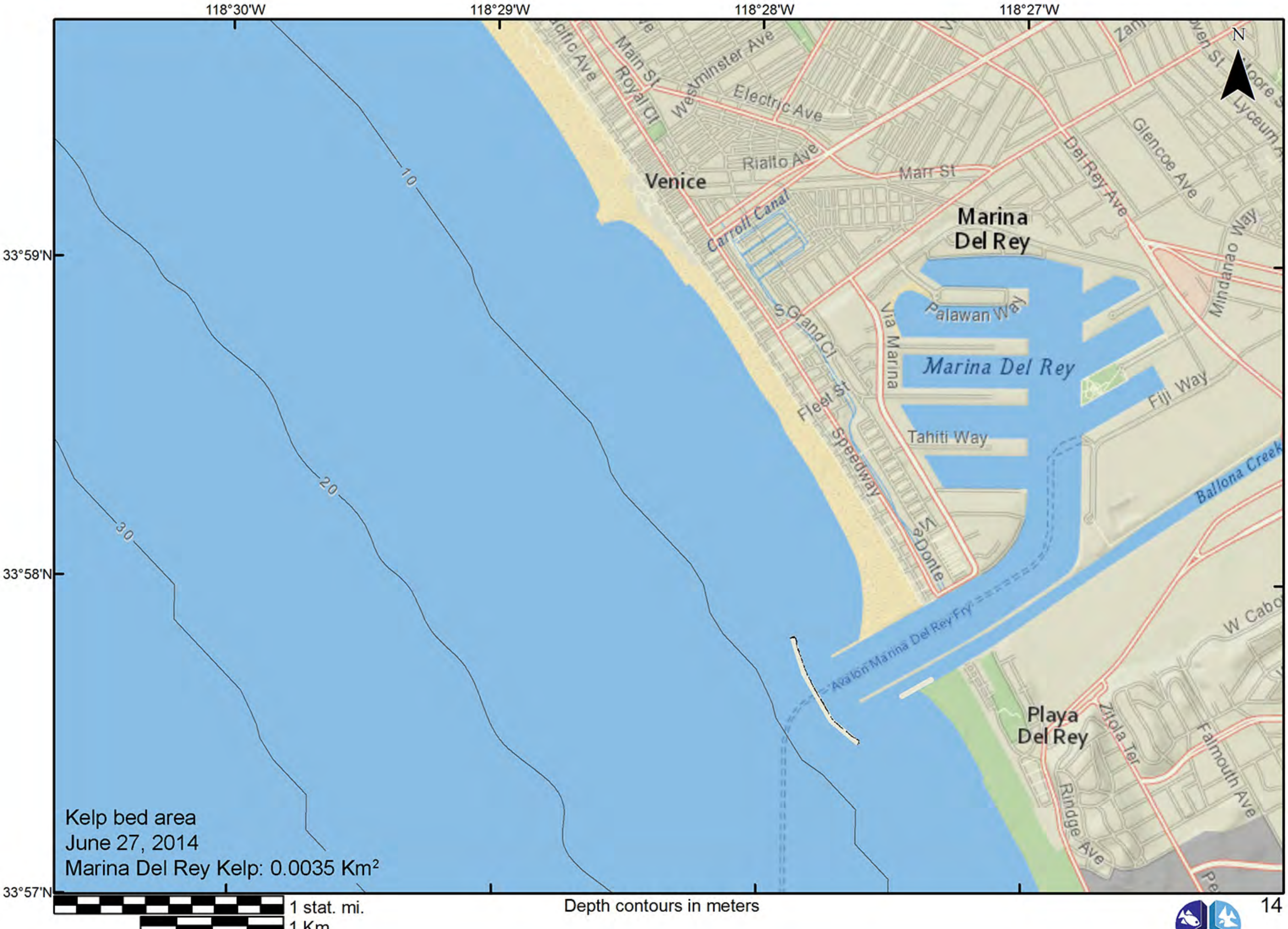

118°45'W
118°44'W
118°43'W
118°42'W
34°2'N
34°1'N
34°0'N
N
Pepperdine University-Malibu
Malibu
Solstice Canyon Rd
Willmott Ln
Puerco Canyon Rd
Huntsinger Cir
Via Pacifica
Civic Center Way
Malibu Rd
Malibu Bluffs State Recreation Area
Pacific Coast Hwy
Latigo Shore Dr
10
20
30
Kelp bed area
June 27, 2014
Esondido Wash Kelp: 0.2808 Km²
Latigo Canyon Kelp: 0.2122 Km²
Puerco/Amarillo Kelp: 0.1298 Km²
1 stat. mi.
1 Km.
Depth contours in meters

MBC


118°41'W
118°40'W
118°39'W
118°38'W
118°37'W
34°3'N
34°2'N
34°1'N
N
Palm Canyon Ln
Malibu
Cross Creek Rd
Serra Rd
Sweetwater Mesa Rd
Ridgemont Dr
Carbon Mesa Rd
Carbon Canyon Rd
Castlewood Dr
Rambla Vis
Big Rock Mtwy
Big Rock Lateral
Seaboard Rd
Pacific Ocean
10
20
30
Kelp bed area
June 27, 2014
Malibu Point Kelp: 0.0389 Km²
La Costa Kelp: 0.0005 Km²
Las Flores Kelp: 0.0155 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

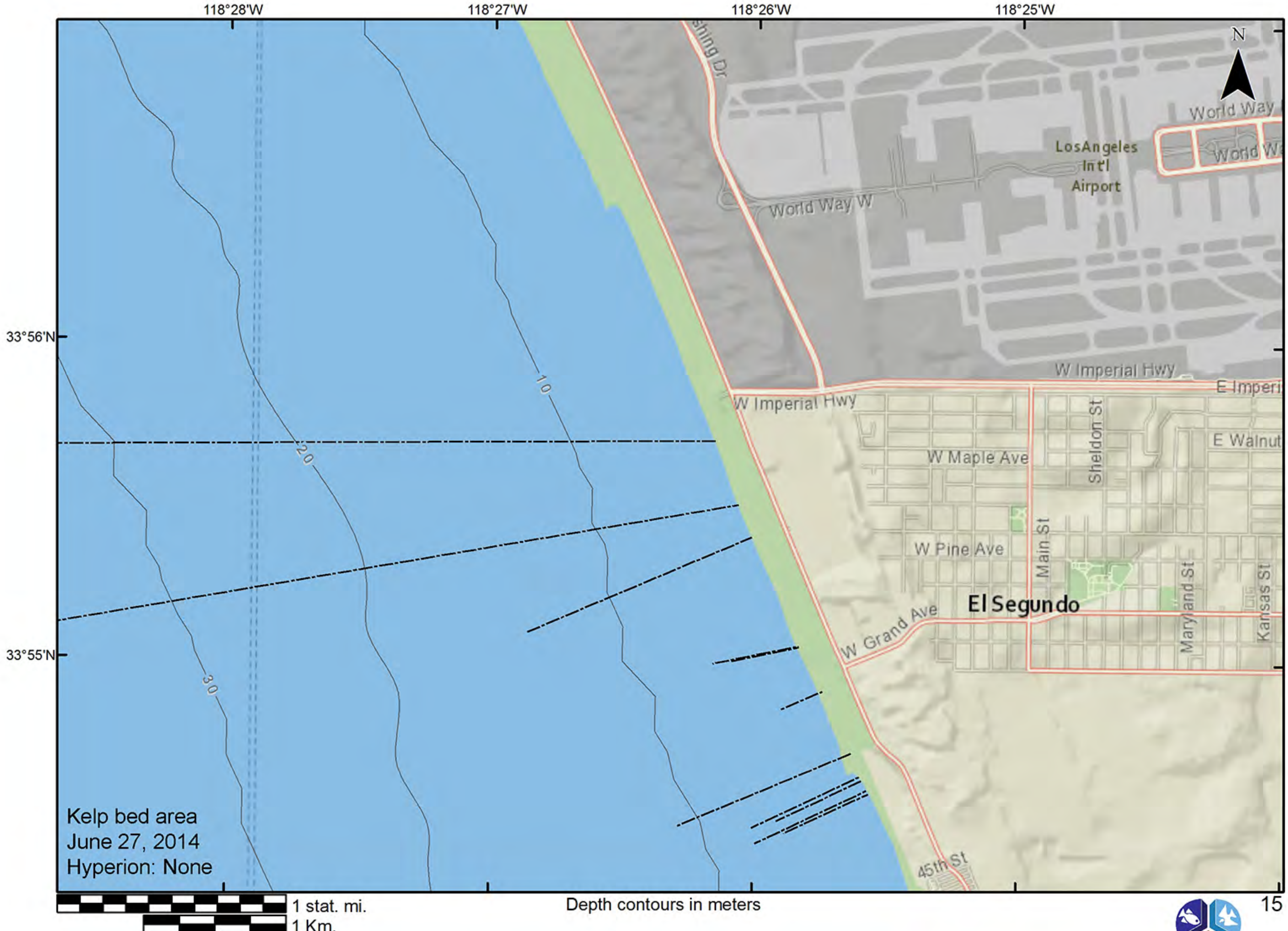

118°37'W
118°36'W
118°35'W
118°34'W
118°33'W
34°3'N
34°2'N
34°1'N
N
Topanga Canyon Blvd
Surfwood Rd
Bellino Dr
Jacon Way
Bollinger Dr
Big Rock Dr
Coastline Dr
Castellammare Dr
Revello Dr
Pacific Coast Hwy
1
10
20
30
Kelp bed area
June 27, 2014
Big Rock Kelp: 0.0109 Km²
Las Tunas Kelp: 0.0116 Km²
Topanga Kelp: 0.0163 Km²
Sunset Kelp: 0.0096 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


118°33'W
118°32'W
118°31'W
118°30'W
118°29'W
34°2'N
34°1'N
34°0'N
Palisades Park
Santa Monica
Ocean Ave
Ocean Frnt
San Vicente Blvd
Idaho Ave
Washington Ave
Broadway
Entrada Dr
20
10
Kelp bed area
June 27, 2014
Sunset Kelp: 0.0096 Km²
1 stat. mi.
1 Km.
Depth contours in meters



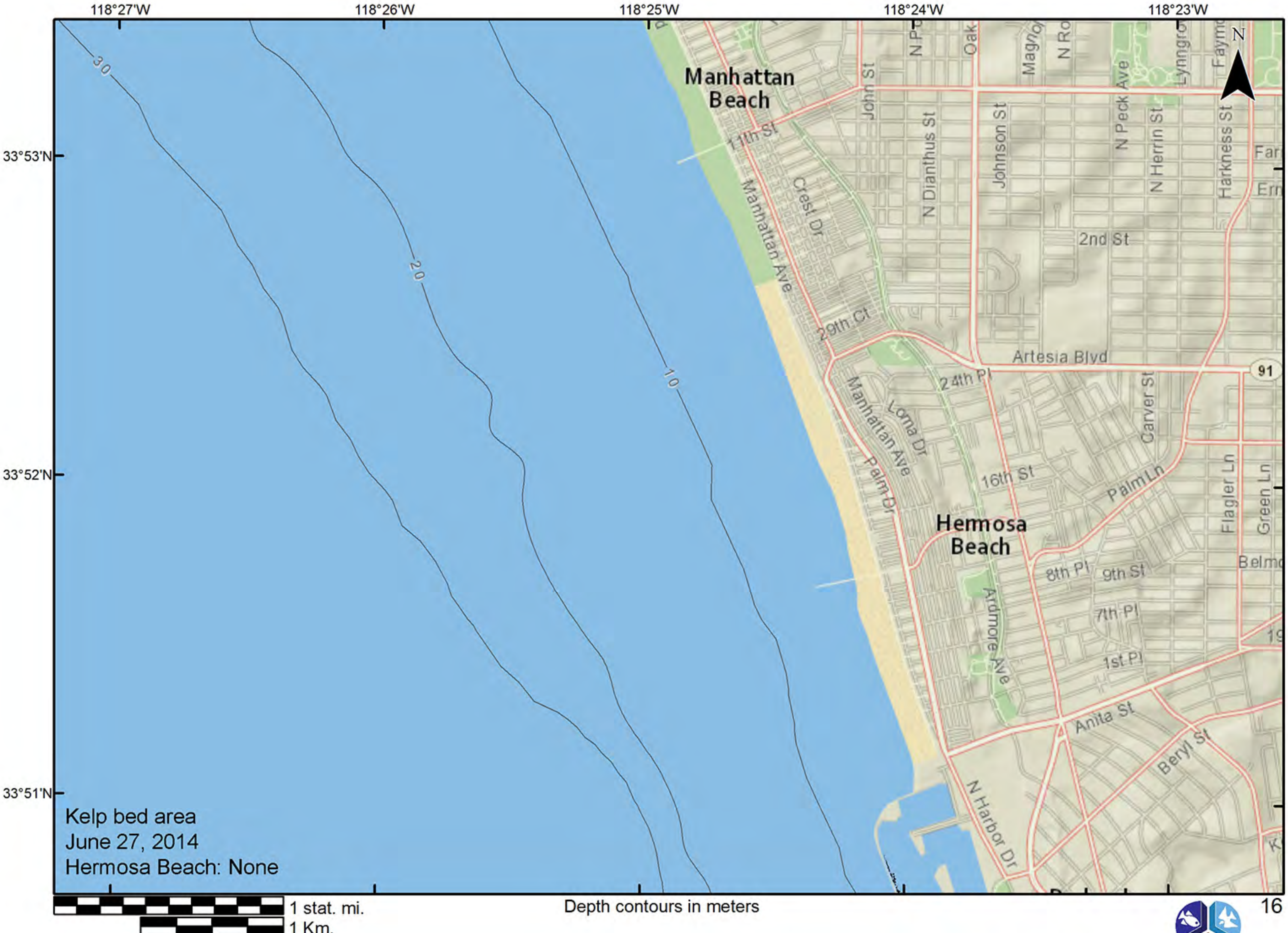
Depth contours in meters

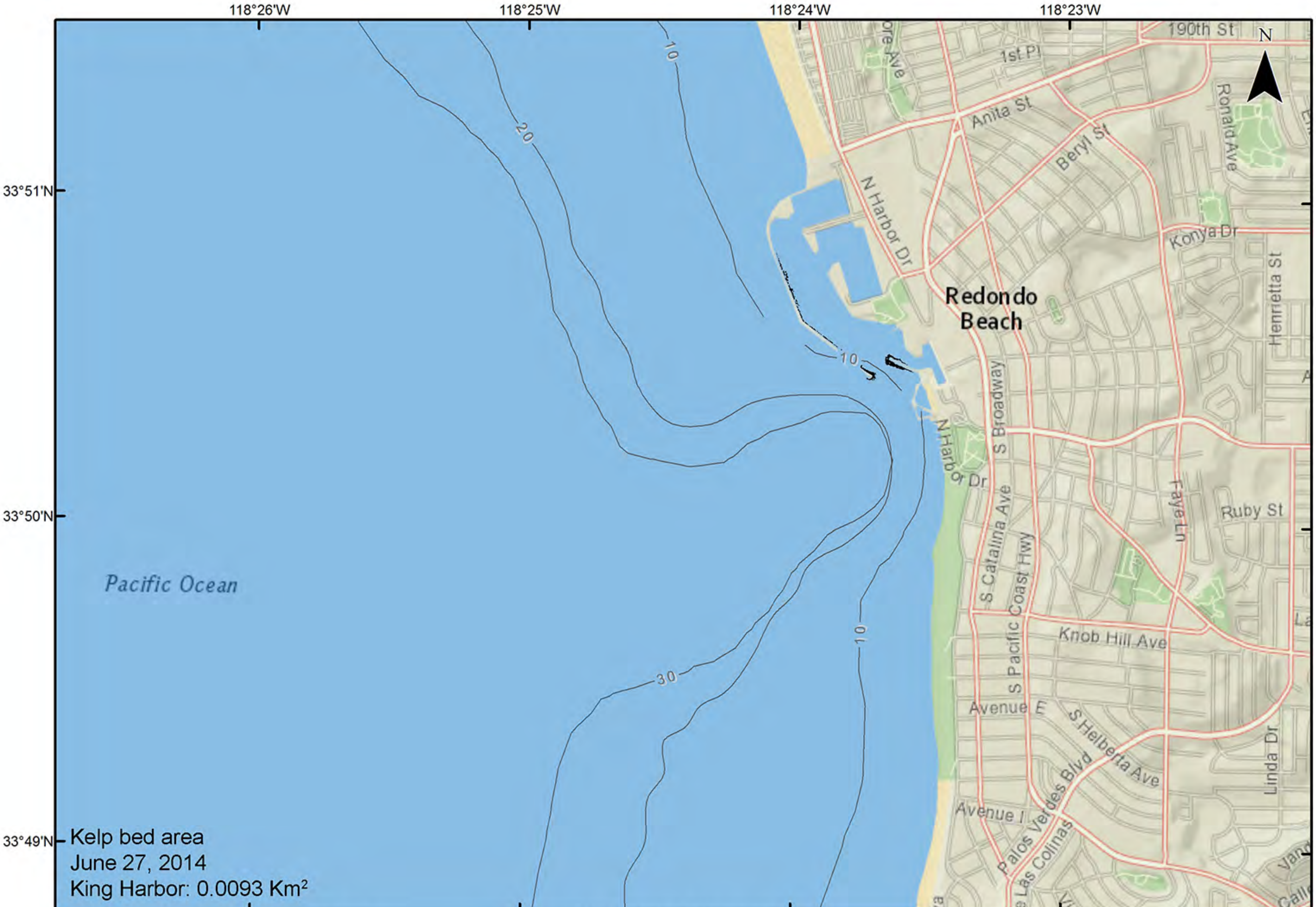
MBC



Depth contours in meters

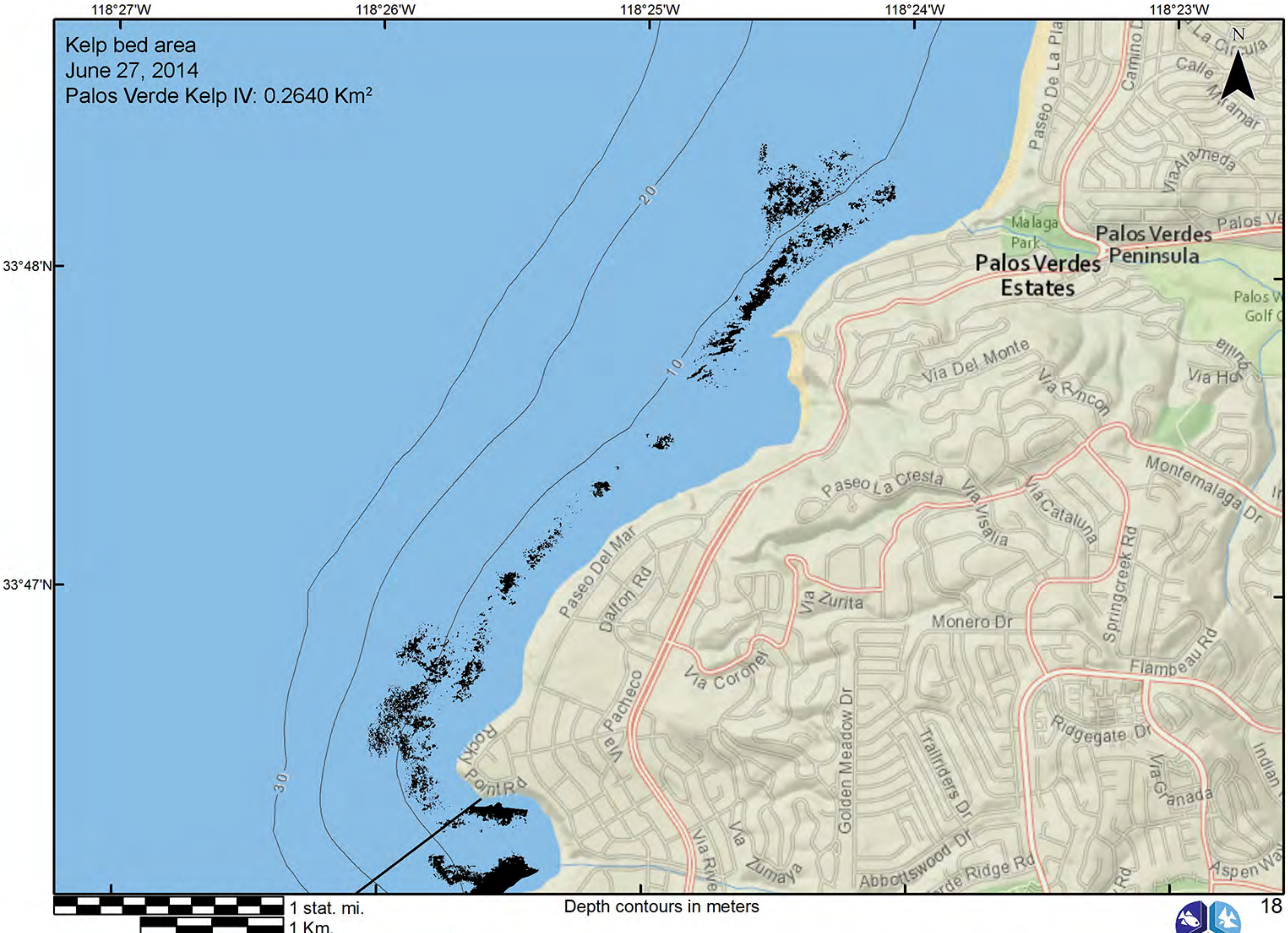
MBC


118°27'W
118°26'W
118°25'W
118°24'W
118°23'W
33°53'N
33°52'N
33°51'N
Manhattan Beach
Hermosa Beach
30
20
10
11th St
Manhattan Ave
Crest Dr
John St
N Dianthus St
Johnson St
N Peck Ave
N Herrin St
Harkness St
2nd St
29th Ct
Artesia Blvd
24th Pl
91
Loma Dr
Palm Dr
Carver St
16th St
Palm Ln
Flagler Ln
Green Ln
8th Pl
9th St
7th Pl
Ardmore Ave
1st Pl
Anita St
Beryl St
N Harbor Dr
N
Kelp bed area
June 27, 2014
Hermosa Beach: None
1 stat. mi.
1 Km.
Depth contours in meters

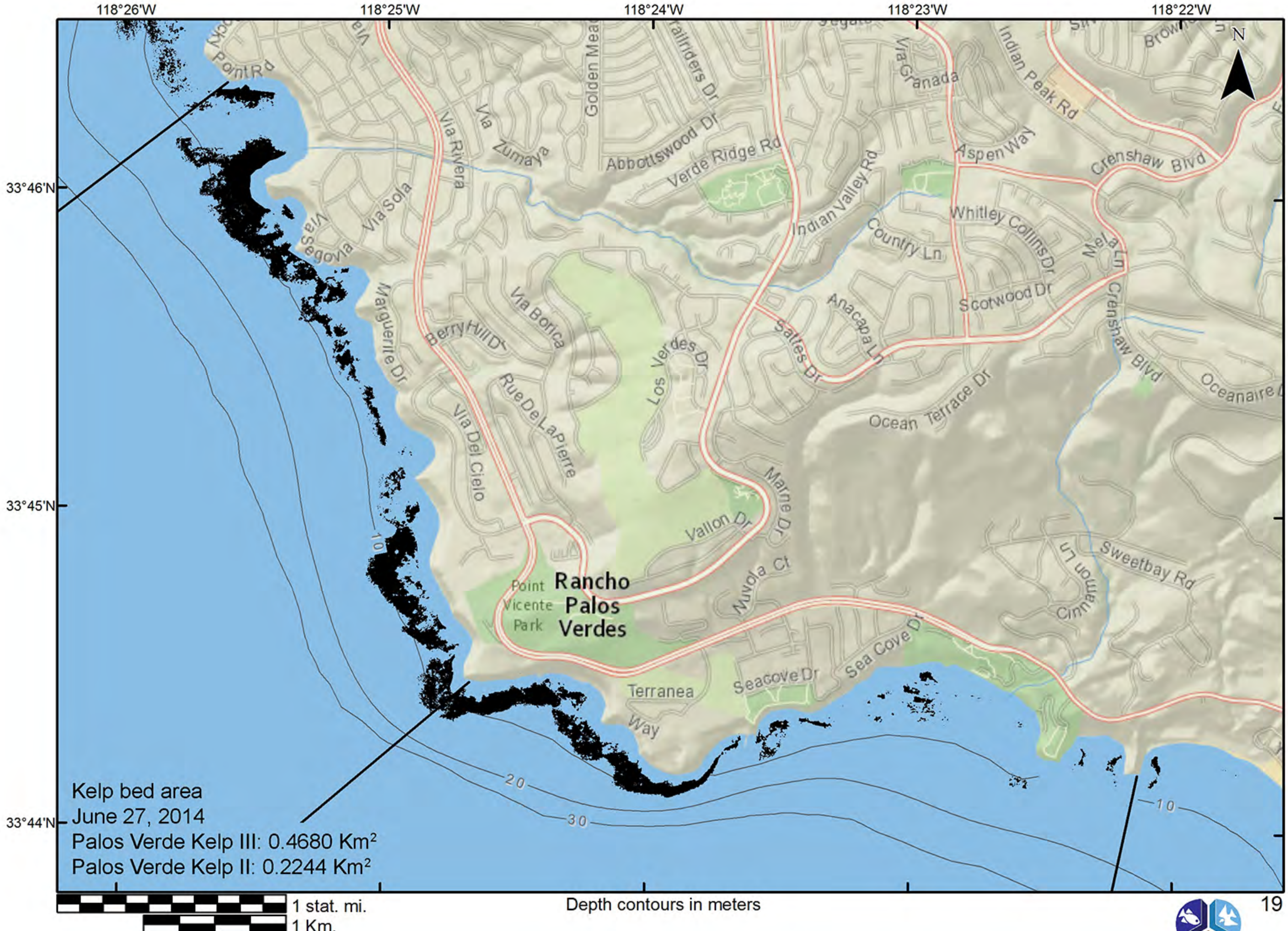


1 stat. mi.
1 Km.

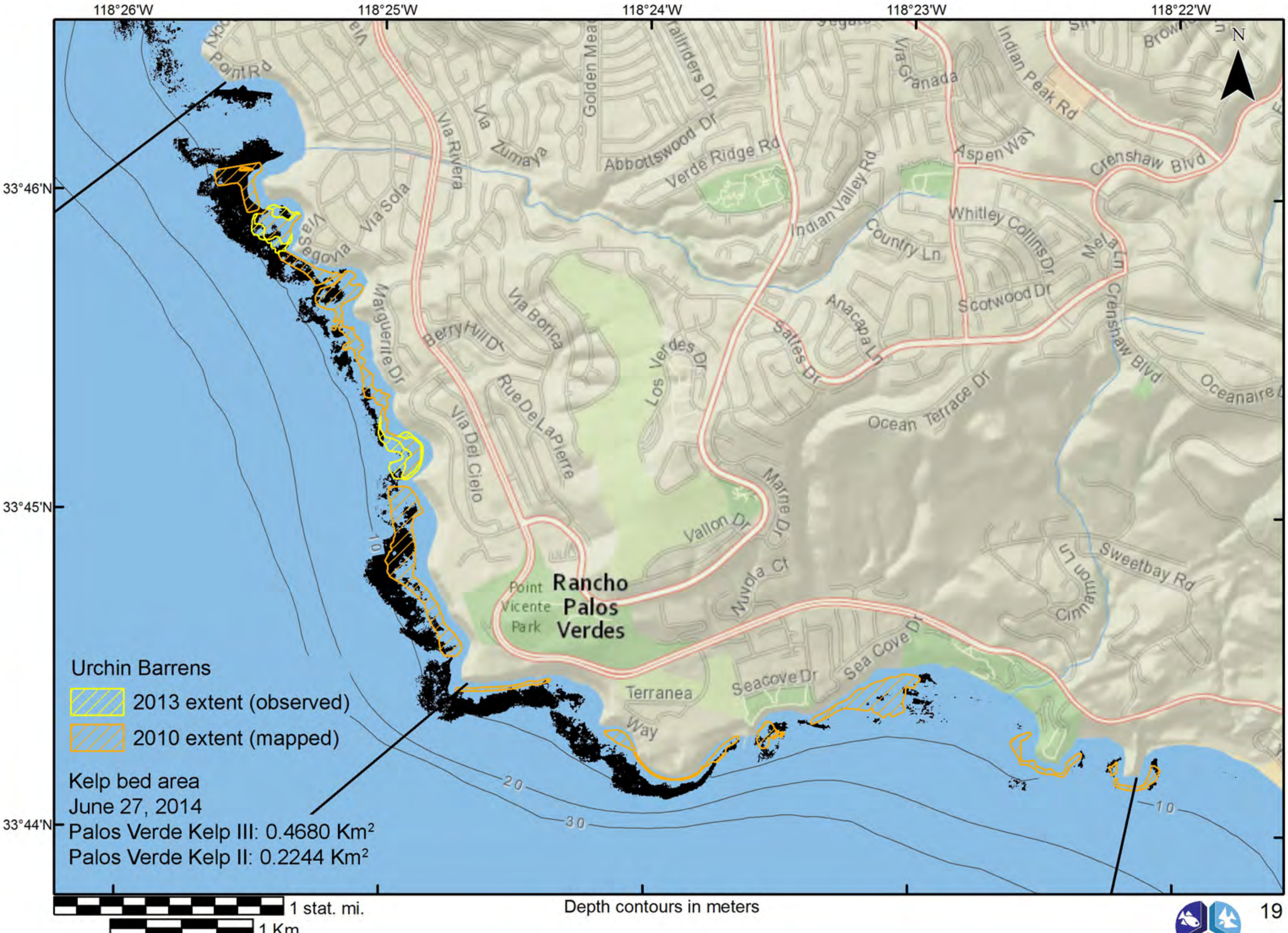
Depth contours in meters

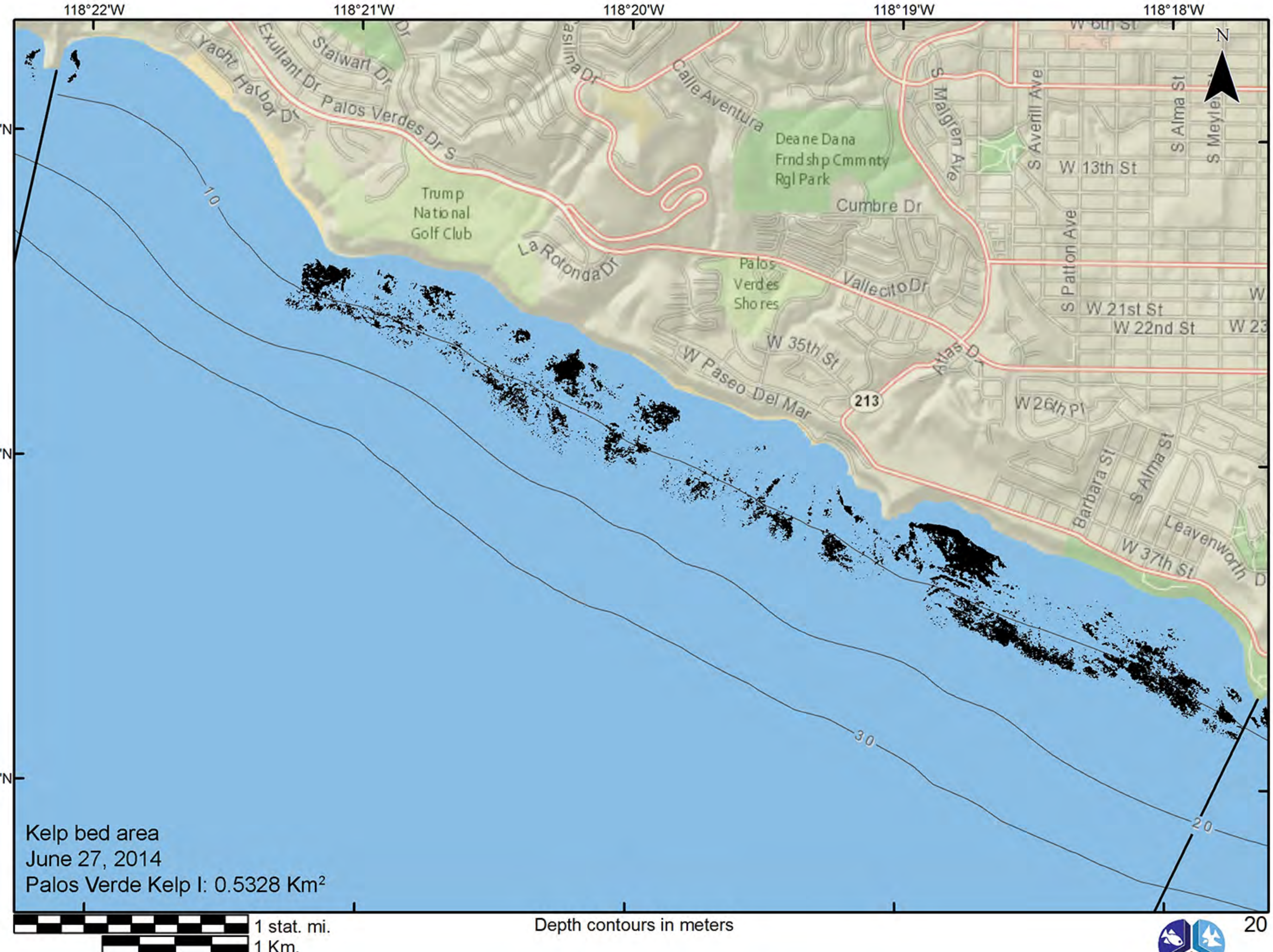

Kelp bed area
June 27, 2014
Palos Verde Kelp IV: 0.2640 Km²
118°27'W
118°26'W
118°25'W
118°24'W
118°23'W
33°48'N
33°47'N
N
20
10
30
Palos Verdes Estates
Palos Verdes Peninsula
Malaga Park
Paseo De La Playa
Camino De
Calle Miramar
Via Alameda
Via Del Monte
Via Rincon
Montemalaga Dr
Paseo La Cresta
Via Visalia
Via Cataluna
Paseo Del Mar
Dalton Rd
Via Zurita
Monero Dr
Springcreek Rd
Flambeau Rd
Via Coronel
Via Pacheco
Rocky Point Rd
Golden Meadow Dr
Trailriders Dr
Ridgegate Dr
Via Granada
Via Zumaya
Abbottswood Dr
Aspen Way
1 stat. mi.
1 Km.
Depth contours in meters

MBC

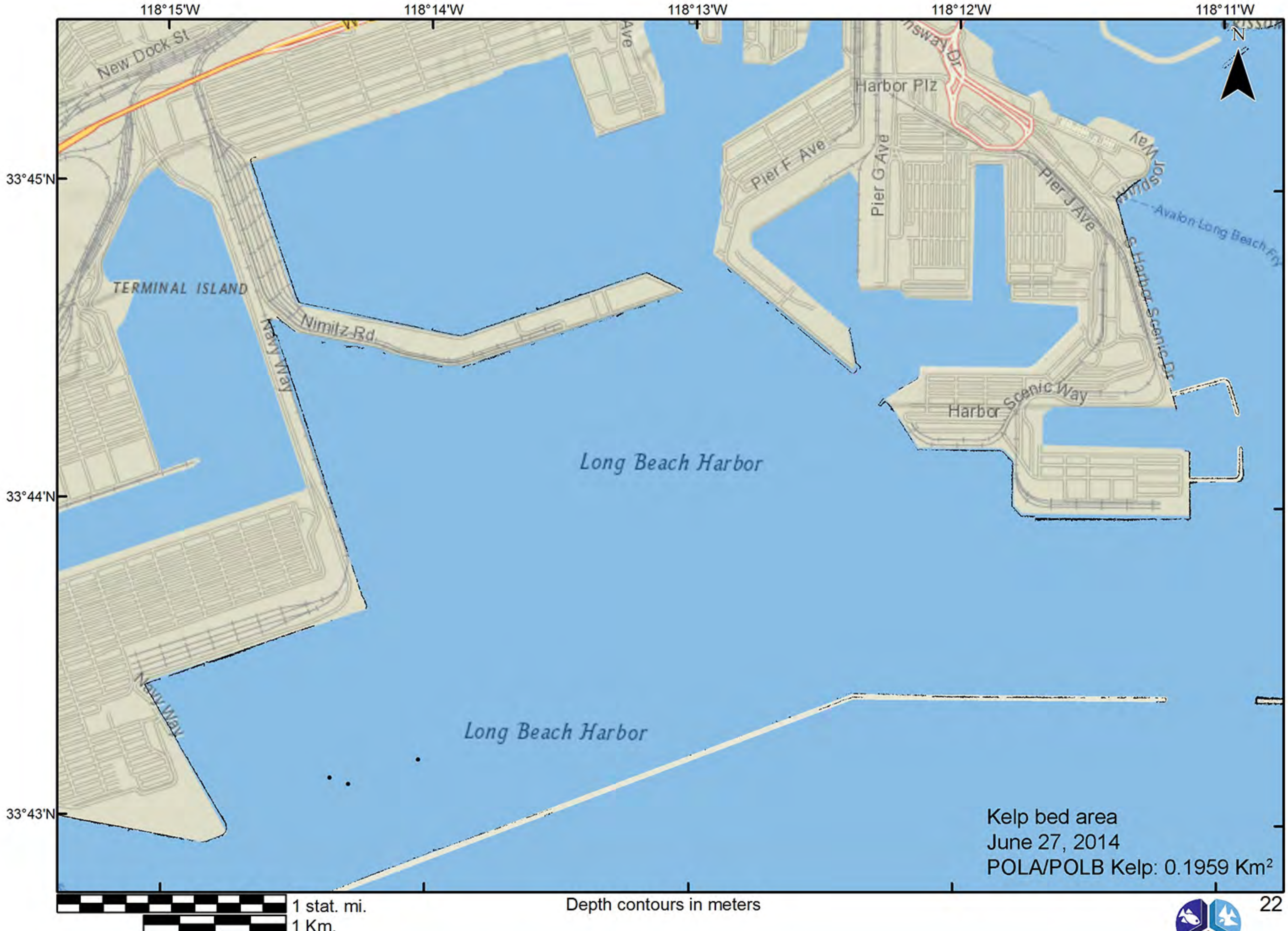


Depth contours in meters


118°26'W
118°25'W
118°24'W
118°23'W
118°22'W
33°46'N
33°45'N
33°44'N
N
Rancho Palos Verdes
Point Vicente Park
Via Zumaya
Abbottswood Dr
Verde Ridge Rd
Via Rivera
Golden Meadow
Trailriders Dr
Via Granada
Indian Peak Rd
Aspen Way
Crenshaw Blvd
Indian Valley Rd
Whitley Collins Dr
Country Ln
Via Sola
Via Segovia
Marguerite Dr
Berry Hill Dr
Via Borica
Los Verdes Dr
Anacapa Ln
Scotwood Dr
Mela Ln
Oceanaire Dr
Ocean Terrace Dr
Rue De La Pierre
Via Del Cielo
Marne Dr
Vallon Dr
Nuvola Ct
Sweetbay Rd
Cinnamon Ln
Sea Cove Dr
Seacove Dr
Terranea Way
10
20
30
Urchin Barrens
2013 extent (observed)
2010 extent (mapped)
Kelp bed area
June 27, 2014
Palos Verde Kelp III: 0.4680 Km²
Palos Verde Kelp II: 0.2244 Km²
1 stat. mi.
1 Km.
Depth contours in meters


118°22'W
118°21'W
118°20'W
118°19'W
118°18'W
33°44'N
33°43'N
33°42'N
N
Yacht Harbor Dr
Exultant Dr
Stalwart Dr
Palos Verdes Dr S
Calle Aventura
Deane Dana Frndshp Cmmnty Rgl Park
S Malgren Ave
S Averill Ave
S Alma St
W 13th St
Cumbre Dr
Trump National Golf Club
La Rotonda Dr
Palos Verdes Shores
Vallecito Dr
S Patton Ave
W 21st St
W 22nd St
W 35th St
W Paseo Del Mar
Atlas Dr
213
W 26th Pl
Barbara St
S Alma St
Leavenworth Dr
W 37th St
10
20
30
Kelp bed area
June 27, 2014
Palos Verde Kelp I: 0.5328 Km²
1 stat. mi.
1 Km.
Depth contours in meters

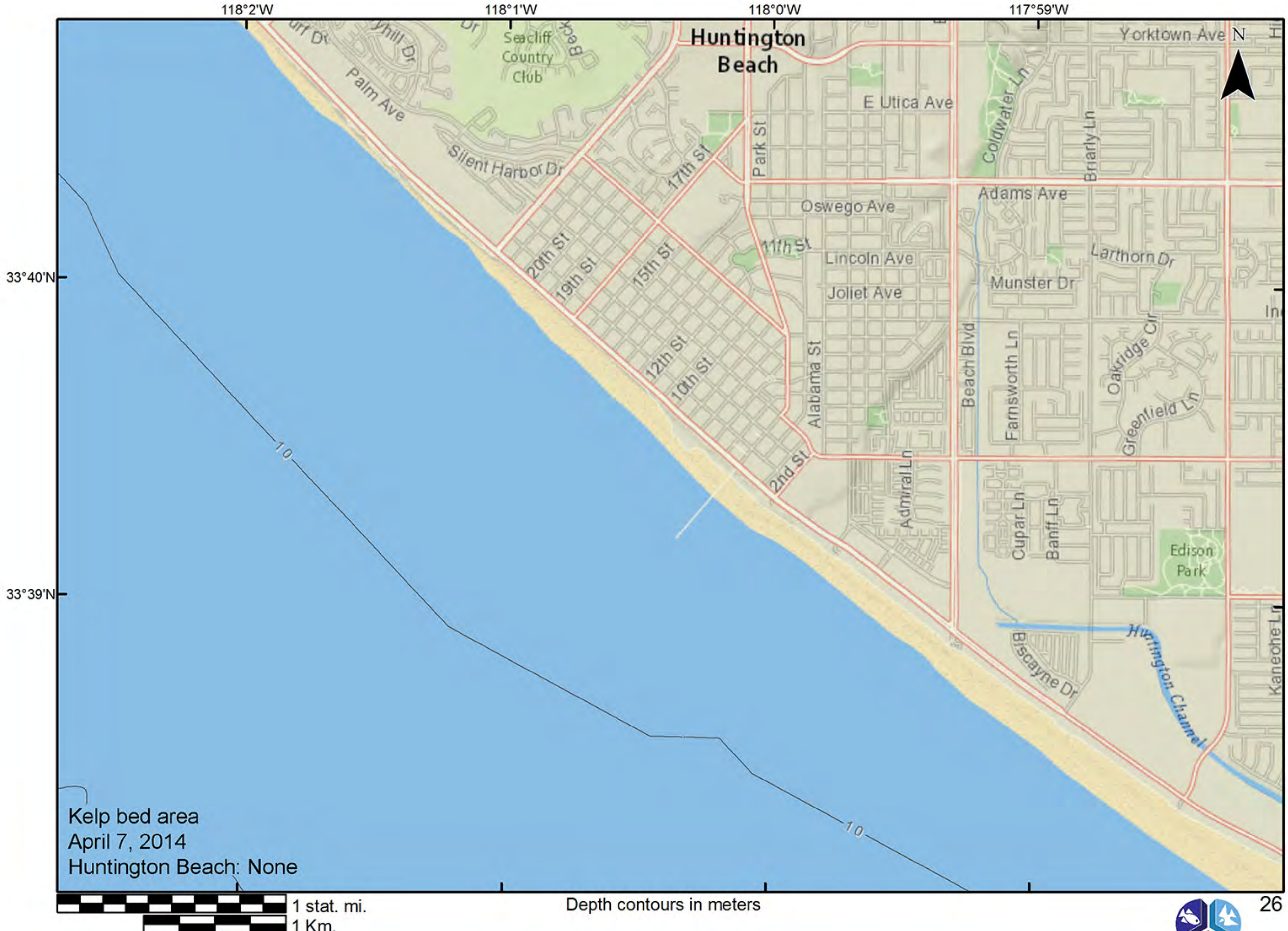

118°18'W
118°17'W
118°16'W
118°15'W
33°44'N
33°43'N
33°42'N
N
San Pedro
W 6th St
W 7th St
W 13th St
W 20th St
W 21st St
W 22nd St
W 23rd St
W 22nd St
E 22nd St
W 26th Pl
W 37th St
Leavenworth Dr
S Averill Ave
S Alma St
S Meyler St
S Grand Ave
S Pacific Ave
S Mesa St
Sampson Way
S Patton Ave
Barbara St
S Alma St
S Peck Ave
S Pacific Ave
Via Cabrillo Marina
Miner St
Signal St
S Seaside Ave
Ways St
Earle St
Navy Way
Avalon San Pedro Fry
San Pedro-Two
Los Angeles Harbor
10
Kelp bed area
June 27, 2014
Cabrillo Kelp: 0.1579 Km²
POLA/POLB Kelp: 0.1959 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


118°15'W
118°14'W
118°13'W
118°12'W
118°11'W
33°45'N
33°44'N
33°43'N
New Dock St
Harbor Plz
Pier F Ave
Pier G Ave
Pier J Ave
TERMINAL ISLAND
Nimitz Rd
Navy Way
Avalon Long Beach Fry
S Harbor Scenic Dr
Harbor Scenic Way
Harbor
Long Beach Harbor
Navy Way
Long Beach Harbor
N
Kelp bed area
June 27, 2014
POLA/POLB Kelp: 0.1959 Km²
1 stat. mi.
1 Km.
Depth contours in meters


118°13'W
118°12'W
118°11'W
118°10'W
33°45'N
33°44'N
N
Bluff Park
ISLAND GRISSOM
Pier D Ave
Pier E St
Pier T Ave
Queensway Dr
Harbor Plz
Pier F Ave
Pier G Ave
Pier J Ave
Windsor Way
S Harbor Scenic Dr
Harbor Scenic Way
Avalon Long Beach Fry
10
10
Long Beach Harbor
Beach Harbor
Kelp bed area
June 27, 2014
POLA/POLB Kelp: 0.1959 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


118°9'W
118°8'W
118°7'W
118°6'W
118°5'W
33°45'N
33°44'N
33°43'N
N
NAPLES ISLAND
LOS ANGELES
ORANGE
Gum Grove Park
Seal Beach
Pacific Ocean
Surfside
ISLAND CHAFFEE
Kelp bed area
June 27, 2014
POLA/POLB Kelp: 0.1959 Km²
1 stat. mi.
1 Km.
Depth contours in meters

118°5'W
118°4'W
118°3'W
118°2'W
33°43'N
33°42'N
33°41'N
N
HUMBOLDT ISLAND
DAVENPORT ISLAND
Sunset Beach
S Pacific Ave
N Pacific Ave
Warner Ave
Saybrook Ln
Bolsa Chica St
Caliente Dr
Middlecoff Dr
Plaza Ln
Meadowlark Golf Course
Tiara Dr
Los Patos Ave
Oceanridge Dr
Berlin Ln
Apel Ln
Wild Rose Ln
Busby Ln
Serene Dr
Selkirk Dr
Bellfield
Pacific Coast Hwy
Bolsa Chica Ecological Reserve
Harriett M Wieder Regional Park
Doral Dr
1
10
Kelp bed area
April 7, 2014
Sunset Beach: None
1 stat. mi.
1 Km.
Depth contours in meters
MBC

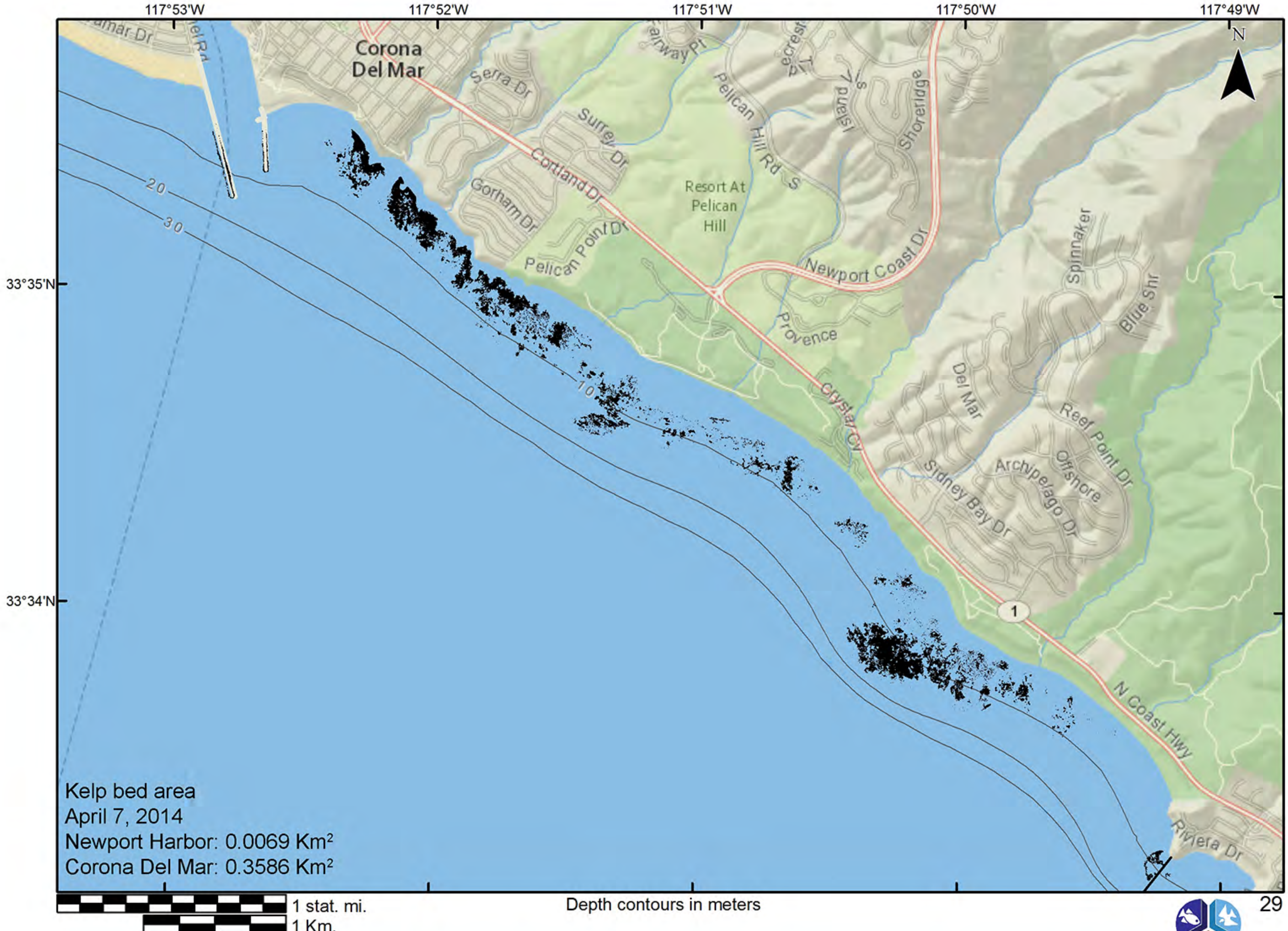


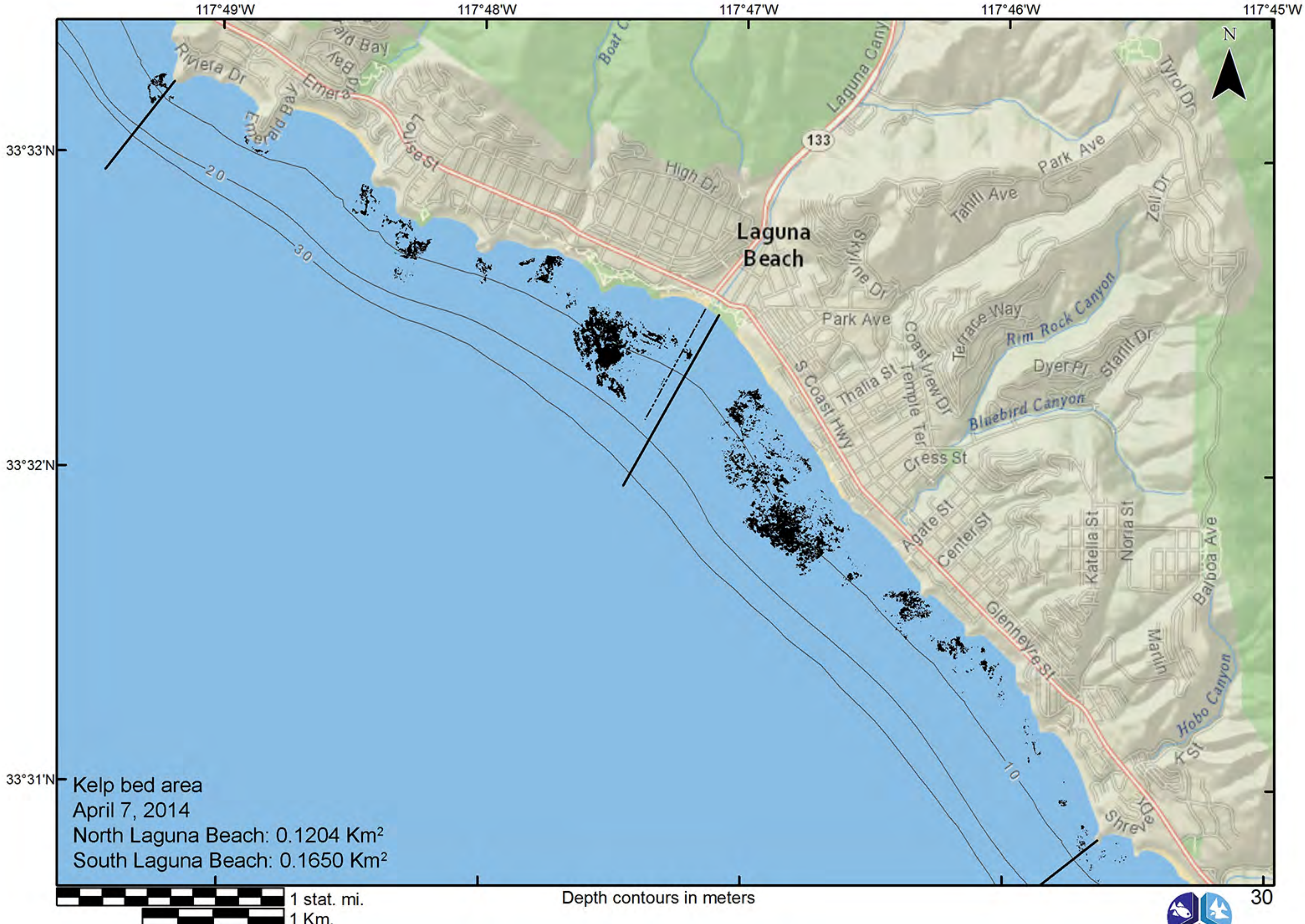
Depth contours in meters

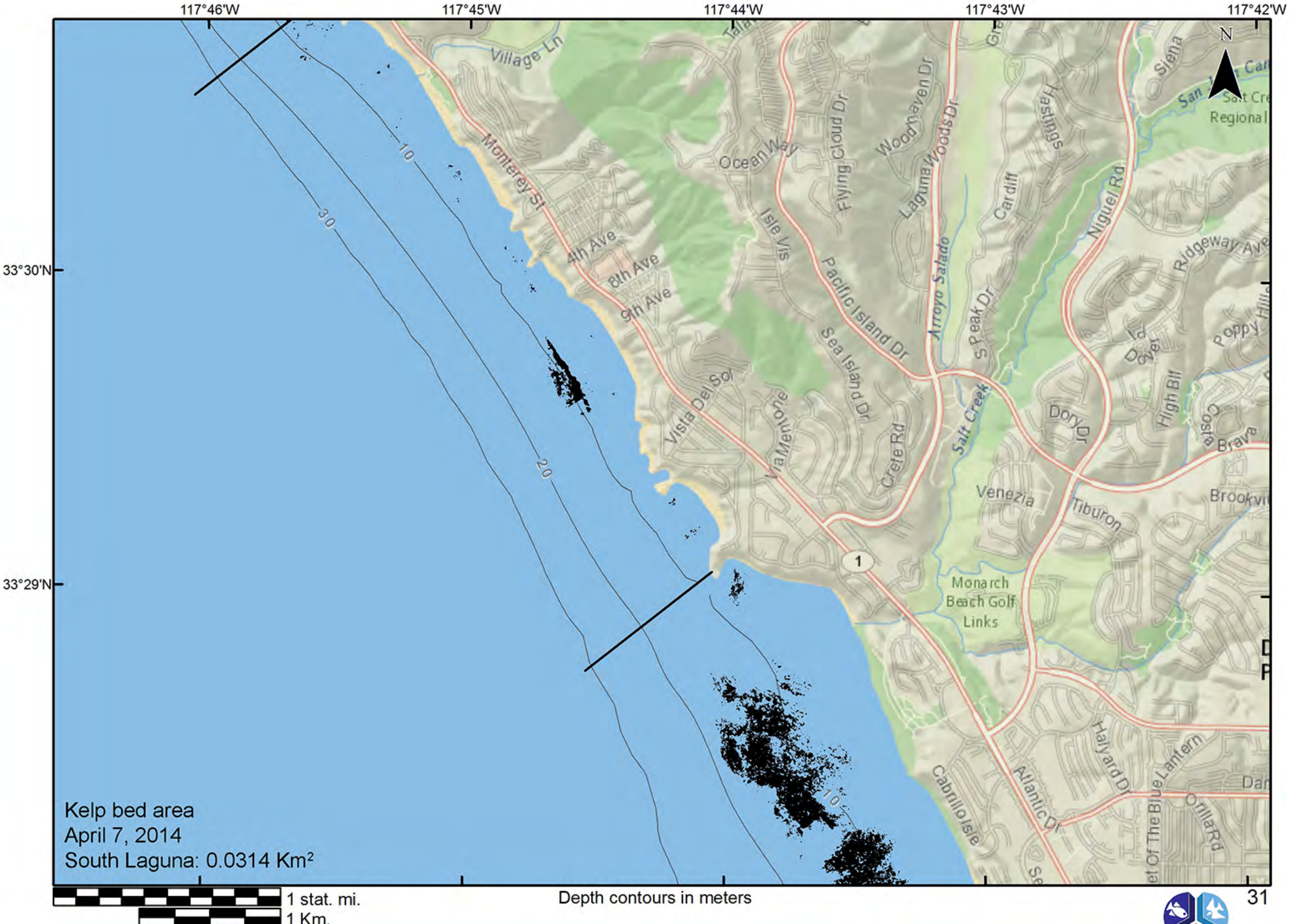
MBC


117°58'W
117°57'W
117°56'W
117°55'W
33°38'N
33°37'N
33°36'N
N
Talbert Channel
Colton St
Whittier Ave
Park Dr
Anaheim
Costa Mesa St
E 18th St
E 19th St
Cabrillo St
E 17th St
W 16th St
W 15th St
Knox St
Ogle St
Westcliff Dr
Catalina Dr
Clay St
River Ave
Aliso Ave
Dover Dr
NEWPORT ISLE
Newport Beach
W Balboa Blvd
31st St
Kings Pl
1
Bayshore Dr
LIDO ISLE
Via Lido Nord
Beach Dr
Newport Bay
W Oceanfront
8th St
6th St
10
20
Kelp bed area
April 7, 2014
Newport Beach: None
1 stat. mi.
1 Km.
Depth contours in meters
MBC

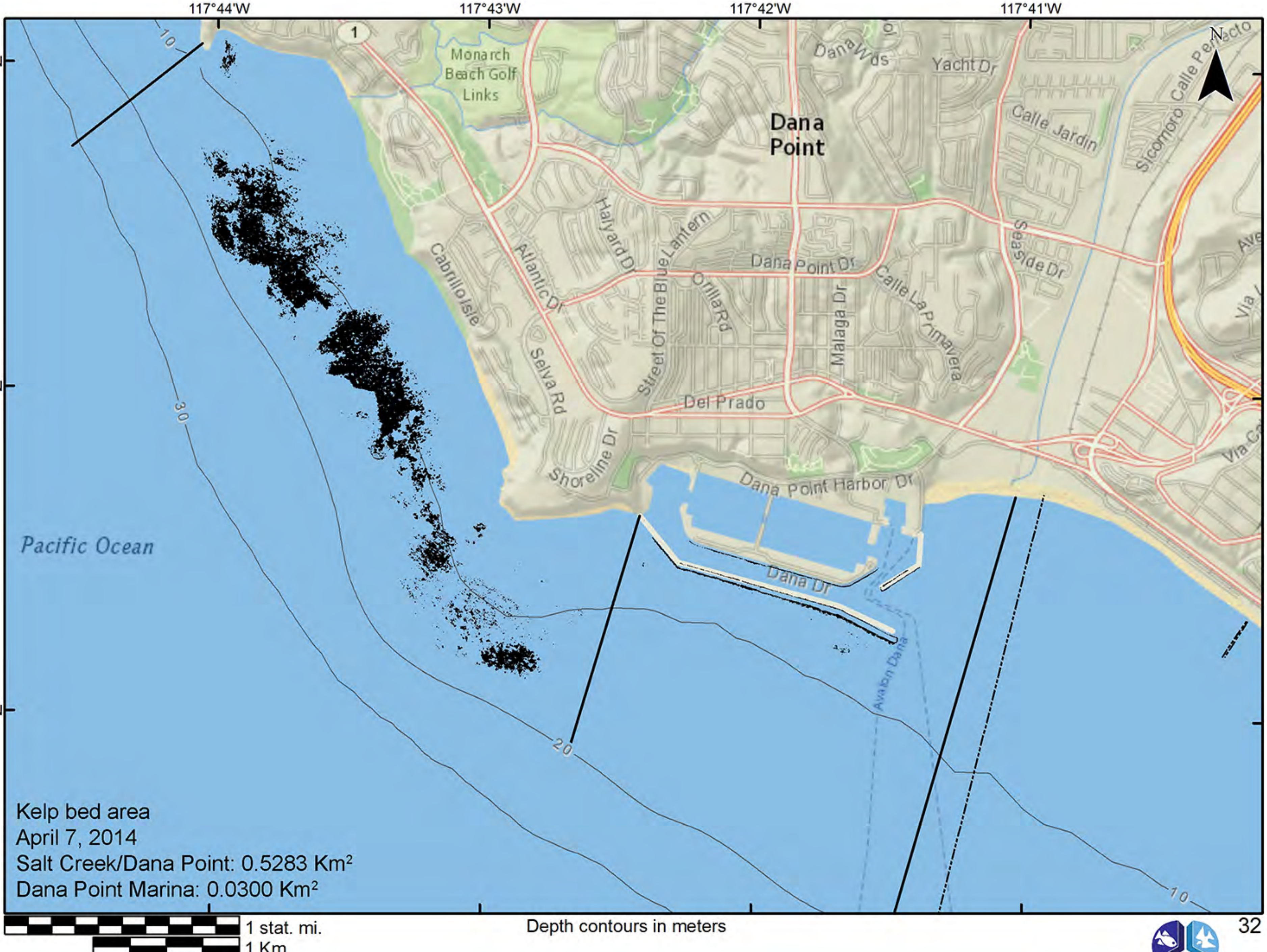
Depth contours in meters

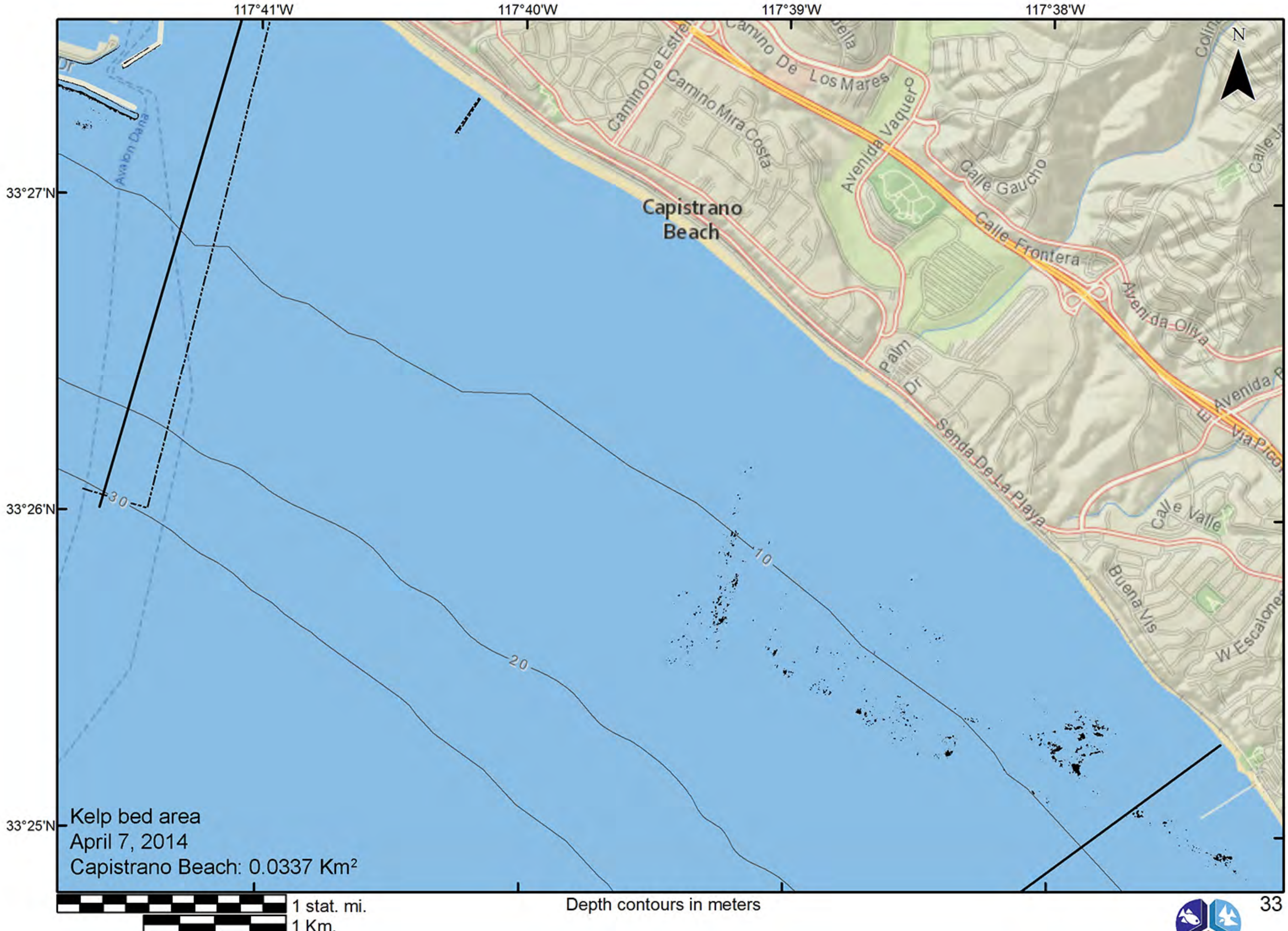

117°53'W
117°52'W
117°51'W
117°50'W
117°49'W
33°35'N
33°34'N
N
Corona Del Mar
Serra Dr
Surrey Dr
Cortland Dr
Gorham Dr
Pelican Point Dr
Pelican Hill Rd S
Resort At Pelican Hill
Fairway Pl
Island
Shoreridge
Newport Coast Dr
Provence
Crystal Cv
Spinnaker
Blue Shr
Del Mar
Reef Point Dr
Archipelago Dr
Offshore
Sidney Bay Dr
1
N Coast Hwy
Riviera Dr
10
20
30
Kelp bed area
April 7, 2014
Newport Harbor: 0.0069 Km²
Corona Del Mar: 0.3586 Km²
1 stat. mi.
1 Km.
Depth contours in meters


117°49'W
117°48'W
117°47'W
117°46'W
117°45'W
33°33'N
33°32'N
33°31'N
N
Laguna Beach
Riviera Dr
Emerald Bay
Louise St
High Dr
133
Park Ave
Tahiti Ave
Skyline Dr
Terrace Way
Rim Rock Canyon
Coast View Dr
Temple Ter
Thalia St
S Coast Hwy
Dyer Pl
Starlit Dr
Bluebird Canyon
Cress St
Agate St
Center St
Katella St
Noria St
Balboa Ave
Glenneyre St
Marlin
Hobo Canyon
K St
Shreve
Zell Dr
Tyrol Dr
20
30
10
Kelp bed area
April 7, 2014
North Laguna Beach: 0.1204 Km²
South Laguna Beach: 0.1650 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

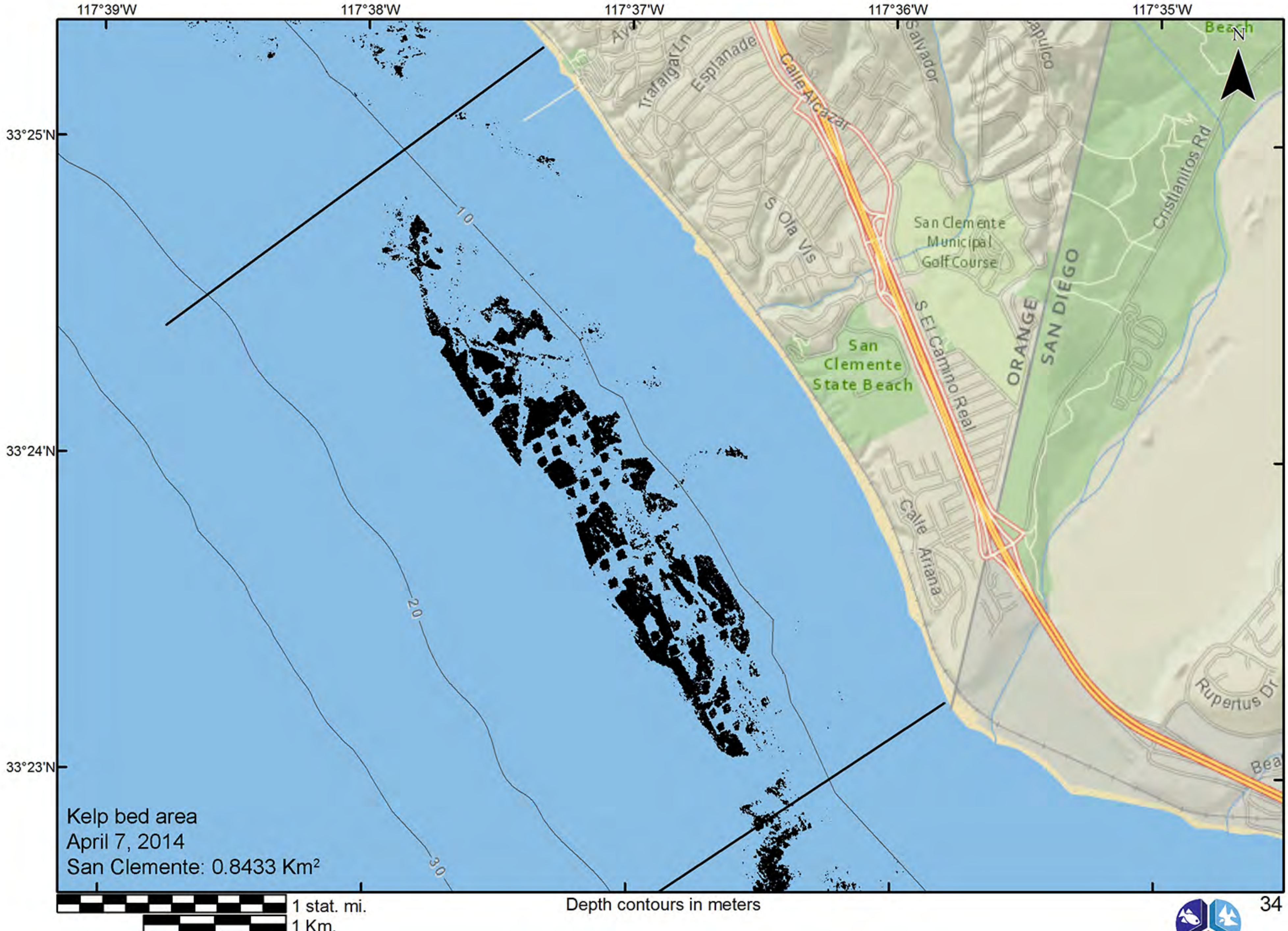

117°46'W
117°45'W
117°44'W
117°43'W
117°42'W
33°30'N
33°29'N
N
10
20
30
Village Ln
Monterey St
4th Ave
8th Ave
9th Ave
Ocean Way
Isle Vis
Flying Cloud Dr
Woodhaven Dr
Laguna Woods Dr
Hastings
Cardiff
Niguel Rd
Pacific Island Dr
Arroyo Salado
S Peak Dr
Sea Island Dr
Vista Del Sol
Via Mentone
Crete Rd
Salt Creek
Dory Dr
Venezia
Tiburon
Ridgeway Ave
Dover
High Blf
Costa Brava
Brookvi
Siena
Regional
Poppy Hills
1
Monarch
Beach Golf
Links
Cabrillo Isle
Atlantic Dr
Halyard Dr
Blue Lantern
Kelp bed area
April 7, 2014
South Laguna: 0.0314 Km²
1 stat. mi.
1 Km.
Depth contours in meters

MBC


117°44'W
117°43'W
117°42'W
117°41'W
33°29'N
33°28'N
33°27'N
Monarch Beach Golf Links
Dana Point
Pacific Ocean
Kelp bed area
April 7, 2014
Salt Creek/Dana Point: 0.5283 Km²
Dana Point Marina: 0.0300 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC

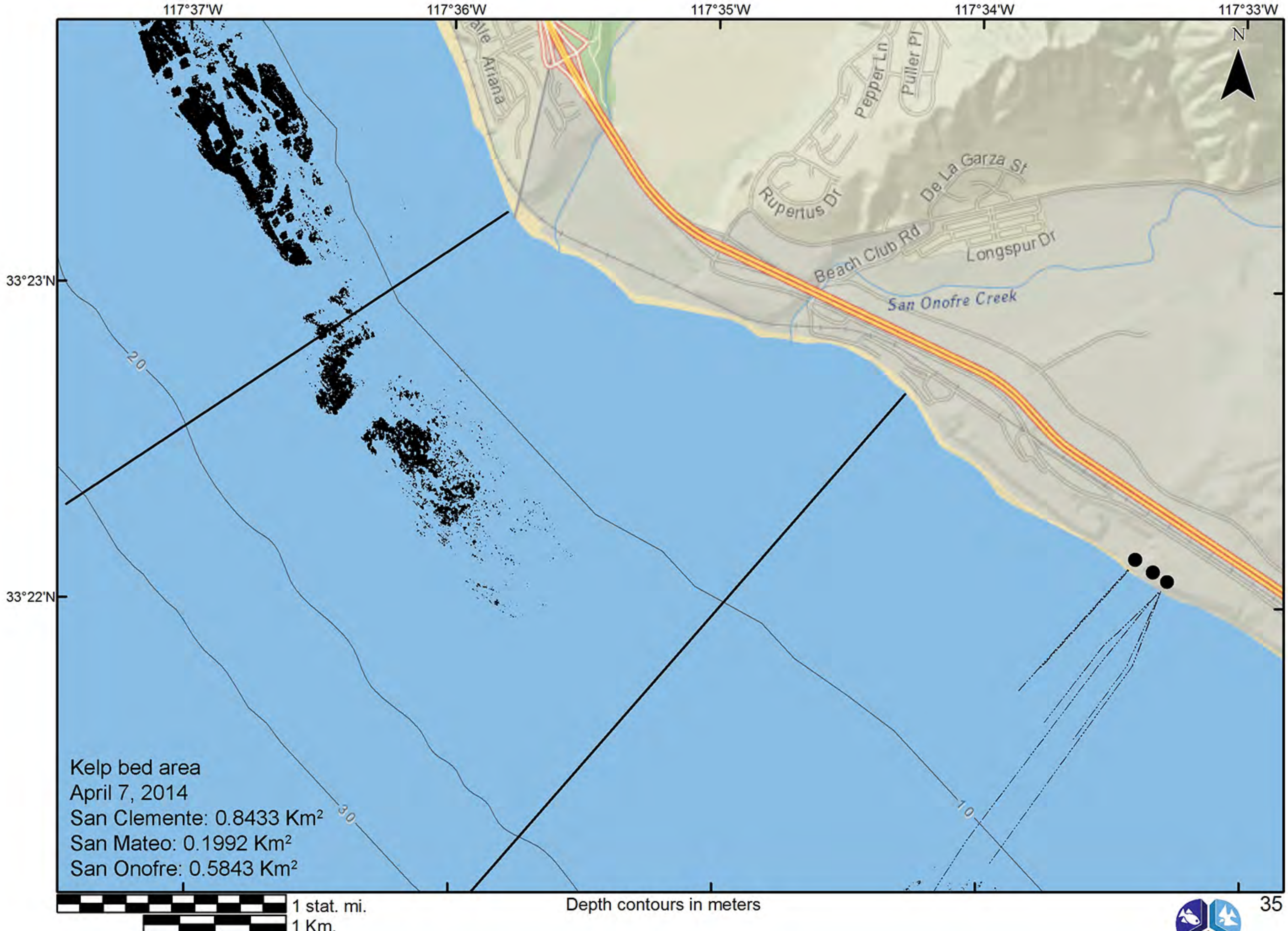

117°41'W
117°40'W
117°39'W
117°38'W
33°27'N
33°26'N
33°25'N
N
Capistrano Beach
Camino De Los Mares
Camino Mira Costa
Avenida Vaquero
Calle Gaucho
Calle Frontera
Avenida Oliva
Palm Dr
Senda De La Playa
Calle Valle
Buena Vis
W Escalones
Via Pico
Avalon Dana
30
20
10
Kelp bed area
April 7, 2014
Capistrano Beach: 0.0337 Km²
1 stat. mi.
1 Km.
Depth contours in meters

MBC

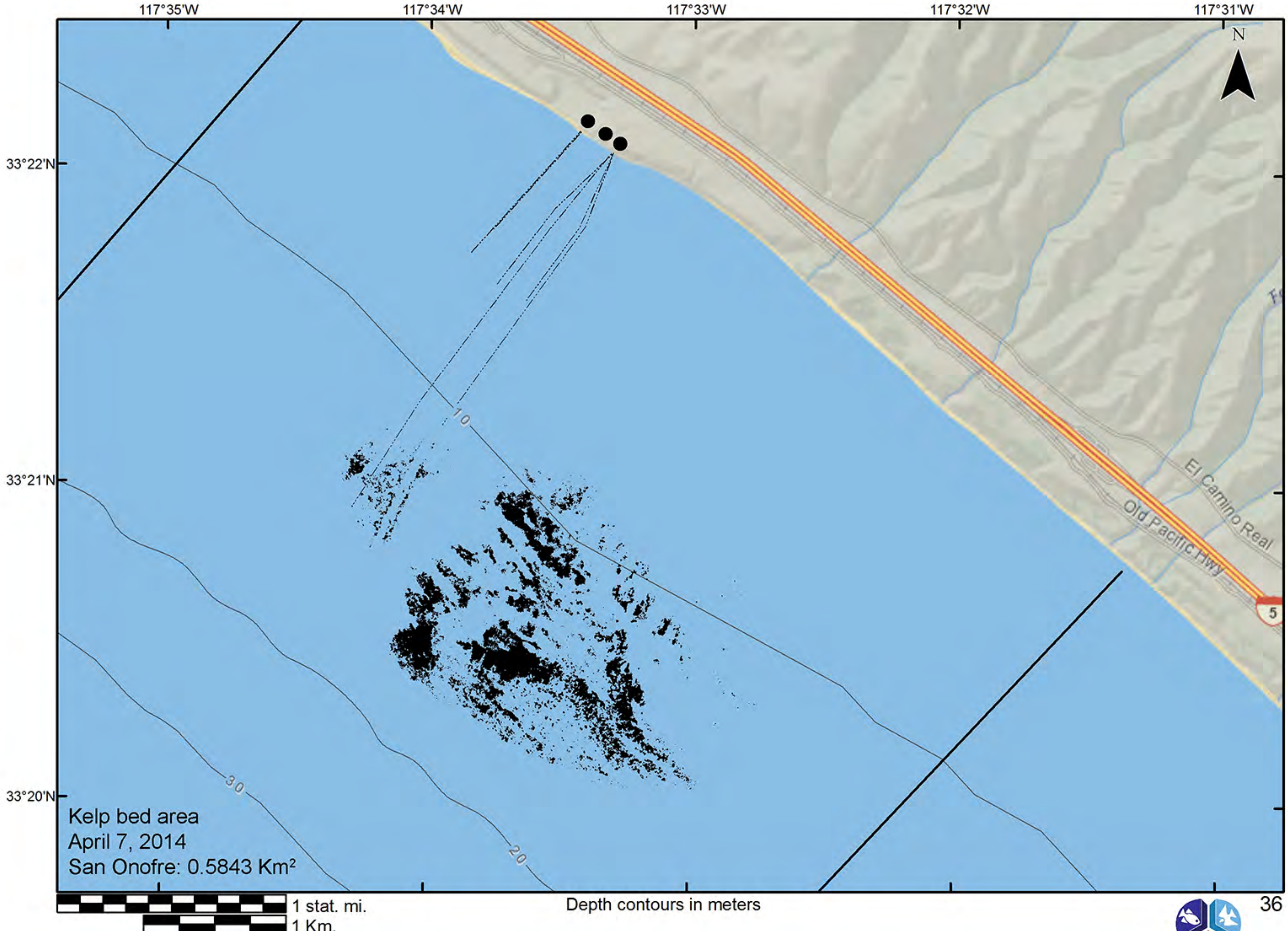


117°39'W
117°38'W
117°37'W
117°36'W
117°35'W
33°25'N
33°24'N
33°23'N
N
Trafalgar Ln
Esplanade
Calle Alcazar
Salvador
S Ola Vis
San Clemente Municipal Golf Course
San Clemente State Beach
S El Camino Real
ORANGE
SAN DIEGO
Cristianitos Rd
Calle Ariana
Rupertus Dr
10
20
30
Kelp bed area
April 7, 2014
San Clemente: 0.8433 Km²
1 stat. mi.
1 Km.
Depth contours in meters

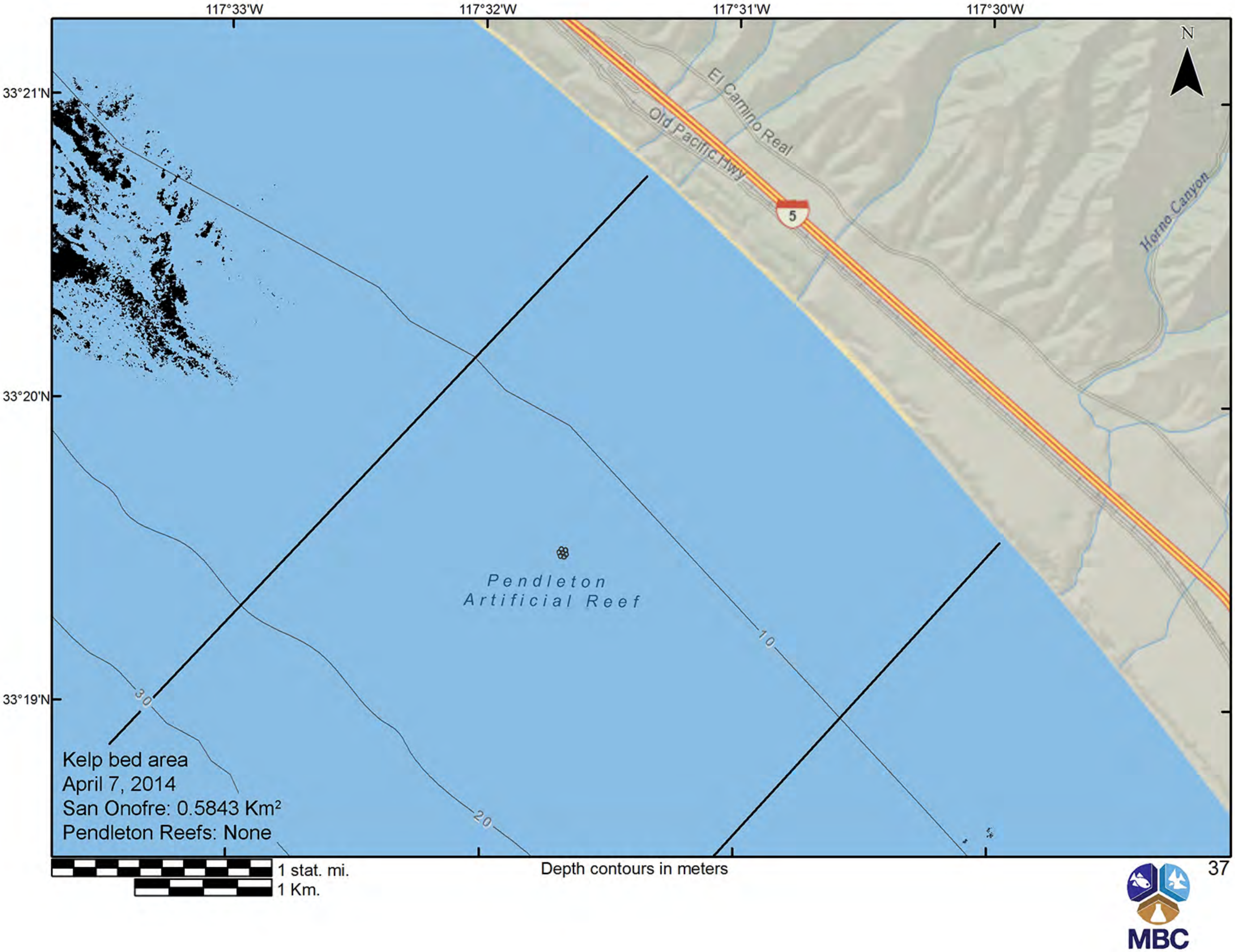
MBC

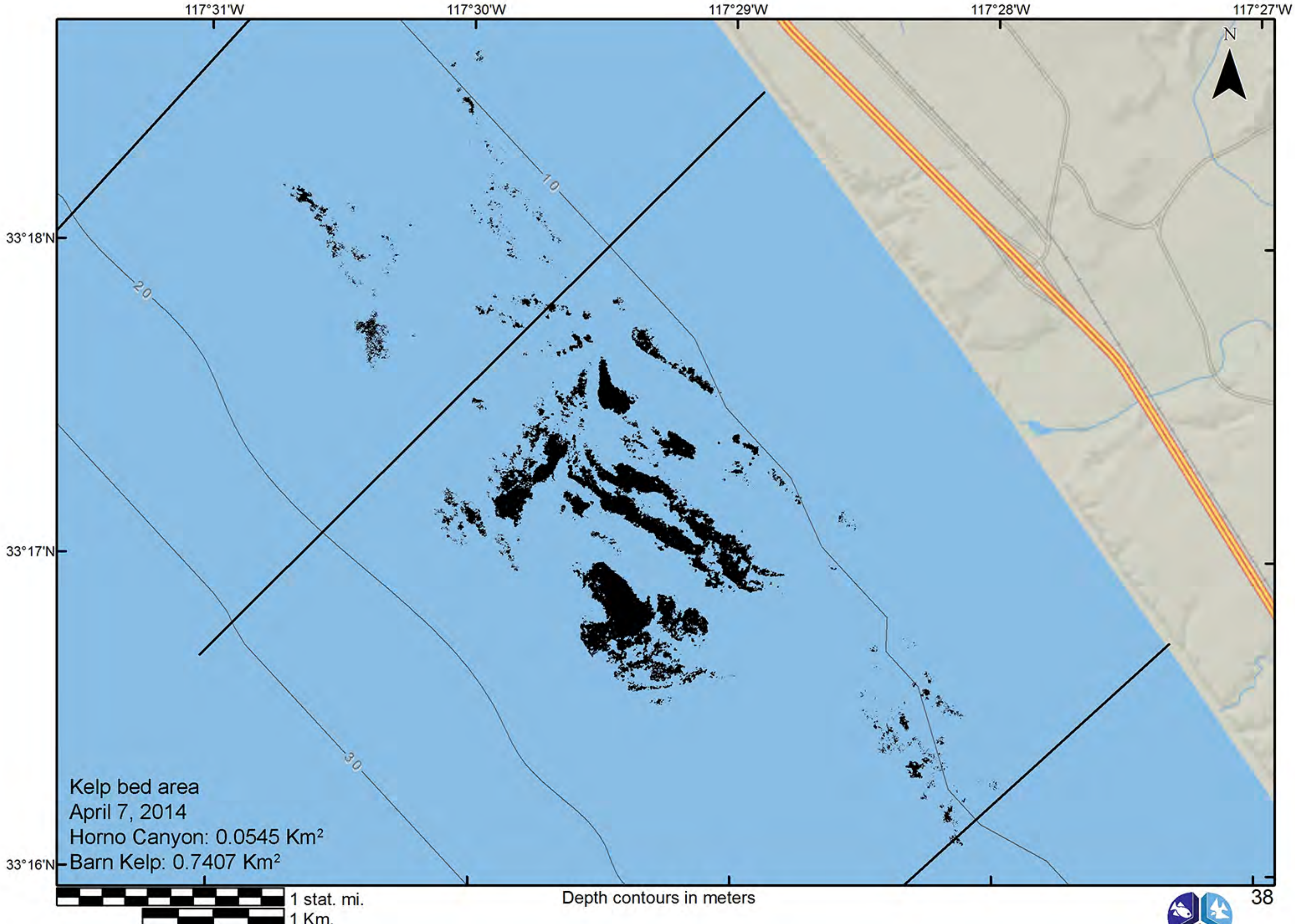


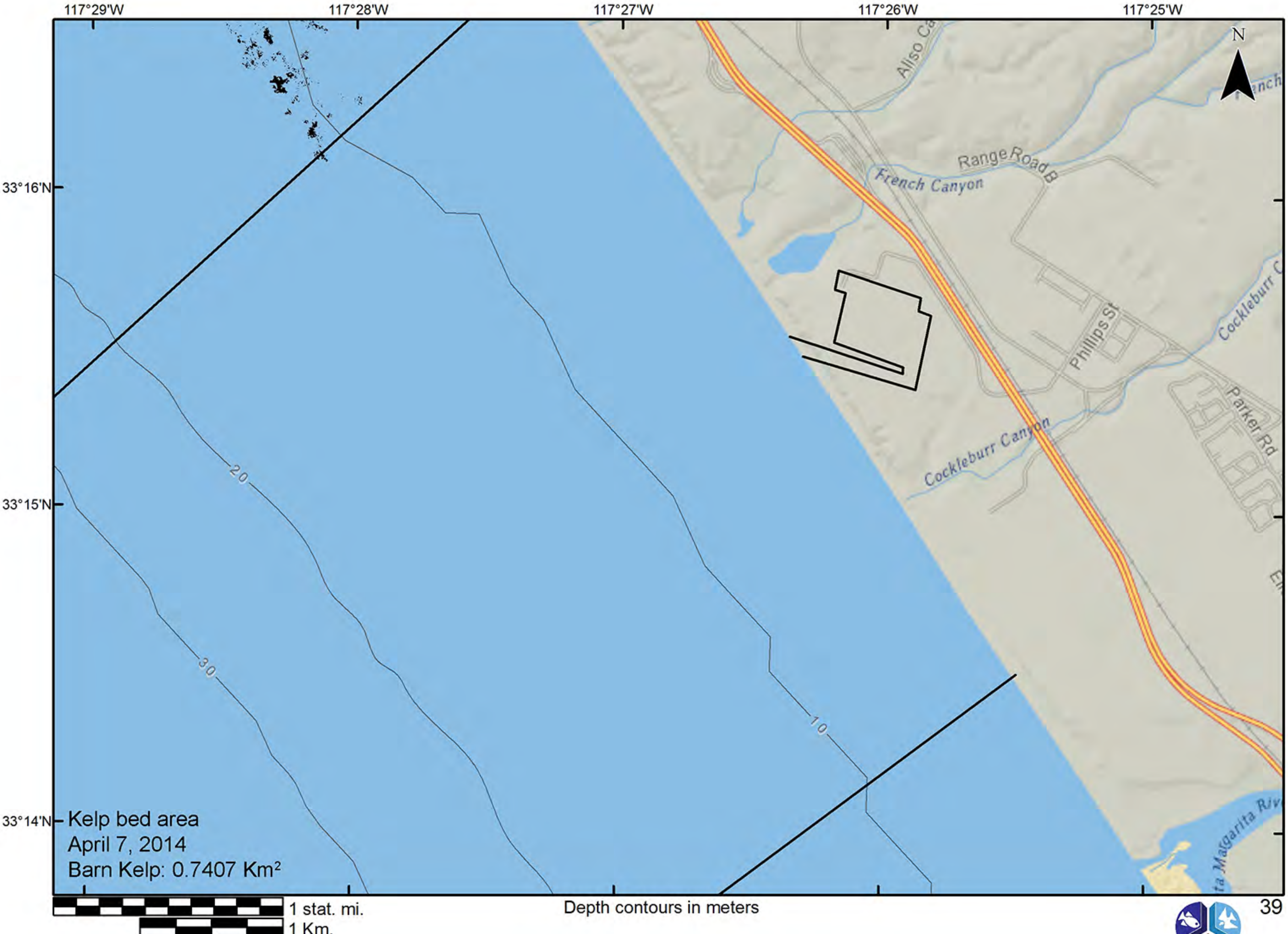
117°37'W
117°36'W
117°35'W
117°34'W
117°33'W
33°23'N
33°22'N
N
Ariana
Pepper Ln
Puller Pl
De La Garza St
Rupertus Dr
Beach Club Rd
Longspur Dr
San Onofre Creek
20
30
10
Kelp bed area
April 7, 2014
San Clemente: 0.8433 Km²
San Mateo: 0.1992 Km²
San Onofre: 0.5843 Km²
1 stat. mi.
1 Km.
Depth contours in meters


117°35'W
117°34'W
117°33'W
117°32'W
117°31'W
33°22'N
33°21'N
33°20'N
N
10
20
30
El Camino Real
Old Pacific Hwy
5
Kelp bed area
April 7, 2014
San Onofre: 0.5843 Km²
1 stat. mi.
1 Km.
Depth contours in meters

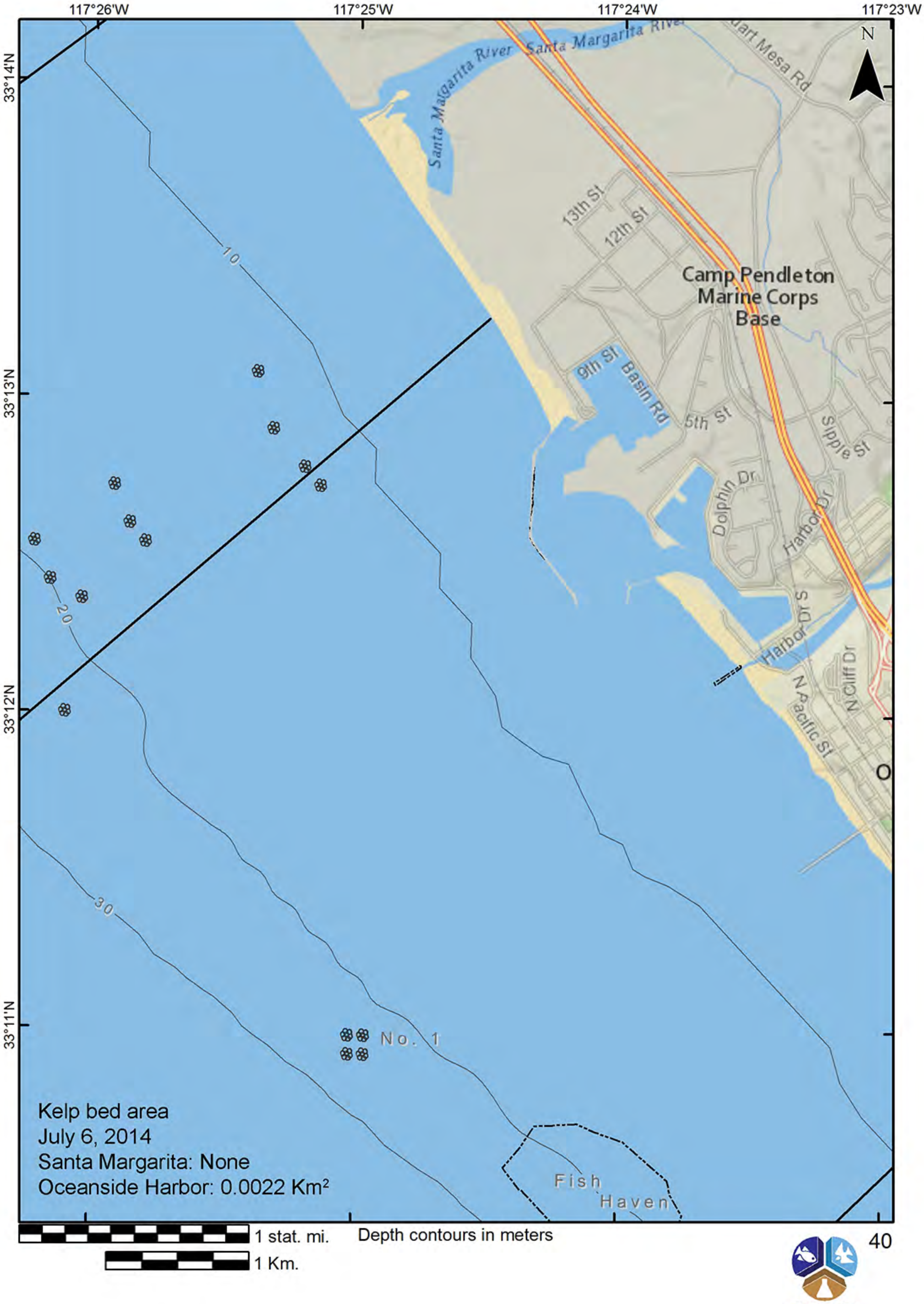
MBC


117°33'W
117°32'W
117°31'W
117°30'W
33°21'N
33°20'N
33°19'N
N
El Camino Real
Old Pacific Hwy
5
Horno Canyon
Pendleton
Artificial Reef
10
20
30
Kelp bed area
April 7, 2014
San Onofre: 0.5843 Km²
Pendleton Reefs: None
1 stat. mi.
1 Km.
Depth contours in meters
MBC

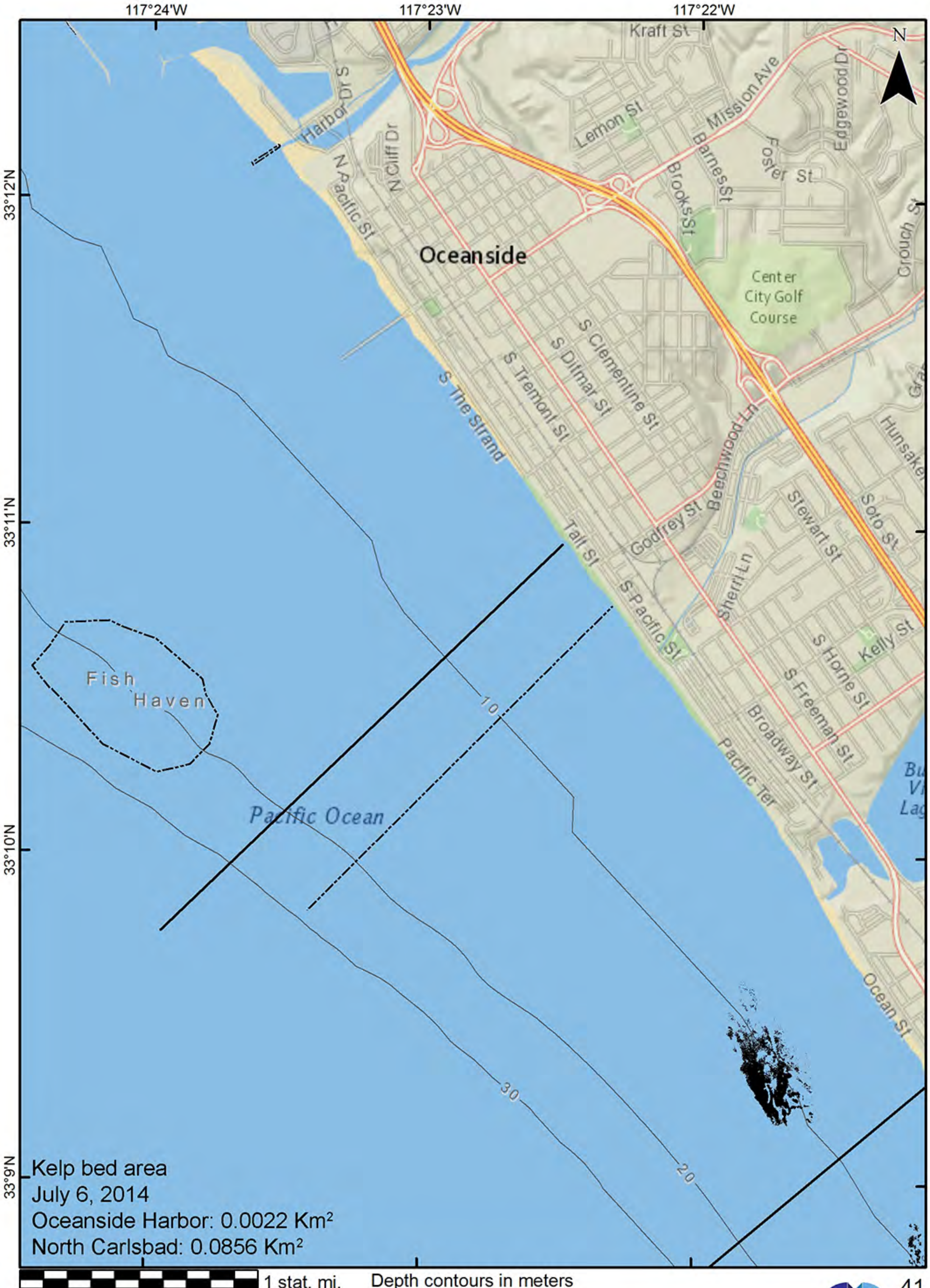

117°31'W
117°30'W
117°29'W
117°28'W
117°27'W
N
33°18'N
33°17'N
33°16'N
10
20
30
Kelp bed area
April 7, 2014
Horno Canyon: 0.0545 Km²
Barn Kelp: 0.7407 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC



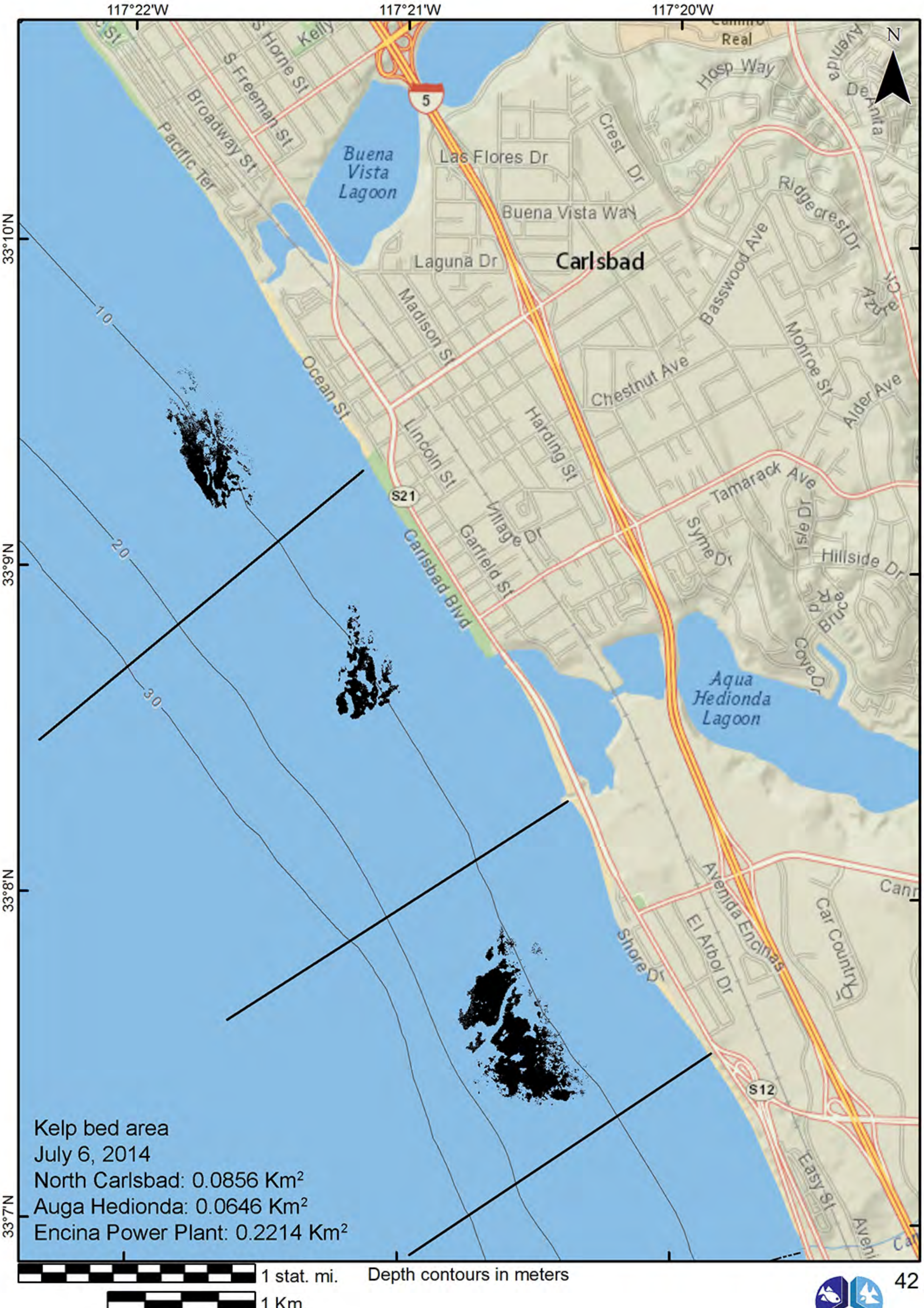
117°29'W
117°28'W
117°27'W
117°26'W
117°25'W
33°16'N
33°15'N
33°14'N
N
Aliso Ca
Range Road B
French Canyon
Phillips St
Cockleburr C
Parker Rd
Cockleburr Canyon
20
30
10
Kelp bed area
April 7, 2014
Barn Kelp: 0.7407 Km²
1 stat. mi.
1 Km.
Depth contours in meters


117°26'W
117°25'W
117°24'W
117°23'W
33°14'N
33°13'N
33°12'N
33°11'N
N
Santa Margarita River
Santa Margarita River
Santa Margarita River
Stuart Mesa Rd
13th St
12th St
Camp Pendleton Marine Corps Base
9th St
Basin Rd
5th St
Sipple St
Dolphin Dr
Harbor Dr
Harbor Dr S
N Cliff Dr
N Pacific St
10
20
30
No. 1
Fish Haven
Kelp bed area
July 6, 2014
Santa Margarita: None
Oceanside Harbor: 0.0022 Km²
1 stat. mi.
1 Km.
Depth contours in meters

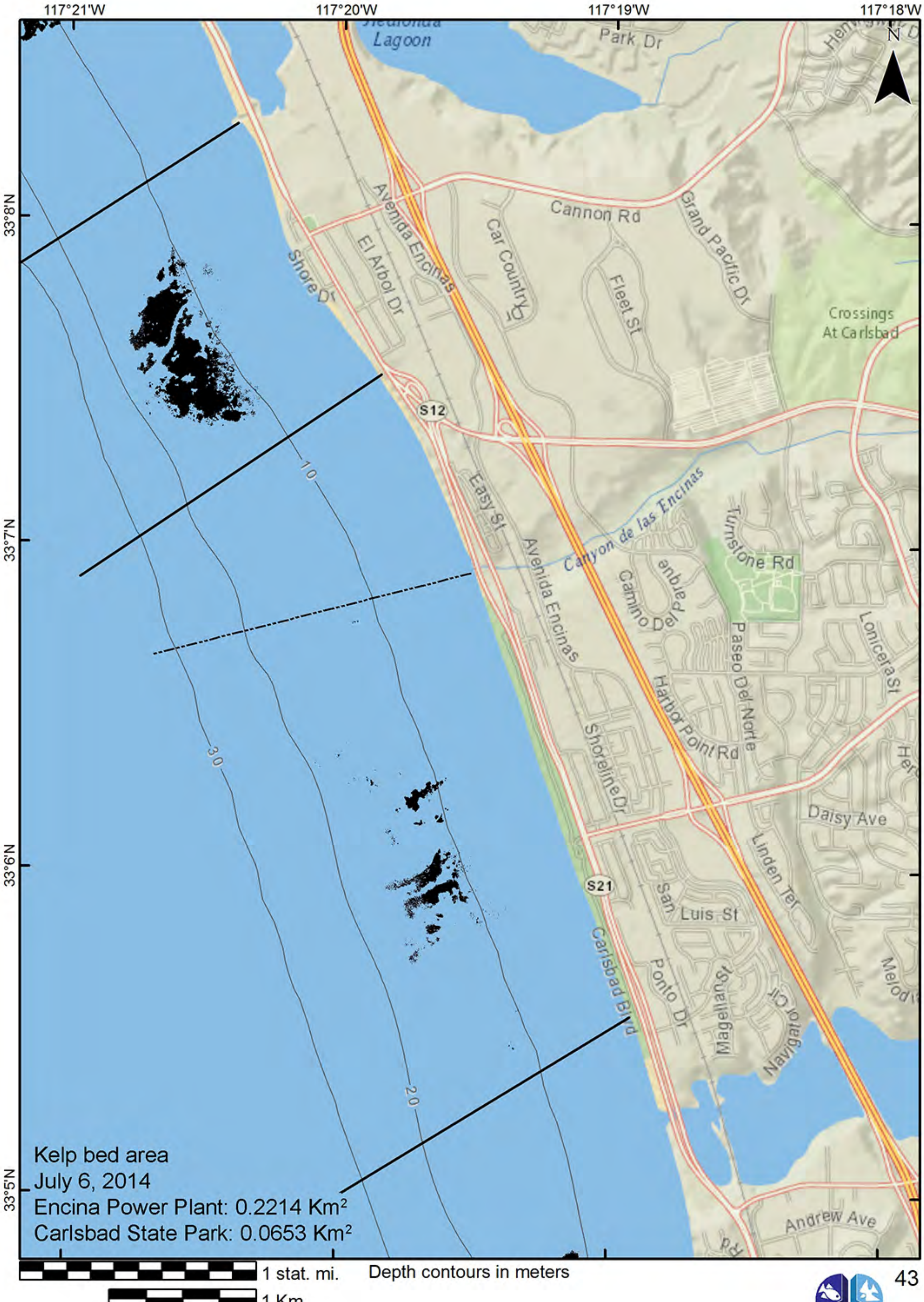
MBC

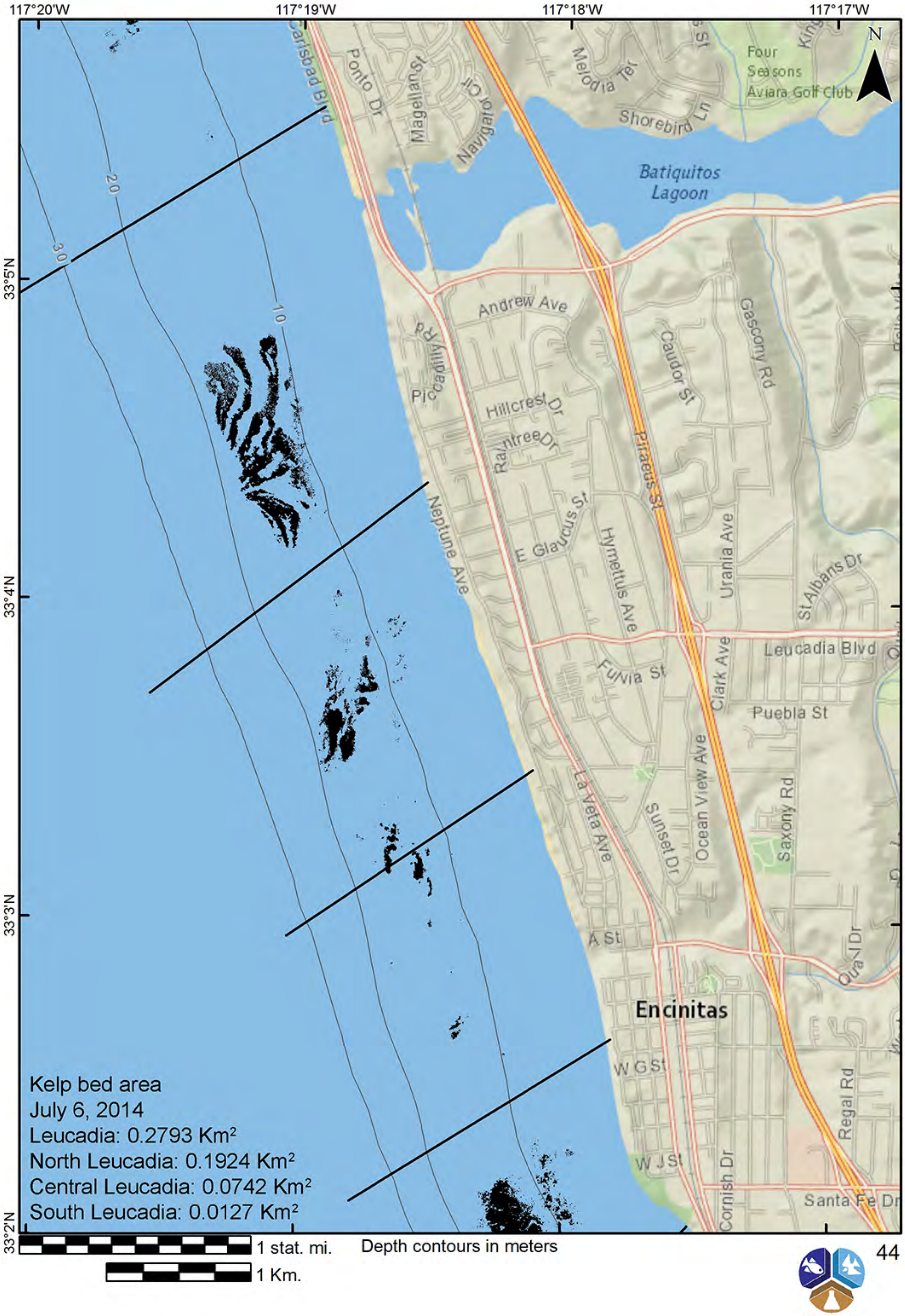

117°24'W
117°23'W
117°22'W
33°12'N
33°11'N
33°10'N
33°9'N
N
Oceanside
Kraft St
Harbor Dr S
N Cliff Dr
N Pacific St
Lemon St
Mission Ave
Edgewood Dr
Barnes St
Brooks St
Foster St
Crouch St
Center City Golf Course
S The Strand
S Tremont St
S Ditmar St
S Clementine St
Beechwood Ln
Hunsaker
Tait St
Godfrey St
Stewart St
Soto St
Sherri Ln
S Pacific St
Kelly St
S Horne St
S Freeman St
Broadway St
Pacific Ter
Ocean St
Fish Haven
Pacific Ocean
10
20
30
Kelp bed area
July 6, 2014
Oceanside Harbor: 0.0022 Km²
North Carlsbad: 0.0856 Km²
1 stat. mi.
1 Km.
Depth contours in meters

MBC

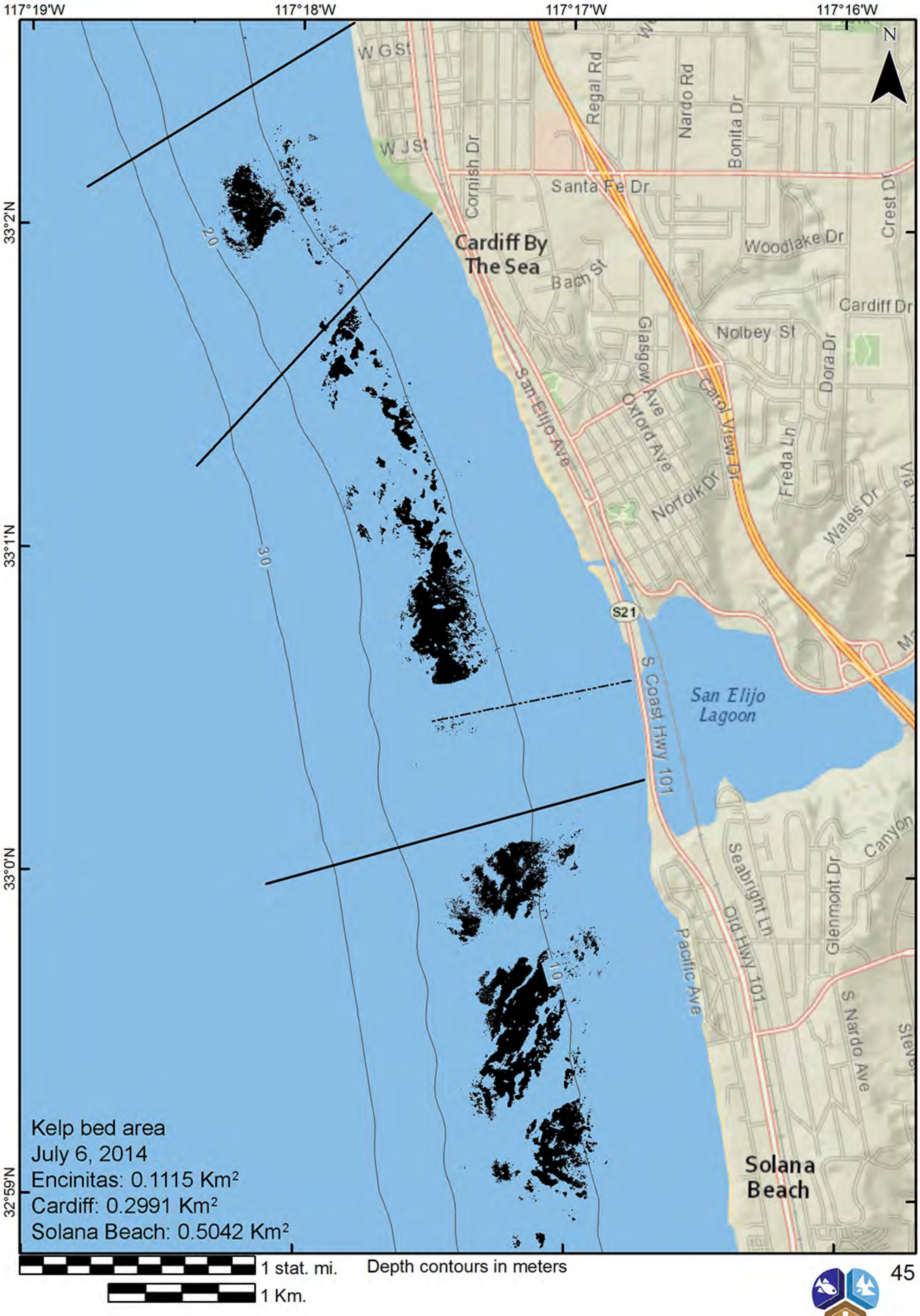


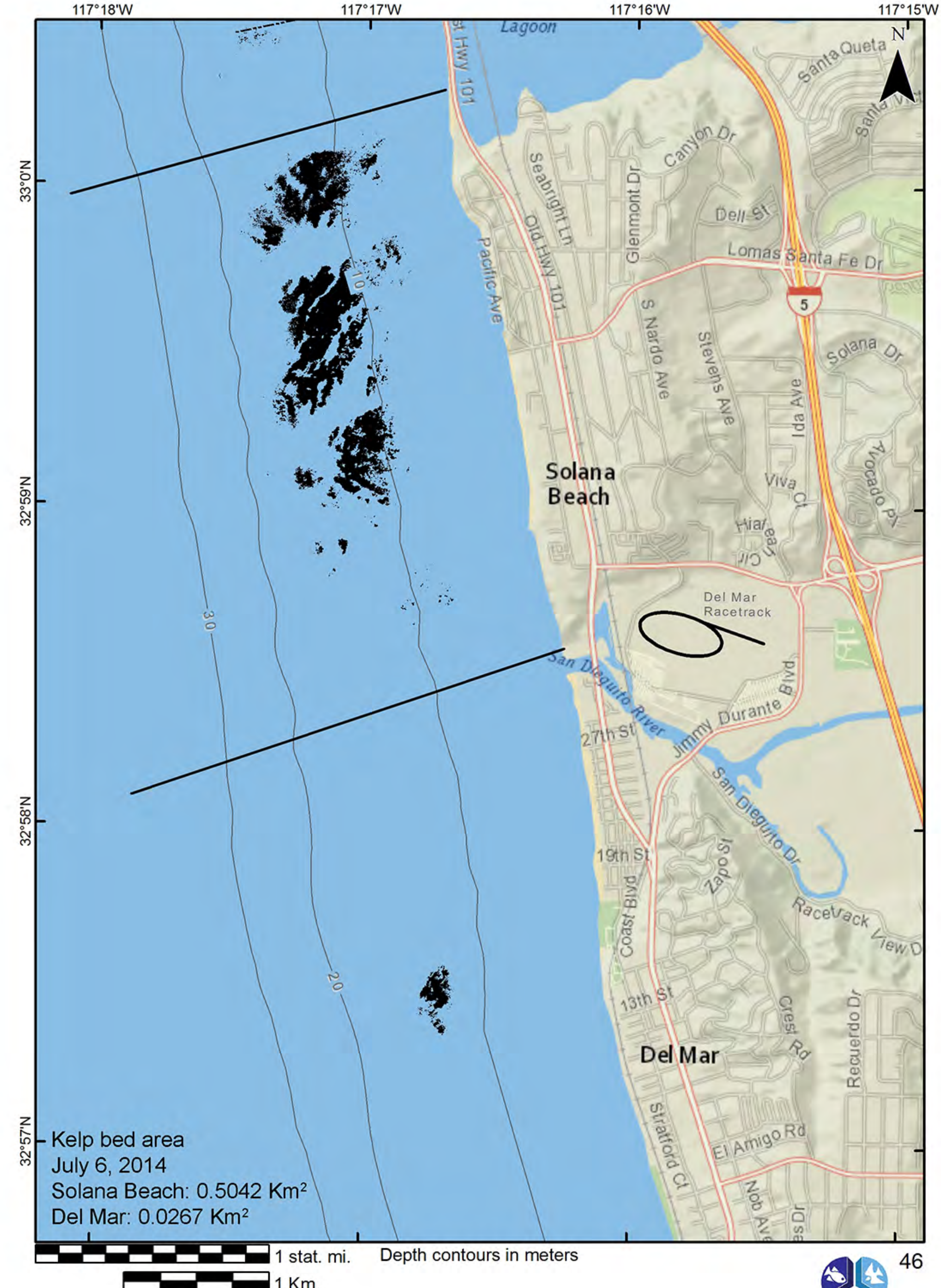
117°22'W
117°21'W
117°20'W
33°10'N
33°9'N
33°8'N
33°7'N
N
Buena Vista Lagoon
Carlsbad
Aqua Hedionda Lagoon
Las Flores Dr
Buena Vista Way
Laguna Dr
Crest Dr
Hosp Way
Ridgecrest Dr
Basswood Ave
Madison St
Ocean St
Chestnut Ave
Monroe St
Alder Ave
Harding St
Lincoln St
Tamarack Ave
Carlsbad Blvd
Garfield St
Village Dr
Syme Dr
Isle Dr
Hillside Dr
Cove Dr
Bruce Rd
Broadway St
Pacific Ter
S Freeman St
S Horne St
Kelly
Real
Avenida Encinas
El Arbol Dr
Shore Dr
Car Country Dr
Easy St
S21
S12
5
10
20
30
Kelp bed area
July 6, 2014
North Carlsbad: 0.0856 Km²
Auga Hedionda: 0.0646 Km²
Encina Power Plant: 0.2214 Km²
1 stat. mi.
1 Km.
Depth contours in meters

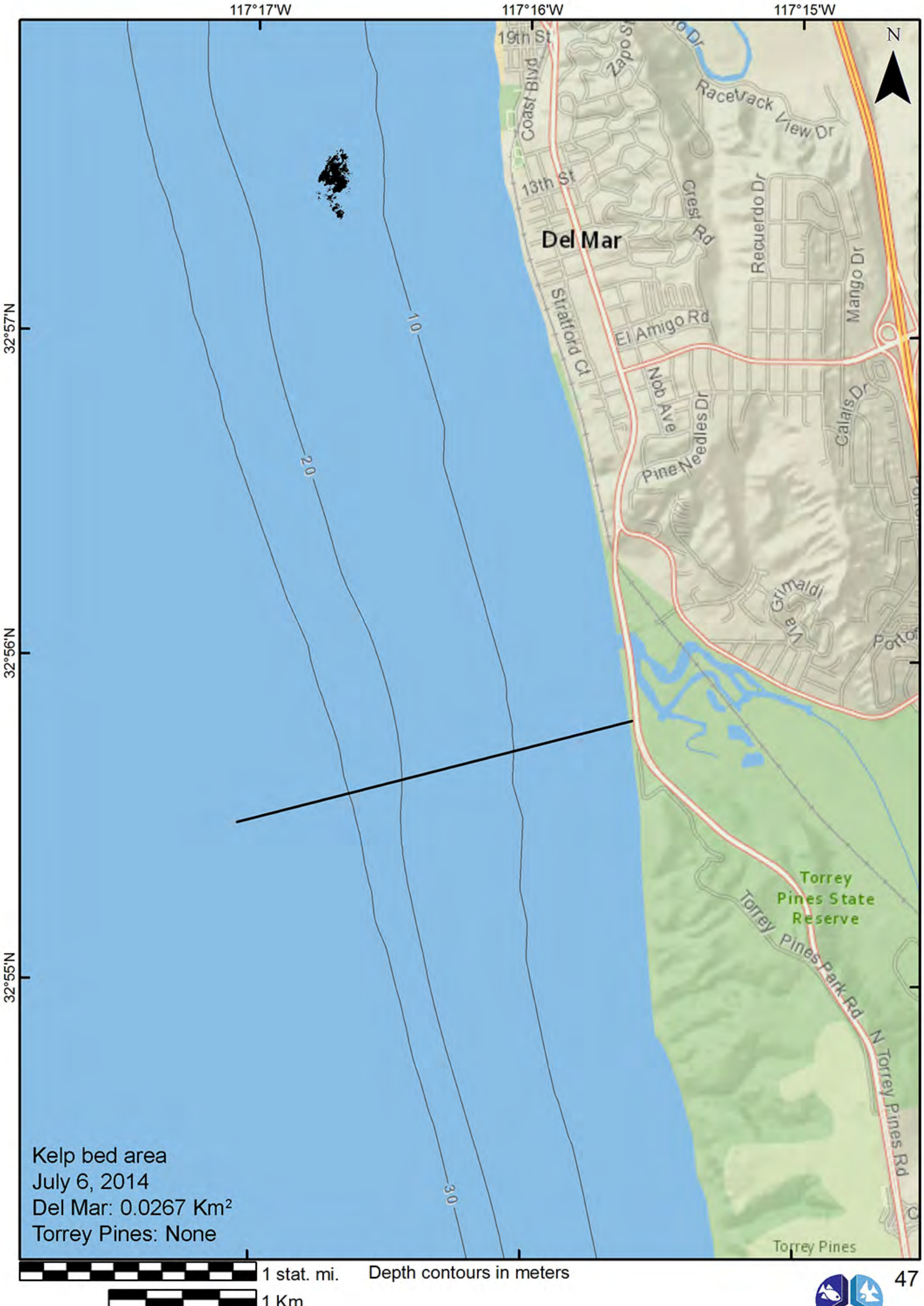

117°21'W
117°20'W
117°19'W
117°18'W
33°8'N
33°7'N
33°6'N
33°5'N
N
Lagoon
Park Dr
Cannon Rd
Grand Pacific Dr
Car Country Dr
Fleet St
Avenida Encinas
El Arbol Dr
Shore Dr
Crossings At Carlsbad
S12
Easy St
Canyon de las Encinas
Turnstone Rd
Camino Del Parque
Paseo Del Norte
Lonicera St
Harbor Point Rd
Shoreline Dr
Daisy Ave
Linden Ter
S21
San Luis St
Carlsbad Blvd
Ponto Dr
Magellan St
Navigator Cir
Andrew Ave
10
20
30
Kelp bed area
July 6, 2014
Encina Power Plant: 0.2214 Km²
Carlsbad State Park: 0.0653 Km²
1 stat. mi.
1 Km.
Depth contours in meters


117°20'W
117°19'W
117°18'W
117°17'W
33°5'N
33°4'N
33°3'N
33°2'N
N
Batiquitos Lagoon
Four Seasons Aviara Golf Club
Encinitas
Carlsbad Blvd
Ponto Dr
Magellan St
Navigator Cir
Melodia Ter
Shorebird Ln
Andrew Ave
Piccadilly Rd
Hillcrest Dr
Raintree Dr
Piraeus St
Caudor St
Gascony Rd
Neptune Ave
E Glaucus St
Hymettus Ave
Urania Ave
St Albans Dr
Leucadia Blvd
Fulvia St
Clark Ave
Puebla St
La Veta Ave
Sunset Dr
Ocean View Ave
Saxony Rd
A St
Quail Dr
W G St
W J St
Cornish Dr
Regal Rd
Santa Fe Dr
10
20
30
Kelp bed area
July 6, 2014
Leucadia: 0.2793 Km²
North Leucadia: 0.1924 Km²
Central Leucadia: 0.0742 Km²
South Leucadia: 0.0127 Km²
1 stat. mi.
1 Km.
Depth contours in meters

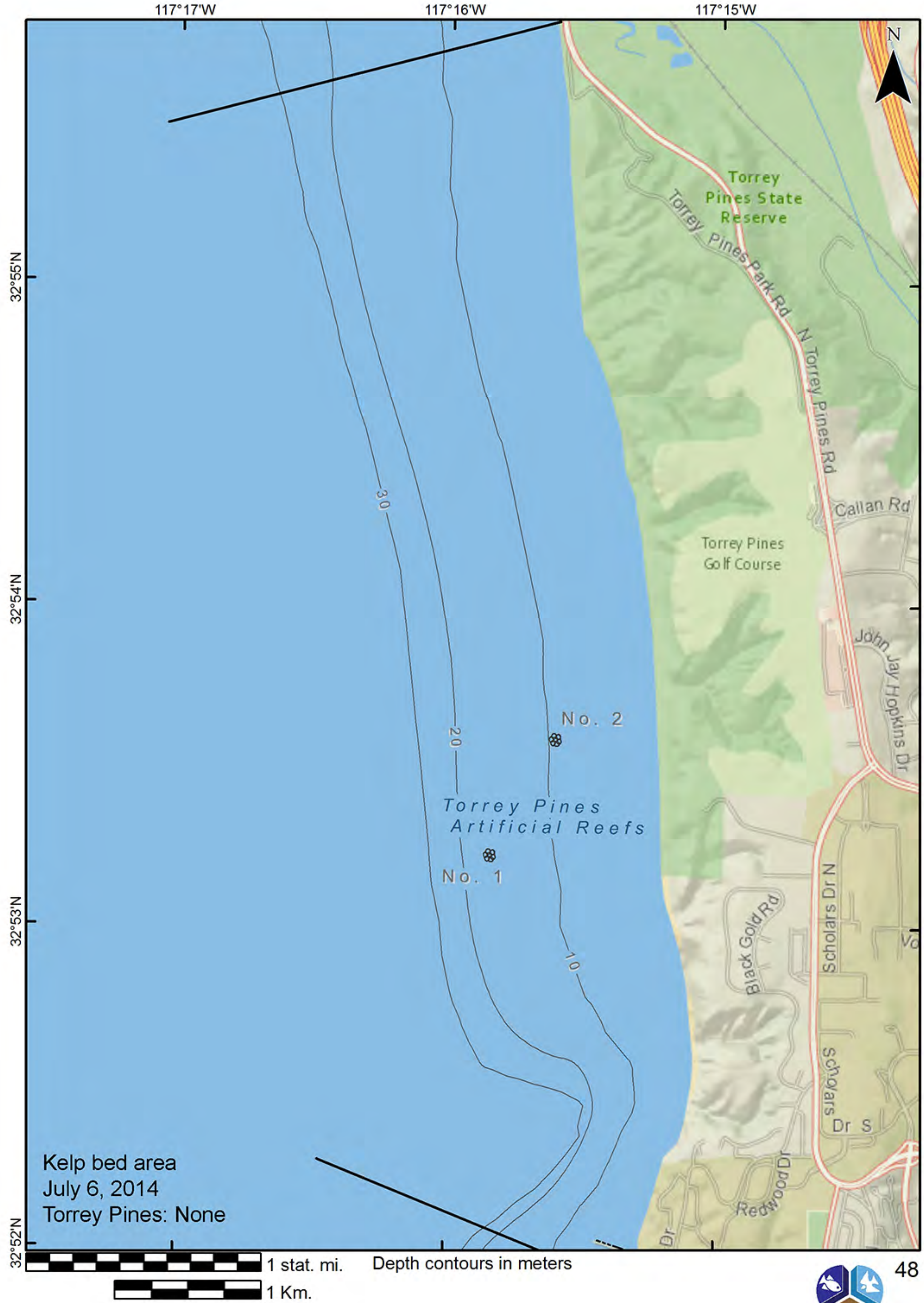
MBC

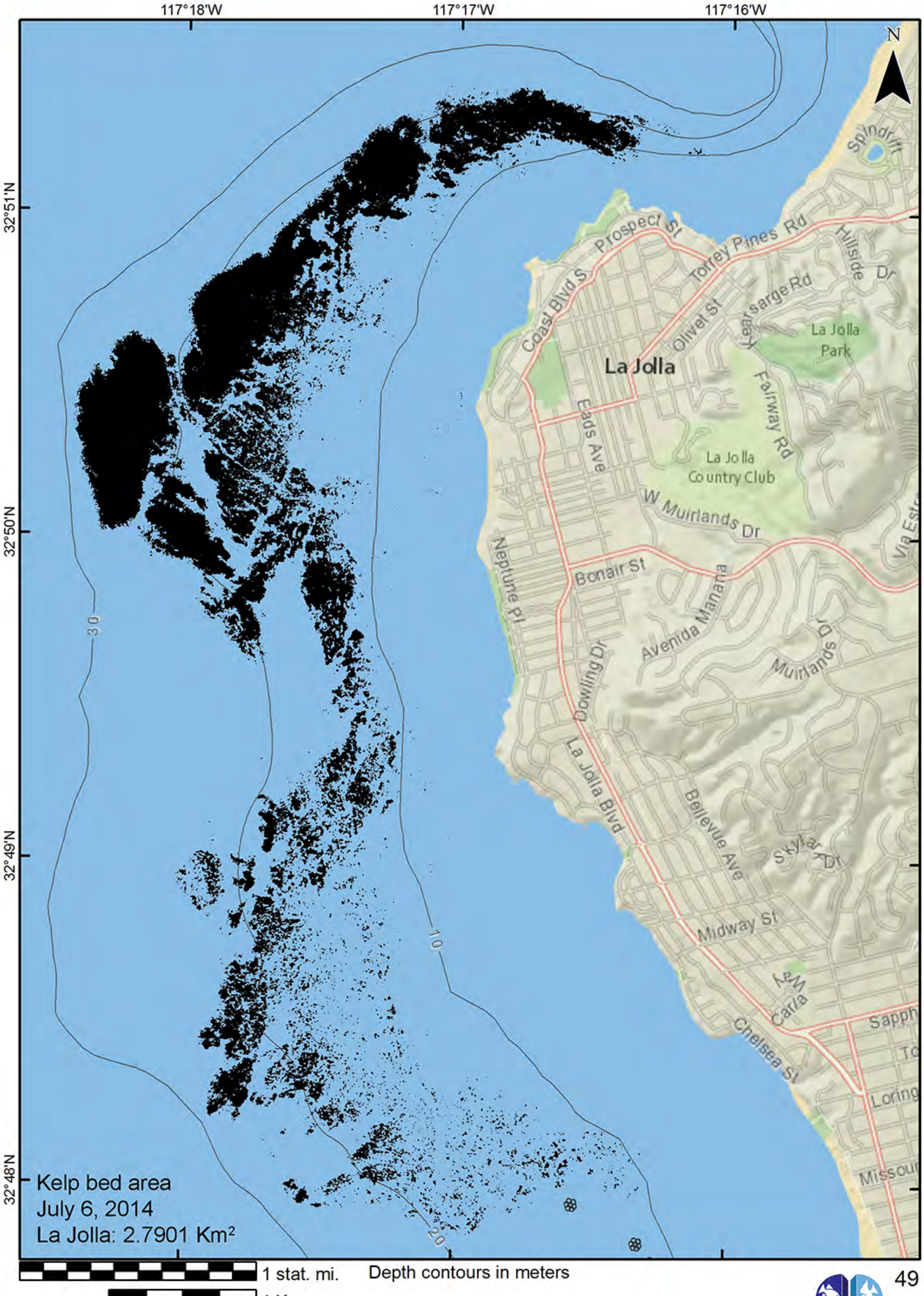

117°19'W
117°18'W
117°17'W
117°16'W
33°2'N
33°1'N
33°0'N
32°59'N
N
W G St
W J St
Regal Rd
Nardo Rd
Bonita Dr
Cornish Dr
Santa Fe Dr
Crest Dr
Cardiff By The Sea
Woodlake Dr
Bach St
Cardiff Dr
Nolbey St
Glasgow Ave
Dora Dr
San Elijo Ave
Oxford Ave
Carol View Dr
Freda Ln
Norfolk Dr
Wales Dr
20
30
10
S21
S Coast Hwy 101
San Elijo Lagoon
Seabright Ln
Glenmont Dr
Canyon
Old Hwy 101
Pacific Ave
S Nardo Ave
Solana Beach
Kelp bed area
July 6, 2014
Encinitas: 0.1115 Km²
Cardiff: 0.2991 Km²
Solana Beach: 0.5042 Km²
1 stat. mi.
1 Km.
Depth contours in meters
MBC


117°18'W
117°17'W
117°16'W
117°15'W
33°0'N
32°59'N
32°58'N
32°57'N
N
Lagoon
Hwy 101
Santa Queta
Canyon Dr
Seabright Ln
Glenmont Dr
Dell St
Old Hwy 101
Pacific Ave
Lomas Santa Fe Dr
5
S Nardo Ave
Stevens Ave
Solana Dr
Ida Ave
Avocado Pl
Viva Ct
Solana
Beach
Del Mar
Racetrack
San Dieguito River
Jimmy Durante Blvd
27th St
San Dieguito Dr
19th St
Zapo St
Racetrack View Dr
Coast Blvd
13th St
Crest Rd
Recuerdo Dr
Del Mar
Stratford Ct
El Amigo Rd
Nob Ave
10
30
20
Kelp bed area
July 6, 2014
Solana Beach: 0.5042 Km²
Del Mar: 0.0267 Km²
1 stat. mi.
1 Km.
Depth contours in meters


117°17'W
117°16'W
117°15'W
32°57'N
32°56'N
32°55'N
N
19th St
Coast Blvd
13th St
Racetrack View Dr
Crest Rd
Recuerdo Dr
Mango Dr
Del Mar
Stratford Ct
El Amigo Rd
Nob Ave
Pine Needles Dr
Calais Dr
Via Grimaldi
Torrey Pines State Reserve
Torrey Pines Park Rd
N Torrey Pines Rd
Torrey Pines
10
20
30
Kelp bed area
July 6, 2014
Del Mar: 0.0267 Km²
Torrey Pines: None
1 stat. mi.
1 Km.
Depth contours in meters

MBC


117°17'W
117°16'W
117°15'W
32°55'N
32°54'N
32°53'N
32°52'N
N
Torrey Pines State Reserve
Torrey Pines Park Rd
N Torrey Pines Rd
Callan Rd
Torrey Pines Golf Course
John Jay Hopkins Dr
30
20
10
No. 2
No. 1
Torrey Pines Artificial Reefs
Black Gold Rd
Scholars Dr N
Scholars Dr S
Redwood Dr
Kelp bed area
July 6, 2014
Torrey Pines: None
1 stat. mi.
1 Km.
Depth contours in meters


117°18'W
117°17'W
117°16'W
N
32°51'N
32°50'N
32°49'N
32°48'N
30
10
20
Spindrift
Prospect St
Torrey Pines Rd
Hillside Dr
Coast Blvd S
Olivet St
Kearsarge Rd
La Jolla Park
La Jolla
Eads Ave
Fairway Rd
La Jolla Country Club
W Muirlands Dr
Via Estr
Neptune Pl
Bonair St
Avenida Manana
Muirlands Dr
Dowling Dr
La Jolla Blvd
Bellevue Ave
Skylark Dr
Midway St
Carla Way
Chelsea St
Sapph
To
Loring
Missour
Kelp bed area
July 6, 2014
La Jolla: 2.7901 Km²
1 stat. mi.
1 Km.
Depth contours in meters

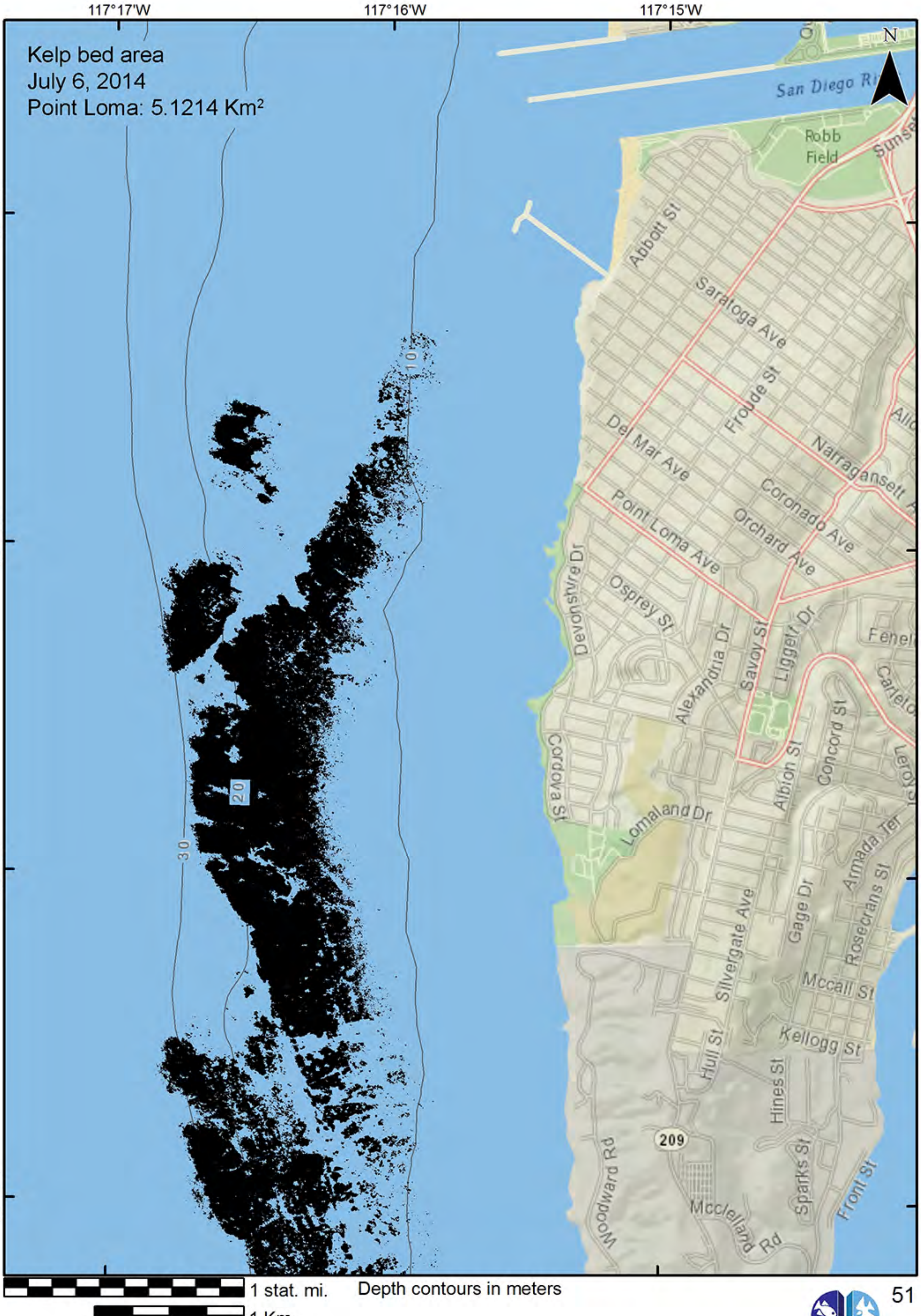
MBC

1 stat. mi.

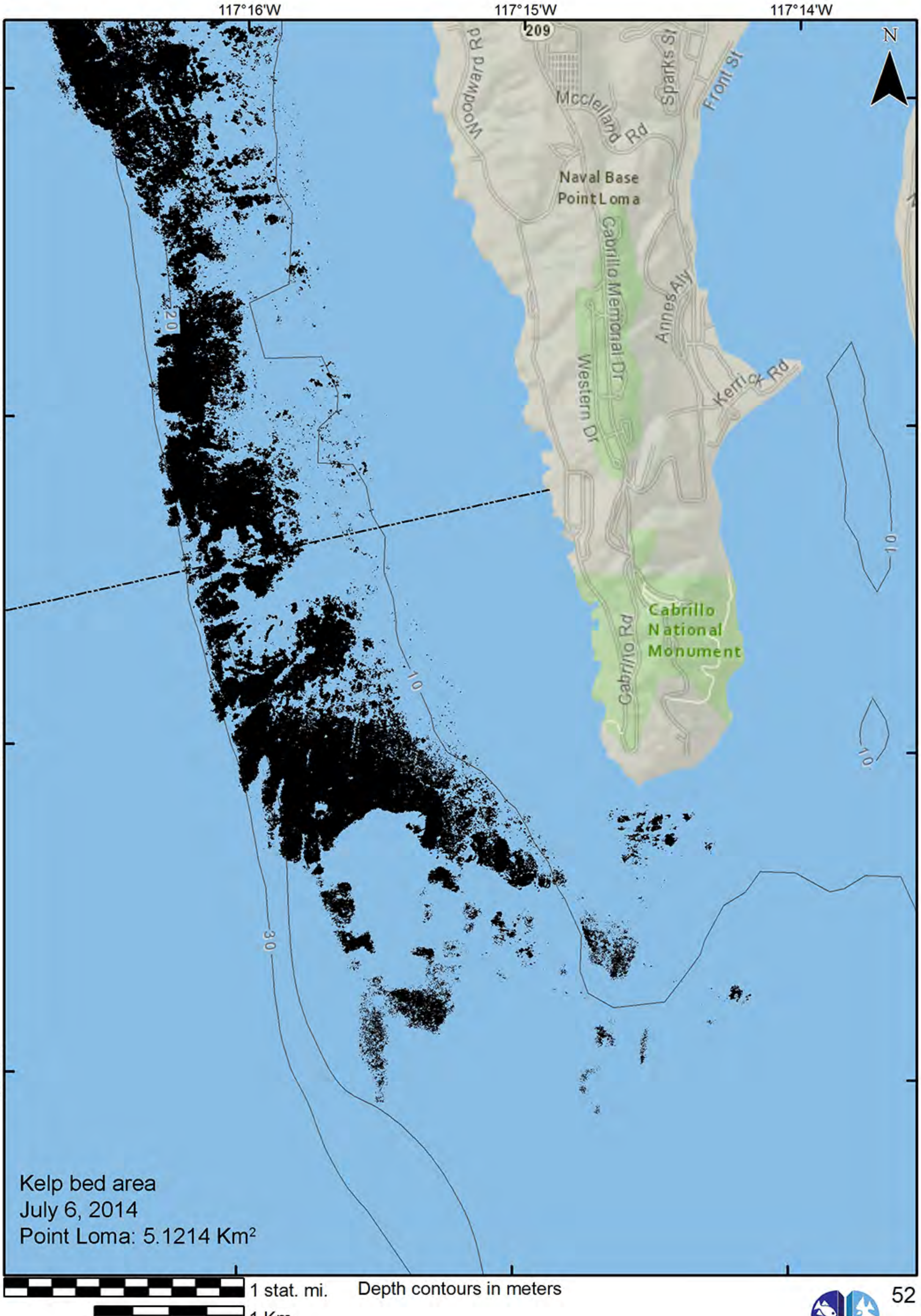
1 Km.

Depth contours in meters

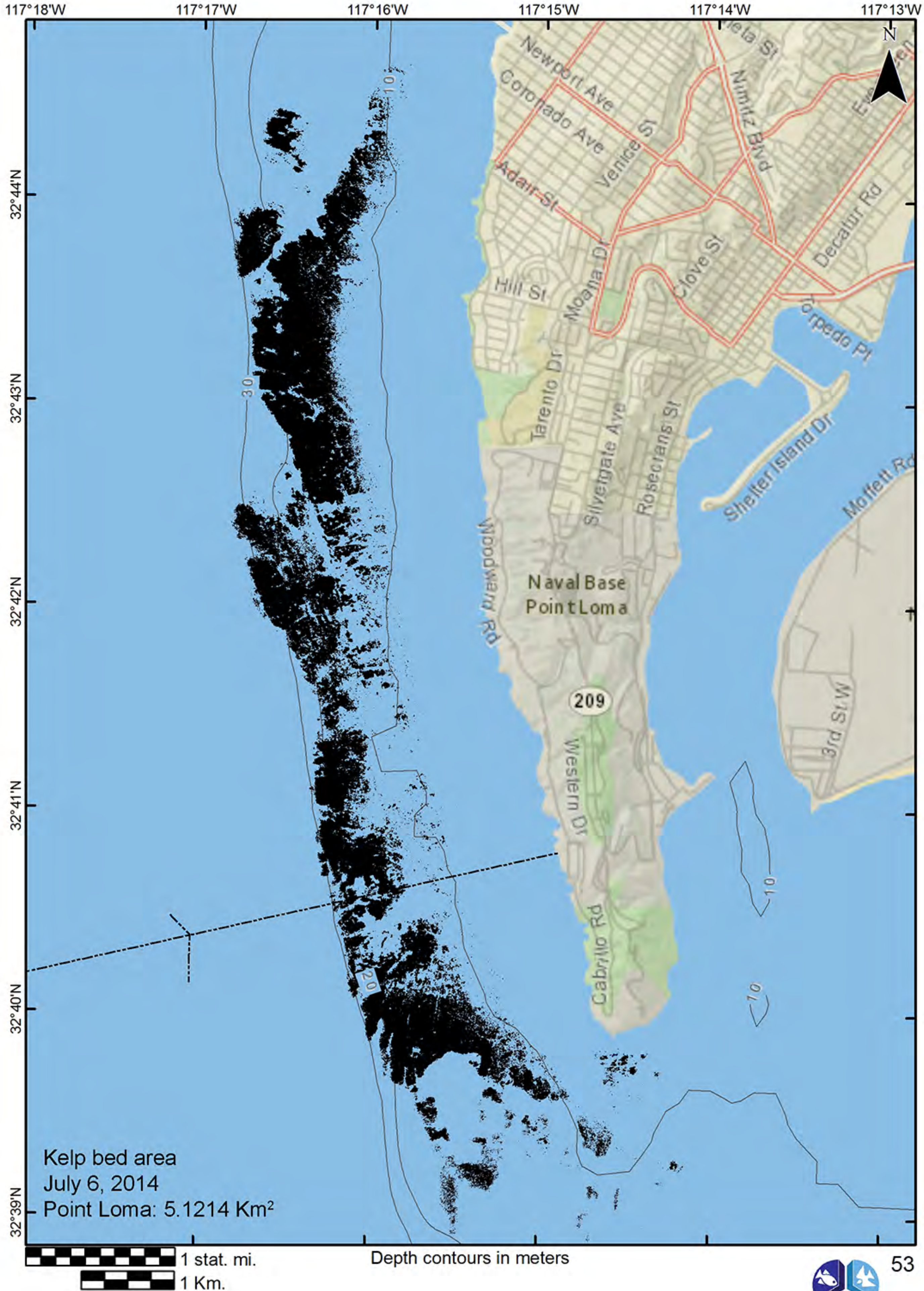
MBC


117°17'W
117°16'W
117°15'W
Kelp bed area
July 6, 2014
Point Loma: 5.1214 Km²
N
San Diego Ri
Robb Field
Abbott St
Saratoga Ave
Froude St
Del Mar Ave
Narragansett
Coronado Ave
Point Loma Ave
Orchard Ave
Osprey St
Devonshire Dr
Alexandria Dr
Savoy St
Liggett Dr
Cordova St
Lomaland Dr
Albion St
Concord St
Silvergate Ave
Gage Dr
Rosecrans St
Armada Ter
Mccall St
Kellogg St
Hull St
Hines St
209
Woodward Rd
Mcclelland Rd
Sparks St
Front St
32°45'N
32°44'N
32°43'N
32°42'N
10
20
30
1 stat. mi.
1 Km.
Depth contours in meters

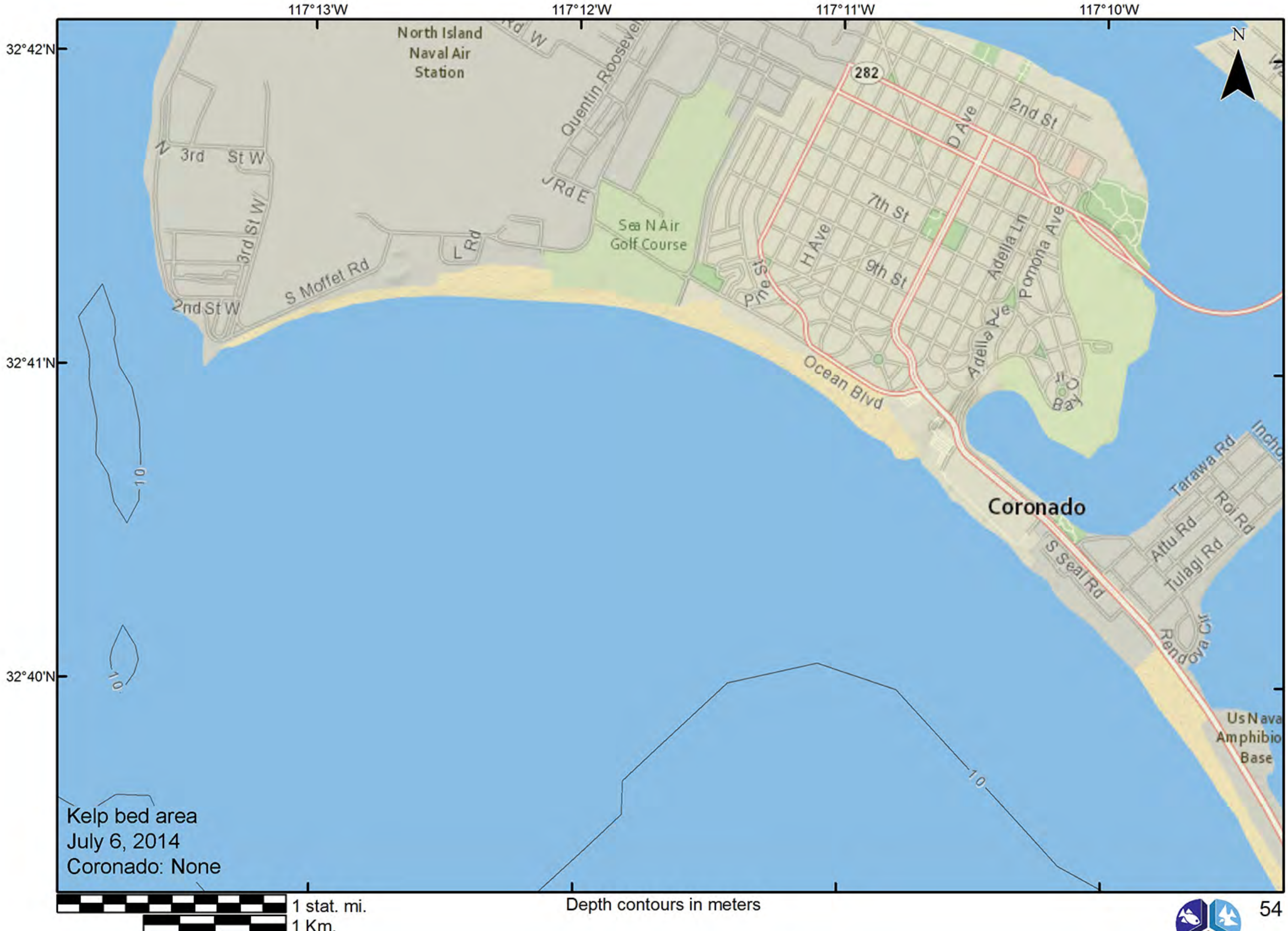
MBC


117°16'W
117°15'W
117°14'W
32°42'N
32°41'N
32°40'N
32°39'N
209
Woodward Rd
Mcclelland Rd
Sparks St
Front St
Naval Base
Point Loma
Cabrillo Memorial Dr
Annes Aly
Western Dr
Kerrick Rd
Cabrillo Rd
Cabrillo
National
Monument
N
20
10
30
Kelp bed area
July 6, 2014
Point Loma: 5.1214 Km²
1 stat. mi.
1 Km.
Depth contours in meters

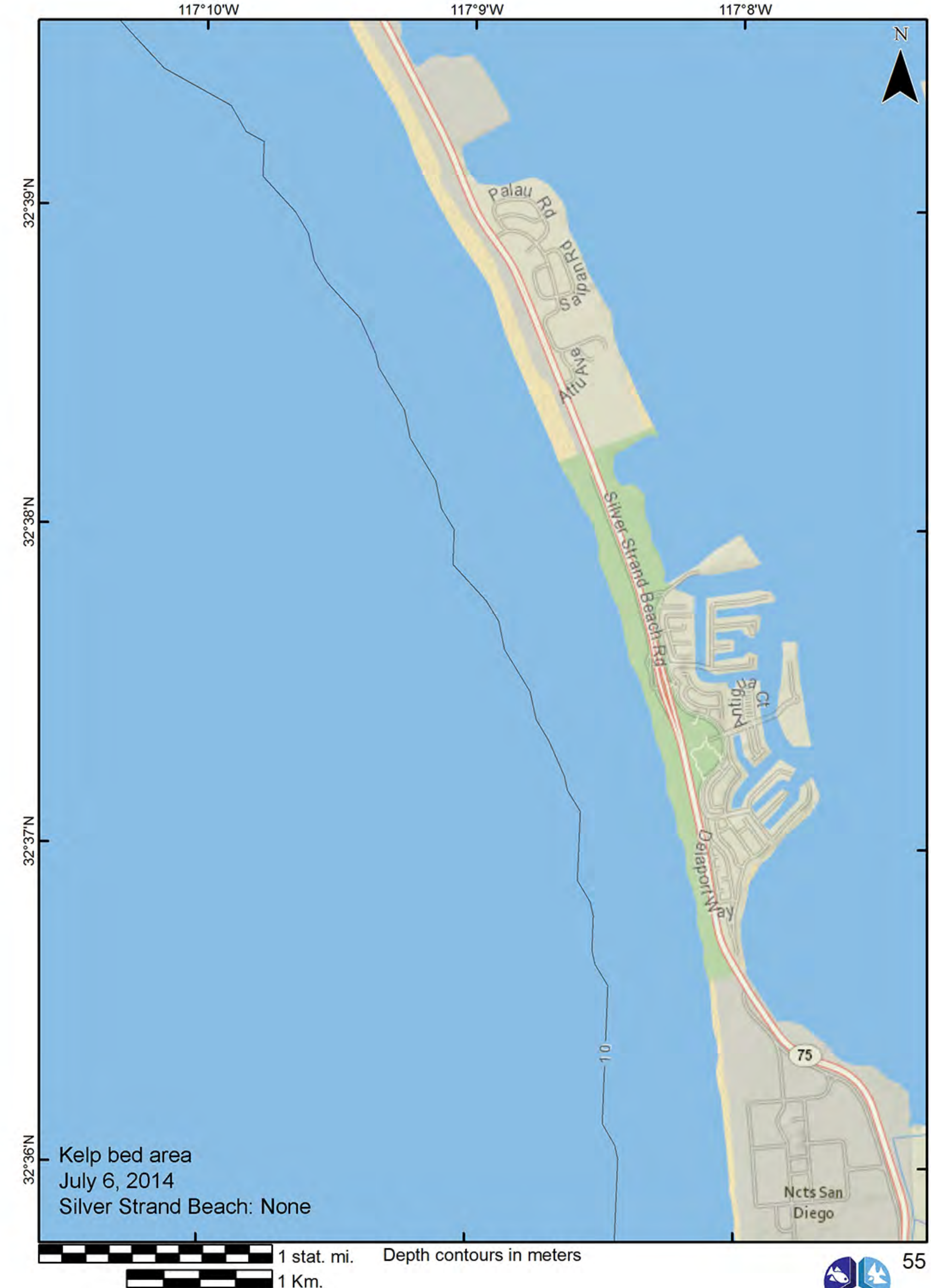
MBC


117°18'W
117°17'W
117°16'W
117°15'W
117°14'W
117°13'W
32°44'N
32°43'N
32°42'N
32°41'N
32°40'N
32°39'N
N
Newport Ave
Coronado Ave
Adair St
Venice St
Nimitz Blvd
Decatur Rd
Hill St
Moana Dr
Clove St
Torpedo Pt
Tarento Dr
Silvergate Ave
Rosecrans St
Shelter Island Dr
Moffett Rd
Woodward Rd
Naval Base
Point Loma
209
Western Dr
Cabrillo Rd
3rd St W
10
20
30
Kelp bed area
July 6, 2014
Point Loma: 5.1214 Km²
1 stat. mi.
1 Km.
Depth contours in meters

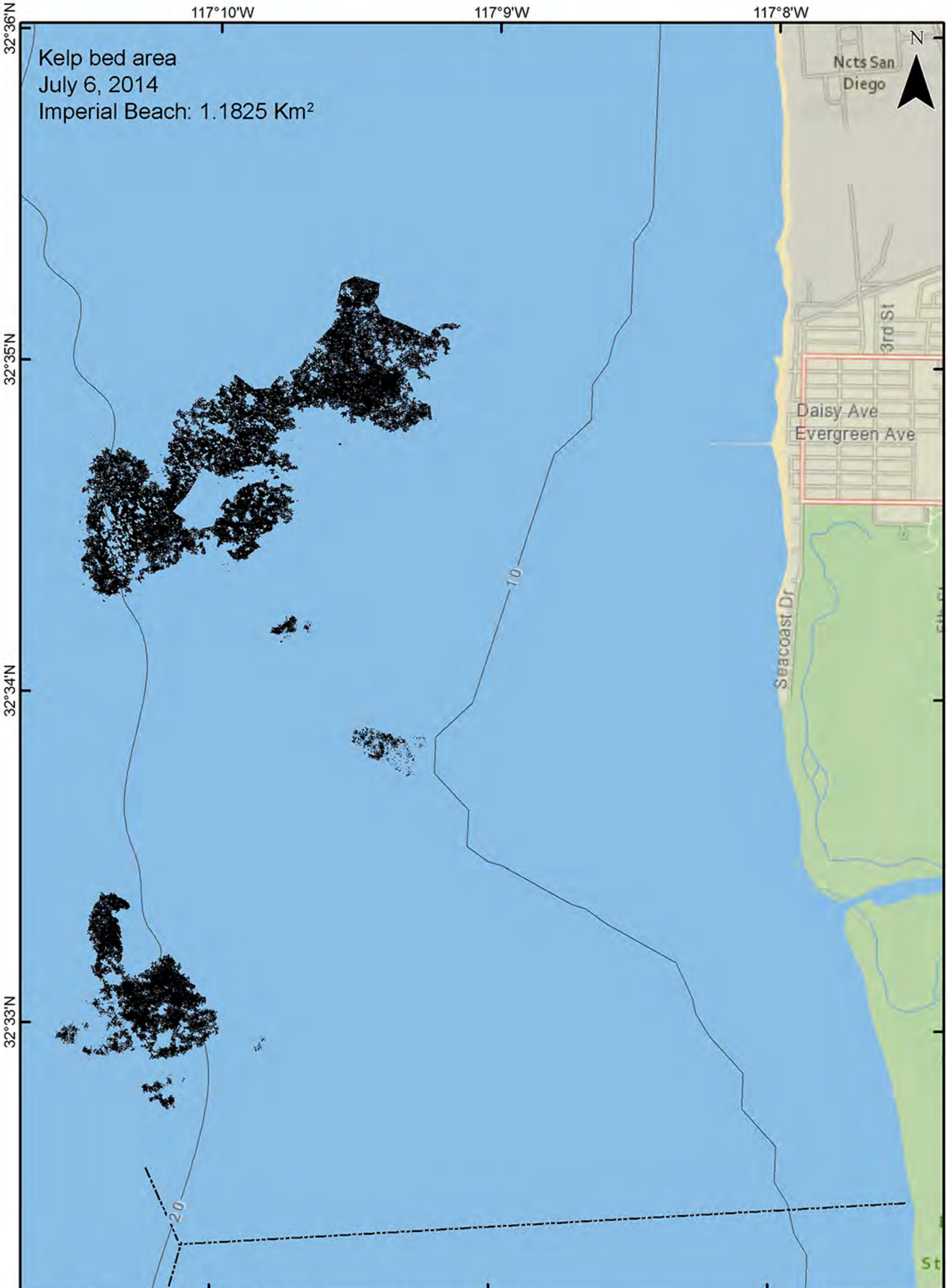
MBC


117°13'W
117°12'W
117°11'W
117°10'W
32°42'N
32°41'N
32°40'N
N
North Island Naval Air Station
Quentin Roosevelt
3rd St W
3rd St W
2nd St W
S Moffet Rd
J Rd E
L Rd
Sea N Air Golf Course
282
2nd St
D Ave
7th St
9th St
H Ave
Pine St
Adella Ln
Pomona Ave
Adella Ave
Ocean Blvd
Coronado
Tarawa Rd
Roi Rd
Attu Rd
Tulagi Rd
S Seal Rd
Rendova Cir
Us Naval Amphibious Base
10
10
10
Kelp bed area
July 6, 2014
Coronado: None
1 stat. mi.
1 Km.
Depth contours in meters

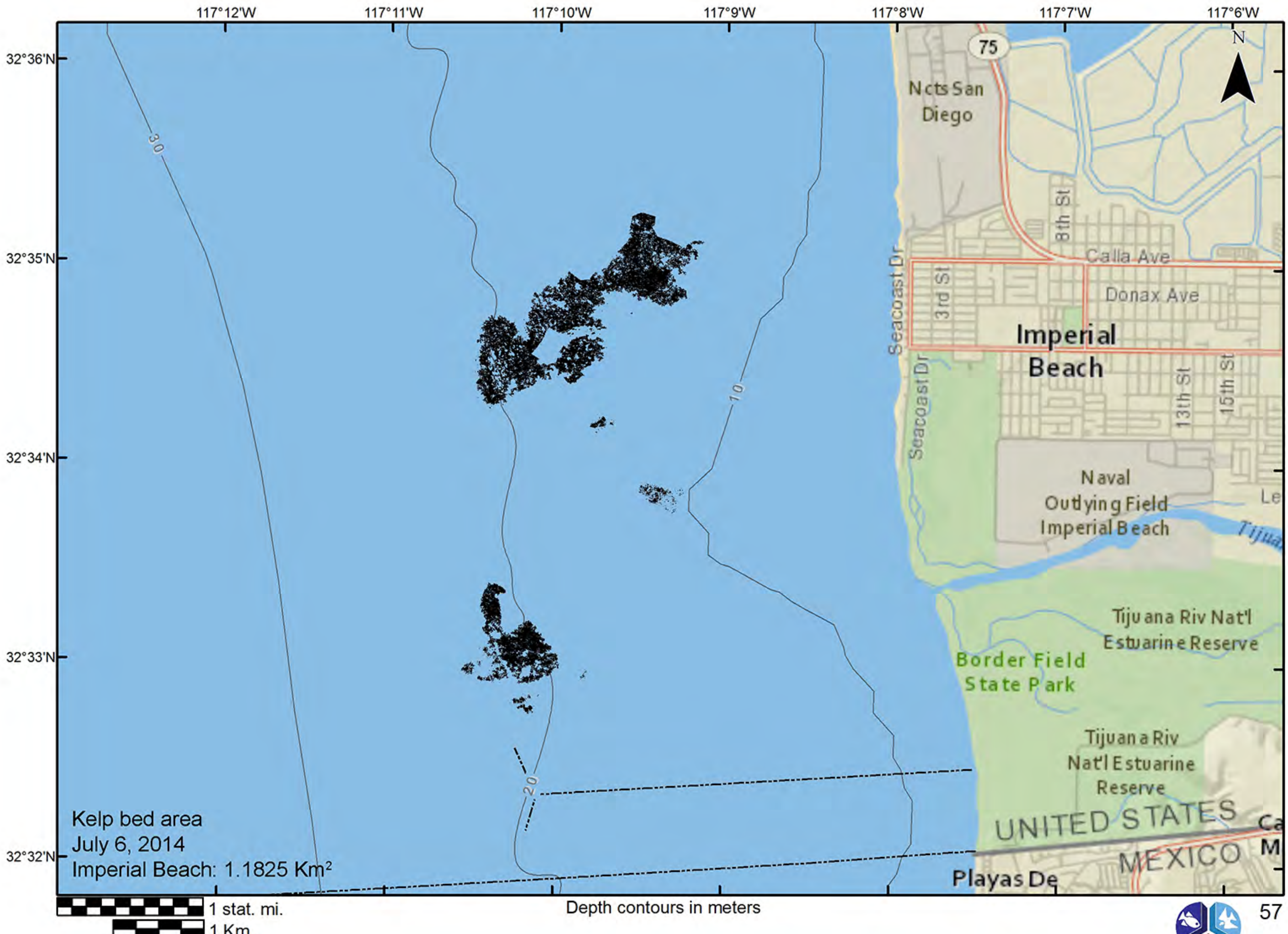
MBC


117°10'W
117°9'W
117°8'W
N
32°39'N
32°38'N
32°37'N
32°36'N
Palau Rd
Saipan Rd
Attu Ave
Silver Strand Beach Rd
Delaport Way
75
10
Ncts San Diego
Kelp bed area
July 6, 2014
Silver Strand Beach: None
1 stat. mi.
1 Km.
Depth contours in meters

MBC



1 stat. mi.
1 Km.
Depth contours in meters


117°12'W
117°11'W
117°10'W
117°9'W
117°8'W
117°7'W
117°6'W
32°36'N
32°35'N
32°34'N
32°33'N
32°32'N
N
75
Ncts San Diego
8th St
Calla Ave
Donax Ave
3rd St
Seacoast Dr
Seacoast Dr
Imperial Beach
13th St
15th St
Naval Outlying Field Imperial Beach
Tijuana Riv Nat'l Estuarine Reserve
Border Field State Park
Tijuana Riv Nat'l Estuarine Reserve
UNITED STATES
MEXICO
Playas De
30
20
10
Kelp bed area
July 6, 2014
Imperial Beach: 1.1825 Km²
1 stat. mi.
1 Km.
Depth contours in meters

APPENDIX B

Historic Narrative and Kelp Coverage

HISTORICAL KELP SURVEYS

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

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

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

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

Due to the large sizes reported by Crandall, Neushul (1981) assumed there was a scaling error, re-measured the maps, and calculated a value that was 10% less than Crandall's original measurement. However, Neushul (1981) wrote that his measurements resulted in

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

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

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

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

The next complete kelp survey of the southern California region was not undertaken until 1955. By that time, the beds in the Central Region had decreased greatly (to 6.750 km^2), and were only 36% of that recorded in 1911 (18.815 km^2). Beds in Region Nine were similarly reduced to 40% (16.310 km^2) of the 1911 total of 41.563 km^2. The most significant loss during this period was that of Sunset Kelp (offshore of Santa Monica); Sunset Kelp covered almost 1.0 km^2 in 1911, but was very small by 1955. The Sunset kelp bed remained small or completely missing through the intervening years, and the Palos Verdes beds were also small, having decreased sometime after 1945. By 1947, the Palos Verdes beds were only 3.6 km^2, and further to 1.5 km^2 by 1953. During an aerial survey conducted in 1963, kelp canopies were in very poor condition, with Palos Verdes covering only 0.180 km^2 and the La Jolla and Point Loma beds covering only 0.9 km^2. Exceptionally good conditions in 1967 resulted in a total of 7.856 km^2 of kelp canopy coverage in the Central Region, but this was only about 42% of the estimate from 1911. Palos Verdes kelp beds south of Point Vicente were missing, but north of Point Vicente, they totaled almost 1.0 km^2. In Region Nine, similar results were observed in 1967 with the La Jolla/Point Loma kelp beds covering 3.03 km^2 and the total for the region only 4.4 km^2. La Jolla kelp bed was only about 0.330 km^2 in 1967, and it stayed small until after 1975, when it became a consistently large kelp bed (over 1 km^2) through most of the next four decades.

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

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

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

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

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

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

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

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

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

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

Table 4. Historical canopy coverage in km² of the Ventura, Los Angeles, and Orange County kelp beds to Laguna Beach, from 2003 to 2014. Areal estimates for 2003-2014 were derived from infrared aerial photographs.

	Canopy Area (km²)											
Kelp Bed	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1 Deer Creek	0.089	0.107	0.053	0.026	0.046	0.074	0.105	0.062	0.055	0.041	0.104	0.103
2 Leo Carillo	0.318	0.399	0.171	0.150	0.145	0.207	0.255	0.232	0.226	0.337	0.366	0.261
3 Nicolas Canyon	0.308	0.362	0.195	0.038	0.473	0.268	0.433	0.291	0.130	0.240	0.369	0.288
4 El Pesc/La Piedra	0.243	0.314	0.141	0.063	0.255	0.173	0.238	0.164	0.136	0.173	0.236	0.244
5 Lechuza	0.105	0.104	0.041	0.022	0.106	0.075	0.105	0.096	0.096	0.066	0.154	0.137
Total 1-5 (F&W 17)	1.063	1.286	0.600	0.298	1.025	0.797	1.136	0.844	0.642	0.857	1.229	1.034
6 Pt. Dume	0.012	0.029	0.028	0.053	0.065	0.070	0.104	0.094	0.078	0.154	0.113	0.092
7 Paradise Cove	0.162	0.258	0.035	0.036	0.100	0.223	0.244	0.259	0.109	0.346	0.244	0.223
8 Escondido Wash	0.214	0.250	0.078	-	0.339	0.278	0.321	0.267	0.104	0.248	0.243	0.281
9 Latigo Canyon	0.125	0.161	0.032	0.007	0.186	0.124	0.195	0.142	0.070	0.202	0.133	0.212
10 Puerco/Amarillo	0.074	0.051	0.039	0.055	0.095	0.064	0.115	0.126	0.069	0.153	0.105	0.130
11 Malibu Pt.	0.011	0.013	0.008	0.008	0.016	0.011	0.012	0.066	0.074	0.084	0.060	0.039
Total 6-11 (F&W 16)	0.598	0.762	0.220	0.158	0.801	0.769	0.991	0.954	0.504	1.189	0.897	0.976
12 La Costa	0.001	0.002	-	-	-	-	0.001	0.001	-	0.003	0.003	0.001
13 Las Flores	0.009	0.023	0.004	-	0.005	0.001	0.005	0.005	0.008	0.025	0.022	0.016
14 Big Rock	0.005	0.014	0.002	0.001	0.004	0.002	0.005	0.006	0.007	0.018	0.017	0.011
15 Las Tunas	0.003	0.018	0.004	-	0.008	0.005	0.019	0.015	0.007	0.030	0.029	0.012
16 Topanga	0.0002	0.002	0.0001	-	-	0.001	0.002	0.052	0.041	0.048	0.044	0.016
17 Sunset	-	-	-	-	-	-	0.004	0.008	0.007	0.008	0.010	0.010
Total 12-17 (F&W 15)	0.017	0.059	0.010	0.001	0.017	0.009	0.035	0.087	0.069	0.131	0.123	0.064
18 Malaga Cove-PV Pt. (IV)	0.196	0.245	0.204	0.859	1.151	1.839	2.122	1.136	1.139	1.337	0.974	0.264
19 PV Pt-PT. Vic (III)	0.045	0.040	0.056	0.135	0.074	0.300	0.570	0.624	0.452	0.488	0.502	0.468
Total 18-19 (F&W 14)	0.241	0.285	0.260	0.993	1.225	2.140	2.692	1.760	1.591	1.825	1.476	0.732
20 Pt Vic to Pt Insp (II)	0.059	0.023	0.034	0.082	0.034	0.108	0.163	0.222	0.238	0.295	0.279	0.224
21 Pt Insp to Cabr (I)	1.063	0.211	0.702	0.951	0.703	0.608	0.980	0.389	0.465	0.384	0.672	0.533
22 Cabrillo	0.062	0.070	0.102	0.161	0.100	0.060	0.163	0.124	0.103	0.095	0.174	0.158
Total 20-22 (F&W 13)	1.184	0.304	0.838	1.194	0.837	0.776	1.306	0.734	0.805	0.774	1.124	0.915
Total 18-22 PV	1.425	0.589	1.098	2.187	2.062	2.916	3.998	2.494	2.396	2.599	2.600	1.647
23 POLA-POLB Harbor	ND	ND	0.147	0.494	0.118	0.213	0.151	0.277	0.397	0.495	0.337	0.196
24 Horseshoe	-	-	-	-	-	-	-	-	-	-	-	-
25 Huntington Flats	-	-	-	-	-	-	-	-	-	-	-	-
26 Newport-Irvine Coast	0.002	0.002	0.000	0.023	0.054	0.089	0.095	0.161	0.419	0.395	0.428	0.366
Total 23-26 (F&W 10)	0.002	0.002	0.147	0.517	0.172	0.302	0.246	0.438	0.816	0.890	0.765	0.561
TOTAL	3.105	2.698	2.075	3.161	4.076	4.793	6.406	4.817	4.427	5.665	5.614	4.283

ND = No Data; "-" = 0

Sources: Veisze et al. (2004); MBC (2004a-2012a, 2013, 2014).

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

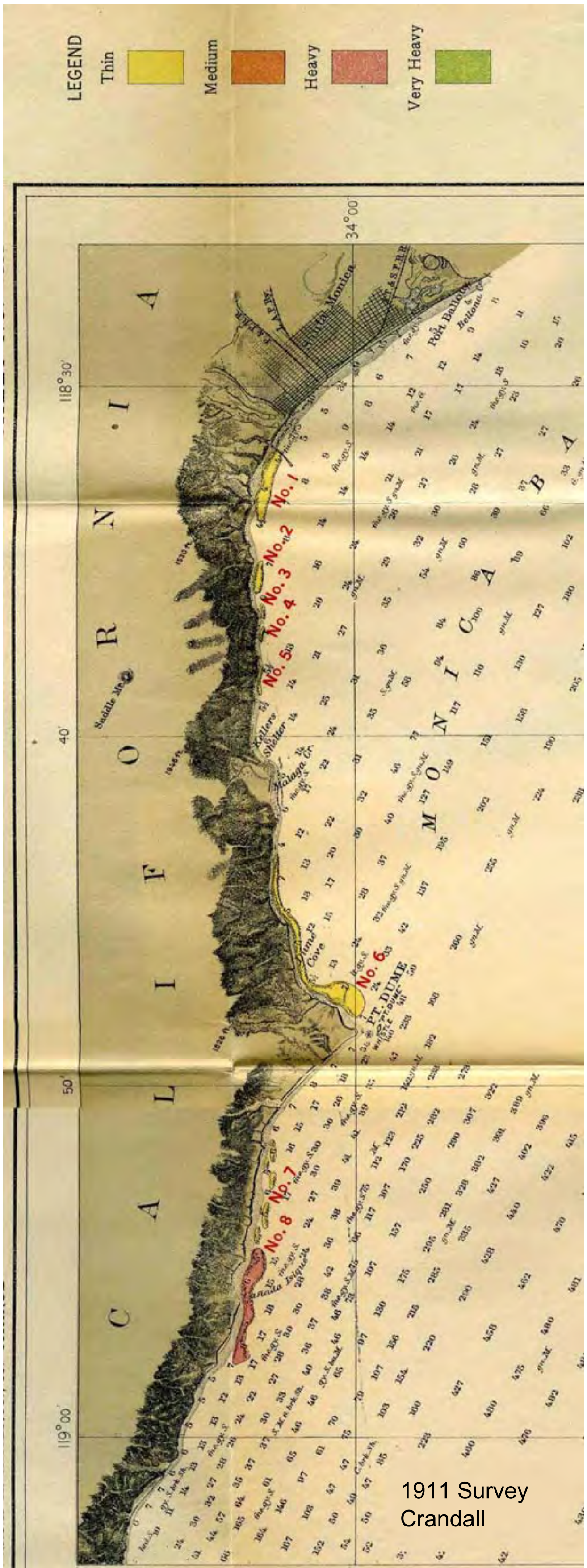
As these measurements indicate, most of the beds remain smaller than those of a century ago. Ongoing surveys attempt to determine what environmental factors have changed in the intervening years to cause such large declines.

Table 5. Canopy coverages in km² of the southern Orange County and San Diego County kelp beds from 1995 to 2014 surveys. Values approximate the maximum coverages for each year. Areal estimates derived from charts based on infrared aerial photographs.

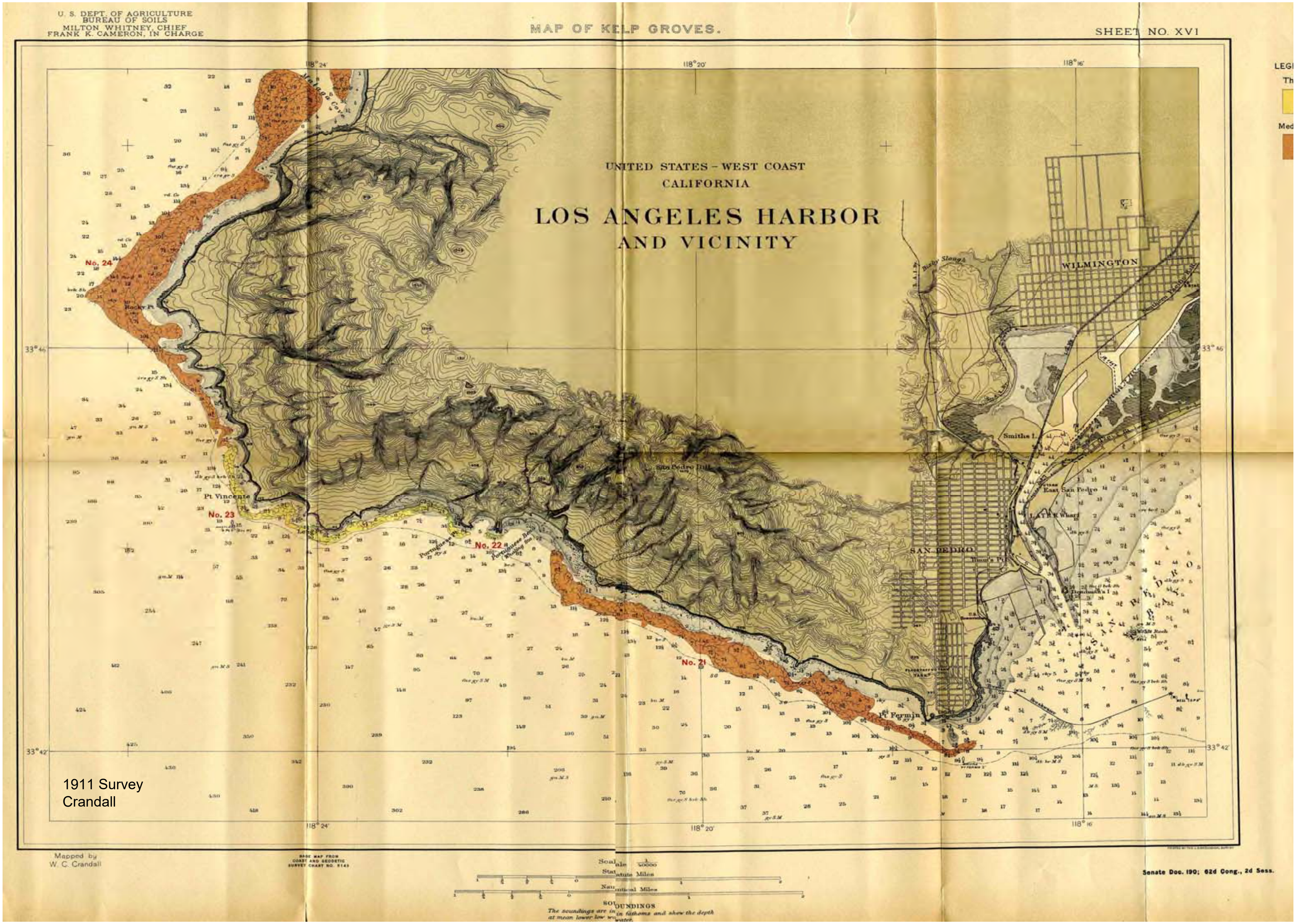
	Canopy Area (km²)																			
Kelp Bed	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
N Laguna Beach	-	0.001	-	-	-	-	-	-	0.0004	-	-	-	-	0.002	0.005	0.093	0.147	0.192	0.142	0.120
S Laguna Beach	-	-	-	-	-	-	-	0.005	0.0002	0.008	-	-	0.001	0.025	0.058	0.098	0.221	0.214	0.273	0.165
South Laguna	-	-	-	-	-	0.003	0.002	<0.001	0.004	0.009	0.003	-	0.004	0.023	0.017	0.023	0.018	0.017	0.038	0.031
Dana Pt/Salt Crk	0.076	0.061	0.034	0.005	0.080	0.170	0.314	0.432	0.303	0.278	0.123	-	0.302	1.068	0.892	0.839	0.442	0.607	0.835	0.528
Capistrano Beach	-	-	-	-	<0.001	<0.001	0.044	0.118	0.069	0.008	-	0.011	0.002	0.071	0.071	0.124	0.010	0.056	0.099	0.034
Total F&W 9	0.076	0.062	0.034	0.005	0.080	0.173	0.359	0.555	0.376	0.303	0.126	0.011	0.309	1.189	1.043	1.178	0.838	1.086	1.385	0.879
San Clemente	0.010	0.047	-	-	0.006	0.005	0.124	0.316	0.352	0.182	0.178	0.014	0.016	0.203	0.210	0.710	0.795	0.874	1.097	0.843
San Mateo Point	0.010	0.073	0.098	-	0.051	0.050	0.090	0.155	0.242	0.123	0.258	0.016	0.201	0.487	0.545	0.583	0.203	0.216	0.219	0.199
San Onofre	0.096	0.196	0.108	<0.001	0.005	0.020	0.041	0.030	0.162	0.109	0.065	-	0.320	0.476	0.419	0.458	0.127	0.191	0.767	0.584
Total F&W 8	0.116	0.316	0.206	-	0.062	0.075	0.255	0.501	0.755	0.414	0.501	0.030	0.536	1.166	1.174	1.750	1.124	1.281	2.083	1.627
Horno Canyon	-	-	-	-	-	0.002	0.034	-	0.001	-	-	-	0.015	0.083	0.018	0.081	-	0.008	0.125	0.055
Barn Kelp	0.172	0.204	0.178	-	0.310	0.375	0.547	0.667	0.492	0.075	0.064	-	0.466	0.858	0.926	0.500	0.095	0.442	0.868	0.741
Santa Margarita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.080	-
Total F&W 7	0.172	0.204	0.178	-	0.310	0.377	0.581	0.667	0.494	0.075	0.064	-	0.481	0.941	0.944	0.581	0.095	0.450	1.073	0.795
North Carlsbad	0.008	-	-	0.003	-	-	0.017	0.053	0.017	0.003	0.013	-	0.026	0.108	0.135	0.078	0.017	0.052	0.125	0.086
Agua Hedionda	0.008	0.009	-	-	-	-	-	<0.001	0.002	0.001	0.008	-	0.016	0.080	0.092	0.031	0.022	0.046	0.102	0.065
Encina Power Plant	0.058	0.032	0.013	-	-	0.002	0.029	0.097	0.178	0.067	0.001	-	0.081	0.306	0.215	0.176	0.084	0.216	0.352	0.221
Carlsbad St. Bch	0.025	0.013	-	-	-	0.003	0.023	0.047	0.002	0.0001	-	-	0.064	0.121	0.127	0.069	0.024	0.058	0.178	0.065
Total F&W 6	0.099	0.054	0.013	0.003	-	0.005	0.069	0.197	0.199	0.070	0.023	-	0.187	0.615	0.569	0.354	0.147	0.372	0.757	0.437
Leucadia	0.189	0.087	0.062	-	0.015	0.090	0.209	0.334	0.185	0.048	0.001	0.016	0.233	0.421	0.429	0.215	0.119	0.232	0.541	0.279
Encinitas	0.061	0.023	0.048	-	0.029	0.040	0.131	0.153	0.050	0.016	-	0.002	0.205	0.346	0.205	0.128	0.124	0.260	0.231	0.112
Cardiff	0.092	0.026	0.031	0.016	0.063	0.150	0.309	0.405	0.202	0.045	-	0.004	0.286	0.484	0.520	0.213	0.395	0.459	0.590	0.299
Solana Beach	0.134	0.003	0.073	0.009	0.091	0.200	0.407	0.488	0.245	0.022	0.093	0.0003	0.457	0.823	0.505	0.328	0.504	0.442	0.606	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	0.024	0.056	0.027
Torrey Pines	-	-	-	-	-	-	-	-	-	-	-	0.010	-	0.001	0.0004	0.003	0.031	0.034	0.081	-
Total F&W 5	0.558	0.139	0.214	0.029	0.198	0.486	1.071	1.415	0.712	0.131	0.094	0.032	1.218	2.133	1.703	0.925	1.247	1.452	2.106	1.221
La Jolla F & W 4	0.824	0.371	0.478	0.215	1.146	1.250	2.555	3.366	3.444	1.029	0.873	0.117	2.750	4.145	2.274	2.776	2.565	1.569	4.006	2.790
Point Loma F & W 3&2	1.134	1.187	2.235	0.295	1.725	3.290	6.574	3.799	4.509	1.924	2.152	1.767	3.616	6.623	4.909	3.977	4.212	5.340	5.127	5.121
Imperial Beach F & W 1	0.053	0.008	0.027	-	0.019	0.020	0.078	0.210	0.083	0.191	0.400	0.400	1.493	1.895	0.861	0.004	0.152	0.333	0.526	1.183
TOTAL	3.032	2.341	3.385	0.547	3.540	5.676	11.542	10.710	10.572	4.136	4.233	2.358	10.591	18.706	13.476	11.545	10.379	11.882	17.064	14.053

'NOTE: "-" = 0; Tr = Trace <100 m²

Sources: MBC 1994-2003; 2004b-2012b, 2013, 2014.

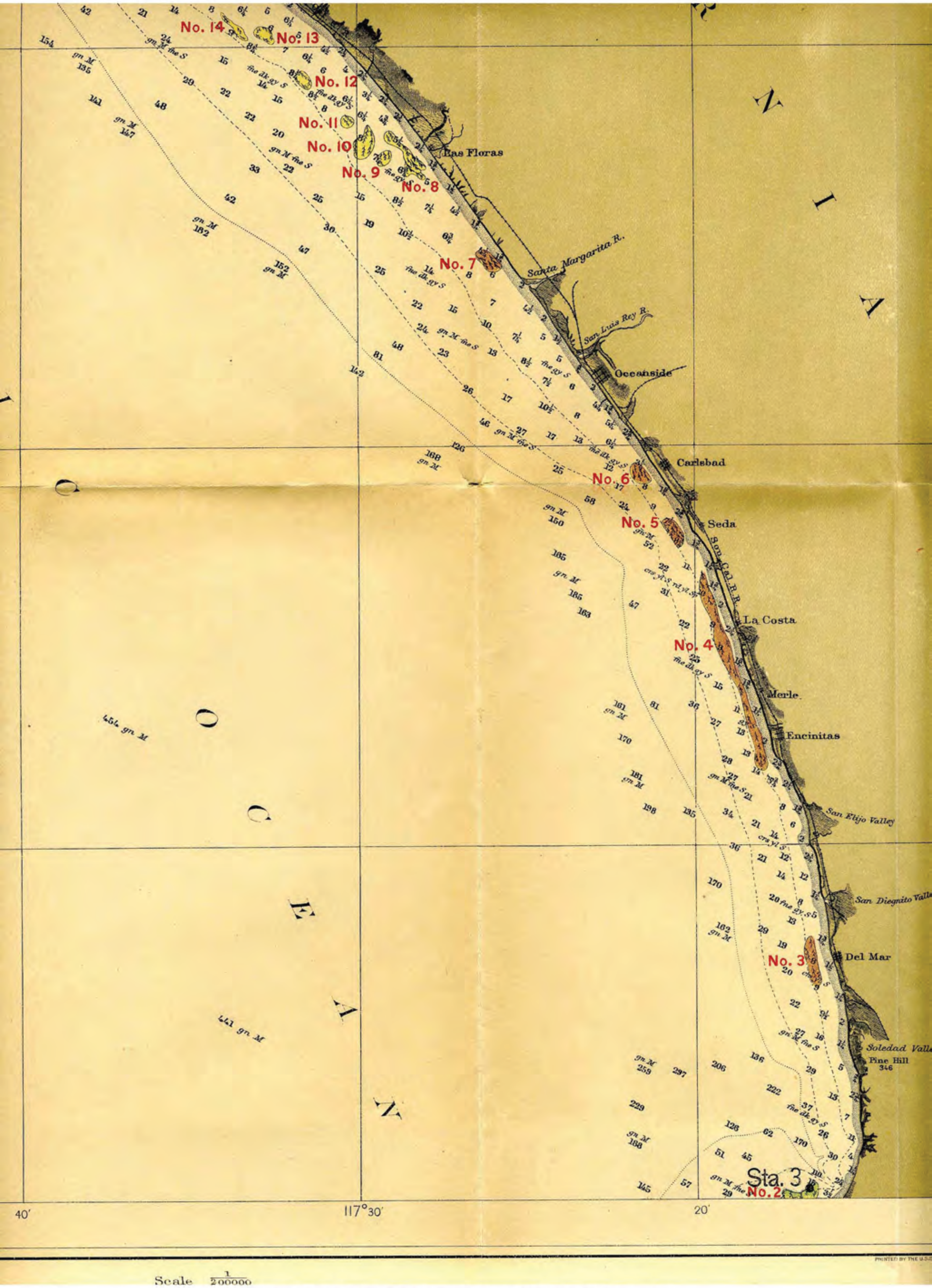


1911 Survey
Crandall

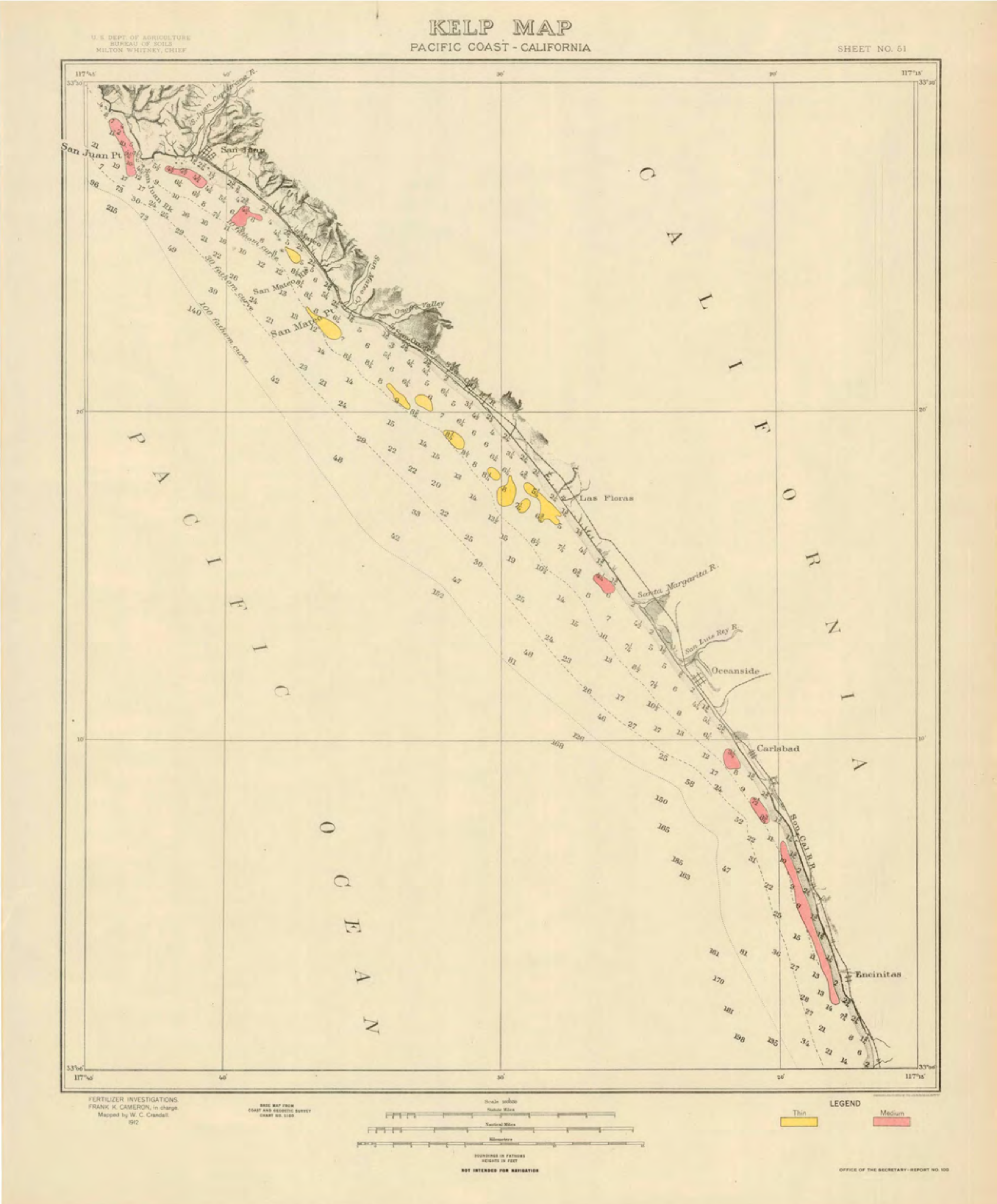


1911 Survey
Crandall

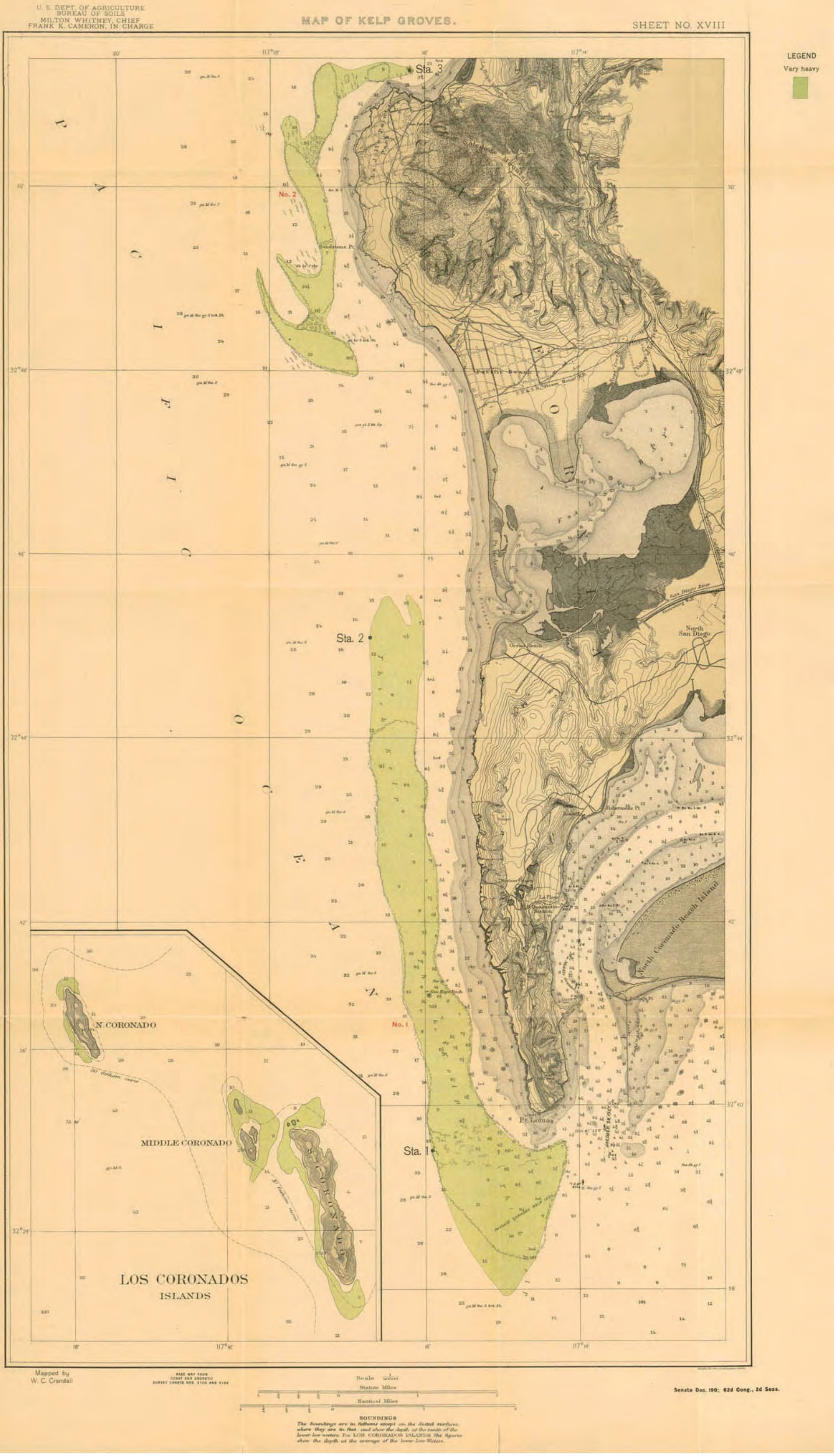
1911 Crandall kelp bed survey, Newport to San Onofre



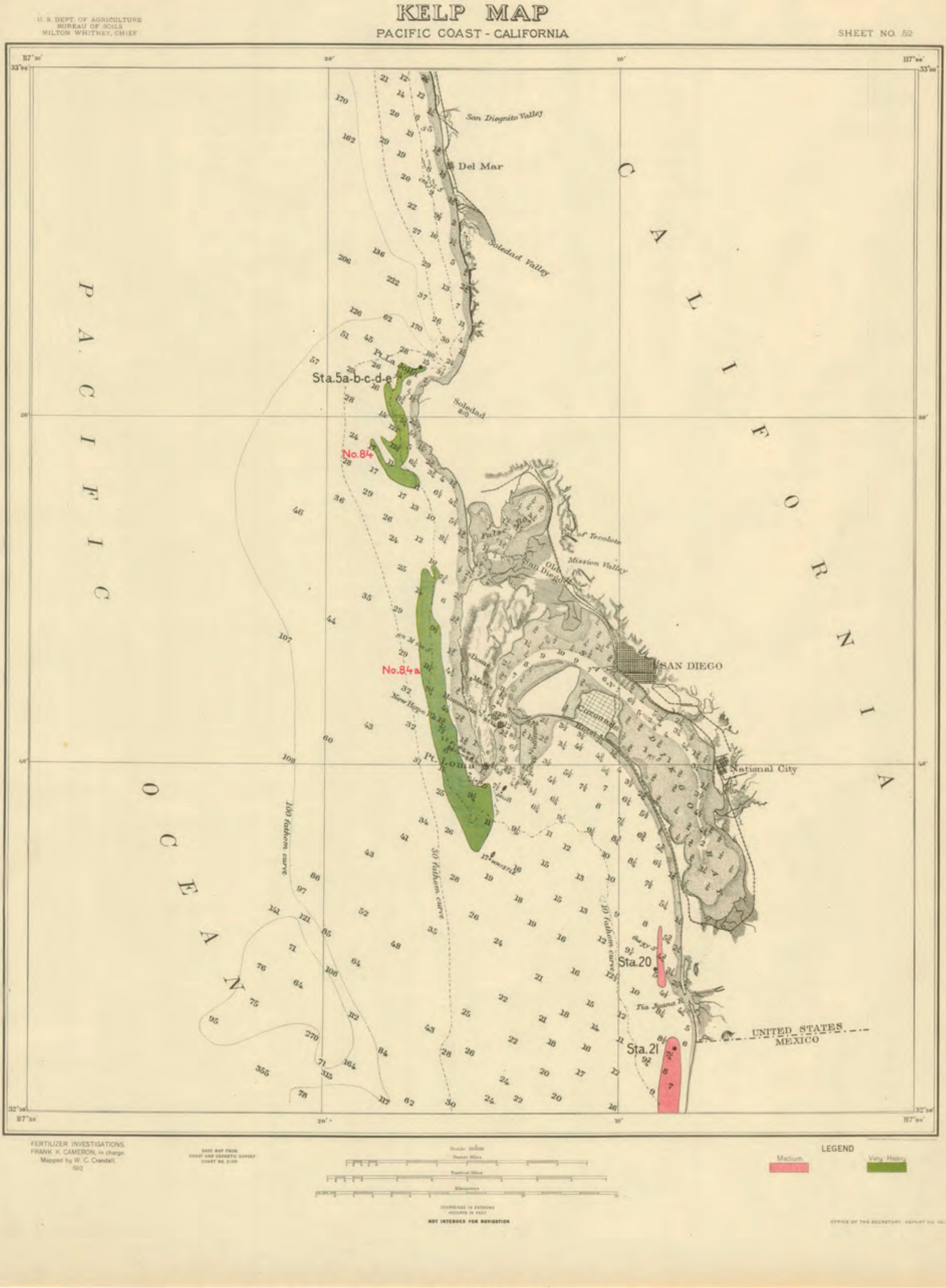
1911 Crandall kelp bed survey, San Onofre to Del Mar



1911 Crandall kelp bed survey, San Juan to Encinitas



1911 Crandall kelp bed survey, La Jolla to Point Loma

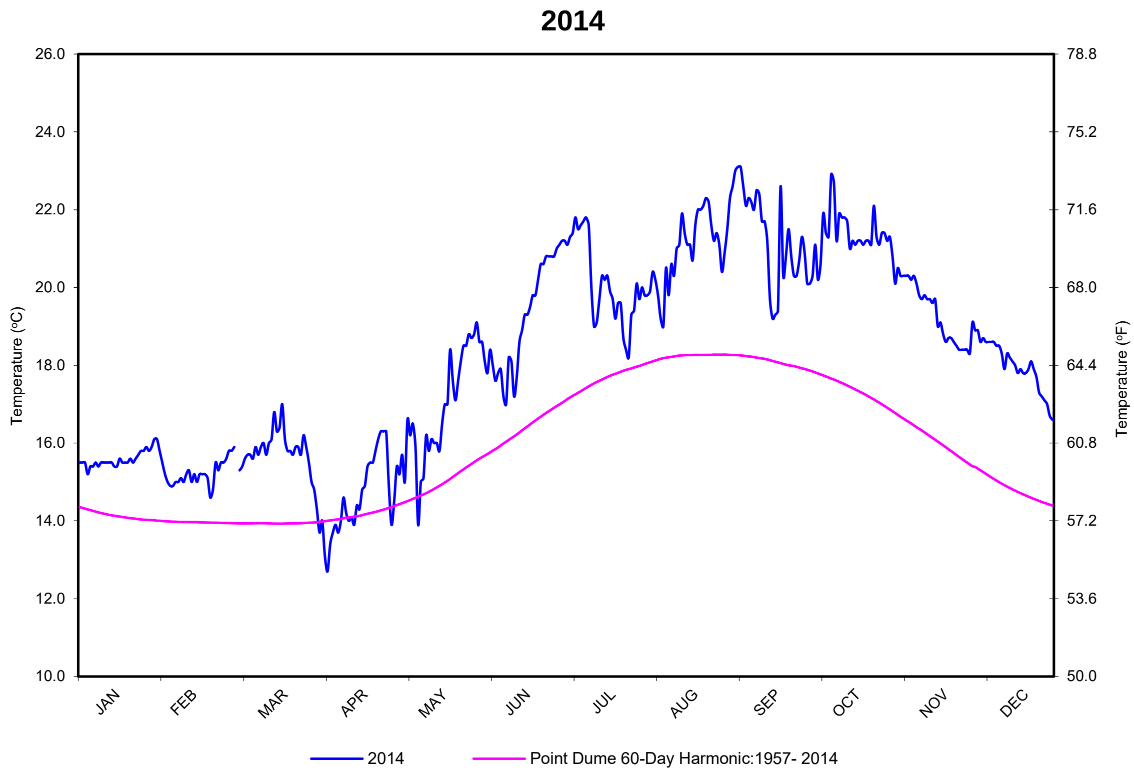


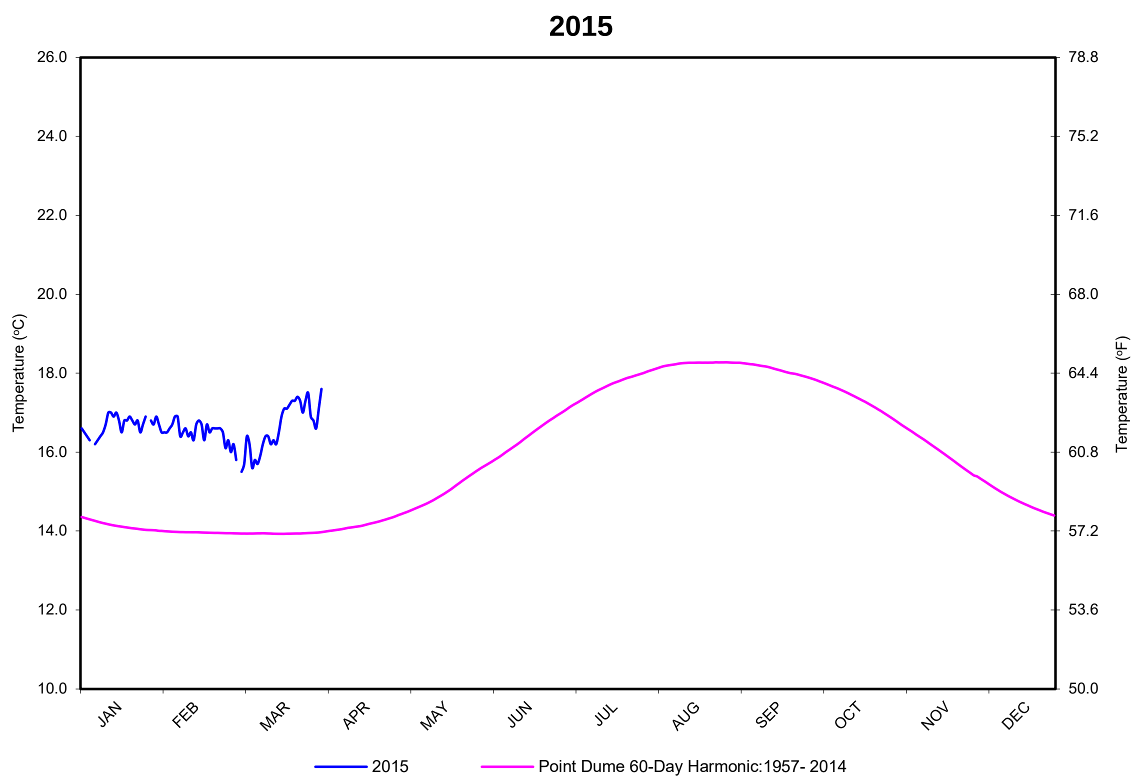
1911 Crandall kelp bed survey, La Jolla to Imperial Beach

APPENDIX C

Sea Surface Temperatures

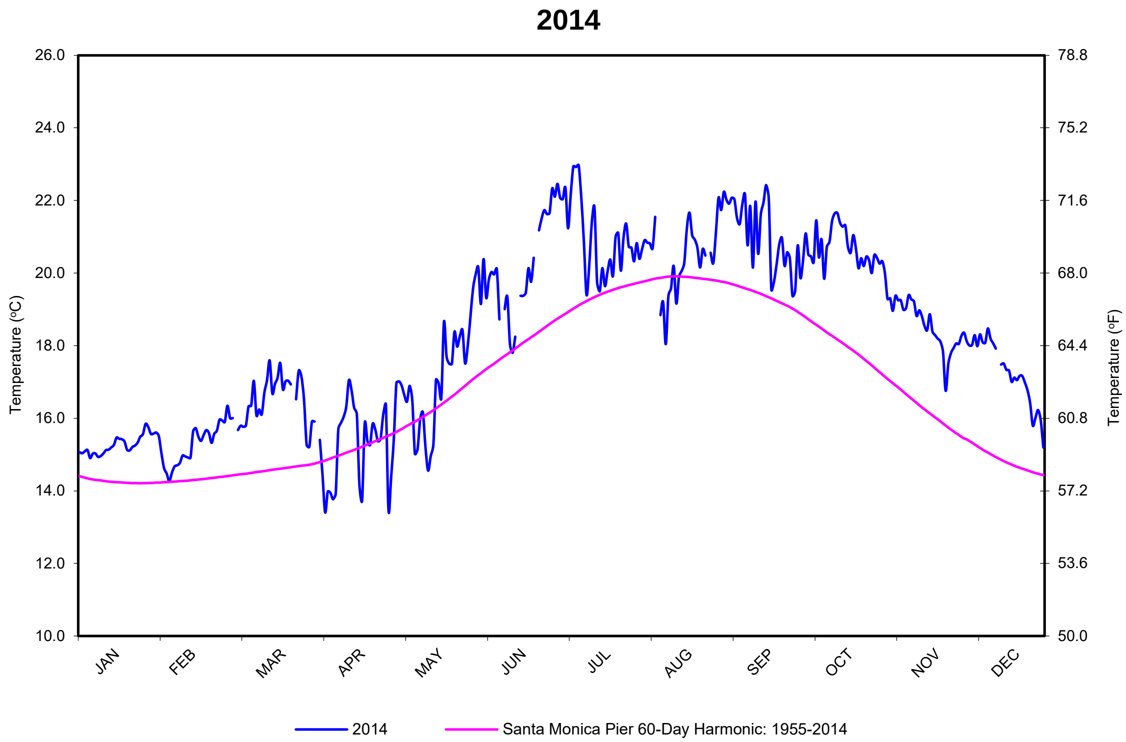
Point Dume
Sea Surface Temperature

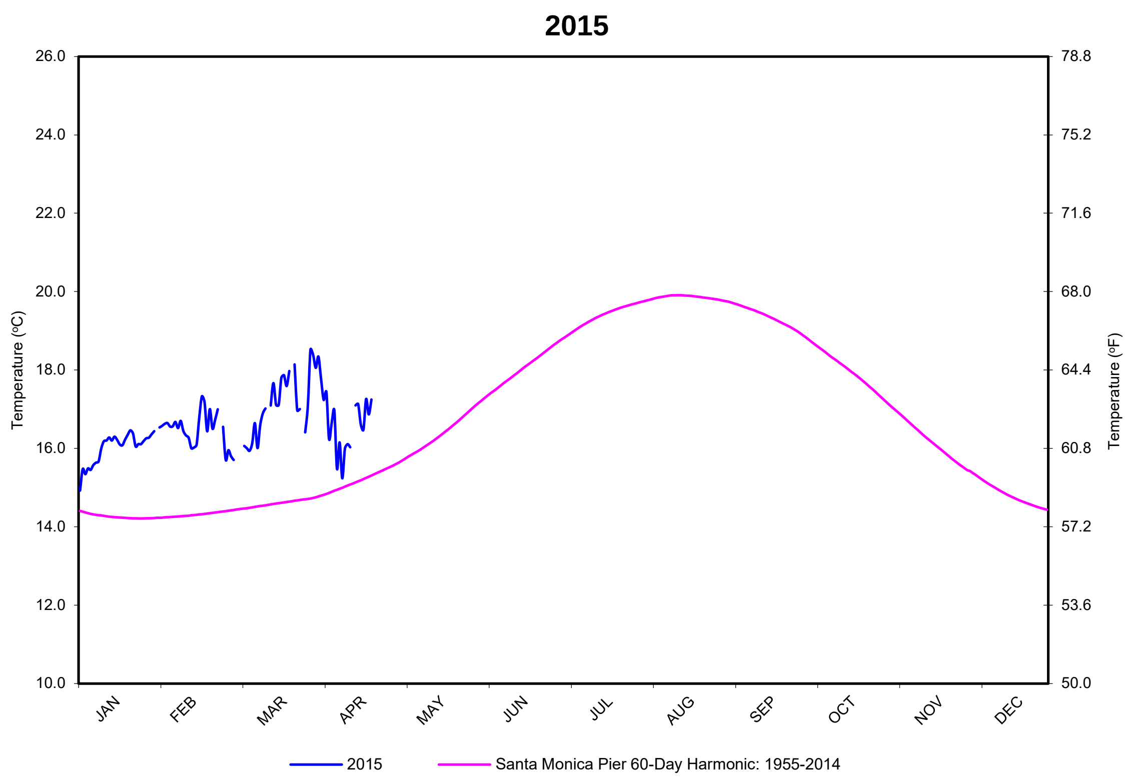




Daily sea surface temperatures (SST) at Point Dume for 2014 and through March 2015.

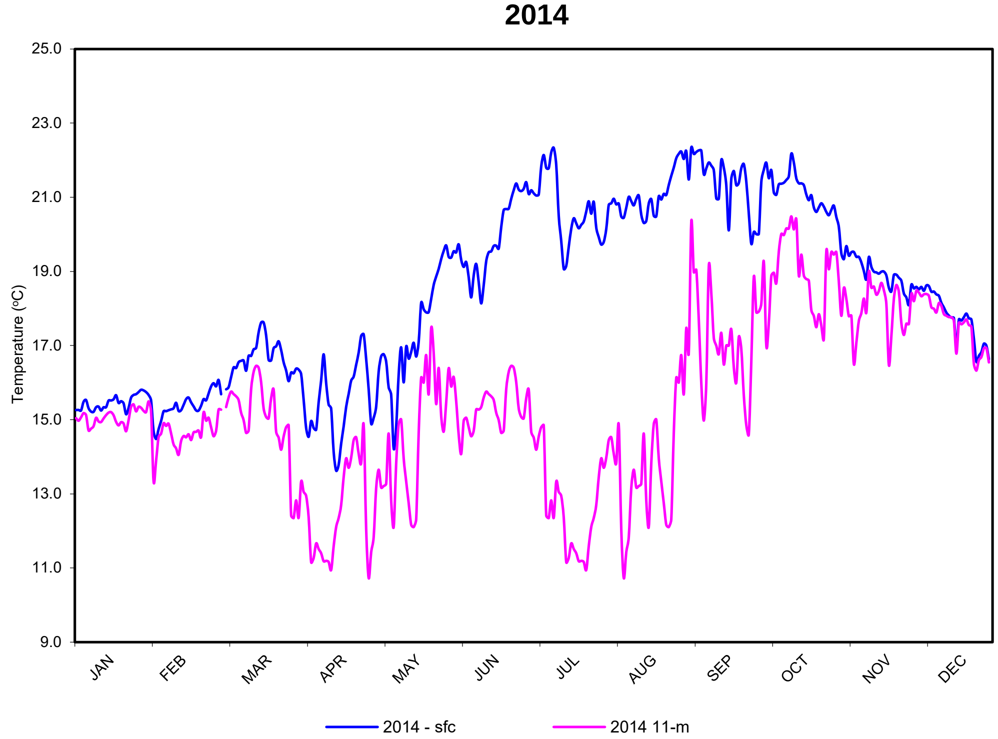
Santa Monica Pier
Sea Surface Temperature

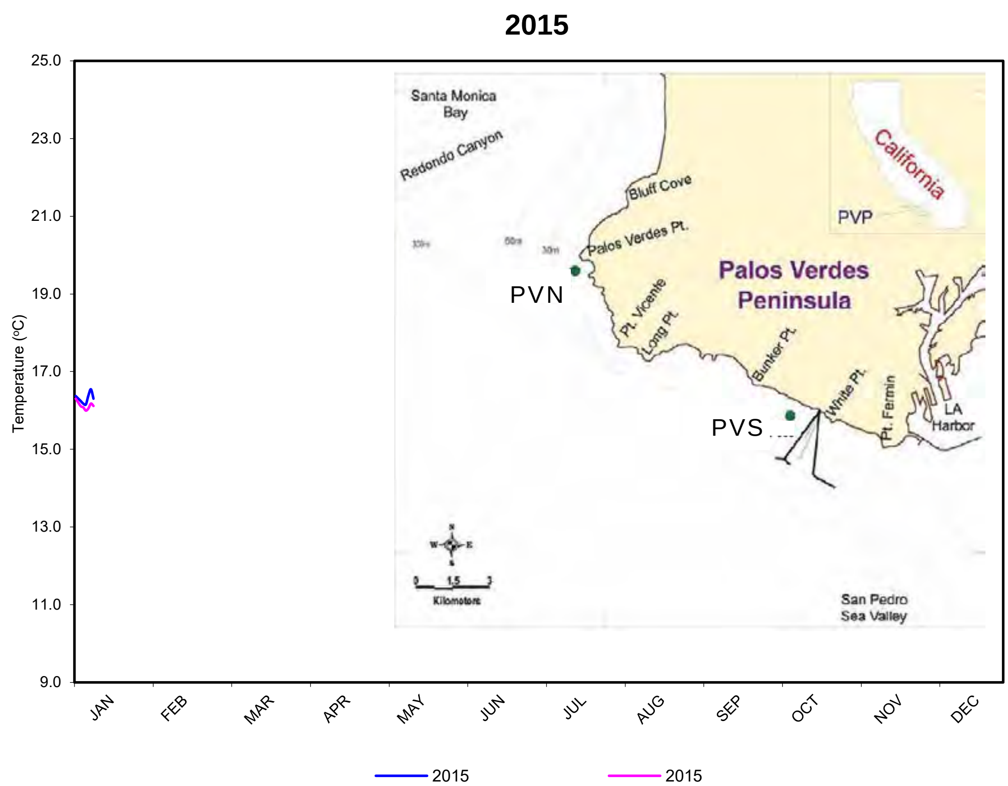




Daily sea surface temperatuares (SST) at Santa Monica Pier for 2014 and to April 2015.

Palos Verdes PVN
Sea Surface Temperature

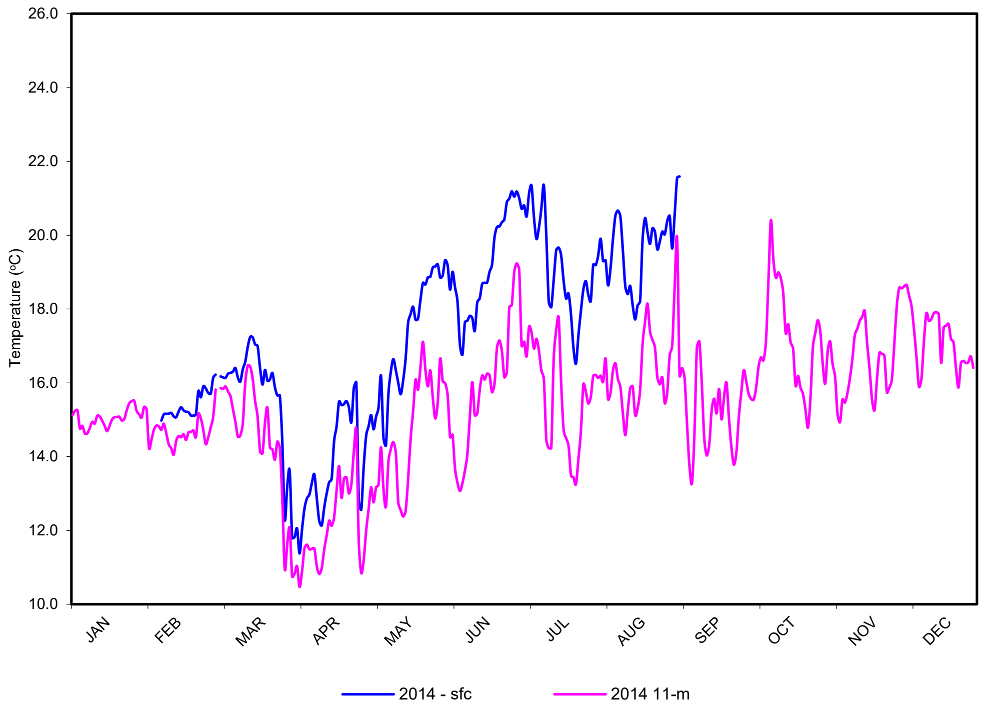




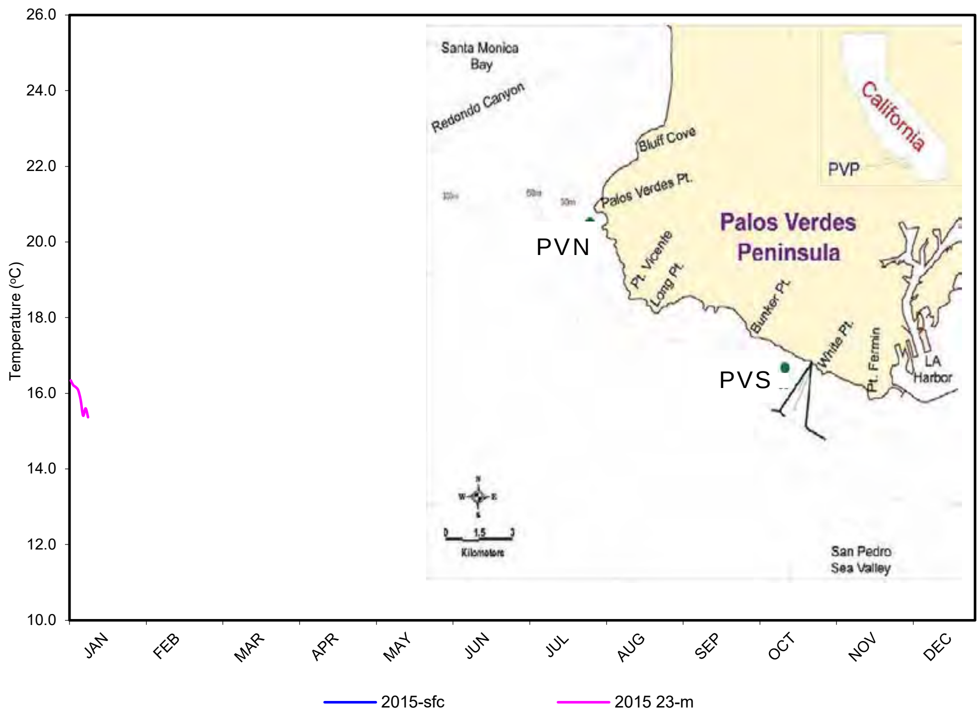
Daily sea surface temperatures (SST) at Station Palos Verdes North for 2014 and through January 15, 2015.

Palos Verdes PVS
Sea Surface Temperature

2014

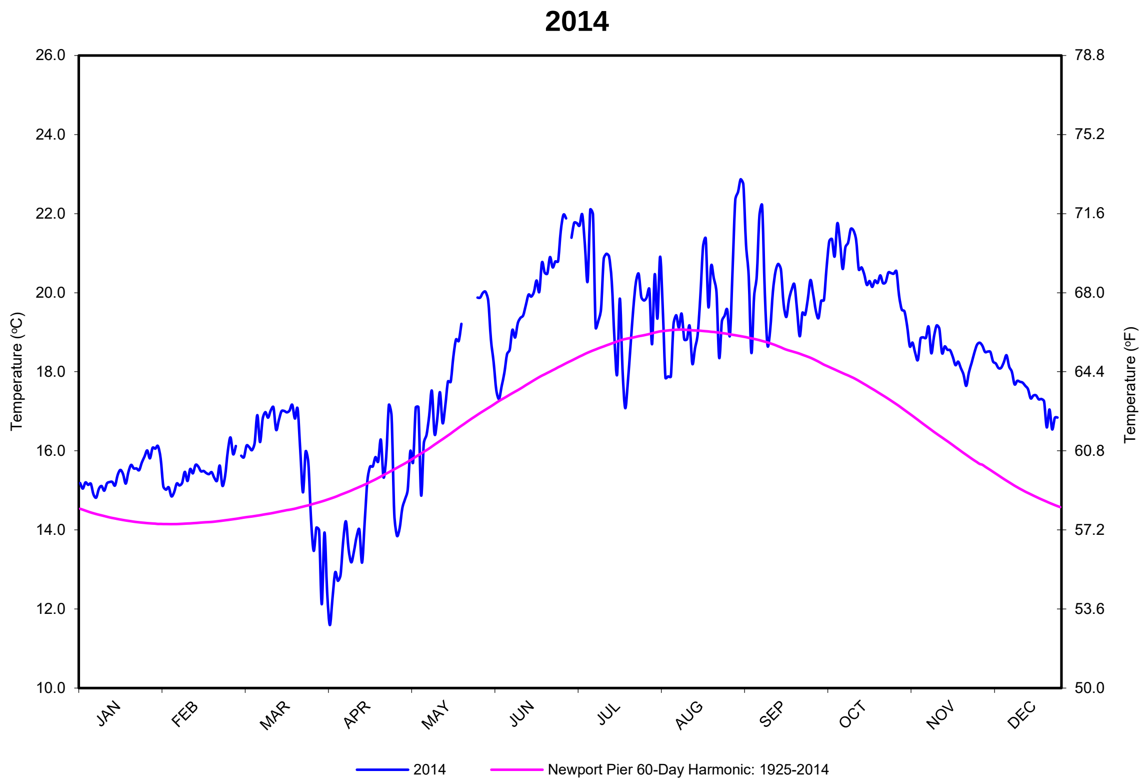


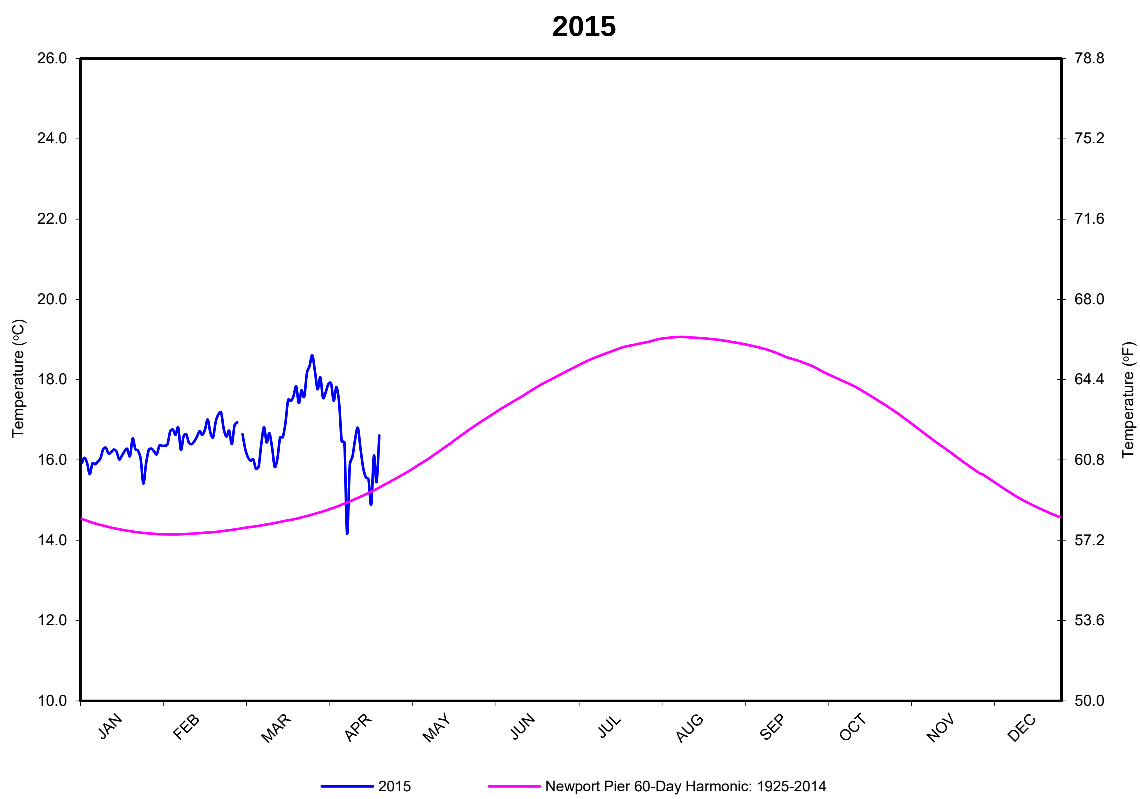
2015



Daily sea surface temperatures (SST) at Station Palos Verdes South for 2014 and through 8 January 2015. (Note: Temperatures taken at 23-m from 4 September 2014 through 8 January 2015.)

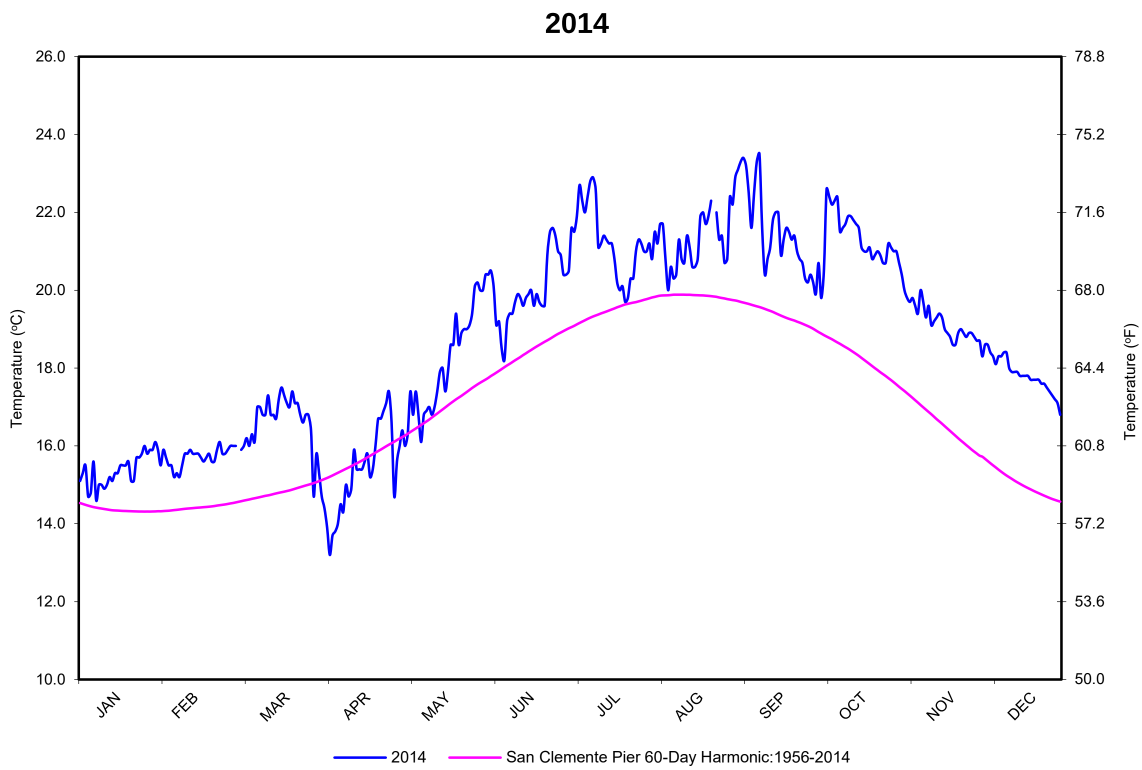
Newport Pier
Sea Surface Temperature

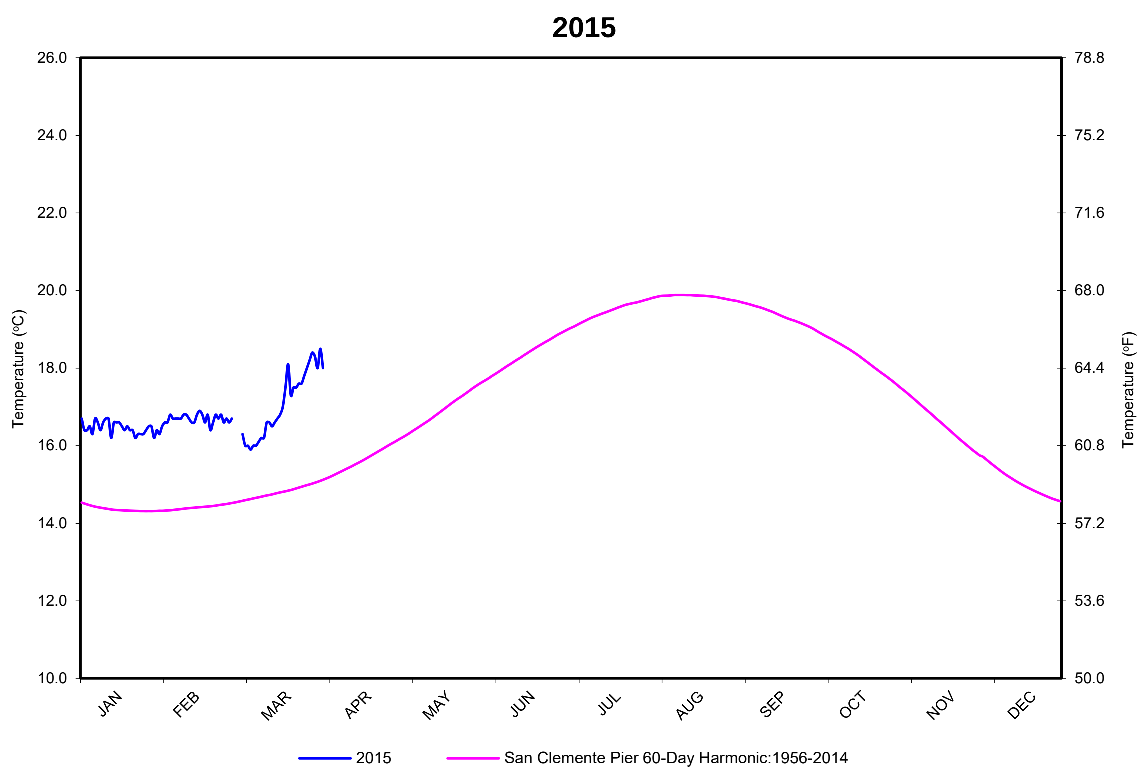




Daily sea surface temperatures (SST) at Newport Pier for 2014 and through May 2015.

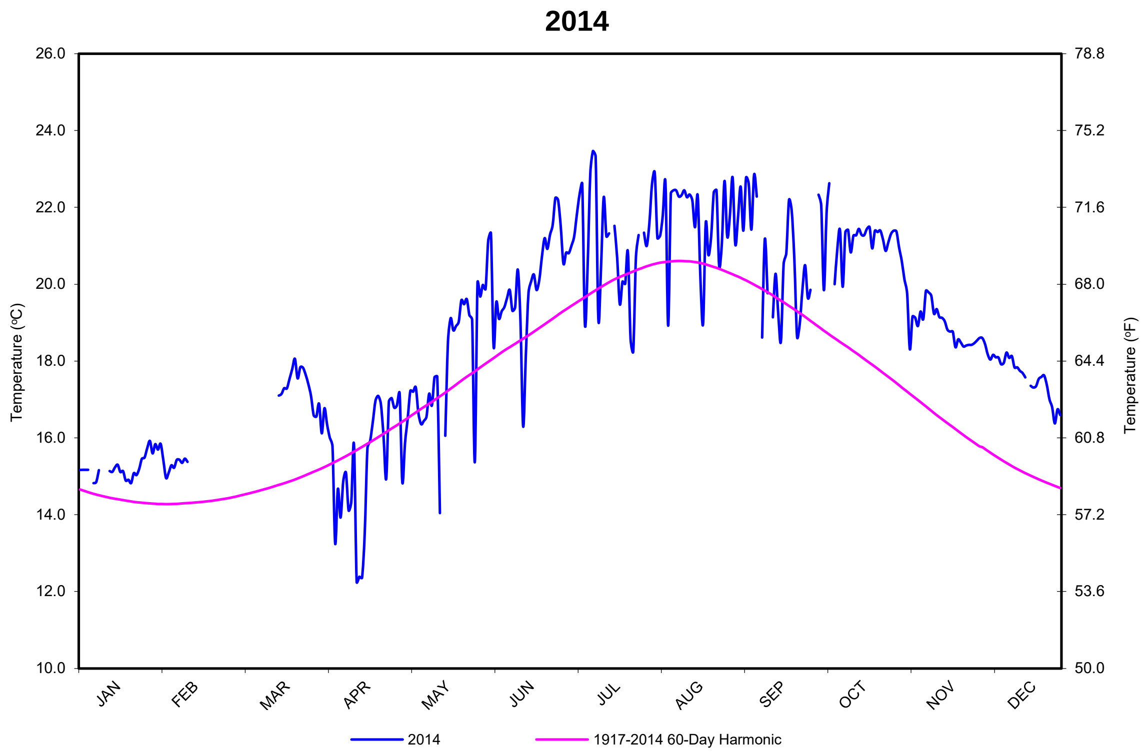
San Clemente Pier
Sea Surface Temperature

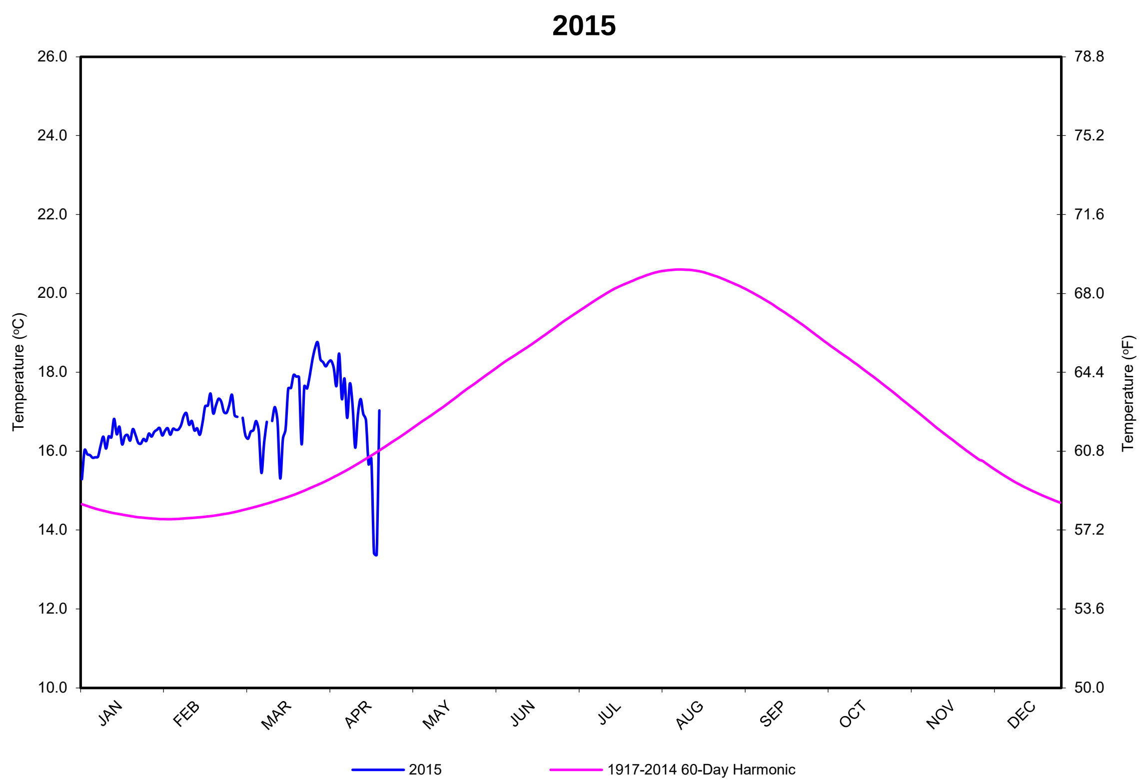




Daily sea surface temperatures (SST) at San Clemente for 2014 and through March 2015.

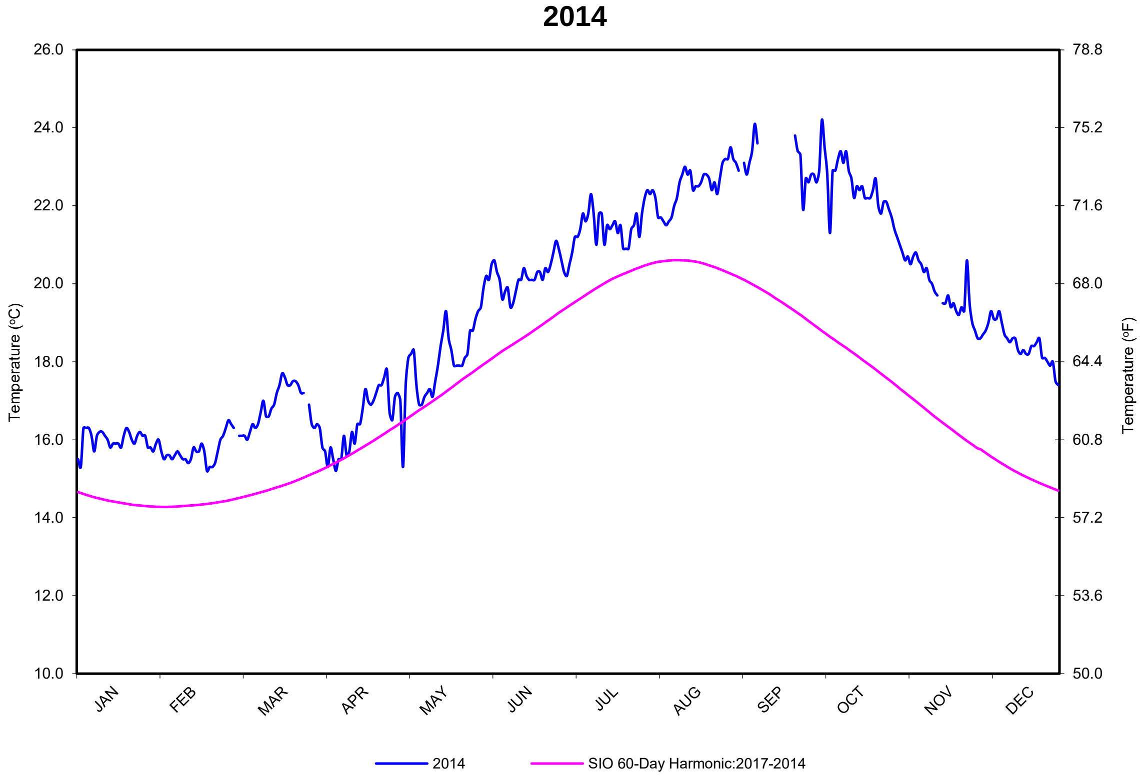
Scripps Pier
Sea Surface Temperature

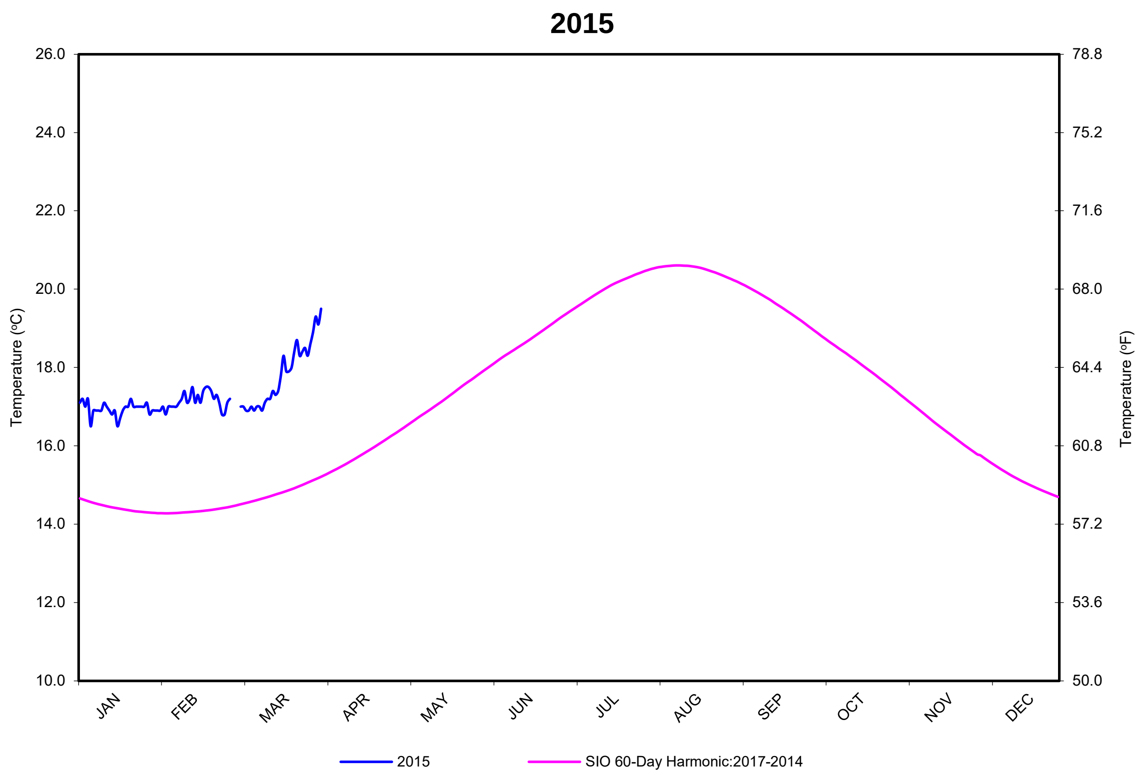




Daily sea surface temperatures (SST) at Scripps Pier for 2014 and to 21 April 2015.

Point Loma South
Sea Surface Temperature





Daily sea surface temperatures (SST) at Point Loma South for 2014 and to May 2015.

APPENDIX D

Flight Path (2013 Survey) and Flight Data Reports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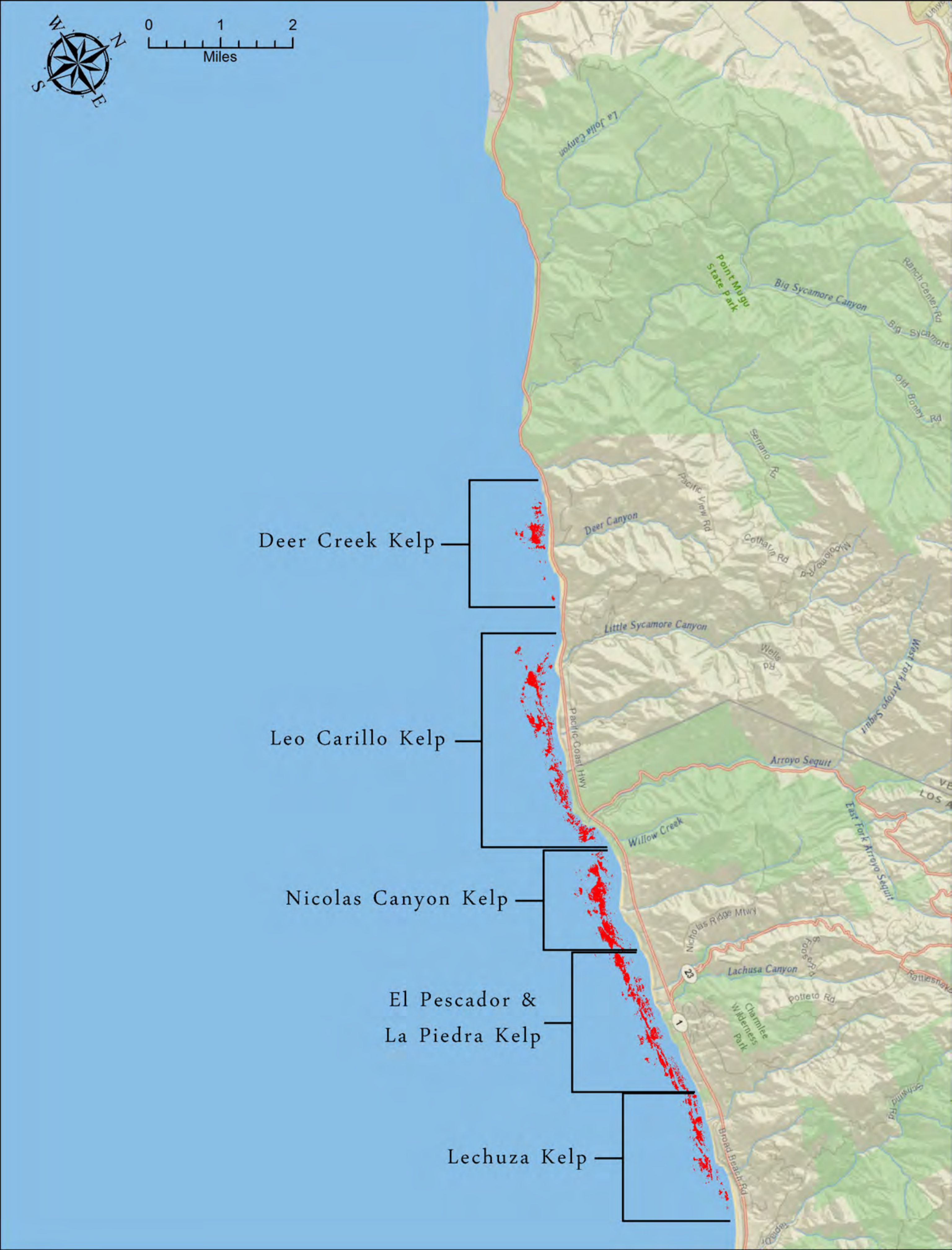
Miles
Ventura Marina
Channel Islands Harbor
Port Hueneme
Oxnard
Port Hueneme Naval Cbc
Port Hueneme
Santa Clara River
Olivas Links
Arundell Barranca
Southern Ca Edison Co Canal
Harbor Blvd
Coral Island



W
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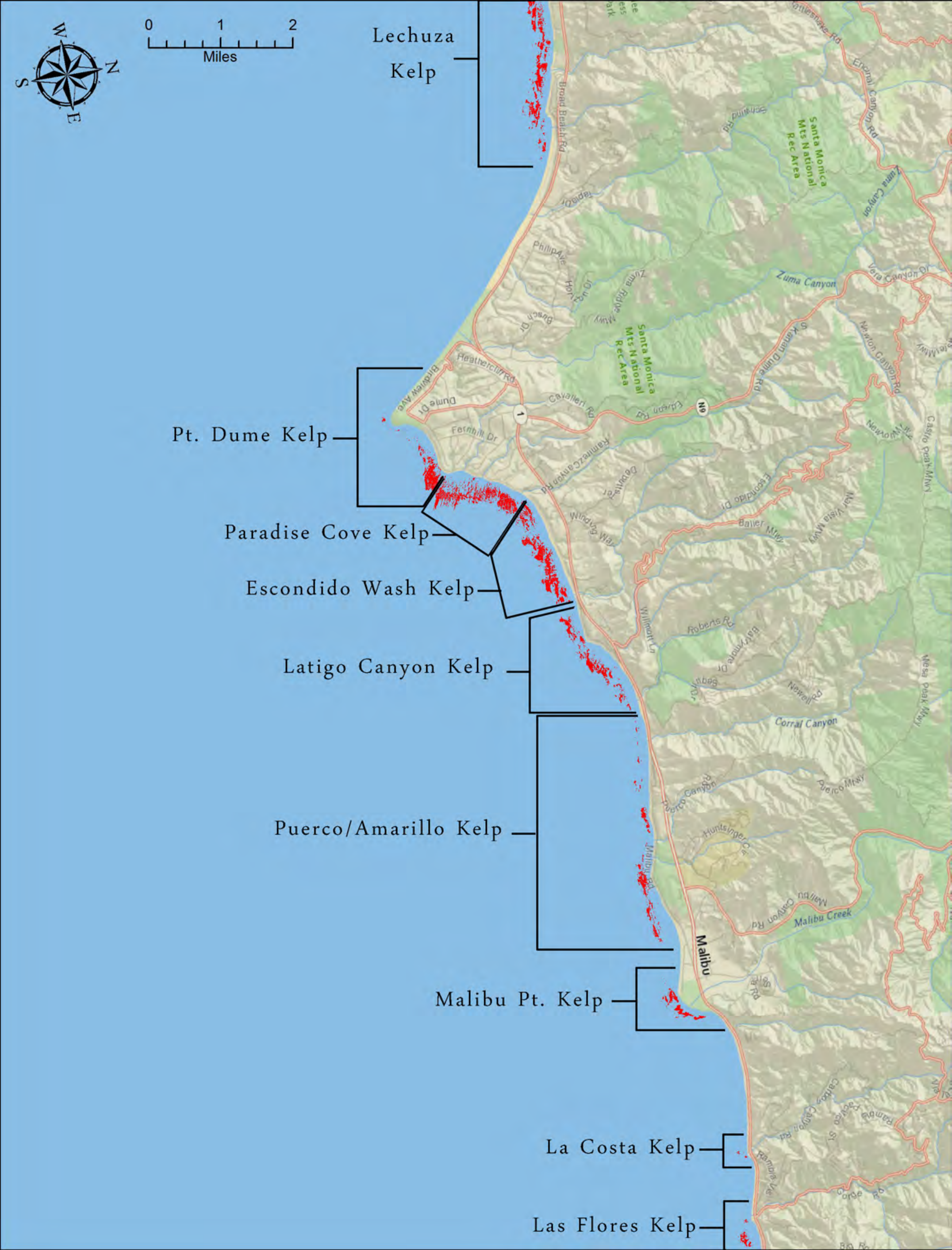
Miles
Deer Creek Kelp
Leo Carillo Kelp
Nicolas Canyon Kelp
El Pescador &
La Piedra Kelp
Lechuza Kelp
La Jolla Canyon
Point Mugu State Park
Big Sycamore Canyon
Ranch Center Rd
Serrano Rd
Pacific View Rd
Deer Canyon
Little Sycamore Canyon
Wells Rd
West Fork Arroyo Sequit
Pacific Coast Hwy
Arroyo Sequit
Willow Creek
East Fork Arroyo Sequit
Nicholas Ridge Mtwy
Lachusa Canyon
Charmlee Wilderness Park
Broad Beach Rd


0
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Miles
W
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Lechuza
Kelp
Pt. Dume Kelp
Paradise Cove Kelp
Escondido Wash Kelp
Latigo Canyon Kelp
Puerco/Amarillo Kelp
Malibu Pt. Kelp
La Costa Kelp
Las Flores Kelp
Santa Monica
Mts National
Rec Area
Malibu
Zuma Canyon
Corral Canyon
Malibu Creek
Broad Beach Rd
Encinal Canyon Rd
Heathercliff Rd
Dume Dr
Birdview Ave
Fernhill Dr
Cavalleri Rd
Ramirez Canyon Rd
Latigo Canyon
Escondido Dr
Winding Way
Baller Mtwy
Roberts Rd
Malibu Rd
Puerco Canyon Rd
Huntsinger Cir
Malibu Canyon Rd
Newell Rd
Puerco Mtwy
Mesa Peak Mtwy
Castro Peak Mtwy
Kanan Dume Rd
Newton Canyon Rd
Vera Canyon Dr
Zuma Ridge Mtwy
Philip Ave
Horizon Dr
Busch Dr
Rambla Vista
N9
1

La Costa Kelp
Las Flores Kelp
Big Rock Kelp
Las Tunas Kelp
Topanga Kelp
Sunset Kelp
Marina Del Rey
0
1
2
Miles
N
E
S
W
Topanga
Pacific Palisades
Santa Monica
Venice
Marina Del Rey
Playa Del Rey
Ballona Creek
Tuna Canyon
Topanga Canyon
Coastline Dr
Ocean Ave
Barnard Way
Lincoln Blvd
Ocean Park Blvd
Pacific Ave
Fiji Way
Culver Blvd


N
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W
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Miles
Marina del Rey
Hyperion Treatment Plant
Scattergood Generating Station
Chevron Refinery
El Segundo Generating Station
King Harbor, Redondo Beach
Venice
Marina Del Rey
Playa Del Rey
Los Angeles Intl Airport
El Segundo
Manhattan Beach
Hermosa Beach
Redondo Beach
Hawthorne
Lawndale
Alondra Golf Course
Ballona Creek

W
N
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0
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Miles
King Harbor
Palos Verdes IV
Palos Verdes III
Palos Verdes II
Palos Verdes I
Cabrillo Kelp
Hermosa Beach
Redondo Beach
Torrance
Palos Verdes Estates
Palos Verdes Peninsula
Rancho Palos Verdes
Rolling Hills Estates
Rolling Hills
Lomita
Harbor City
Torrance Municipal Airport
Defense Fuel Supply Point San Pedro
San Pedro
Wilmington
Los Angeles Harbor
Terminal Island
Paseo Del Mar
Palos Verdes Golf Club
Hawthorne Blvd
Crest Rd
Pacific Coast Hwy
Gaffey St
Anaheim St

POLA/POLB
0 1 2
Miles
N
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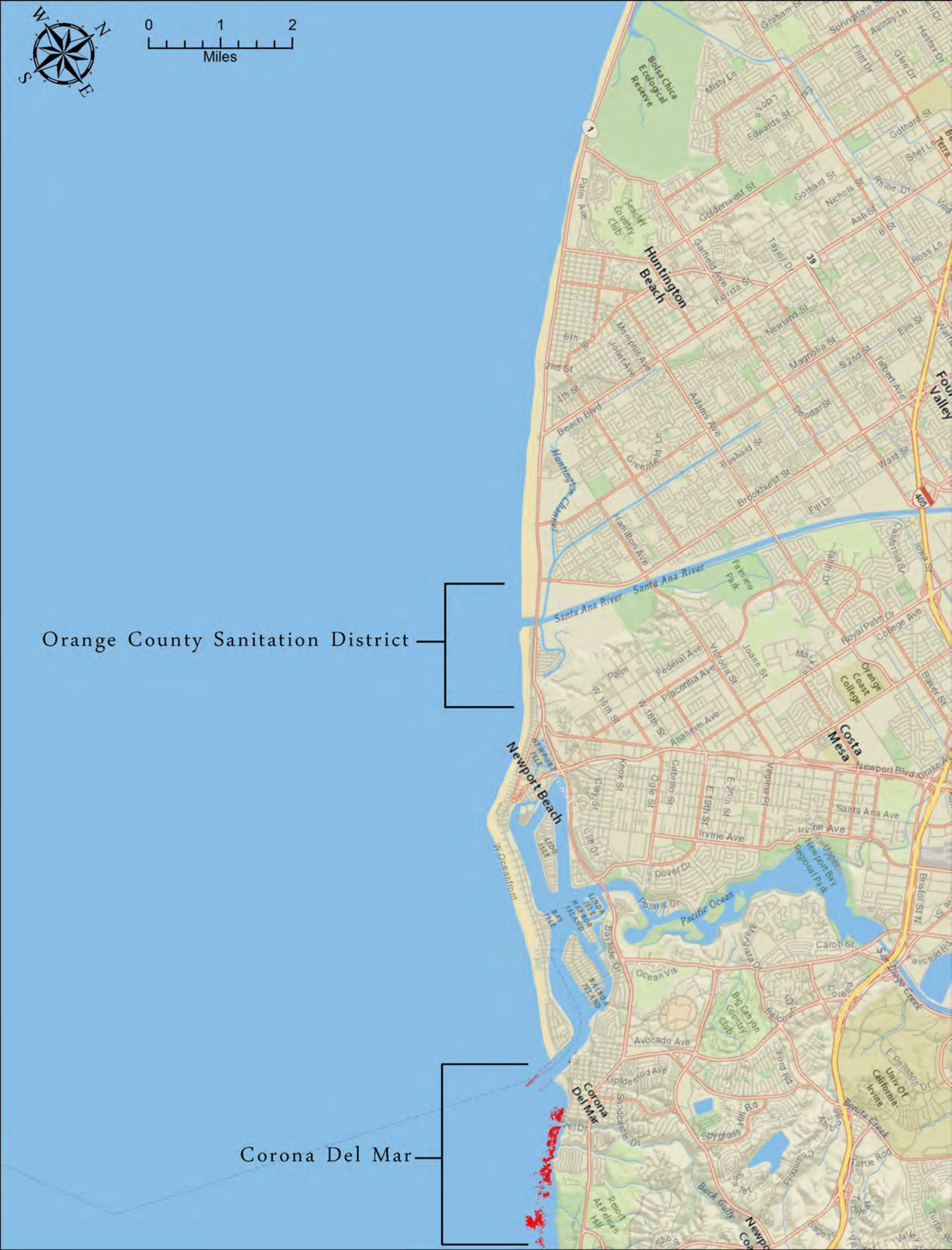
San Pedro
Wilmington
Los Angeles Harbor
Long Beach Harbor
Long Beach Harbor
Terminal Island
Los Angeles River
Pacific Ocean
Seal Beach
Surfside
Sunset Beach
Island Grissom
Island White
Island Freeman
Island Chaffee
Harbor Scenic Way
W Ocean Blvd
New Dock St
Pier A St
Pier E St
Pier F Ave
Pier J Ave
Alameda St
Anchorage Rd
Terminal Way
Paseo Del Mar
Pico Ave
E Ocean Blvd
Long Beach Blvd
Pacific Coast Hwy
Edinger Ave



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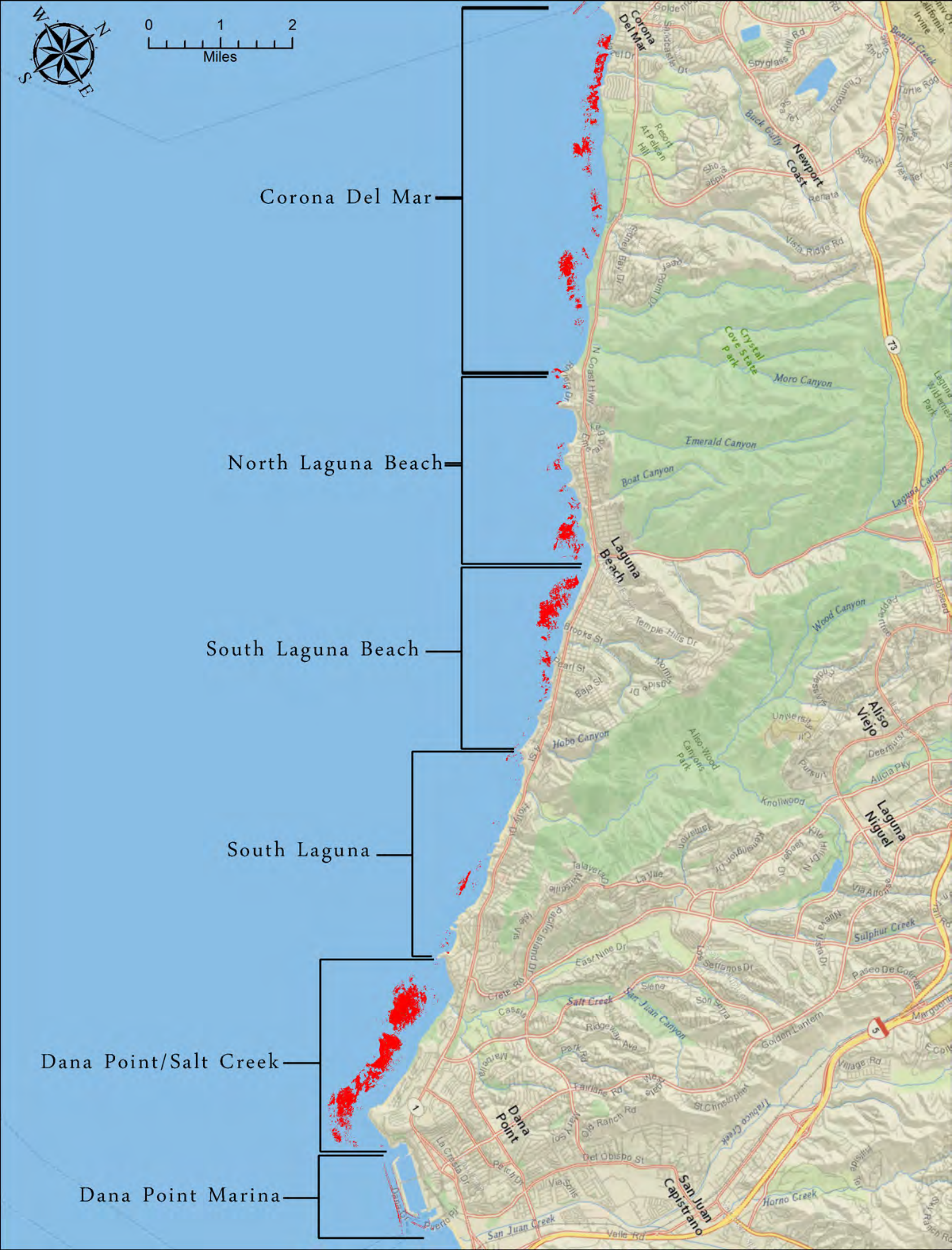
Miles
Orange County Sanitation District
Corona Del Mar
Huntington Beach
Newport Beach
Costa Mesa
Corona Del Mar
Santa Ana River
Bolsa Chica Ecological Reserve
Seacliff Country Club
Orange Coast College
Fairview Park
Upper Newport Bay Regional Park
Big Canyon Country Club
Univ Of California, Irvine
Huntington Channel
Pacific Ocean
Lido Isle
Balboa Island



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Miles
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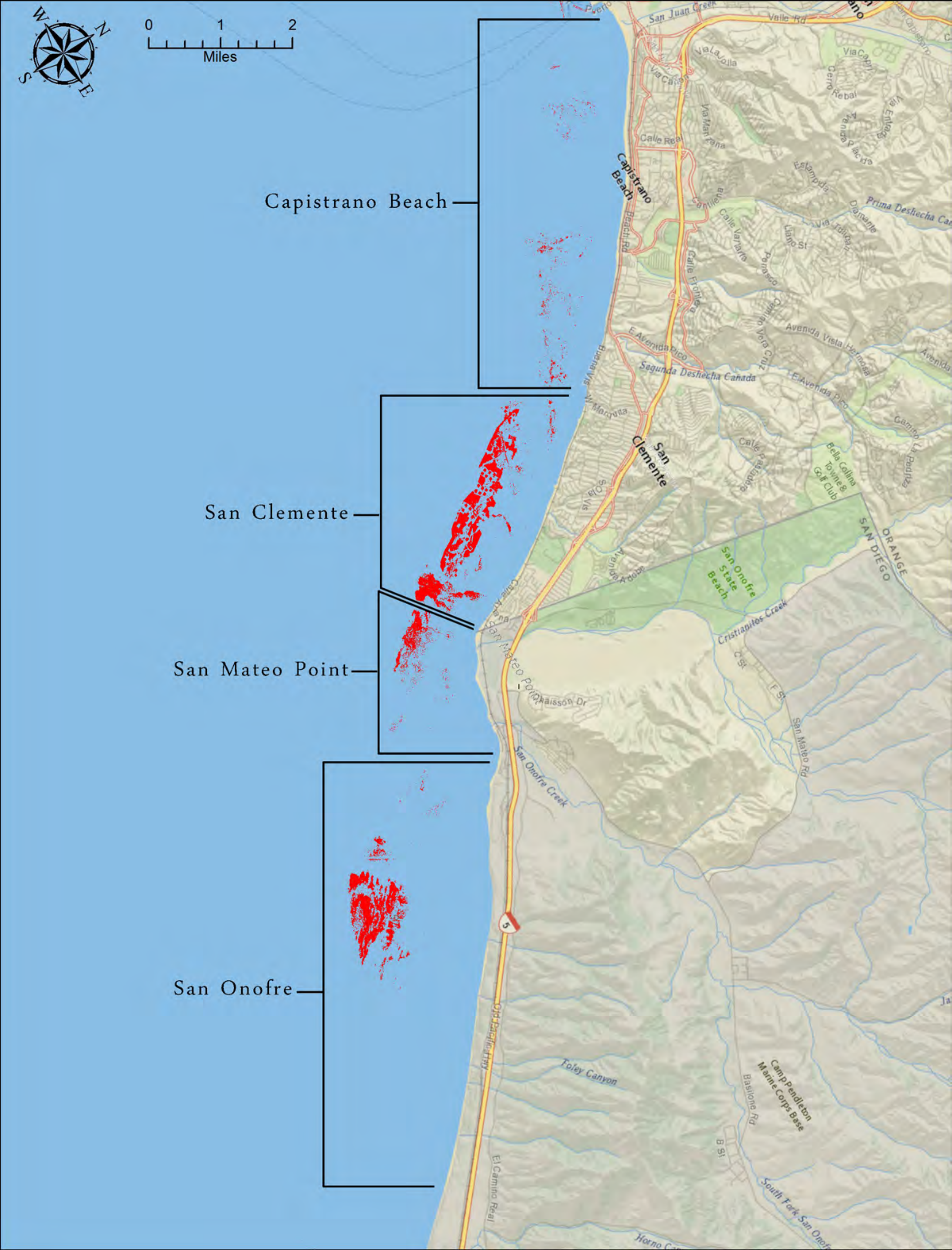
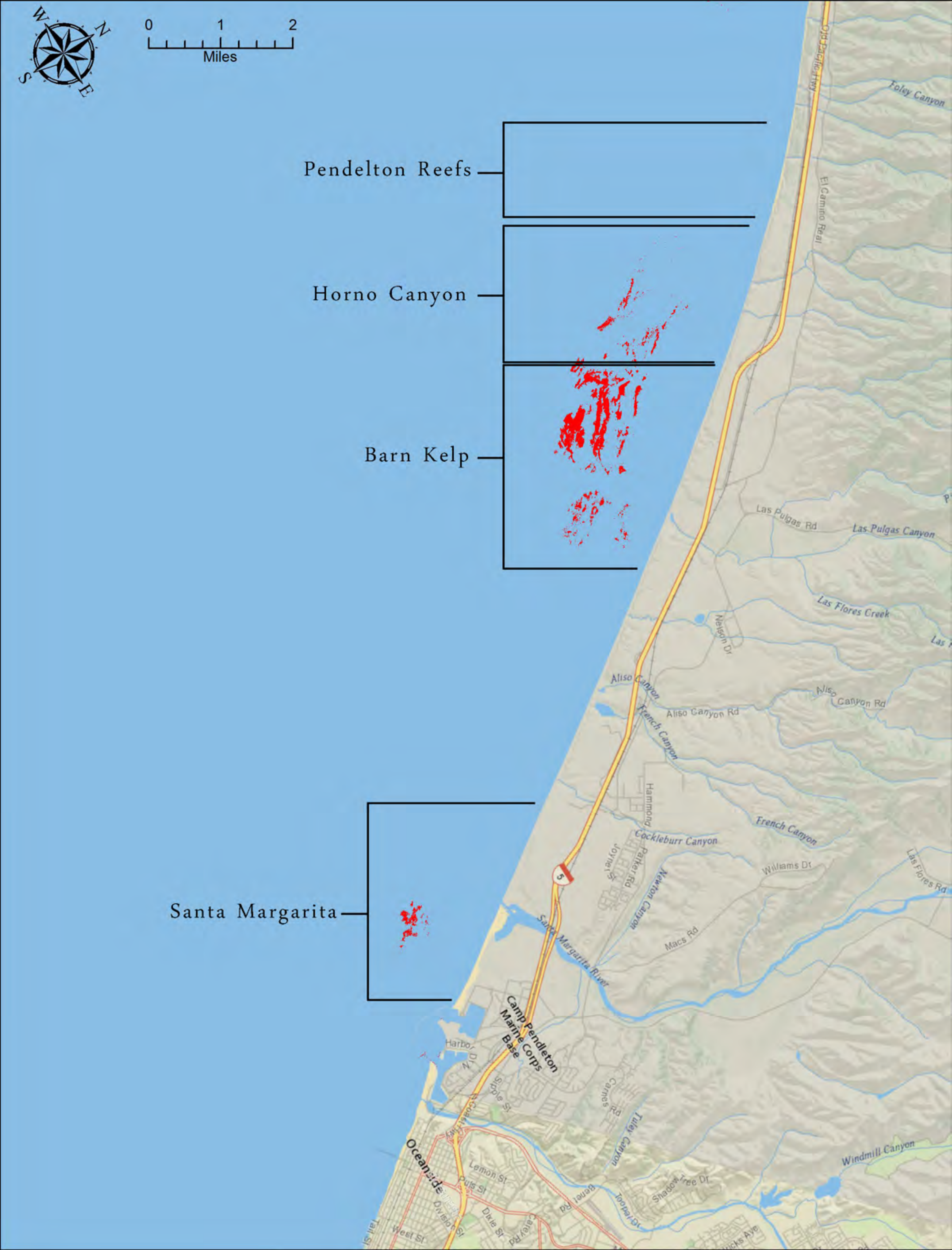
Corona Del Mar
North Laguna Beach
South Laguna Beach
South Laguna
Dana Point/Salt Creek
Dana Point Marina
Corona Del Mar
Newport Coast
Crystal Cove State Park
Moro Canyon
Emerald Canyon
Boat Canyon
Laguna Beach
Wood Canyon
Aliso Viejo
Aliso-Wood Canyons Park
Hobo Canyon
Laguna Niguel
Salt Creek
San Juan Canyon
Dana Point
San Juan Capistrano
San Juan Creek
Trabuco Creek
Horno Creek
Sulphur Creek
Laguna Canyon
Buck Gully
N Coast Hwy
73
5
1



0 1 2
Miles
Capistrano Beach
San Clemente
San Mateo Point
San Onofre
San Onofre State Beach
Cristianitos Creek
San Onofre Creek
Camp Pendleton Marine Corps Base
Foley Canyon
ORANGE
SAN DIEGO


W
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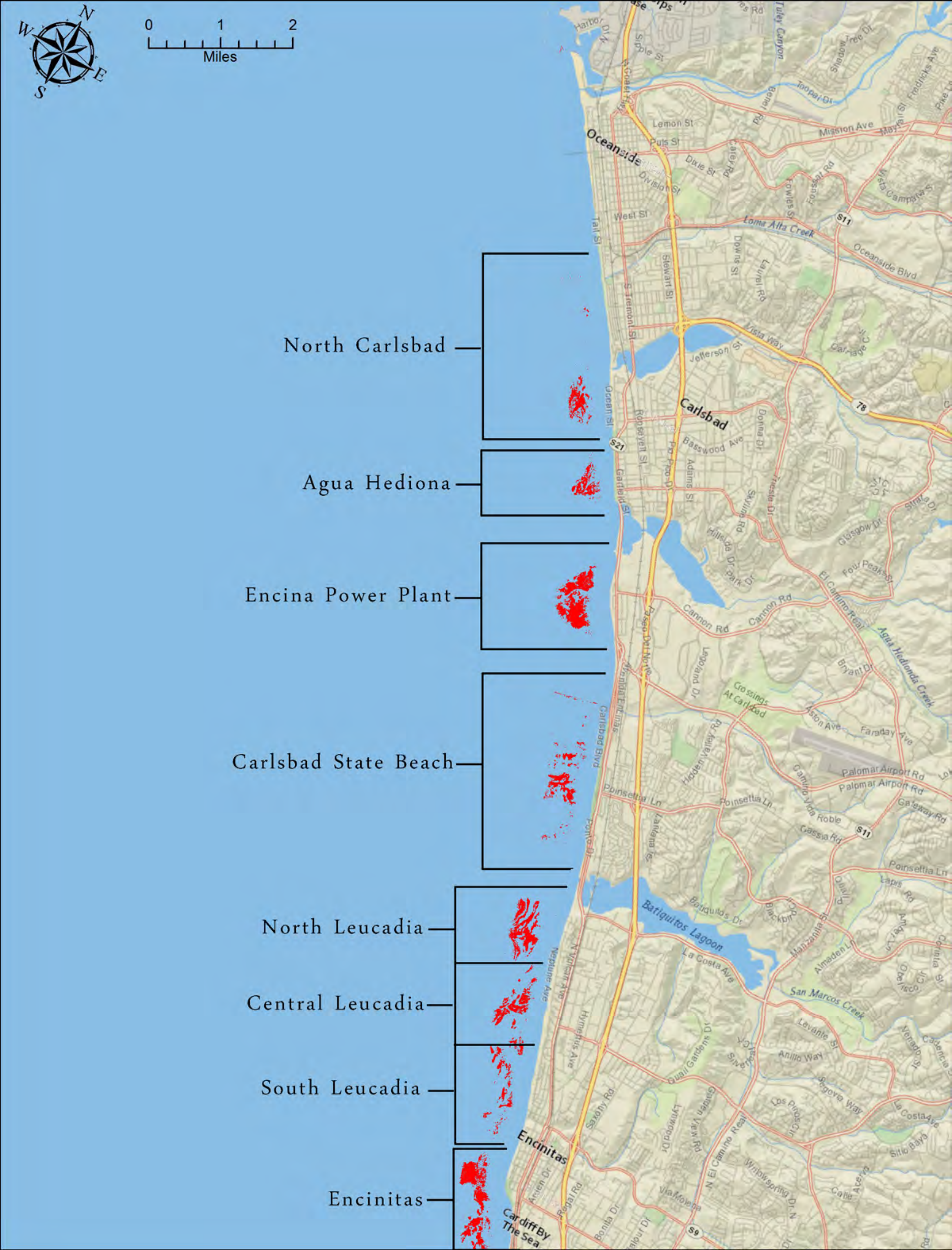
Miles
Pendelton Reefs
Horno Canyon
Barn Kelp
Santa Margarita
Old Pacific Hwy
Foley Canyon
El Camino Real
Las Pulgas Rd
Las Pulgas Canyon
Las Flores Creek
Nelson Dr
Aliso Canyon
Aliso Canyon Rd
French Canyon
Hammond
Cockleburr Canyon
Joyner St
Parker Rd
Newton Canyon
Williams Dr
Las Flores Rd
5
Santa Margarita River
Macs Rd
Camp Pendleton Marine Corps Base
Harbor Dr N
Stuart Mesa Rd
Carnes Rd
Tuley Canyon
Windmill Canyon
Oceanside
Lemon St
Shadow Tree Dr
Division St
Dixie St
West St
Hicks Ave


N
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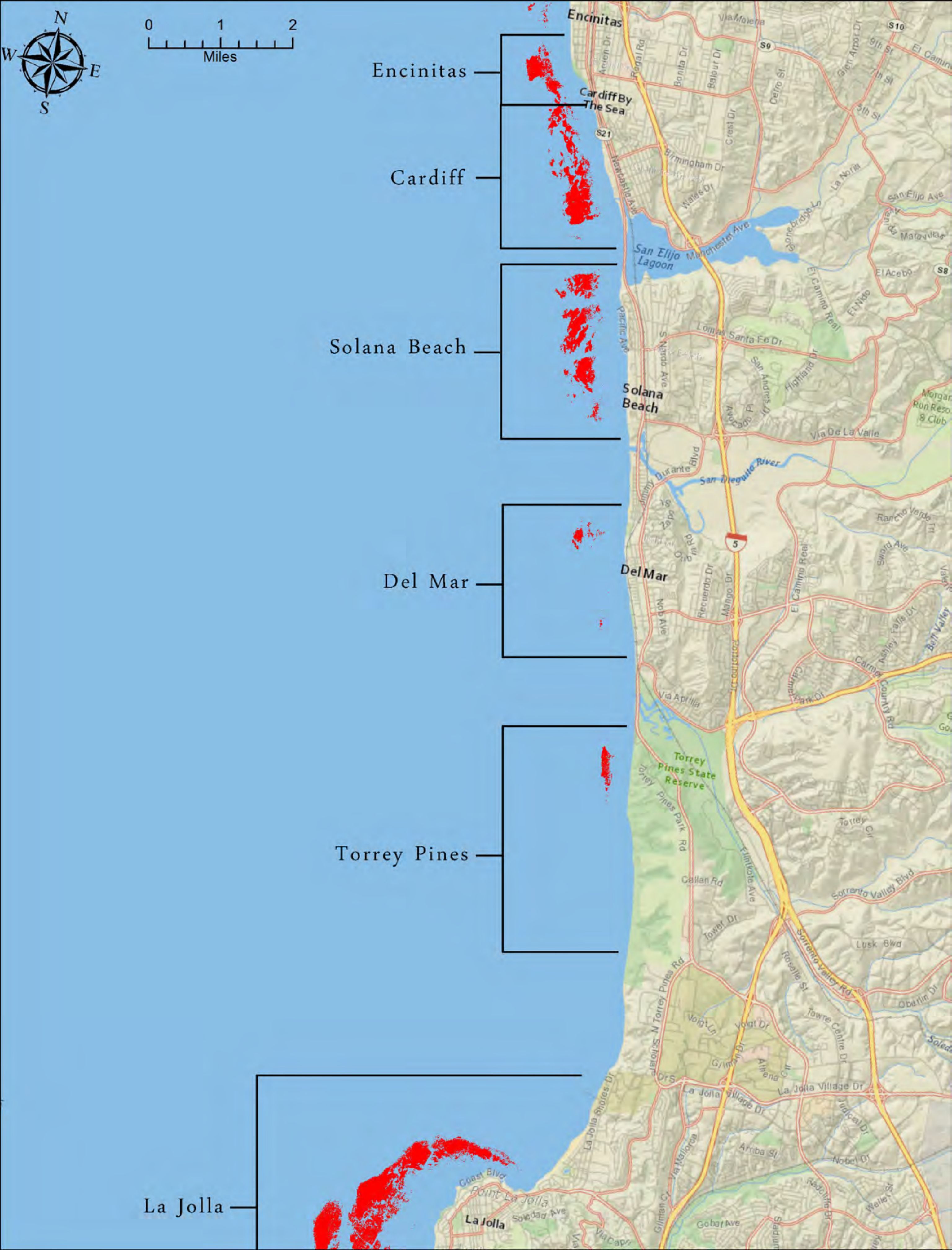
Miles
North Carlsbad
Agua Hediona
Encina Power Plant
Carlsbad State Beach
North Leucadia
Central Leucadia
South Leucadia
Encinitas
Oceanside
Carlsbad
Encinitas
Cardiff By The Sea
Batiquitos Lagoon
Loma Alta Creek
Agua Hedionda Creek
San Marcos Creek
Mission Ave
Oceanside Blvd
Vista Way
Cannon Rd
Palomar Airport Rd
Poinsettia Ln
La Costa Ave
Carlsbad Blvd
El Camino Real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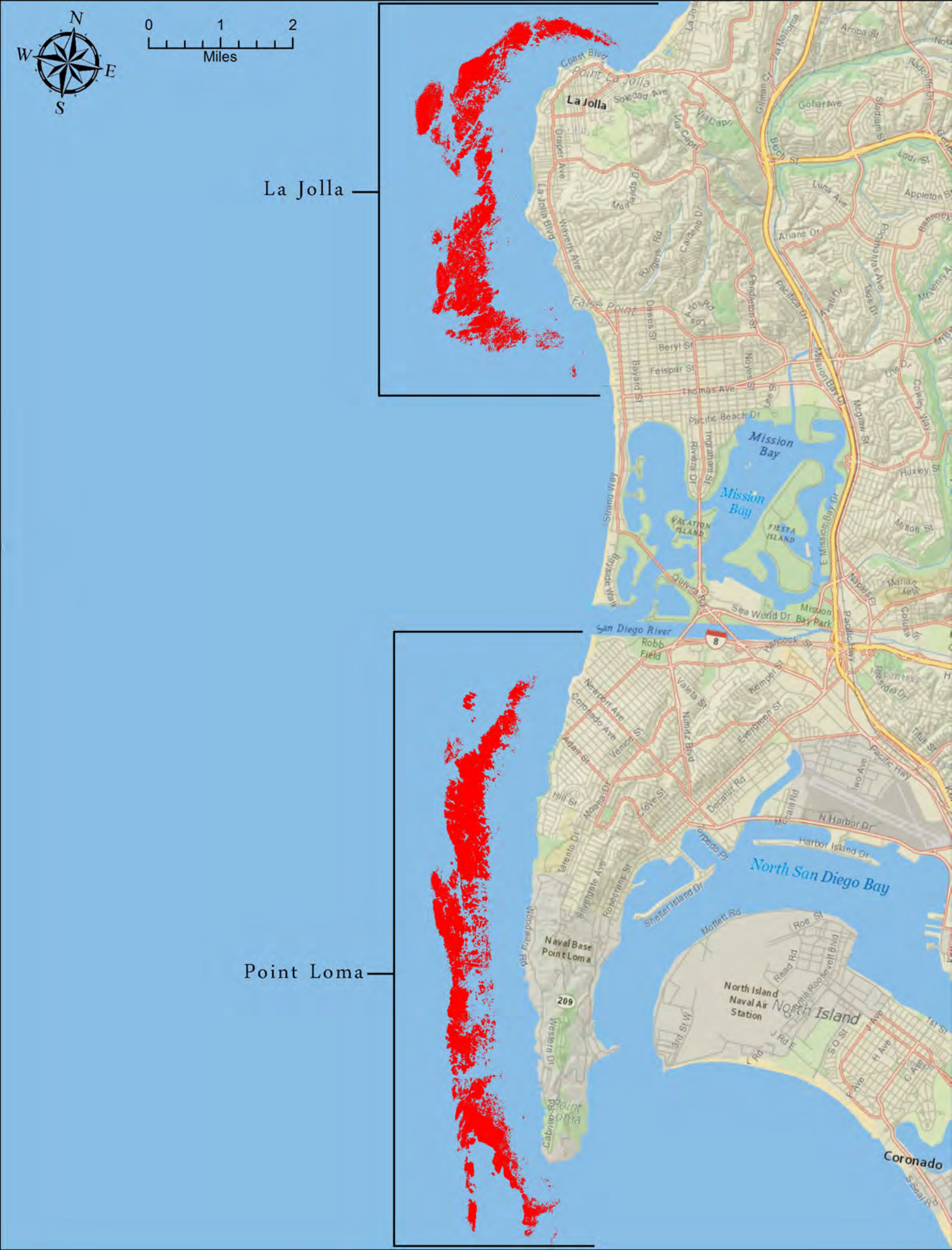
Miles
Encinitas
Cardiff
Solana Beach
Del Mar
Torrey Pines
La Jolla
Encinitas
Cardiff By The Sea
San Elijo Lagoon
Solana Beach
San Dieguito River
Del Mar
Torrey Pines State Reserve
La Jolla
Point La Jolla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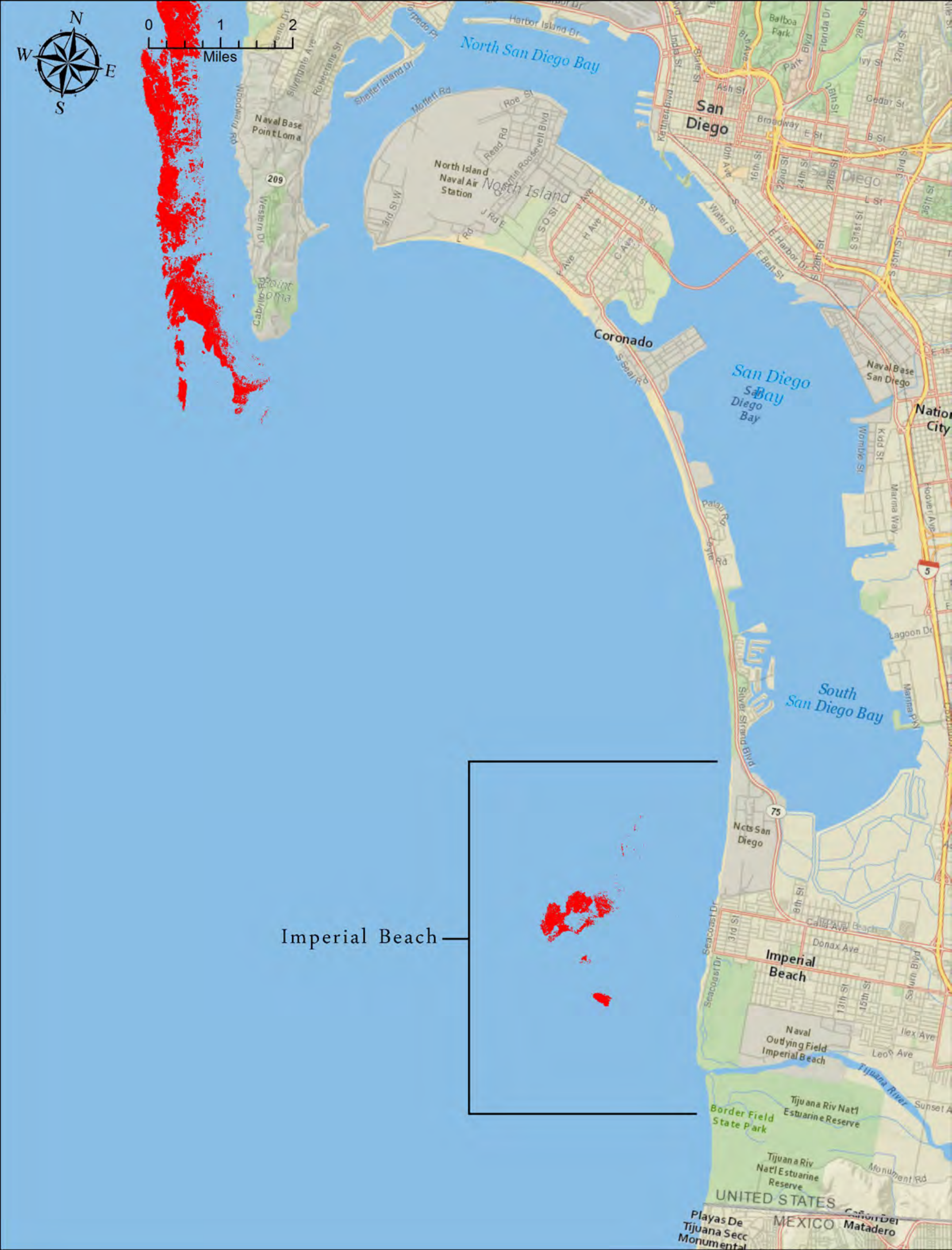
Miles
La Jolla
Point Loma
La Jolla
Point La Jolla
False Point
Mission Bay
VACATION ISLAND
FIESTA ISLAND
San Diego River
Robb Field
North San Diego Bay
Naval Base Point Loma
North Island Naval Air Station
North Island
Coronado



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Miles
North San Diego Bay
Harbor Island Dr
Shelter Island Dr
Naval Base Point Loma
Point Loma
North Island Naval Air Station
North Island
San Diego
Balboa Park
Coronado
San Diego Bay
Naval Base San Diego
National City
South San Diego Bay
Silver Strand Blvd
Imperial Beach
Ncts San Diego
Seacoast Dr
Naval Outlying Field Imperial Beach
Tijuana River
Border Field State Park
Tijuana Riv Nat'l Estuarine Reserve
UNITED STATES
MEXICO
Playas De Tijuana Secc Monumental
Cañon Del Matadero

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:**	3/14
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	4/7/14
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	4/14

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow		
Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- April 7, 2014**
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 7, 2014**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	2-4 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1045-1215
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	0.7' (+) to 0.8' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Excellent Conditions

Range (s) Surveyed	Ventura to Imperial Beach	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed.
Imagery Quality/ Comments	Excellent 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. Some glare present on imagery south of Newport. 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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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:**	6/14
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	7/6/14
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	7/14

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

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- 6/27 & 7/6/2014**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Newport Beach
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:		**June 27, 2014**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear-Fog S of Newport
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	2-4 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1521-1608
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	2.0' (+) to 1.9' (+) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Excellent Conditions

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

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

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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:**	6/14
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	7/6/14
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	7/14

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow		
Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- 6/27 & 7/6/2014**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Newport Beach
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:		**July 6, 2014**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	3-5 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1645-1737
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	4.8' (+) to 4.9' (+) 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	Newport Beach to Imperial Beach	
Target Resource Observations	Kelp Canopies	The kelp canopies throughout the survey range were well developed.
Imagery Quality/ Comments	Excellent Lens Note	All surface kelp canopies, were photographed within the above range and the image processing was conducted normally. All of the imagery was judged of excellent quality and was useable for the subsequent maping of the kelp resource. 30mm (digital SLR camera) is similiar focal length to 50mm (35mm film SLR camera)

Ecoscan Resource Data
143 Browns Valley Rd.
Watsonville, CA 95076
(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:**	9/14
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	9/10/14
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	9/14

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

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- 9/10/2014**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Newport Beach
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:		**September 10, 2014**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	2-4 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1407-1552
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	2.5' (+) to 0.3' (+) 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	Newport Beach to Imperial Beach	
Target Resource Observations	Kelp Canopies	The kelp canopies south of Dana Point were well developed, while those to the north were observed below the surface, but with reduced surface extent.
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
(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:**	12/14
City/State/Zip:	Costa Mesa, CA 92626	**Data Acquisition Completed:**	12/22/14
Phone 1/Phone 2:	(714) 850-4830	**Draft Report Materials Due:**	
Fax/E-Mail:	(714) 850-4840	**Final Report Materials Due:**	1/15

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

Project Title		**California Coastal Kelp Resources - Ventura to Imperial Beach- 12/22/2014**
Target Resource (s)/ Survey Range (s)		Coastal Kelp Canopies Ventura Harbor to Newport Beach
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 22, 2014**			
Survey Type		**Aircraft/Imagery Data**		**Associated Conditions**	
	Aerial Transportation/Observation	Aircraft:	Cessna 182	Sky Conditions:	Mostly Clear
	Photographic Film Imagery - 35 mm	Altitude:	13,500' MSL	Sun Angle:	> 20 degrees from vertical
	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	50+ miles
✓	Digital Color/Color Infrared Imagery	Camera:	Nikon D200	Wind:	5-10 knots
	Videography	Lenses:	30mm (see note)	Sea/Swell:	2-4 feet
	Radio Telemetry	Film:	Digital Color IR	Time:	1315-1445
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	1.0' (+) to 0.9' (-) MLLW
	Other 1:	Photo Scale:	As Displayed	Shadow:	None
	Other 2:	Pilot:	Unsicker	Other:	
	Other 3:	Photographer:	Van Wagenen	Comments:	Excellent Conditions

Range (s) Surveyed	Ventura Harbor to Imperial Beach. A small portion of the Palos Verdes peninsula was not photographed, due to fog.	
Target Resource Observations	Kelp Canopies	The kelp canopies south of Dana Point were well developed, while those to the north were observed below the surface, and with reduced surface extent.
Imagery Quality/ Comments	Excellent Lens Note	All surface kelp canopies were photographed within the above range, with the exception of a small portion of the Palos Verdes peninsula which was obscurred by fog. 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.

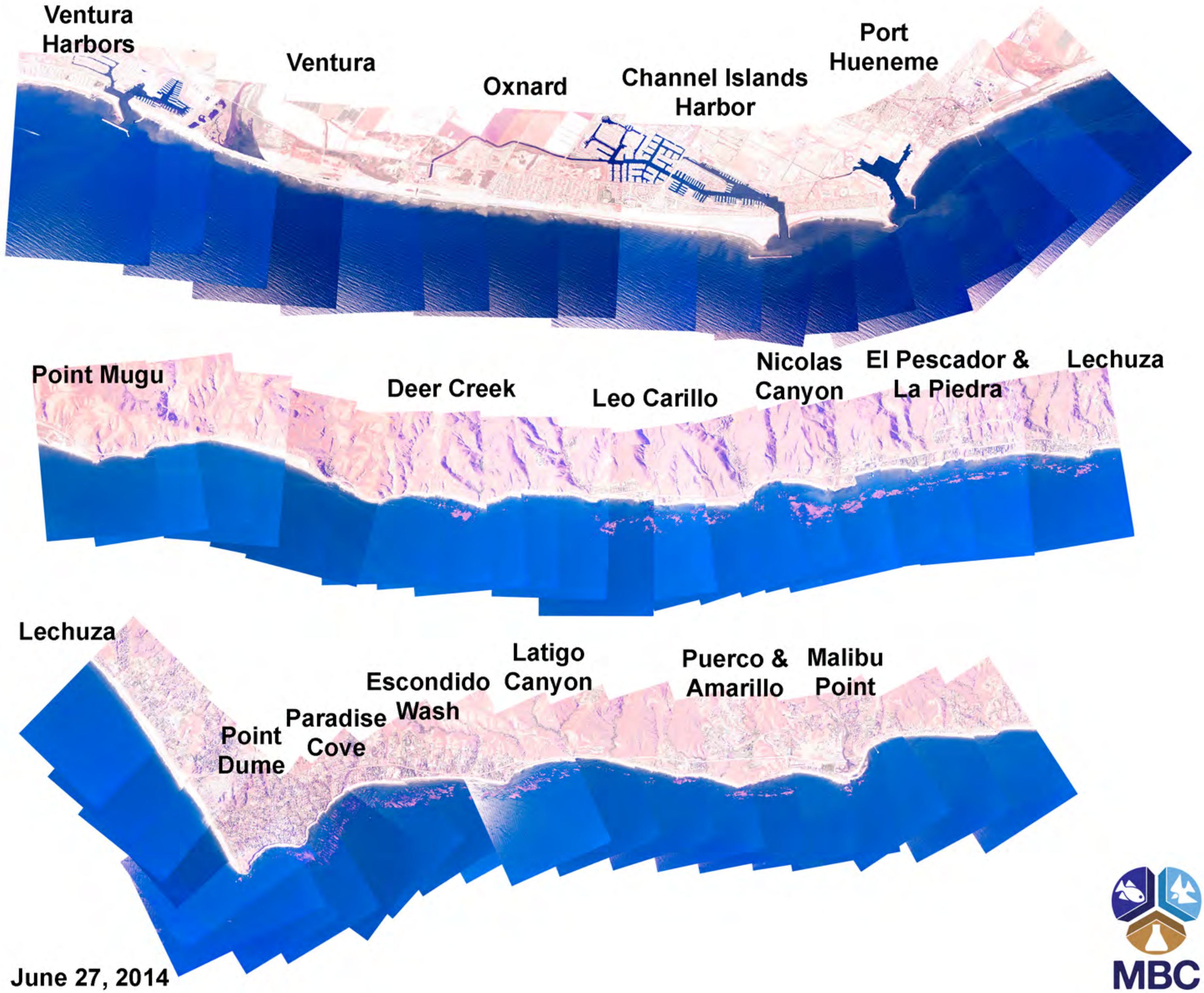
Ecoscan Resource Data
143 Browns Valley Rd.
Watsonville, CA 95076
(831) 728-5900 (ph./fax)

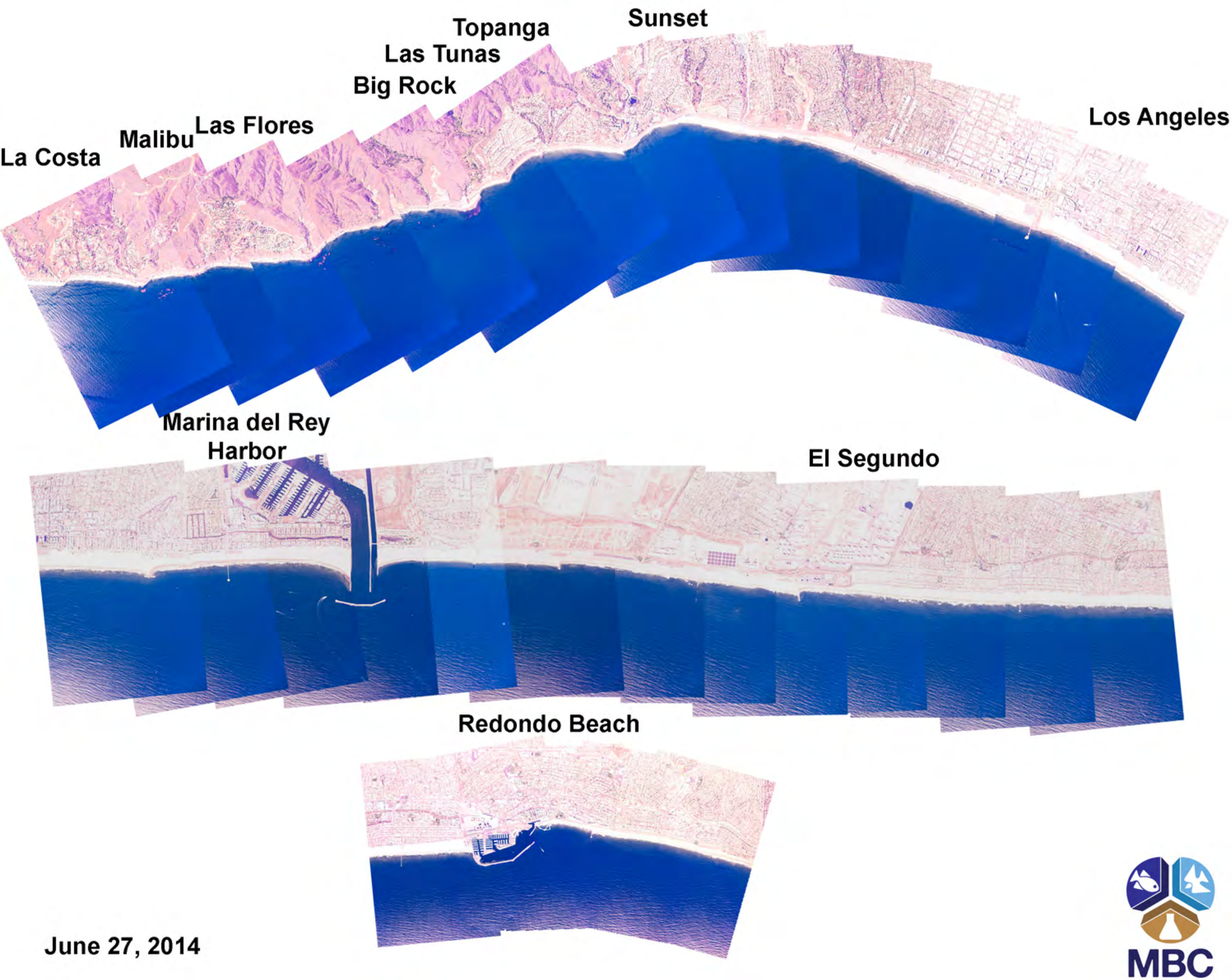
Signed: ______________________ Bob Van Wagenen, Director

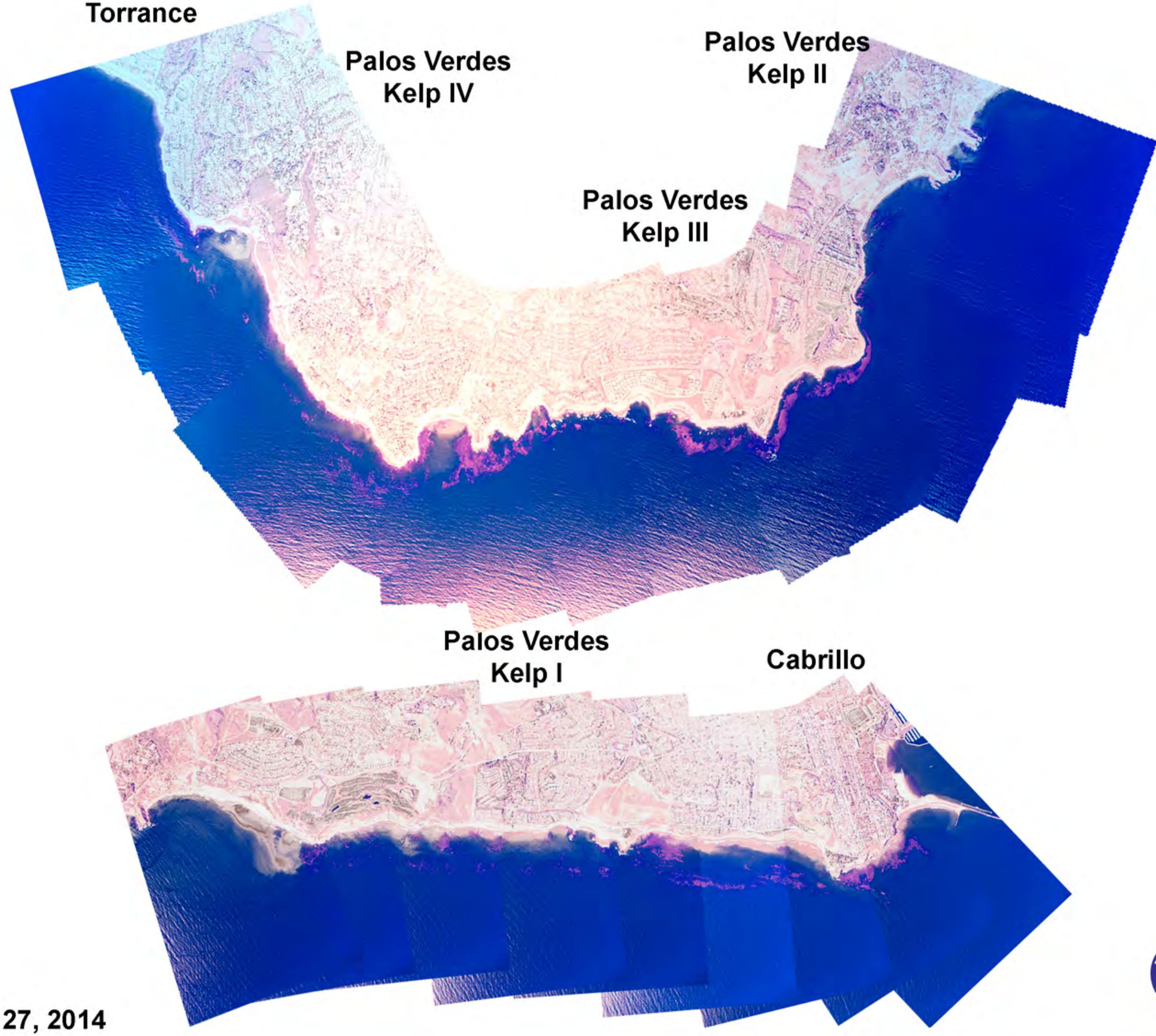
Copy To:

APPENDIX E

Kelp Canopy Aerial Photographs


Ventura Harbors
Ventura
Oxnard
Channel Islands Harbor
Port Hueneme
Point Mugu
Deer Creek
Leo Carillo
Nicolas Canyon
El Pescador & La Piedra
Lechuza
Lechuza
Point Dume
Paradise Cove
Escondido Wash
Latigo Canyon
Puerco & Amarillo
Malibu Point
June 27, 2014
MBC

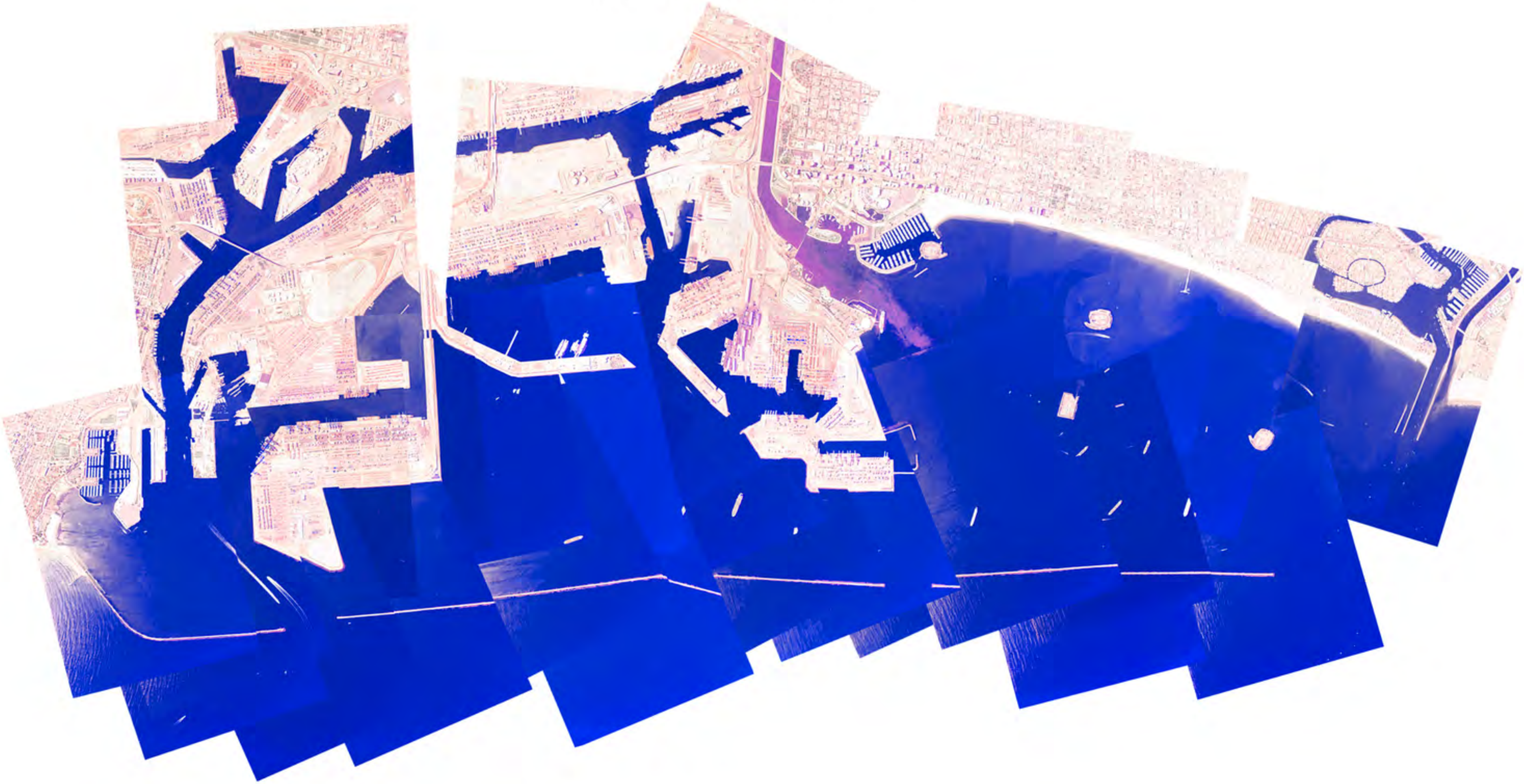

La Costa
Malibu
Las Flores
Big Rock
Las Tunas
Topanga
Sunset
Los Angeles
Marina del Rey
Harbor
El Segundo
Redondo Beach
June 27, 2014
MBC



June 27, 2014

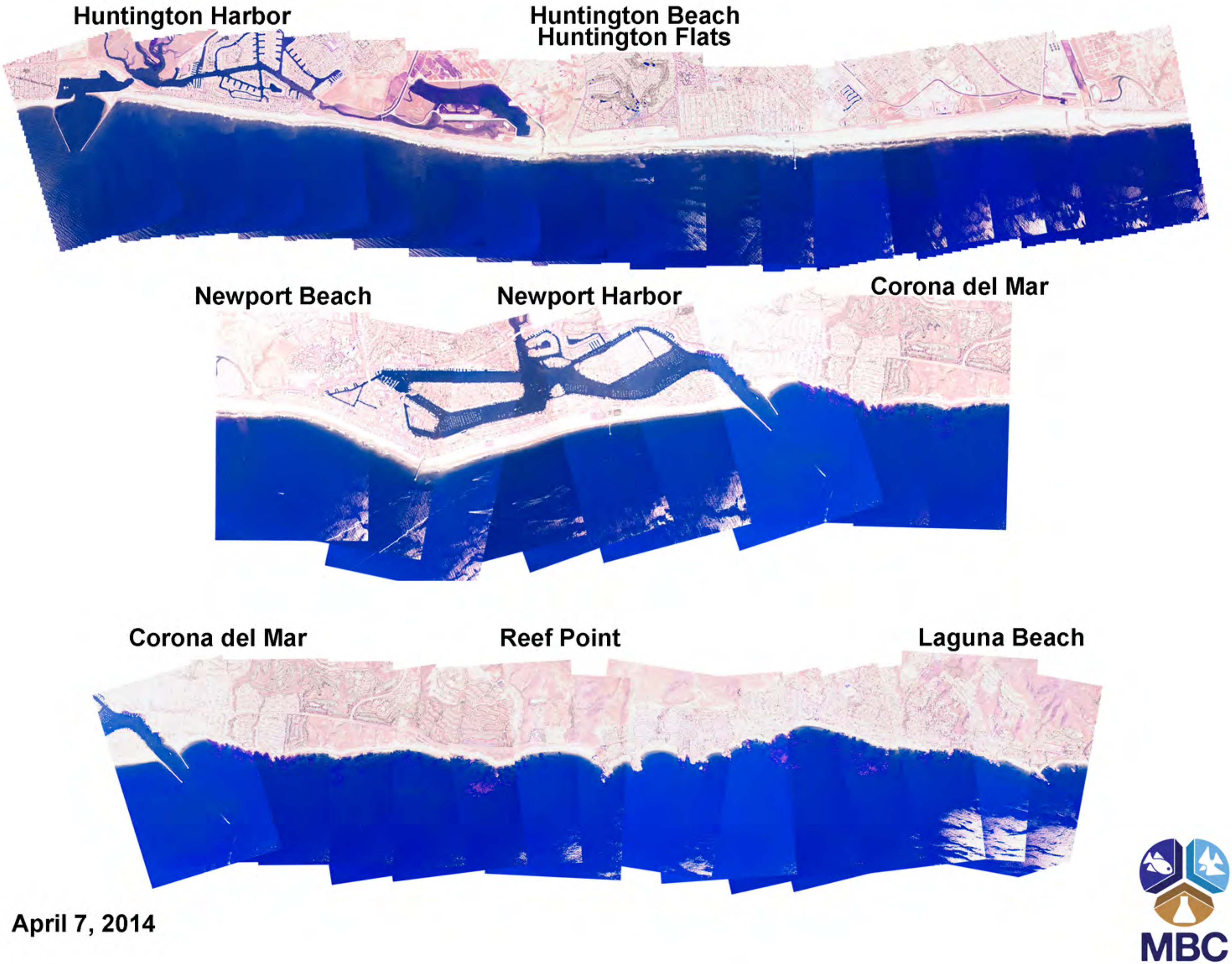
MBC

POLA/POLB Harbors

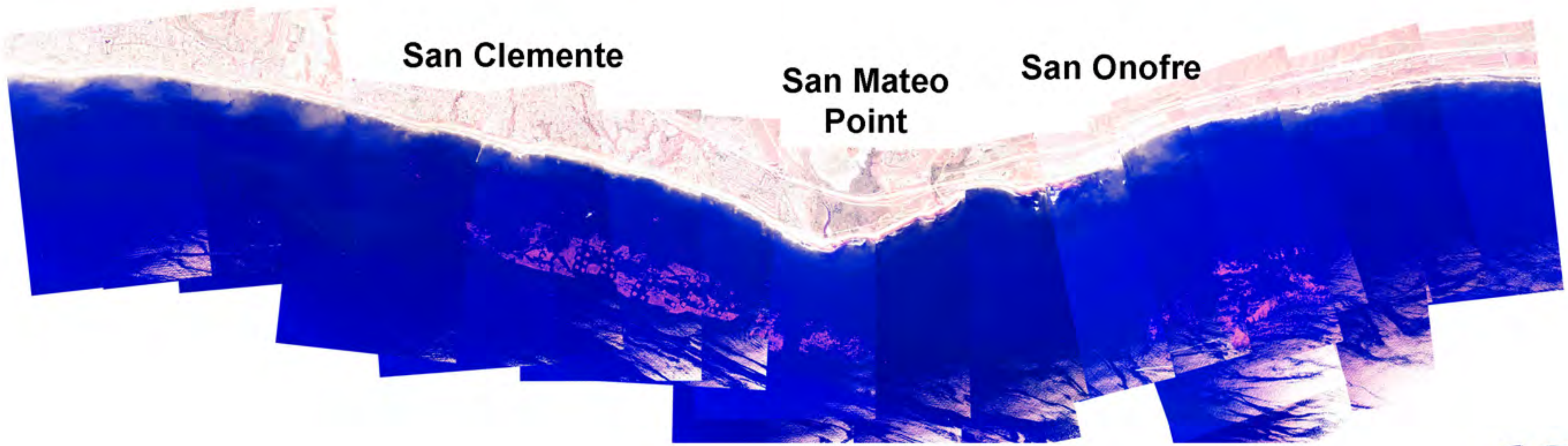


June 27, 2014

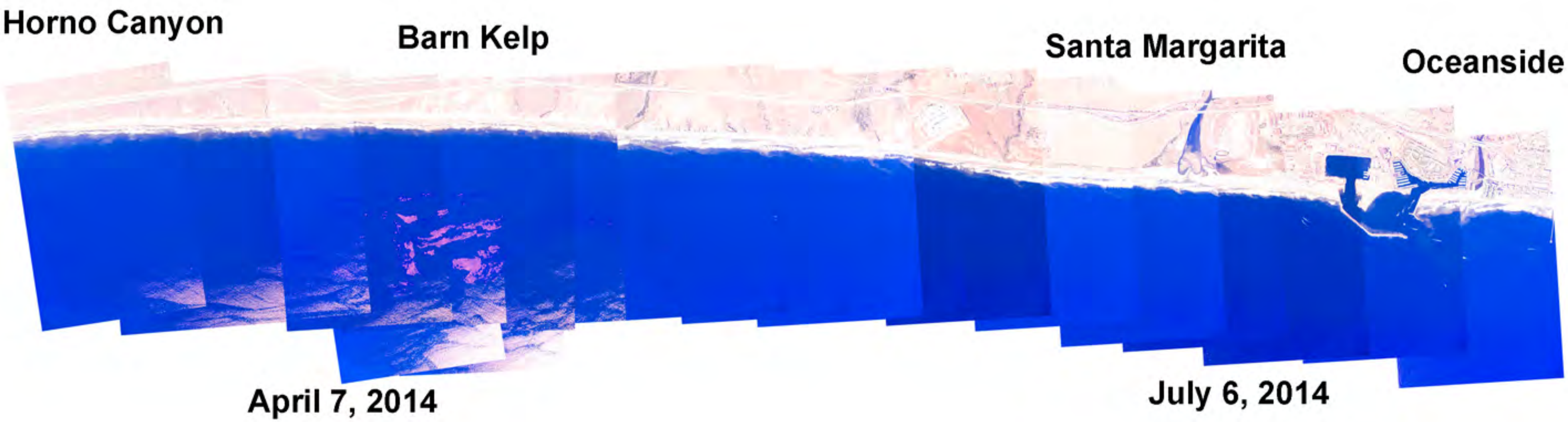
MBC

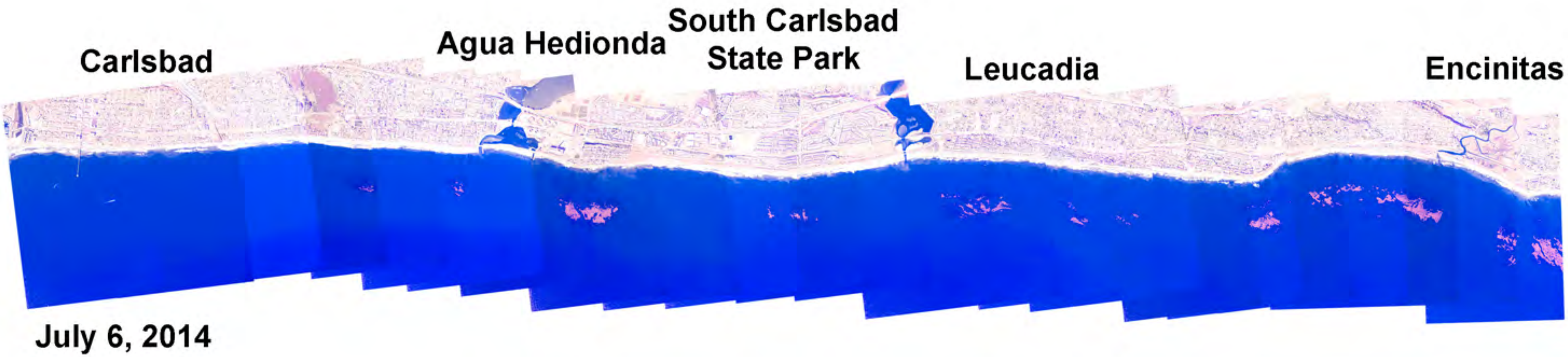

Huntington Harbor
Huntington Beach
Huntington Flats
Newport Beach
Newport Harbor
Corona del Mar
Corona del Mar
Reef Point
Laguna Beach
April 7, 2014
MBC


South Laguna
Dana Point

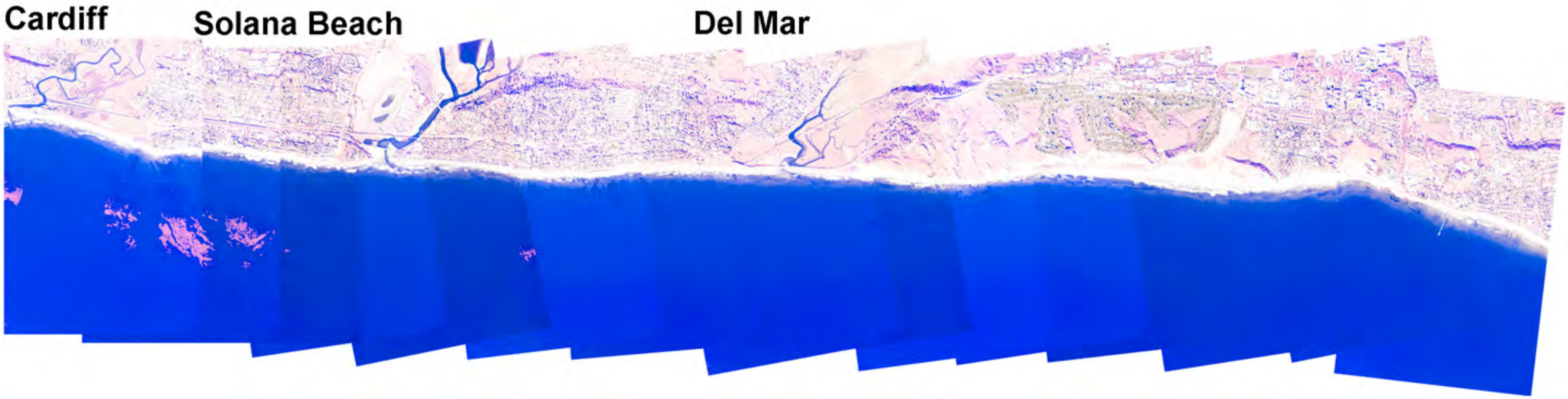

San Clemente
San Mateo Point
San Onofre

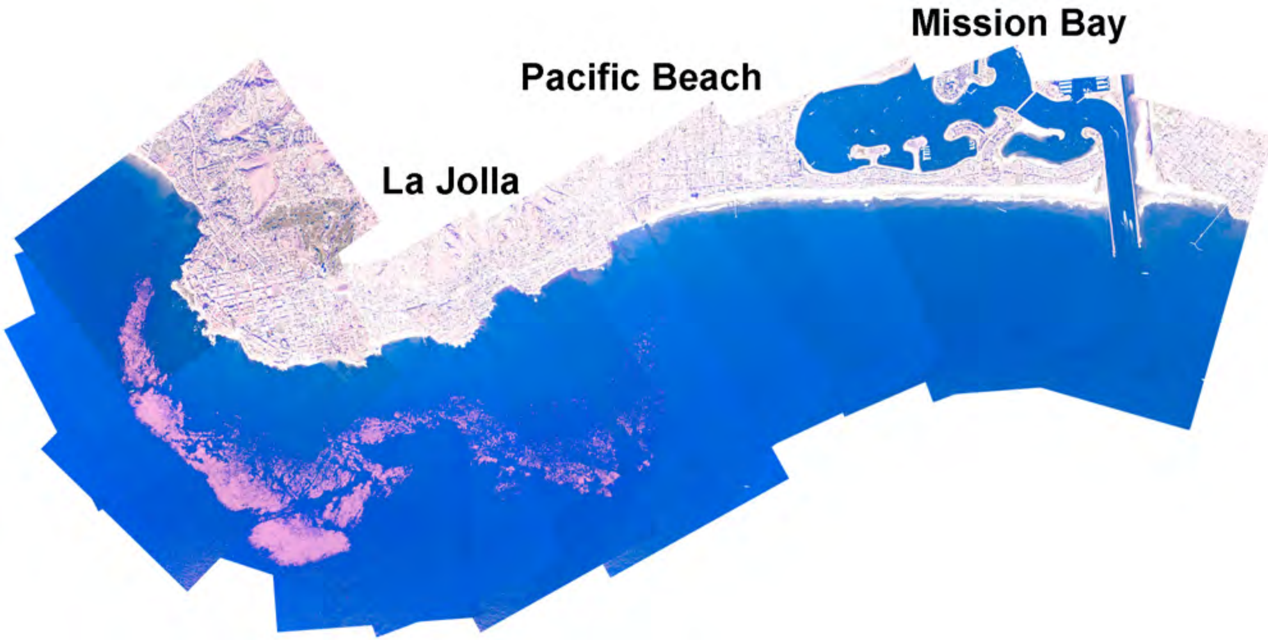
April 7, 2014


Horno Canyon
Barn Kelp
Santa Margarita
Oceanside
April 7, 2014
July 6, 2014


Carlsbad
Agua Hedionda
South Carlsbad State Park
Leucadia
Encinitas
July 6, 2014

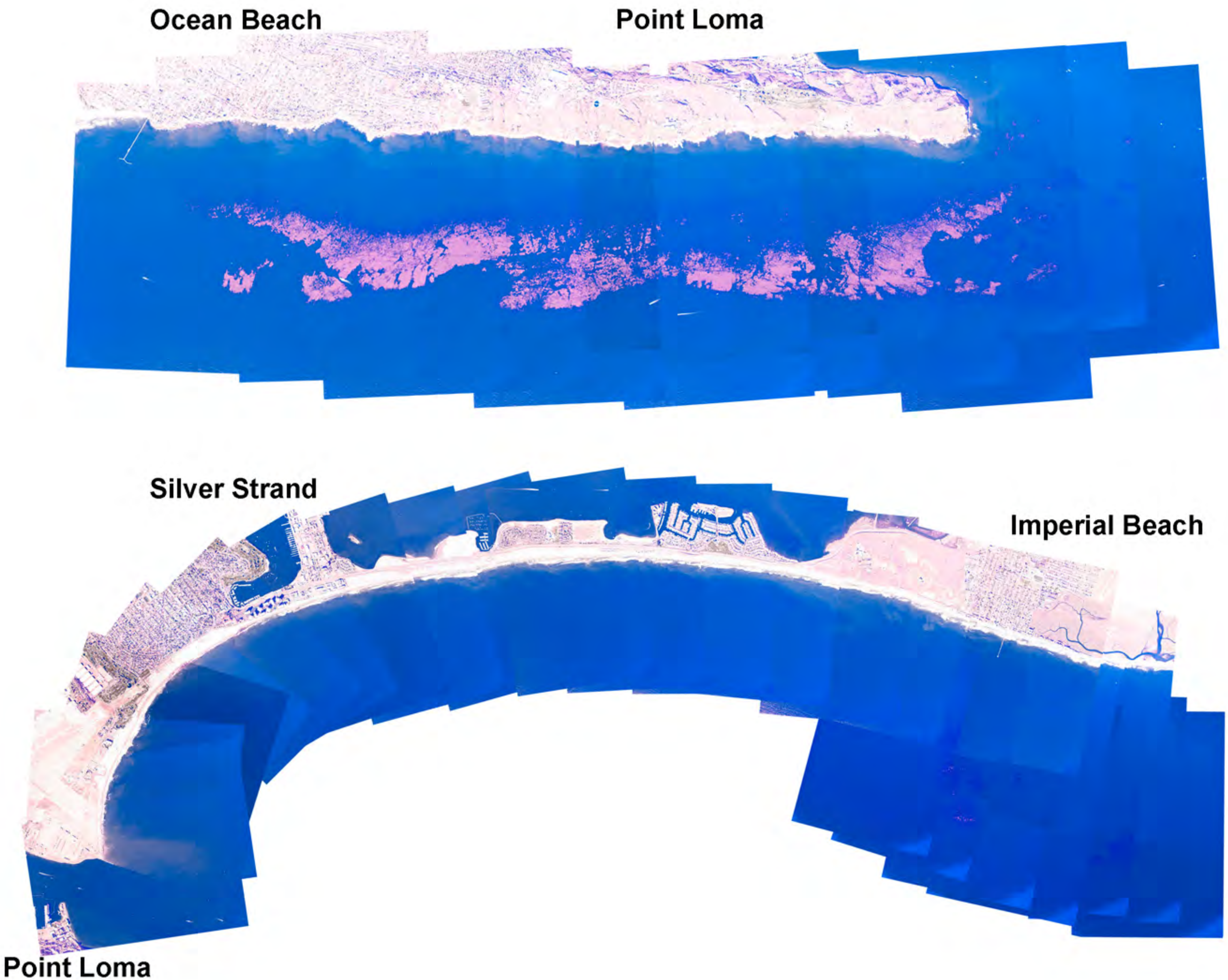
MBC





July 6, 2014

MBC


Ocean Beach
Point Loma
Silver Strand
Imperial Beach
Point Loma

July 6, 2014