California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Summer 2000

Final Report

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by

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1) 2000 kelp resource extent,
2) 1999 kelp resource extent, and
3) Comparisons of the 1999 and 2000 sanctuary-wide coastal kelp resource.

1) Summary of the 2000 Sanctuary-wide Kelp Resource Extent

The total 2000 surface kelp canopy resource, within the MBNMS (CDF&G kelp beds 208-225), occupied canopy/planimeter areas of 17.051 sq. mi. and 24.663 sq. mi., respectively. The relative density index was measured at .71.

2) Summary of the 1999 Sanctuary-wide Kelp Resource Extent

The total 1999 surface kelp canopy resource, within the MBNMS (CDF&G kelp beds 208-225), occupied canopy/planimeter areas of 14.053 sq. mi. and 22.358 sq. mi., respectively. The relative density index was measured at .63.

3) Summary Comparisons of the 1999-2000 Sanctuary-wide Kelp Resource

The total sanctuary-wide kelp resource canopy area significantly increased (p=,05) from 14.053 sq. mi. to 17.451 sq. mi., which represented a 24% increase in surface canopy from that measured in 1999. The 1999-2000 total kelp bed planimeter area also significantly increased from 22.358 to 24.663 sq. mi., which represented a 10% increase in planimeter extent. The relative density index also significantly increased from .63 (1999) to .71 (2000).

Although virtually all canopies within the survey range showed in increase in surface extent, the greatest increase was observed within Monterey Bay itself (CDF&G canopies 222, 221 and 220). Increases in canopy areas of 120%, 206% and 66%, respectively, were noted. In addition, increases in planimeter areas of 59%, 33%, and 43%, respectively, were also observed within these canopies.

The only canopy to experience a substantial loss in surface extent was canopy 208 (Cambria to Pt. Estero), which was reduced by 24% in canopy area and 14% in planimeter area.

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CALIFORNIA COASTAL KELP RESOURCES

Bolinas Lagoon
to
Point Estero

Section 1

Final Report

August 2000

CALIFORNIA COASTAL KELP RESOURCES
Monterey Bay National Marine Sanctuary
Summer 2000

Introduction

Along the California coast there is an abundant "kelp" resource assemblage present (brown seaweeds - Order Laminariales). The dominant, near shore, surface canopy forming species include *Nereocystis luetkeana* (bull kelp) and *Macrocystis pyrifera* (giant kelp). Although the individual species ranges are distinct, surface kelp canopies are present along the entire California coast from Crescent City to Imperial Beach (Abbot and Hollenberg 1976).

Each surface canopy, supported by air-filled pneumatocysts, is composed of individual plants that are attached to the bottom subtidal habitat by root-like "holdfasts." The vertical stipes, stretching from the sea floor to the surface canopy, provide critical habitat for numerous species of commercial and sport fish, invertebrates, marine mammals and related understory marine algae (Foster and Schiel 1985). Along the central California coast, 77 species of fish have been identified in kelp forests (Miller and Geibel 1973), and McLean (1962) identified 204 species of invertebrates in a predominately *Nereocystis luetkeana* kelp forest located south of Monterey. Prominent marine mammals, such as seals, sea lions and California sea otters, are also associated with this important near-shore habitat (Morejohn 1977).

In addition to its role as an essential marine habitat, coastal kelp canopies exhibit some of the highest primary productivities of any ecosystem on earth (Wheeler and Druehl 1986). This material is provided to the food chain in three ways: 1) directly, while the kelp plants are still attached, 2) indirectly, by providing detritus that is eaten after it has fallen to the bottom, and 3) by producing dissolved organic matter (DOM) that is food for many microorganisms (Mumford 1989). Kelp bed primary productivity within *Nereocystis/Macrocystis* beds has been estimated at 350-2,800 g carbon/m^2 (Wheeler 1990), placing them ahead of tropical rain forests, reefs and estuaries, warm temperate forests, and cultivated land with regard to their contribution to the overall food chain.

Nereocystis luetkeana occurs from Point Conception to the eastern Aleutian Islands (Druehl 1970), and is the dominant, surface canopy kelp north of Santa Cruz, California. Its hydrodynamic shape makes it especially well suited to high exposure, "open coast" environments (Foster and Schiel 1985). *Nereocystis* is predominately an annual (Abbot and Hollenberg 1976), although mature plants have been seen to persist for up to 18 months. Impressive growth rates of up to 10 cm per day have been observed in young plants, and the mature surface canopy reaches its maximum extent in July through October. Sporangial sori mature at the surface between May and December, drop from the blade, and sink to the sea floor before releasing their spores (Abbot and Hollenberg 1976).

Macrocystis pyrifera has a range in North America from Alaska to Magdalena Bay in Baja California (Abbot and Hollenberg 1976), and frequently forms thick canopies on rocky substrata at depths of from 6-20 meters. *Macrocystis* is a perennial, at least the basal holdfast and attached sporangial thalli, and develops its maximum surface canopy between May and October. *M. pyrifera* is the predominant canopy forming kelp in species in California south of Sandhill Bluff (Santa Cruz County), and in addition to providing essential marine habitat to hundreds of related species, is utilized commercially as well. Upwards of 140,000 tons wet weight of *M. pyrifera* are harvested annually from state-owned kelp beds for the purpose of extracting alginates and colloids widely used in industry and in the preparation and preservation of certain foods (Abbot and Hollenberg 1976).

Mixed canopies, containing both *Nereocystis* and *Macrocystis,* are present along much of the California coast-line from Sandhill Bluff (Santa Cruz County) to Port San Luis (San Luis Obispo County), and when these species co-occur, *Nereocystis* is most commonly found inshore and *Macrocystis* offshore (Foster and Schiel 1985).

The extent of the total kelp canopy occupied by each of these individual species is dynamic from year to year. Annual fluctuations in canopy species composition are thought to be the result of a complex combination of physical, chemical, and biological factors (Foster and Schiel 1985). Water motion (Rosenthal et al. 1974), water temperature/nutrients (Craig Barilotti pers. comm.), light intensity (Luning 1981), and available habitat, and exposure (Foster and Schiel 1985) have all been associated with kelp canopy health and development. In addition, warm water temperature anomalies, especially those associated with the "El Nino Southern Oscillation" (ENSO), have been known to dramatically reduce the abundance, diversity and stability of the near-shore kelp forest community (Tegner and Dayton 1991). In the latter months of 1997 and early 1998, the west coast of North America was again influenced by a significant ENSO countercurrent. It lasted several months, and raised surface sea temperatures by as much as eight degrees Fahrenheit in southern California and five degrees off the Washington coast (NOAA 1998). Aerial imagery obtained in the summer of 1998 revealed that the substantial southern California near shore *Macrocystis pyrifera* kelp canopy resource had been largely eliminated south of Newport Beach, presumably by these elevated temperatures or by resultant invertebrate overgrazing. Little is known regarding the effects of the ENSO, or other sea temperature anomalies, on the *Nereocystis* kelp resource.

The relationships of these individual physical factors, and identification of those that may be "limiting" at any one time, have yet to be fully understood, and continue to be the subject of numerous ongoing research investigations. In addition, adjacent kelp forests that appear to be exposed to similar physical factors may frequently produce vastly different canopy species compositions, further revealing the complexity of this dynamic habitat.

Biological factors, including the impact of herbivorous grazers such as sea urchins, are also a major element determining the extent and diversity of the near shore kelp resource (Foster and Schiel 1985). In that regard, the effects of a resident sea otter

population on the central California kelp resource, and a better understanding of the role of the otter in structuring near shore ecology are the subject of ongoing research interest. Their predation on invertebrate kelp grazers, mainly sea urchins (Jameson 1986), has been shown to dramatically reduce the density of these species, and to increase kelp canopy extent in areas of significant otter abundance (Kivitek 1989). This increase in the kelp resource has been observed to have dramatic effects on the diversity and abundance of associated species, and the resulting near shore community structure (Estes and Palmisano 1974). This otter/urchin/kelp interrelationship has resulted in the sea otters designation as a "keystone predator". Kvitek (1998) supported this designation by showing that sea otter predation along the Washington outer coast has significantly reduced the numbers of sea urchins and the grazing pressure that they exert. It was concluded that in the presence of an established otter population, sea urchin grazing was not the dominant force structuring the near-shore community. Continued research will be necessary to determine the impact of this important marine mammal on the nearshore kelp forest community.

In addition to the natural effects of physical, chemical, and biological factors on the near-shore environment, occasional "man-caused" pollution events may have significant additional effects on species abundance and diversity (Foster and Schiel 1985). In 1991, the collision of two ships, approximately 22 miles WNW of Cape Flattery, Washington (Rogne *et al* 1993), resulted in the release of an estimated 100,000 gallons of #2 diesel fuel into the marine environment. In addition, oil continued to be released at a rate of 500 gallons/per day during the subsequent weeks. The prevailing WNW winds and seas carried the fuel oil towards both Vancouver Island and the Cape Flattery area. During its time at sea the oil was weathered, and would eventually be observed as "tar balls" in both the kelp beds, and to a lesser extent on rocks and beaches from Neah Bay to Cape Alava. Ongoing clean-up operations continued for several months after the spill in an attempt to minimize damage to the marine environment. Questions were raised from this event regarding the long-term effects of petroleum pollution on these kelp canopy forming species, and the resultant vulnerability of the related marine community.

Macrocystis canopies have been observed to be largely unaffected by hydrocarbon pollution, presumably due to the temporary protection provided by plant produced mucus (Mitchell *et al.* 1970), and the physical location of the reproductive sporophylls near the basal holdfast. Pollution effects on *Nereocystis* canopies have only been recently investigated (Antrim *et al.* 1995). Surface stipe tissue bleaching and loss, as a result of hydrocarbon contact, was observed both by Antrim (1995), and during the field clean-up operation following the 1991 Washington oil spill. However, it is still unclear whether or not subsequent seasonal *Nereocystis* recruitment is affected by these polluting elements.

The dynamic and sometimes vulnerable nature of the coastal kelp resource, considering its importance as habitat and food for hundreds of related species, points out the need for systematic methods of accurately assessing its extent and vitality. Until 1989, the California state-wide coastal kelp resource had only been sporadically mapped and analyzed since an initial state-wide visual survey conducted in 1915 (Rigg

1915). Earlier ground based estimates of kelp canopy extent have given way to modern aerial surveys, which provide a cost effective and accurate methodology for the mapping and quantification of near shore kelp resources (Jamison 1971).

A substantial portion of this dynamic kelp resource habitat falls within the Monterey Bay National Marine Sanctuary (MBNMS), established in 1992 as the largest United States marine sanctuary. The management area includes 276 miles of the California coastal zone between Rocky Point (7 miles north of the Golden Gate Bridge) and Cambria Rock (San Luis Obispo County), and extends from the beach to approximately 30 miles offshore. Within this management zone, occupying 5,322 square miles, 26 species of marine mammals, 94 species of seabirds, 345 species of fish, 31 phyla of invertebrates and over 450 species of marine algae have been observed. The MBNMS administration has four major components and mandates: 1) enhance resource protection, through comprehensive and coordinated conservation and management tailored to the specific resources, 2) support, promote and coordinate scientific research on, and monitoring of, the site-specific marine resources to improve management decision-making in National Marine Sanctuaries, 3) enhance public awareness, understanding, and wise use of the marine environment through public interpretive and recreational programs, and 4) facilitate, to the extent compatible with the primary objective of resource protection, multiple uses of these marine areas not prohibited pursuant to other authorities.

In response to this conservation and management mandate, Ecoscan Resource Data was contracted in this study to establish a kelp resource inventory program within the sanctuary-wide coastal zone between Rocky Pt. and Pt Estero. A state-wide kelp resource inventory, utilizing similar methodology, was conducted in 1989 (Van Wagenen 1989) for the California Department of Fish and Game (CDF&G), Marine Resources Division, and again in 1999 (Van Wagenen 1999) for the Monterey Bay National Marine Sanctuary.

The primary objective of this inventory was the continuation of a coastal kelp resource mapping and monitoring program that would accurately reflect the current sanctuary-wide seasonal maximum kelp resource extent. The methodology utilized was designed to not only allow a systematic, accurate analysis of multi-year data from current and future inventories, but to also allow meaningful comparisons with historic surveys as well.

Data acquisition was accomplished utilizing cost-effective medium format (70 mm) vertical aerial infrared photography. Data processing included the mapping of the imaged kelp canopies onto a consistent baseline map series, followed by a computer measurement of kelp canopy extent. Data analysis for short term trends in kelp canopy extent was accomplished by statistically comparing indices from the current inventory with those of the previous systematic study conducted in 1999. Mapping products from both surveys, at several scales, were included to graphically depict the spatial extent of this important resource.

Methods and Results

The methodology utilized in this kelp resource inventory, to document the extent of the kelp resource within the MBNMS, was divided into four phases:

1) Kelp canopy aerial photography,
2) Qualitative kelp bed canopy mapping,
3) Quantitative kelp bed canopy/planimeter area and density analysis (2000), and
4) Quantitative comparison of 1999 and 2000 kelp resource extent within the Monterey Bay National Marine Sanctuary.

The methods utilized in this current survey were similar to those used in the 1989 and 1999 inventories, to ensure data compatibility and comparability with these and other subsequent studies. Although the defined scope of this study was limited to the measurement of current resource abundance, specific comparisons were made with the last previous systematic analysis (1999), to document short-term changes in kelp canopy extent.

1) Kelp Canopy Aerial Photography

The methodology related to obtaining high-quality imagery of the fully developed 2000 California coastal kelp resource was divided into two sections: 1) survey timing, imaging, and logistic considerations, and 2) photography of the 2000 kelp resource.

1) Survey Timing, Imaging, and Logistic Considerations

The seasonal timing, photographic scale, and flight parameters of this aerial survey were established, as in previous surveys, to systematically obtain imagery that best represented the maximum extent of the current kelp resource. Acceptable "survey windows" were chosen for the aerial over-flights in response to several biological (seasonal timing of maximum canopy development), physical (tidal level, weather and sea state) and logistic factors (length of survey range).

Seasonal timing of maximum kelp canopy development was the major biological factor involved in scheduling this resource survey, and established the criteria around which all other logistic decisions were made. Within California, it has been observed, that the maximum extent of canopy forming kelp species occurs in August through October, with maturity of the *Nereocystis* canopy determining the beginning of this "biological window", and early season storms determining the end.

Within this three month period, several acceptable "tidal windows" were selected (utilizing NOAA tide tables for Monterey and San Simeon) that would allow the aerial imagery to be obtained at tidal levels of less than +1.0' MLLW. Once the tidal windows were established, the actual survey was conducted during the first window that had acceptable associated environmental conditions. These conditions included adequate ceiling and visibility (>10,000' MSL and five miles), surface winds less than ten knots, sea/swell less than five feet, and a sun angle of greater than 30 degrees from vertical.

In California, changeable weather (especially coastal fog, high winds and sea state) can be a major limiting factor on survey timing, and can frequently reduce the number of acceptable survey days in a given season to less than twenty. During the previous (1999) survey, the aerial imagery was obtained within these optimum biological, tidal, and environmental windows, thereby allowing meaningful comparisons of seasonal kelp resource areal extent.

The aircraft altitude (9,500' MSL) and photographic scale (1"=3,217') used for these surveys was selected to provide a good balance between resource resolution and rendition on the imagery, the selected base-mapping scale (1:24,000), and the overall length of the survey area (276 miles). At this altitude and photographic scale, the entire survey range (Cambria to Rocky Point) could be accurately recorded, under optimum conditions, during two low-tidal periods. Considering the changeable nature of California coastal weather; this methodology allowed the maximum utilization of the few optimum survey dates. With regards to resource resolution on the imagery; ground truth measurements have indicated that the smallest kelp "dots" on the 1:24,000 scale maps (approximately the size of a text "period" from this document), represent as few as six surface stipes from a single *Macrocystis* kelp plant.

The film used on this survey was 70 mm Kodak color infrared - type 2443, the accepted standard for use in documenting the areal extent of marine surface vegetation. Its ability to increase the contrast between kelp and the surrounding water, without sacrificing resolution, made it ideal for resource surveys of this type. Despite this ability, infrared film does have limitations regarding its utility in recording sub-surface coastal kelp canopies. Due to its poor water penetration properties of approximately two feet (Helgeson 1970); this film will not record kelp stipes that are significantly pulled below the surface due to high winds and seas, high tides, and tidal currents. This especially affects sparse *Nereocystis* canopies, which can be completely submerged by the above factors (especially tidal currents), and not recorded on the imagery. Careful attention to survey timing that corresponded with acceptable winds, seas, and the "time of the low tide" at each coastal location, was necessary to insure accurate canopy rendition on the imagery.

2) Photography of the 2000 Kelp Resource

When the biological, tidal, imaging, and logistic factors were considered together, three possible "optimum survey windows". were established for the 2000 kelp resource inventory: 1) August 1 - 5, 2) August 10 - 19, and 3) August 27 - 31, 2000.

Aerial photography of the 2000 kelp resource was accomplished on August 10 and August 30, 2000 during the second and third optimum survey windows. Calm winds, low seas, and mostly clear skies were present throughout the survey range on both dates, with the exception of patchy mid-level clouds (4,000' MSL) from Pt. Sur south to Pt. Piedras Blancas on August 30. A summary of associated environmental conditions, in addition to visual observations taken during the survey were presented in figures 1.1 and 1.2.

Continuous, sequential, vertical photographs (20%-30% overlap) were taken from 9,500' MSL (75mm lens) of the coastal zone between Rocky Point and Seacliff Beach on August 10, and from Seaside to Point Estero on August 30. Approximately 20% shoreline was included on each image to facilitate accurate projection onto the base-line maps. Larger canopies, that were not fully recorded on the initial "in-shore" photographic transect, were referenced on parallel "off-shore" flight lines. Each new transect was "side-lapped" by 30%-40% with those in-shore, to facilitate the accurate mapping of these off-shore canopies.

The imagery from each of the survey dates was processed normally, judged of excellent quality, and allowed the complete and subsequent mapping of the coastal kelp canopies within the study range. This indexed imagery was presented as: "California Coastal Kelp Resources – Monterey Bay National Marine Sanctuary - Summer 2000 -Aerial Survey Imagery" – Binder 1/1 "Bolinas Lagoon to Pt. Estero".

2) Qualitative Kelp Bed Canopy Mapping

Kelp bed mapping was accomplished in two phases: A) base-line map preparation, and B) kelp bed canopy area mapping and indexing.

A) Base-line Map Preparation

The base-line maps for this coastal kelp survey were originally designed for the 1989 inventory, and subsequently used again in this effort. This base-map series presents an accurate and continuous depiction of the California state coastal zone from the Oregon to the Mexican borders, including southern California offshore islands, and allowed the systematic mapping of the sanctuary-wide resource.

Eighty-three contiguous base-line maps (24"x36", scale 1:24,000) were made of the California coastal zone using USGS 7 1/2' quadrangle maps (scale 1:24,000) as a reference. These maps offered extensive shoreline detail, high accuracy, and continuous coastal coverage for the entire state. Each of the "quad" maps was copied on a calibrated photocopier (Sharp "8400"). The contiguous "shoreline" portions of each of the map copies were then assembled together, and became the land reference on each of the base maps. All standard detail from these USGS maps was preserved, including prominent shoreline features, offshore rocks, rivers, beaches, rocky intertidal habitat, towns, harbors, and topographic relief. In addition, the CDF&G kelp bed numbering system, which divides the state-wide kelp resource into discrete beds based on bearings from key geographic points, was also included.

The coastal zone, within the MBNMS, from Rocky Point to Cambria Rock, was located on maps 27 – 44 within this 83 map set. These maps were indexed by map number (table 1), and map name (table 2), and CDF&G numbered kelp beds present on each map page were also included. To aid in orientation and facilitate the "field use" of the maps, prominent geographic features were listed alphabetically in tabular form (table 3), with cross-references to the map name and number where they were found.

B) Kelp Bed Canopy Area Mapping and Indexing

All color infrared slides from the survey were projected onto the base-line maps, and after aligning common shoreline features from each media, individual kelp plants and kelp canopies (see glossary) were hand transferred. The transfer process specifically involved: 1) the visual analysis of the extent of kelp represented on each slide by reference to color and surface appearance, 2) the identification of the "usable" portion of the image that was largely distortion-free (center three-fourths), 3) positioning this "usable" portion of the projected image in its proper location on the base-map, with regard to both shore-line features and kelp from other overlapping imagery, and 4) the black shading of all visible kelp, both developed canopies and individual plants. These black-shaded areas represented the areal extent of the actual kelp plants composing the surface canopy, and areas within the perimeter of the canopy that did not contain kelp were left un-shaded. When fully rendered from the survey imagery, each mapped canopy closely resembled the appearance of the actual surface canopy when viewed from above.

These mapped canopies represented the qualitative kelp bed canopy area (see glossary) occupied within the survey range, and were presented in Section 4 - "Kelp Bed Canopy Area Maps: 27-44" – August 2000 (24"x36", 11"x17", and 8.5"x11"). Similar maps from the 1999 inventory were presented in Section 5 - "Kelp Bed Canopy Area Maps: 27-44" - October 1999 (8.5"x11") for comparative purposes.

3) Quantitative Kelp Canopy/Planimeter Areas and Relative Density Analysis

The quantitative analysis of the sanctuary-wide kelp resource abundance within the MBNMS was divided into three sections: a) analysis of the 2000 MBNMS sanctuary-wide coastal kelp resource, by CDF&G kelp bed number, and b) comparison of the 2000 kelp resource extent with that measured during the 1999 inventory. Observed large-scale changes in resource abundance were presented in the "Data Summary/Principle Findings" section.

A) Analysis of the 2000 MBNMS Sanctuary-wide Coastal Kelp Resource

Quantitative kelp bed canopy and planimeter areas (see glossary) were accurately determined from the maps using computer image processing techniques. Each map page was scanned full scale at 100 dots/inch (dpi) using a "Microtek" 9600 XL flat-bed image scanner. Area values were determined by screen "pixel counting", utilizing "Global Lab Image" (V3.1) image processing software (Data Translation).

Kelp bed canopy/planimeter areas and values for the relative density index (see glossary) were tabulated by CDF&G kelp bed number, presented in table 4, and plotted in figure 2.

Similar indices from the 1999 inventory were presented, by CDF&G kelp bed number, in table 5, and plotted in figure 3.

B) Comparisons of the 1999 and 2000 MBNMS Coastal Kelp Resource

Kelp bed canopy/planimeter areas and values for the relative density index, from the 1999 inventory in addition to similar values from the current inventory were presented in Table 6 and plotted in figure 4

In order to evaluate the significance of observed changes in resource extent between the two surveys, a t-test ("paired two sample for means") was applied to the sequential data sets from tables 6. This test evaluated whether a samples' means were distinct, and did not assume equal population variance (Sokal and Rohlf, 1981). This test was judged appropriate, since there was a natural pairing of measurements making up each distinct value for canopy/planimeter area and RDI. Each data pair were analyzed at the 95% confidence level ($p = .05$), and the results of the tests were summarized in the "data summary/principle findings" section.

All spreadsheet data from tables 1-6 are provided in "Excel 95/97" ("XLS" - Microsoft Inc.) file format. The data file, MBNMSK00.XLS, was included on two 3.5" floppy disks, and presented in each of the data binders in Section 6 – Electronic Data.

Data Summary

This data summary will focus mainly on a "large scale" assessment of the 2000 MBNMS coastal kelp resource, and changes observed since the 1999 inventory. As a result of this data tabulation method, though, additional "small scale" changes in kelp resource extent may become apparent, as further research is conducted. Investigators are encouraged to use these data in that regard. Care must be taken, though, in interpreting these observed changes, since only two data sets were involved, spanning one year. At best, these data represent short-term changes only and don't necessarily reflect long-term trends in kelp resource extent and distribution.

In addition, it is intended in future surveys, to substantially expand the scope of this analysis to include numerous areas of research interest, and to track the sanctuary-wide kelp resource, by kelp species, to better understand the inter-specific interactions and environmental structuring elements of the MBNMS kelp resource.

Principle Findings

The principle findings from the 2000 Monterey Bay National Marine Sanctuary kelp resource inventory were summarized, by CDF&G kelp bed numbers, as follows:

1) 2000 kelp resource extent,
2) 1999 kelp resource extent, and
3) Comparisons of the 1999 and 2000 sanctuary-wide coastal kelp resource.

1) Summary of the 2000 Sanctuary-wide Kelp Resource Extent

The total 2000 surface kelp canopy resource, within the MBNMS (CDF&G kelp beds 208-225), occupied canopy/planimeter areas of 17.051 sq. mi. and 24.663 sq. mi., respectively. The relative density index was measured at .71.

2) Summary of the 1999 Sanctuary-wide Kelp Resource Extent

The total 1999 surface kelp canopy resource, within the MBNMS (CDF&G kelp beds 208-225), occupied canopy/planimeter areas of 14.053 sq. mi. and 22.358 sq. mi., respectively. The relative density index was measured at .63.

3) Summary Comparisons of the 1999-2000 Sanctuary-wide Kelp Resource

The total sanctuary-wide kelp resource canopy area significantly increased (p=,05) from 14.053 sq. mi. to 17.451 sq. mi., which represented a 24% increase in surface canopy from that measured in 1999. The 1999-2000 total kelp bed planimeter area also significantly increased from 22.358 to 24.663 sq. mi., which represented a 10% increase in planimeter extent. The relative density index also significantly increased from .63 (1999) to .71 (2000).

Although virtually all canopies within the survey range showed in increase in surface extent, the greatest increase was observed within Monterey Bay itself (CDF&G canopies 222, 221 and 220). Increases in canopy areas of 120%, 206% and 66%, respectively, were noted. In addition, increases in planimeter areas of 59%, 33%, and 43%, respectively, were also observed within these canopies.

The only canopy to experience a substantial loss in surface extent was canopy 208 (Cambria to Pt. Estero), which was reduced by 24% in canopy area and 14% in planimeter area.

Discussion

This scope of this inventory was established to provide a current, accurate measurement of the coastal kelp resource located within the Monterey Bay National Marine Sanctuary. In addition, future inventories may expand on this analysis in an effort to promote a better understanding of the seasonal dynamics of this important resource. In this regard, discussion will be limited to comparative methodology and sources of error that may affect the accuracy of this current inventory, and its subsequent utility for multi-year comparative purposes.

The data acquisition methodology utilized in this survey was established for the 1989 California state-wide inventory, and, with limited exception, has remained consistent in this current effort. The only change in data acquisition parameters has involved changing the camera/film format from 35mm in 1989 to 70mm in 1999, and the flight altitude from 7,500' MSL in 1989 to 9,500' MSL in 1999. The larger film format utilized in 1999 allowed this increase in altitude without sacrificing resolution on the imagery,

and permitted the kelp canopies to be more quickly imaged on the few optimum survey days.

Imagery for the 2000 inventory was also collected from 9,500' MSL using a 75mm lens (scale 1:3,217), except within the range from Pt. Sur to Pt. Piedras Blancas. Within this range a mid-level cloud layer at 4,000' MSL forced the imagery to be collected from 3,500' MSL, using a 35mm lens (scale 1:2,540). Although a lower altitude was required for imagery acquisition, optimum associated environmental conditions were present. The slight difference in photographic scale was judged insignificant with regard to the utility of the imagery for mapping the current resource and for multi-year comparative purposes.

An additional difference in methodology involved the timing of imagery acquisition for the 1999 and 2000 inventories. Persistent coastal fog during August and September 1999 delayed imagery acquisition until early October and may have underrepresented the kelp located in Monterey Bay proper (canopies 222, 221, and 220). In recent years, these surface kelp canopies have been observed to reach their summer maximum in June through August and begin to lose surface extent through canopy senescence due to elevated temperatures and reduced nutrients present in September and October each year. The outer coast has not been observed to experience this early loss of surface canopy, presumably due to increased nutrient availability in the late summer months. Favorable weather permitted all of the imagery for the 2000 inventory to be completed within the month of August, and likely better represented the maximum summer canopy present within the Monterey Bay proper.

With limited noted exceptions, all other data processing, mapping and analysis methodology, in addition to computation, tabulation, and presentation formats have remained consistent in this 2000 inventory, when compared to the previous 1999 effort. This should allow valid future quantitative comparisons of trends in kelp resource abundance as this inventory is continued.

Conclusion

This coastal kelp resource inventory was established to be a tool in the hands of researchers, and agency management professionals, leading toward a better understanding of the marine environment within the Monterey Bay National Marine Sanctuary.

In response to the stated resource monitoring and research mandate of the sanctuary program; this survey provided important data regarding the status of current kelp canopy abundance, in addition to comparisons with the 1999 inventory. We acknowledge the Monterey Bay National Marine Sanctuary for their encouragement and support of this work, and for their commitment to a better understanding of the complex processes structuring the nearshore marine environment.

Glossary

Kelp Bed Canopy - An aggregation of surface kelp plants in close proximity to each other which produced a consistent infrared return on the imagery, such that individual plants were indistinguishable when projected at mapping scale (1:24,000)

Kelp Bed Qualitative Canopy Area - The geographic (spatial) extent of individual surface kelp plants and canopies, as fully rendered from the original imagery. Each visible individual kelp plant and canopy was hand transferred to the "canopy area" maps, and represented by black-shading wherever present. Areas within the perimeter of the canopy that did not contain kelp were left un-shaded. This index depicted the actual appearance of the surface kelp canopy, as viewed on the original imagery.

Kelp Bed Quantitative Canopy Area - The numeric extent (sq. mi.) of individual surface kelp plants and canopies. Each qualitative canopy area map was scanned into the image processing system at full scale (1:24,000), and subsequent screen "pixel counts" conducted. All "black-shaded" pixels that represented actual kelp at the surface were counted, individual pixel area determined, and a quantitative kelp canopy area established. This index represented, numerically, the actual extent of the surface kelp canopy, as mapped from the original imagery.

Kelp Bed Qualitative Planimeter Area - The geographic (spatial) extent of the surface kelp canopy contained within its own perimeter, assuming continuous kelp coverage within. Since the surface kelp resource was composed of individual plants and established canopies; this measurement systematically defined the perimeter and subsequent enclosed area of this plant assemblage. This value depicted kelp canopy areal extent in slightly different terms than "canopy area", as previously defined, and served three purposes in this analysis: 1) it allowed comparisons of current and historic estimates of kelp resource abundance, which utilized similar "perimeter" estimation methods, 2) it allowed an understanding of the sea surface area that was actually occupied or influenced by the kelp canopy, and 3) it allowed a measurement of kelp canopy density (see "kelp bed relative density index").

Qualitative planimeter area, by kelp bed number, was established by computer enhancement of each scanned "canopy area" map. This methodology systematically established perimeter polygons around each kelp canopy, and included all kelp plants inside the polygons that were within 50 meters of each other, giving each plant a 25 meter "radius of association" (1 mm at the 1:24,000 mapping scale). Within the analysis software ("Global Lab Image"-V3.1-Data Translation), individual kelp plants and canopies within were "dilated" (expanded) with a "5x5" pixel "structuring element", thereby adding a 25 meter radius of kelp to each existing kelp pixel. Individual kelp plants within 50 meters of each other became part of the same perimeter, while plants greater than 50 meters apart retained discrete perimeters. Within established canopies, this transform had the effect of defining the canopy perimeter 25 meters beyond that visually apparent on the "canopy area" maps, as well as filling in the all of the "holes" in kelp coverage within the canopy. This computer synthesized value is spatially similar to that obtained by using a hand planimeter to determine kelp canopy

areal extent, and hence the name. Many environmental surveys have used planimeter areas to describe resource abundance, since prior to computers, this was all that was available. In addition, by the nature of the process, area statistics from other hand digitized kelp resource maps (for data entry into a geographic information system; see definition), will closely approximate the quantitative planimeter area (see definition), thereby allowing comparisons. This index is always larger than the kelp "canopy area", which is a depiction and measurement of the sea surface area actually occupied by visible kelp plants.

In addition to allowing comparisons with both historic (planimeter derived), and computer (digitizer derived) data, planimeter area measurements more accurately depict the extent, or sea surface area occupied, by kelp canopy species that have more irregular distributions (dense canopies in some areas and sparse areas containing individual plants in others). *Nereocystis sp.* canopies are frequently observed with this growth pattern, and their prominence underrepresented by a strict "canopy area" analysis only.

Kelp Bed Quantitative Planimeter Area - The numeric extent (sq. mi)) of the qualitative planimeter area (see glossary). Each quantitative planimeter area, by CDF&G canopy number was scanned into the image processing program, and a screen "pixel count" conducted. All pixels within the individual perimeters were counted, individual pixel area determined, and a quantitative canopy planimeter area established.

Kelp Bed Relative Density Index (RDI) - The percentage of the planimeter area that actually contained surface kelp plants. This index was calculated by dividing the canopy area by the planimeter area and approximated the probability of encountering kelp at a random point within the canopy perimeter. This value approaches "1" for very dense canopies and "0" for very sparse canopies. The measurement is independent of canopy size, and a good indicator of changes in density over time. In considering the relationship between canopy area and planimeter area, several examples underscore this basic relationship, and subsequent multi-year trends.

Canopy Area (sq. mi.)	Planimeter Area (sq. mi.)	Relative Density (RDI)	Interpretation
1.0	2.0	.5	1.0 sq. mi. of kelp is contained within 2.0 sq. mi. of the sea surface that it occupies (prob. of encountering kelp within perimeter = .5)
.5	2.0	.25	.5 sq. mi. of kelp is contained within 2.0 sq. mi. of the sea surface that it occupies (prob. of encountering kelp within perimeter = .25)
Can. Chg.	**Plan. Chg.**	**Den. Ch**	**Interpretation - Multi-Year Trends**
1.0 to 1.0	2.0 to 2.0	.5 to .5	Kelp resource area (canopy area), spatial extent (plan. area), and density (RDI) **stable** over time
1.0 to 1.5	2.0 to 2.0	.5 to .75	**Increased** resource area within **similar** spatial extent at **inc. dens.**
1.0 to 2.0	2.0 to 4.0	.5 to .5	**Inc.** resource area and spatial extent at **similar** densities
1.0 to 2.0	2.0 to 3.0	.5 to .66	**Inc.** resource area and spatial extent at **increasing** densities

1.0 to 1.5	2.0 to 4.0	.5 to .38	**Inc.** resource area and spatial extent at **decreasing** densities
1.0 to .5	2.0 to 2.0	.5 to .25	**Dec.** resource area within **similar** spatial extent at **dec. density**
1.0 to .5	2.0 to 1.0	.5 to .5	**Dec.** resource area and spatial extent at **similar** densities
1.0 to .5	2.0 to 1.5	.5 to .33	**Dec.** resource area and spatial extent at **decreasing** densities
1.0 to .5	2.0 to 3.0	.5 to .16	**Dec.** resource area within **inc.** spatial extent at **dec.** densities

Geographic Information System (GIS) - A computer software platform designed to facilitate the assembly and analysis of diverse data sets pertaining to specific geographic areas using spatial locations of the data as the basis for the information system

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CALIFORNIA COASTAL KELP RESOURCES

Bolinas Lagoon
to
Point Estero

Section 2

Tables

August 2000

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Computer Data File (Disk 1/1)
(Section 6)
FILE: MBNMSK00.XLS (Excel 97 Format)

Table 1

California Coastal Kelp Resources - Summer 2000

Monterey Bay National Marine Sanctuary

Kelp Resource Map Index

- By Map Number

MAP NUMBER	MAP NAME	CDF&G KELP BED NUMBERS
C-27	Bolinas	
C-28	San Francisco	
C-29	Montara	225
C-30	Half Moon Bay	225
C-31	Pigeon Point	224, 225
C-32	Ano Nuevo	223, 224
C-33	Davenport	222, 223
C-34	Santa Cruz	221, 222
C-35	Moss Landing	221
C-36	Marina	221
C-37	Monterey	217, 218, 219, 220, 221
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C-39	Pfeiffer Pt.	214, 215, 216
C-40	Lopez Pt.	213, 214
C-41	Cape San Martin	212, 213
C-42	Ragged Pt.	211, 212
C-43	Pt. Piedras Blancas	209, 210, 211
C-44	Cambria	208, 209

Table 2

California Coastal Kelp Resources - Summer 2000

Monterey Bay National Marine Sanctuary

Kelp Resource Map Index

- By Map Name

MAP NAME	MAP NUMBER	CDF&G KELP BED NUMBERS
Ano Nuevo	C-32	223, 224
Bolinas	C-27	
Cambria	C-44	208, 209
Cape San Martin	C-41	212, 213
Davenport	C-33	222, 223
Half Moon Bay	C-30	225
Lopez Pt.	C-40	213, 214
Marina	C-36	221
Montara	C-29	225
Monterey	C-37	217, 218, 219, 220, 221
Moss Landing	C-35	221
Pfeiffer Pt.	C-39	214, 215, 216
Pigeon Point	C-31	224, 225
Pt. Piedras Blancas	C-43	209, 210, 211
Pt. Sur	C-38	216, 217
Ragged Pt.	C-42	211, 212
San Francisco	C-28	
Santa Cruz	C-34	221, 222

Table 3

California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Geographic Features Index

- By Location

LOCATION	MAP NAME	MAP NUMBER
17 Mile Dr.	Monterey	C-37
Agate Beach County Park	Bolinas	C-27
Alder Creek	Ragged Pt.	C-42
Anderson Creek	Lopez Pt.	C-40
Anderson Landing	Lopez Pt.	C-40
Ano Nuevo Bay	Ano Nuevo	C-32
Ano Nuevo Island	Ano Nuevo	C-32
Aptos (city)	Santa Cruz	C-34
Aptos Creek	Santa Cruz	C-34
Arroyo de la Cruz	Pt. Piedras Blancas	C-43
Arroyo de los Chinos	Ragged Pt.	C-42
Arroyo del Oso	Pt. Piedras Blancas	C-43
Arroyo del Padre	Pt. Piedras Blancas	C-43
Bean Hollow Beach	Pigeon Pt.	C-31
Bennett Slough	Moss Landing	C-35
Big Creek	Lopez Pt.	C-40
Big Lagoon	Bolinas	C-27
Bird Island	San Francisco	C-28
Bird Island	Monterey	C-37
Bird Rock	Monterey	C-37
Bixby Landing	Pt. Sur	C-38
Bolinas (city)	Bolinas	C-27
Bolinas Bay	Bolinas	C-27
Bolinas Lagoon	Bolinas	C-27
Bolinas Pt.	Bolinas	C-27
Bolsa Pt.	Pigeon Pt.	C-31
Bonita Cove	San Francisco	C-28
Broken Bridge Creek	Pt. Piedras Blancas	C-43
Burns Creek	Lopez Pt.	C-40
Butano Creek	Pigeon Pt.	C-31
Cambria (town)	Cambria	C-44
Cambria Radar Station (former)	Cambria	C-44
Cannery Row	Monterey	C-37
Cape San Martin	Cape San Martin	C-41
Capitola (city)	Santa Cruz	C-34
Capitola State Beach	Santa Cruz	C-34

Table 3

California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Geographic Features Index

- By Location

LOCATION	MAP NAME	MAP NUMBER
Carmel (city)	Monterey	C-37
Carmel Bay	Monterey	C-37
Carmel Highlands	Monterey	C-37
Carmel Pt.	Monterey	C-37
Carmel River	Monterey	C-37
Carmel Valley	Monterey	C-37
Castro Canyon	Pfeiffer Pt.	C-39
Castroville (town)	Moss Landing	C-35
Cement Plant	Davenport	C-33
China Bluff	Ragged Pt.	C-42
Cooper Pt.	Pfeiffer Pt.	C-39
Coral de Tierra	Half Moon Bay	C-30
Corcoran lagoon	Santa Cruz	C-34
Cowell Beach	Santa Cruz	C-34
CSU Monterey Bay	Marina	C-36
Cypress Pt.	Monterey	C-37
Davenport (town)	Davenport	C-33
Davenport Landing	Davenport	C-33
De La Cruz Rock	Pt. Piedras Blancas	C-43
Del Monte Lake	Marina	C-36
Devils Canyon	Lopez Pt.	C-40
Devils Slide	Montara	C-29
Dolan Canyon	Lopez Pt.	C-40
Dolan Creel	Lopez Pt.	C-40
Dolan Rock	Lopez Pt.	C-40
Duxberry Pt.	Bolinas	C-27
Duxberry Reef	Bolinas	C-27
Edgemar (town)	Montara	C-29
Eel Rock	Half Moon Bay	C-30
El Granada Beach	Half Moon Bay	C-30
El Jarro Pt.	Davenport	C-33
Elkhorn Slough	Moss Landing	C-35
Fan Shell Beach	Monterey	C-37
Fort Barry Military Res.	San Francisco	C-28
Fort Old Military Res. (former)	Marina	C-36
Frank Valley	Bolinas	C-27

Table 3

California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Geographic Features Index

- By Location

LOCATION	MAP NAME	MAP NUMBER
Franklin Pt.	Ano Nuevo	C-32
Gamboa Pt.	Lopez Pt.	C-40
Garrapata Creek	Pt. Sur	C-38
Golden Gate Bridge	San Francisco	C-28
Golden Gate Park	San Francisco	C-28
Gorda (town)	Cape San Martin	C-41
Gordola (town)	Davenport	C-33
Green Oaks Creek	Ano Nuevo	C-32
Greyhound Rock	Ano Nuevo	C-32
Grimes Canyon	Pfeiffer Pt.	C-39
Grimes Pt.	Pfeiffer Pt.	C-39
Gull Rock	Bolinas	C-27
Half Moon Bay (city)	Half Moon Bay	C-30
Half Moon bay Airport	Half Moon Bay	C-30
Hare Canyon	Cape San Martin	C-41
Harlan Rock	Cape San Martin	C-41
Harlech Castle Rock	Pt. Piedras Blancas	C-43
Hearst Airport	Pt. Piedras Blancas	C-43
Hearst Castle State Historical Mon.	Pt. Piedras Blancas	C-43
Hearst Ranch	Pt. Piedras Blancas	C-43
Hopkins Marine Station	Monterey	C-37
Hot Springs Canyon	Lopez Pt.	C-40
Hunter Liggett Military Res.	Ragged Pt.	C-42
Hurricane Pt.	Pt. Sur	C-38
Indian Head Beach	Marina	C-36
Kasler Pt.	Pt. Sur	C-38
Kent Island	Bolinas	C-27
Kings Rock	Half Moon Bay	C-30
Kirk Creek	Cape San Martin	C-41
La Selva Beach (town)	Santa Cruz	C-34
Laffler Canyon	Pfeiffer Pt.	C-39
Laguna Creek	Davenport	C-33
Laguna Salada	Montara	C-29
Lake Lucerne	Pigeon Pt.	C-31
Lake Merced	San Francisco	C-28
Lands End	San Francisco	C-28

Table 3

California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Geographic Features Index

- By Location

LOCATION	MAP NAME	MAP NUMBER
Leffingwell Creek	Cambria	C-44
Lime Creek	Lopez Pt.	C-40
Limekiln Creek	Cape San Martin	C-41
Little Pico Creek	Pt. Piedras Blancas	C-43
Little Sur River	Pt. Sur	C-38
Live Oak (town)	Santa Cruz	C-34
Lobos Rocks	Pt. Sur	C-38
Lopez Pt.	Lopez Pt.	C-40
Lopez Rock	Lopez Pt.	C-40
Lovers Pt.	Monterey	C-37
Lucia (town)	Cape San Martin	C-41
Manresa Beach	Santa Cruz	C-34
Manresa Beach	Moss Landing	C-35
Marina (town)	Marina	C-36
Marina State Park	Marina	C-36
Martins Beach	Half Moon Bay	C-30
McClusky Slough	Moss Landing	C-35
McWay Creek	Lopez Pt.	C-40
McWay Slide	Lopez Pt.	C-40
Mile Rock	San Francisco	C-28
Mill Creek	Cape San Martin	C-41
Miramar	Half Moon Bay	C-30
Miramar Beach	Half Moon Bay	C-30
Miramontes Pt.	Half Moon Bay	C-30
Montara (town)	Montara	C-29
Montara Beach	Montara	C-29
Monterey (city)	Monterey	C-37
Monterey Bay Academy	Moss Landing	C-35
Monterey Bay Aquariun	Monterey	C-37
Monterey Coast Guard Station	Monterey	C-37
Monterey County Fairgrounds	Marina	C-36
Monterey Municipal Airport	Marina	C-36
Moore Creek	Davenport	C-33
Moran Lake	Santa Cruz	C-34
Mori Point	Montara	C-29
Moss Beach (town)	Montara	C-29

Table 3

California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Geographic Features Index

- By Location

LOCATION	MAP NAME	MAP NUMBER
Moss Landing (town)	Moss Landing	C-35
Moss Landing Harbor	Moss Landing	C-35
Mt. Tamalpias State Park	Bolinas	C-27
Muir Beach	Bolinas	C-27
Mussel Rock	Montara	C-29
Mussel Rock	Pigeon Pt.	C-31
Natural Bridges Beach State Park	Davenport	C-33
Needle Rock Pt.	Davenport	C-33
New Brighton State Beach	Santa Cruz	C-34
Oak Knoll Creek	Pt. Piedras Blancas	C-43
Olympic Golf Club	San Francisco	C-28
Opal Cliffs Beach	Santa Cruz	C-34
Otter Pt.	Monterey	C-37
Pacific Grove (city)	Monterey	C-37
Pacific Manor (town)	Montara	C-29
Pajaro Dunes Development	Moss Landing	C-35
Pajaro River	Moss Landing	C-35
Palm Beach	Moss Landing	C-35
Palo Colorado Canyon Creek	Pt. Sur	C-38
Partington Creek	Pfeiffer Pt.	C-39
Partington Pt.	Pfeiffer Pt.	C-39
Pebble Beach Golf Course	Monterey	C-37
Pelican Rock	Ano Nuevo	C-32
Pescadero Beach	Pigeon Pt.	C-31
Pescadero Pt.	Pigeon Pt.	C-31
Pfeiffer Big Sur State Park	Pfeiffer Pt.	C-39
Pfeiffer Pt.	Pfeiffer Pt.	C-39
Pfeiffer Rock	Pfeiffer Pt.	C-39
Pfeiffer Rock	Pfeiffer Pt.	C-39
PG&E Moss Landing Power Plant	Moss Landing	C-35
Pico Creek	Pt. Piedras Blancas	C-43
Pico Rock	Pt. Piedras Blancas	C-43
Pigeon Pt.	Pigeon Pt.	C-31
Pillar Pt.	Half Moon Bay	C-30
Pillar Pt. Harbor	Half Moon Bay	C-30
Pirates Cove	Bolinas	C-27

Table 3

California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Geographic Features Index

- By Location

LOCATION	MAP NAME	MAP NUMBER
Plaskett (town)	Cape San Martin	C-41
Plaskett Creek	Cape San Martin	C-41
Plaskett Rock	Cape San Martin	C-41
Pomponio Beach	Pigeon Pt.	C-31
Prewitt Creek	Cape San Martin	C-41
Princeton (town)	Half Moon Bay	C-30
Pt. Ano Nuevo	Ano Nuevo	C-32
Pt. Bonita	San Francisco	C-28
Pt. Cabrillo	Monterey	C-37
Pt. Estero	Cambria	C-44
Pt. Joe	Monterey	C-37
Pt. Lobos	San Francisco	C-28
Pt. Lobos State Reserve	Monterey	C-37
Pt. Montara	Montara	C-29
Pt. Piedras Blancas	Pt. Piedras Blancas	C-43
Pt. Piedras Blancas Lighthouse	Pt. Piedras Blancas	C-43
Pt. Pinos	Monterey	C-37
Pt. San Pedro	Montara	C-29
Pt. Santa Cruz	Santa Cruz	C-34
Pt. Sierra Nevada	Ragged Pt.	C-42
Pt. Sur	Pt. Sur	C-38
Ptl Sur Lighthouse	Pt. Sur	C-38
Purisima Creek	Half Moon Bay	C-30
Ragged Pt.	Ragged Pt.	C-42
Rat Creek	Lopez Pt.	C-40
Redondo beach	Half Moon Bay	C-30
Redwood Gulch	Ragged Pt.	C-42
Rio Del Mar (town)	Santa Cruz	C-34
Rockland Landing	Cape San Martin	C-41
Rocky Point	Bolinas	C-27
Rocky Pt.	Pt. Sur	C-38
Rodeo Cove	San Francisco	C-28
Salinas National Wildlife Refuge	Marina	C-36
Salinas River	Moss Landing	C-35
Salinas River	Marina	C-36
Salmon Cone Mountain	Ragged Pt.	C-42

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California Coastal Kelp Resources
Monterey Bay National Marine Sanctuary
Geographic Features Index
- By Location

LOCATION	MAP NAME	MAP NUMBER
Salmon Creek	Ragged Pt.	C-42
San Carpoforo Creek	Ragged Pt.	C-42
San Francisco (city)	San Francisco	C-28
San Francisco Bay	San Francisco	C-28
San Gregorio Creek	Pigeon Pt.	C-31
San Lorenzo River	Santa Cruz	C-34
San Mateo Coast State Beaches	Half Moon Bay	C-30
San Pedro Rock	Montara	C-29
San Pedro Valley (town)	Montara	C-29
San Simeon (town)	Pt. Piedras Blancas	C-43
San Simeon Bay	Pt. Piedras Blancas	C-43
San Simeon Beach State Park	Cambria	C-44
San Simeon Pt.	Pt. Piedras Blancas	C-43
San Vicente Creek	Montara	C-29
Sand Beach	Pigeon Pt.	C-31
Sand City (town)	Marina	C-36
Sand Hilll Bluff	Davenport	C-33
Santa Cruz (city)	Santa Cruz	C-34
Santa Cruz Harbor	Santa Cruz	C-34
Santa Cruz Municipal Pier	Santa Cruz	C-34
Schwans Lagoon	Santa Cruz	C-34
Scott Creek	Ano Nuevo	C-32
Seacliff State Beach	Santa Cruz	C-34
Seal Cove	Half Moon Bay	C-30
Seal Lion Rocks	Monterey	C-37
Seal Rock	Half Moon Bay	C-30
Seal Rock	Monterey	C-37
Seal Rocks	San Francisco	C-28
Seaside (town)	Marina	C-36
Sharp Park	Montara	C-29
Shelter Cove	Montara	C-29
Slate Rock	Lopez Pt.	C-40
Soberanes Pt.	Pt. Sur	C-38
Soda Spring Creek	Ragged Pt.	C-42
Soquel (city)	Santa Cruz	C-34
Soquel Creek	Santa Cruz	C-34

Table 3
California Coastal Kelp Resources
Monterey Bay National Marine Sanctuary
Geographic Features Index
- By Location

LOCATION	MAP NAME	MAP NUMBER
Soquel Pt.	Santa Cruz	C-34
South Cambria (town)	Cambria	C-44
South Fork Creek	Cape San Martin	C-41
Spanish Bay	Monterey	C-37
Spring Bridge Gulch	Pigeon Pt.	C-31
Square Black Rock	Lopez Pt.	C-40
Stillwater Cove	Monterey	C-37
Stinson Beach	Bolinas	C-27
Sunset Pt.	Monterey	C-37
Sunset State Beach	Moss Landing	C-35
Sycamore Canyon	Pfeiffer Pt.	C-39
Tennessee Pt.	Bolinas	C-27
Terrace Pt.	Davenport	C-33
Thornton Beach State Park	San Francisco	C-28
Torre Canyon	Pfeiffer Pt.	C-39
Tunitas Beach	Pigeon Pt.	C-31
Tunitas Creek	Pigeon Pt.	C-31
Twin Lakes Beach	Santa Cruz	C-34
Vanelcia Creek	Santa Cruz	C-34
Ventura Rocks	Pt. Sur	C-38
Vincente Creek	Lopez Pt.	C-40
Watsonville Slough	Moss Landing	C-35
Whitehouse Creek	Ano Nuevo	C-32
Wild Cattle Creek	Cape San Martin	C-41
Willow Creek	Cape San Martin	C-41
Woods Lagoon	Santa Cruz	C-34
Wreck Beach	Pfeiffer Pt.	C-39
Yankee Gulch	Pigeon Pt.	C-31
Yankee Pt.	Monterey	C-37
Zmudowski Beach State Park	Moss Landing	C-35

Table 4

California Coastal Kelp Resources

Monterey Bay National Marine Sanctuary

Kelp Bed Canopy/Planimeter Area/Relative Density Index

Summer 2000

- By CDF Kelp Bed Number

CDF&G KELP BED NUMBER	Kelp Bed Canopy Area (sq. mi.)	Kelp Bed Planimeter Area (sq. mi.)	Relative Density Index (RDI)
225	0.002	0.024	0.11
224	0.019	0.083	0.22
223	0.094	0.361	0.26
222	0.583	1.060	0.55
221	0.423	0.630	0.67
220	1.262	1.669	0.76
219	1.296	1.494	0.87
218	0.405	0.534	0.76
217	2.120	2.777	0.76
216	2.217	2.647	0.84
215	0.614	0.891	0.69
214	1.811	2.246	0.81
213	1.355	2.037	0.67
212	0.678	0.985	0.69
211	1.249	1.858	0.67
210	1.243	1.902	0.65
209	0.895	1.562	0.57
208	1.187	1.903	0.62
	17.451	**24.663**	**0.71**

Table 5
California Coastal Kelp Resources
Monterey Bay National Marine Sanctuary
Kelp Bed Canopy/Planimeter Area/Relative Density Index
Summer 1999
- By CDF Kelp Bed Number

CDF&G KELP BED NUMBER	Kelp Bed Canopy Area (sq. mi.)	Kelp Bed Planimeter Area (sq. mi.)	Relative Density Index (RDI)
225	0.000	0.000	0.00
224	0.011	0.045	0.24
223	0.077	0.294	0.26
222	0.260	0.664	0.39
221	0.138	0.472	0.29
220	0.760	1.163	0.65
219	1.001	1.434	0.70
218	0.311	0.474	0.66
217	2.133	3.195	0.67
216	1.879	2.535	0.74
215	0.612	0.870	0.70
214	1.299	1.824	0.71
213	0.985	1.679	0.59
212	0.495	0.907	0.55
211	0.653	1.496	0.44
210	1.078	1.709	0.63
209	0.802	1.388	0.58
208	1.560	2.210	0.71
	14.053	**22.358**	**0.63**

Table 6
California Coastal Kelp Resources
Monterey Bay National Marine Sanctuary
Kelp Bed Canopy/Planimeter Area/RDI
Summer 1999 and 2000

CDF&G KELP BED NUMBERS	1999 Canopy Area (sq. mi.)	2000 Canopy Area (sq. mi.)	1999 Planimeter Area (sq. mi.)	2000 Planimeter Area (sq. mi.)	1999 Rel. Dens. Ind. (RDI)	2000 Rel. Dens. Ind. (RDI)
225	0.000	0.002	0.000	0.024	0.00	0.11
224	0.011	0.019	0.045	0.083	0.24	0.22
223	0.077	0.094	0.294	0.361	0.26	0.26
222	0.260	0.583	0.664	1.060	0.39	0.55
221	0.138	0.423	0.472	0.630	0.29	0.67
220	0.760	1.262	1.163	1.669	0.65	0.76
219	1.001	1.296	1.434	1.494	0.70	0.87
218	0.311	0.405	0.474	0.534	0.66	0.76
217	2.133	2.120	3.195	2.777	0.67	0.76
216	1.879	2.217	2.535	2.647	0.74	0.84
215	0.612	0.614	0.870	0.891	0.70	0.69
214	1.299	1.811	1.824	2.246	0.71	0.81
213	0.985	1.355	1.679	2.037	0.59	0.67
212	0.495	0.678	0.907	0.985	0.55	0.69
211	0.653	1.249	1.496	1.858	0.44	0.67
210	1.078	1.243	1.709	1.902	0.63	0.65
209	0.802	0.895	1.388	1.562	0.58	0.57
208	1.560	1.187	2.210	1.903	0.71	0.62
	14.053	**17.451**	**22.358**	**24.663**	**0.63**	**0.71**

CALIFORNIA COASTAL KELP RESOURCES

Bolinas Lagoon
to
Point Estero

Section 3

Figures

August 2000

List of Tables
(Section 2)

List of Figures
(Section 3)

Computer Data File (Disk 1/1)
(Section 6)
FILE: MBNMSK00.XLS (Excel 97 Format)

Figure 1.1

Data Acquisition

Flight Data Report

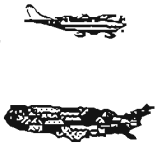
Contracting Agency/Contact		Contract/Order #/Agency File #	
Contracting Agency:	Monterey Bay National Marine Sancturay	Contract/Order #:	
Division:		Agency File #:	
Contact/Title:	Mario Tamburi	Calendar	
Address:	299 Foam St.	Services Ordered:	August 1999
City/State/Zip:	Monterey, CA 93940	Data Acquisition Completed:	August 30, 2000
Phone 1/Phone 2:	(831) 647-4206	Draft Report Materials Due:	
Fax/E-Mail:		Final Report Materials Due:	March 2001

Project Title/Target Resource (s)- Survey Range (s)/Survey Data Flow		
Project Title		California Coastal Kelp Resources - Monterey National Marine Sanctuary - Summer 2000
Target Resource (s)/ Survey Range (s)		Measurement of the areal extent of coastal kelp canopies within the range of Bolinas Lagoon to Pt. Estero.
Survey Data Flow	Acquisition	Vertical aerial color infrared imagery of all kelp canopies within the survey range
	Processing	All kelp canopies projected and rendered onto existing 1:24,000 baseline maps
	Analysis	Area analysis of kelp canopy extent using existing CDF&G numbering system
	Presentation	Maps presented at several sizes/formats for reporting purposes: 24"x36", 11"x17", and 8.5"x11"

Aerial Resource Survey Flight Data for:		August 10, 2000			
	Survey Type/Sensing Equipment	Aircraft/Imagery Data		Associated Conditions	
	Aerial Transportation/Observation	Aircraft:	Cessna 182R	Sky Conditions:	Clear
	Photographic Film Imagery - 35 mm	Altitude:	9,500' MSL	Sun Angle:	> 45 degrees
✓	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	25 + miles
	Digital Color/Color Infrared Imagery	Camera:	Pentax 645	Wind:	10 kts.
	Videography	Lenses:	75mm	Sea/Swell:	3-5 feet
	Radio Telemetry	Film:	Kodak CIR	Time:	1400-1600
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	3.0' to 3.2' (+) MLLW
	Other:	Photo Scale:	1"=3,217'	Shadow:	No significant
	Sensor 1:	Pilot:	Unsicker	Other:	No coastal bluff shadow
	Sensor 2:	Photographer:	Van Wagenen	Comments:	Excellent survey cond

Range (s) Surveyed		Aerial imagery was obtained under optimum survey conditions from Rocky Pt. to Capitola
Target Resource Observations	Kelp Canopies:	The coastal kelp canopies (both Nereocystis and Macrocystis) from Rocky Pt. to Capitola appeared well developed and at their maximum summer extent.
Imagery Quality/ Comments	Quality:	Excellent - All kelp canopies were photographed within the above range and the subsequent film processing was conducted normally.
	Weather Cond:	Clear

Ecoscan Resource Data
143 Browns Valley Rd.
Watsonville, CA 95076
(831) 728-3289 (ph./fax)



Signed: _____ Bob Van Wagenen, Director

Copy To:

Figure 1.2
Data Acquisition
Flight Data Report

Contracting Agency/Contact		Contract/Order #/Agency File #	
Contracting Agency:	Monterey Bay National Marine Sancturay	Contract/Order #:	
Division:		Agency File #:	
Contact/Title:	Mario Tamburi	Calendar	
Address:	299 Foam St.	Services Ordered:	August 1999
City/State/Zip:	Monterey, CA 93940	Data Acquisition Completed:	August 30, 2000
Phone 1/Phone 2:	(831) 647-4206	Draft Report Materials Due:	
Fax/E-Mail:		Final Report Materials Due:	October 2000

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

Project Title		California Coastal Kelp Resources - Monterey National Marine Sanctuary - Summer 2000
Target Resource (s)/ Survey Range (s)		Measurement of the areal extent of coastal kelp canopies within the range of Bolinas Lagoon to Pt. Estero.
Survey Data Flow	Acquisition	Vertical aerial color infrared imagery of all kelp canopies within the survey range
	Processing	All kelp canopies projected and rendered onto existing 1:24,000 baseline maps
	Analysis	Area analysis of kelp canopy extent using existing CDF&G numbering system
	Presentation	Maps presented at several sizes/formats for reporting purposes: 24"x36", 11"x17", and 8.5"x11"

Aerial Resource Survey Flight Data for:		August 30, 2000			
	Survey Type/Sensing Equipment	Aircraft/Imagery Data		Associated Conditions	
	Aerial Transportation/Observation	Aircraft:	Cessna 182R	Sky Conditions:	Clear/Cloudy (4000 ceiling)
	Photographic Film Imagery - 35 mm	Altitude:	3,500'/9,500'	Sun Angle:	> 45 degrees
√	Photographic Film Imagery - 70 mm	Speed:	100 kts.	Visibility:	25 + miles
	Digital Color/Color Infrared Imagery	Camera:	Pentax 645	Wind:	10 kts.
	Videography	Lenses:	35/75mm	Sea/Swell:	3-5 feet
	Radio Telemetry	Film:	Kodak CIR	Time:	1615-1815
	Radiometry/Geophysical Measurements	Angle:	Vertical	Tide:	1.1' (+) to 2.1' (+) MLLW
	Other:	Photo Scale:	1:2,540/3,217	Shadow:	No significant
	Sensor 1:	Pilot:	Unsicker	Other:	No coastal bluff shadow
	Sensor 2:	Photographer:	Van Wagenen	Comments:	Excellent survey cond.

Range (s) Surveyed		Aerial imagery was obtained under optimum survey conditions from Seaside to Pt. Estero
Target Resource Observations	Kelp Canopies:	The coastal kelp canopies (both Nereocystis and Macrocystis) from Seaside to Pt. Estero appeared well developed and at their maximum summer extent.
Imagery Quality/ Comments	Quality:	Excellent - All kelp canopies were photographed within the above range and the subsequent film processing was conducted normally.
	Weather Cond:	Clear to partly cloudy conditions (4,000' MSL ceiling) prevailed throughout the survey range

Ecoscan Resource Data
143 Browns Valley Rd.
Watsonville, CA 95076
(831) 728-3289 (ph./fax)

Signed: _____ Bob Van Wagenen, Director

Copy To:

Figure 2
California Coastal Kelp Resources
Monterey Bay National Marine Sanctuary
Kelp Bed Canopy/Planimeter Area/Relative Density Index
Summer 2000
- By CDF Kelp Bed Number

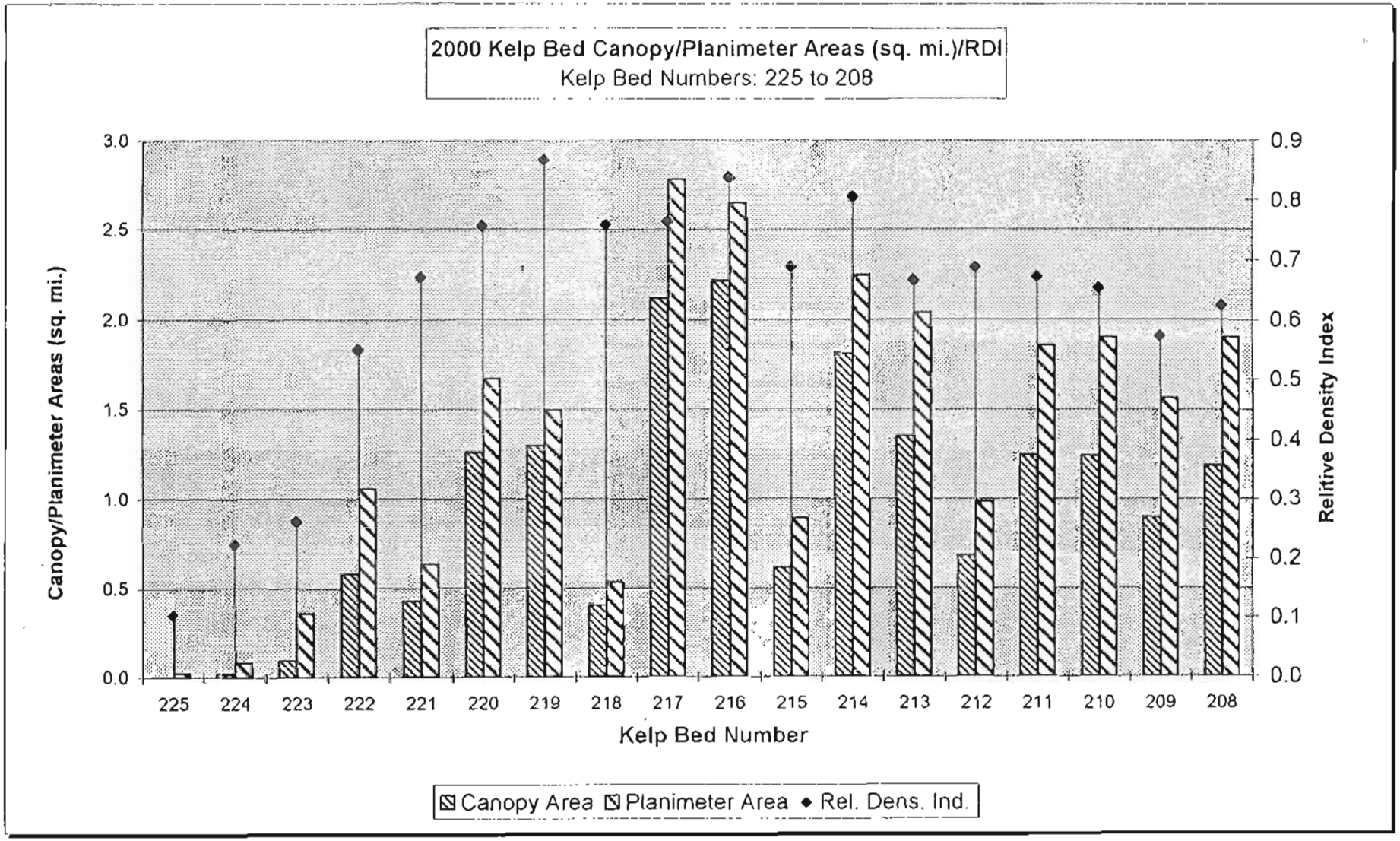


Figure 3
California Coastal Kelp Resources
Monterey Bay National Marine Sanctuary
Kelp Bed Canopy/Planimeter Area/Relative Density Index
Summer 1999
- By CDF Kelp Bed Number

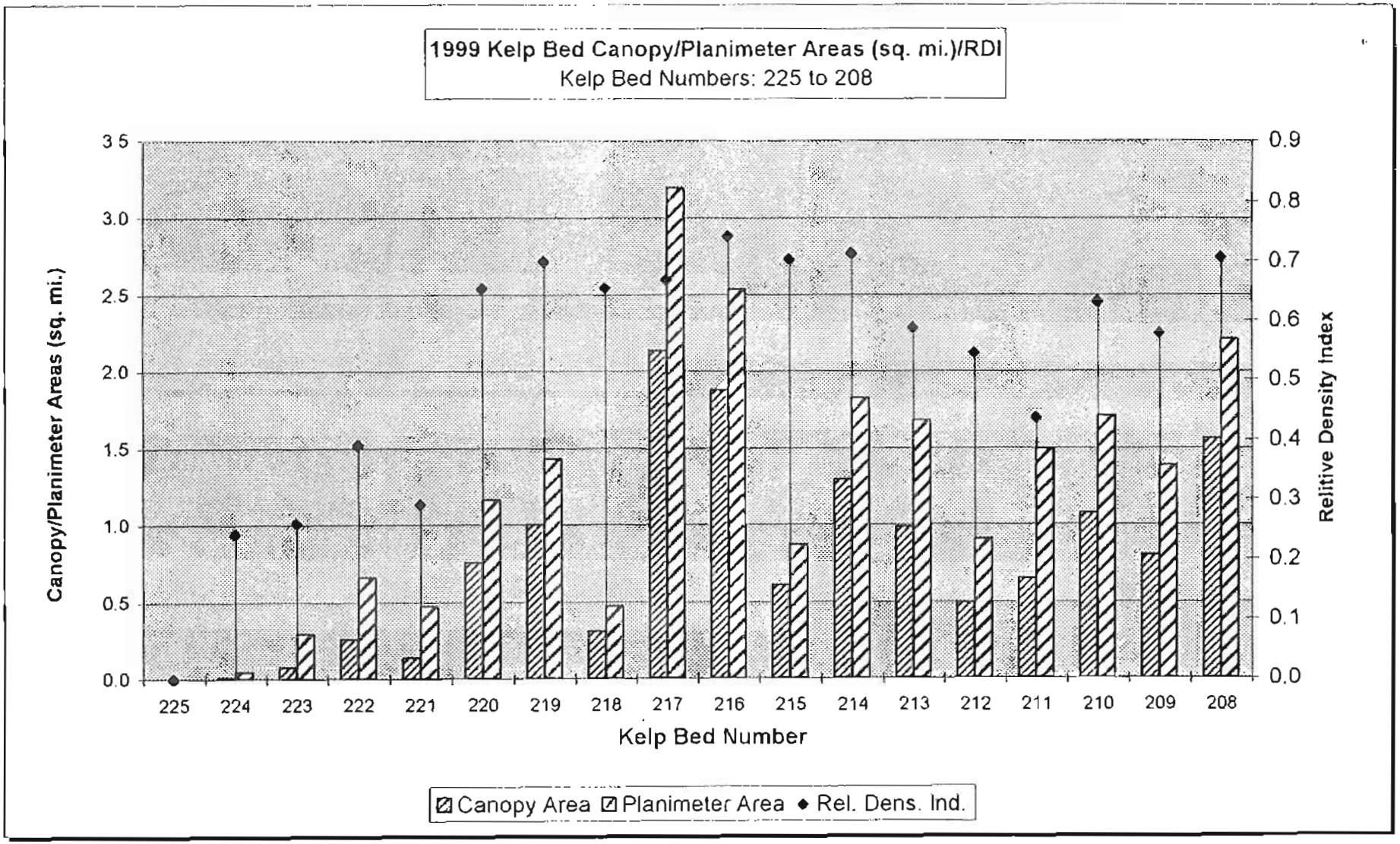
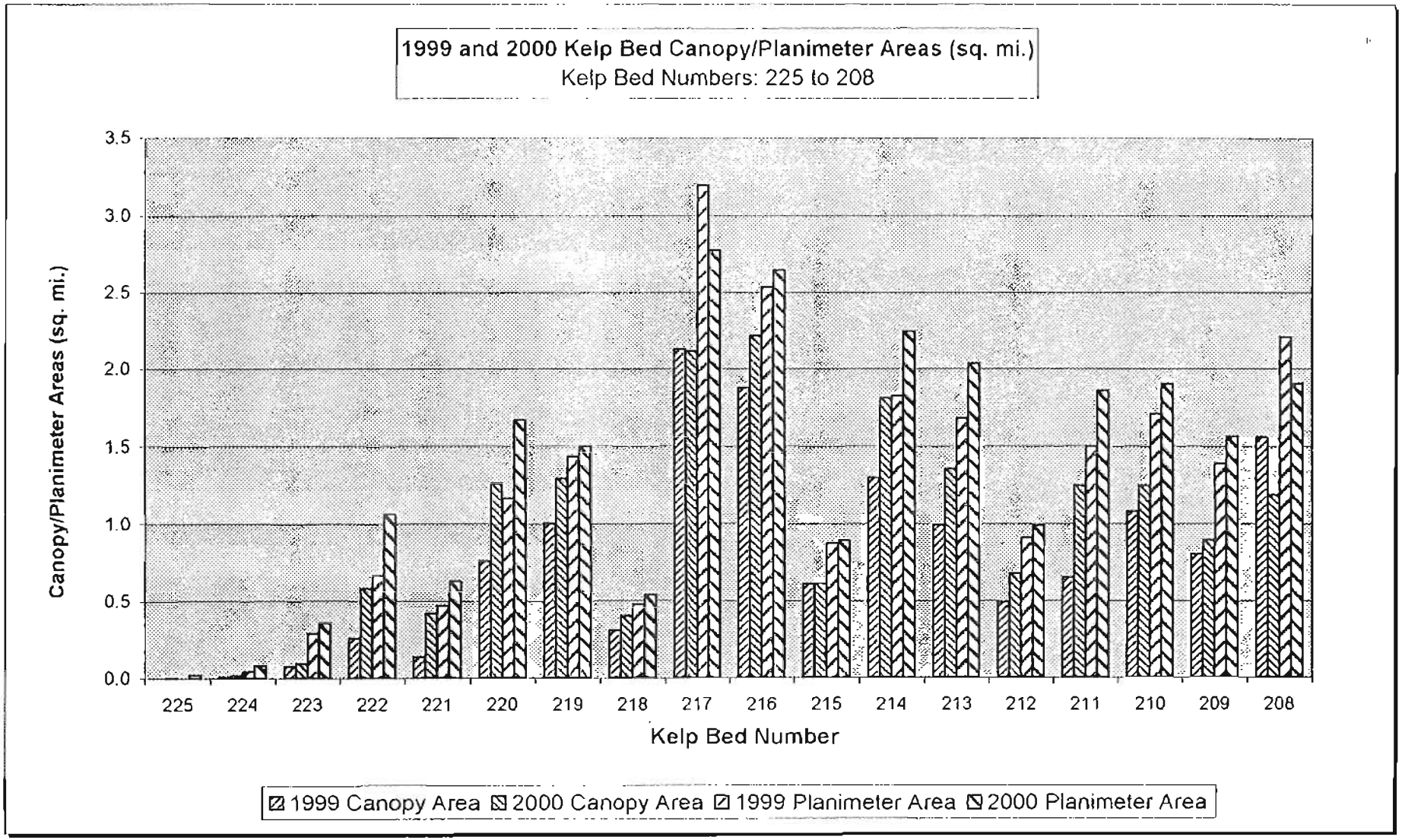


Figure 4
Monterey Bay National Marine Sanctuary
Kelp Bed Canopy/Planimeter Area
Summer 1999 and 2000
- By CDF Kelp Bed Number



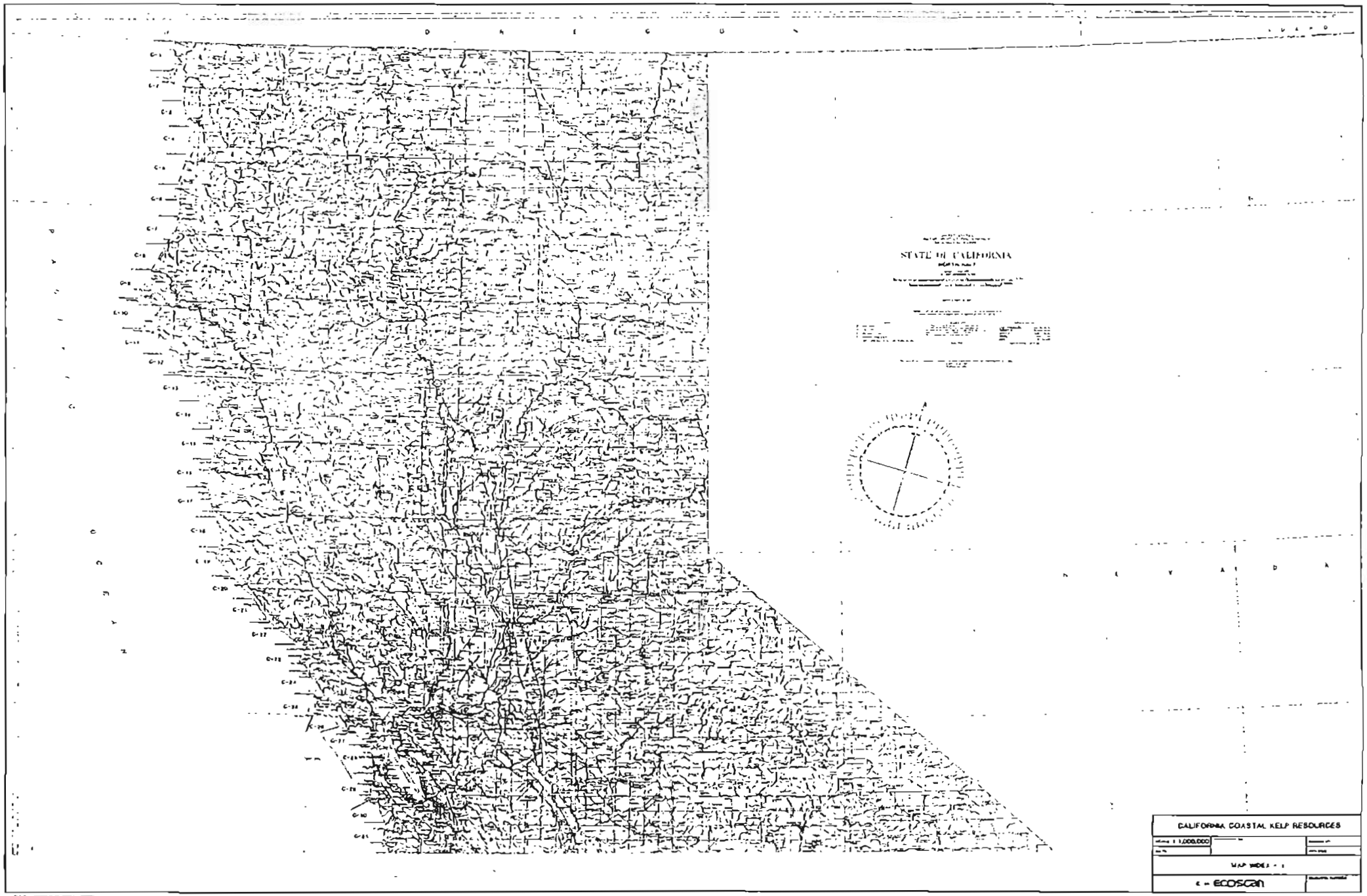
CALIFORNIA COASTAL KELP RESOURCES

Bolinas Lagoon
to
Point Estero

Section 4

Kelp Bed Canopy Area Maps: 27-44

August 2000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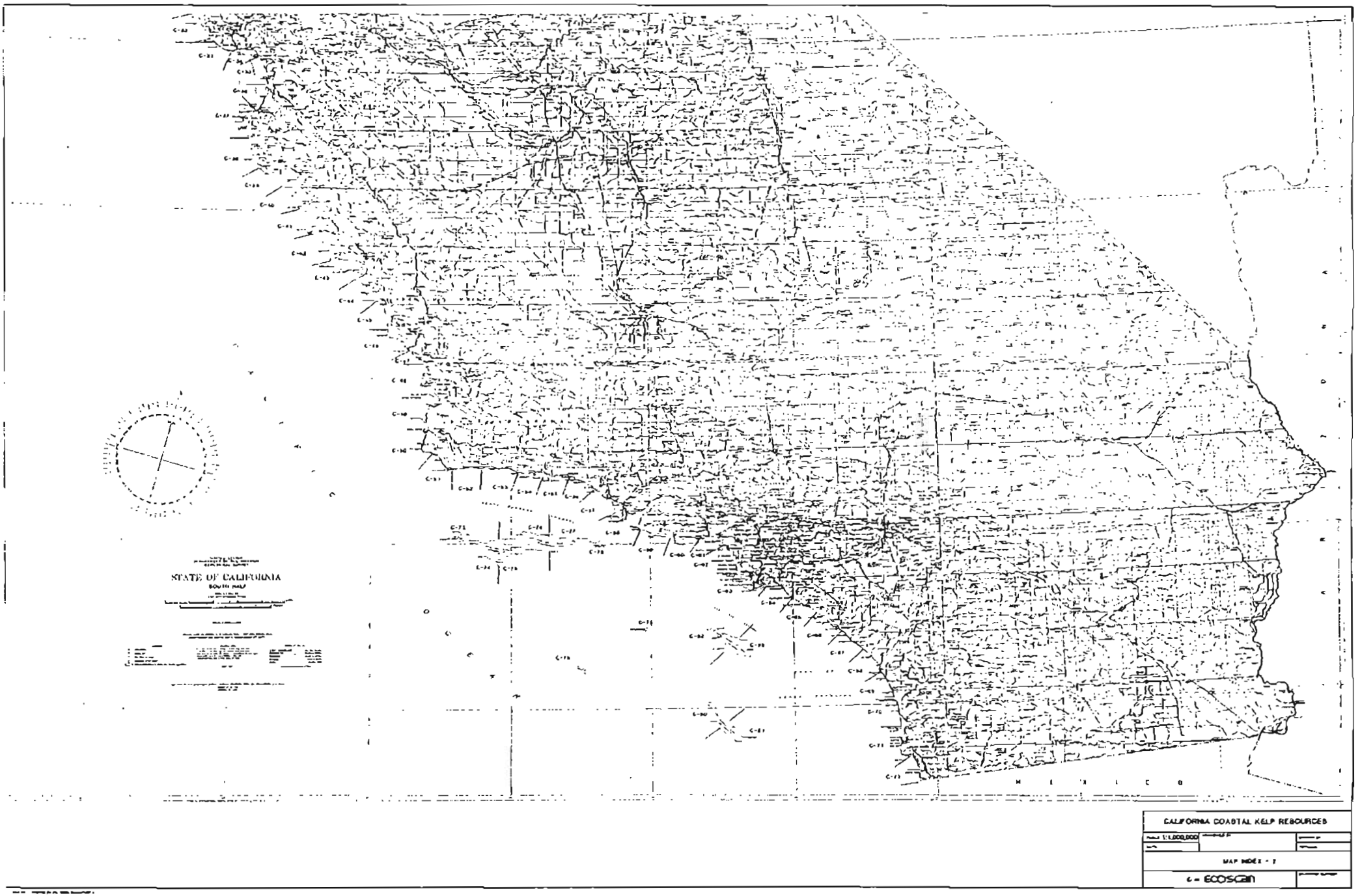
CALIFORNIA COASTAL KELP RESOURCES
ecoscan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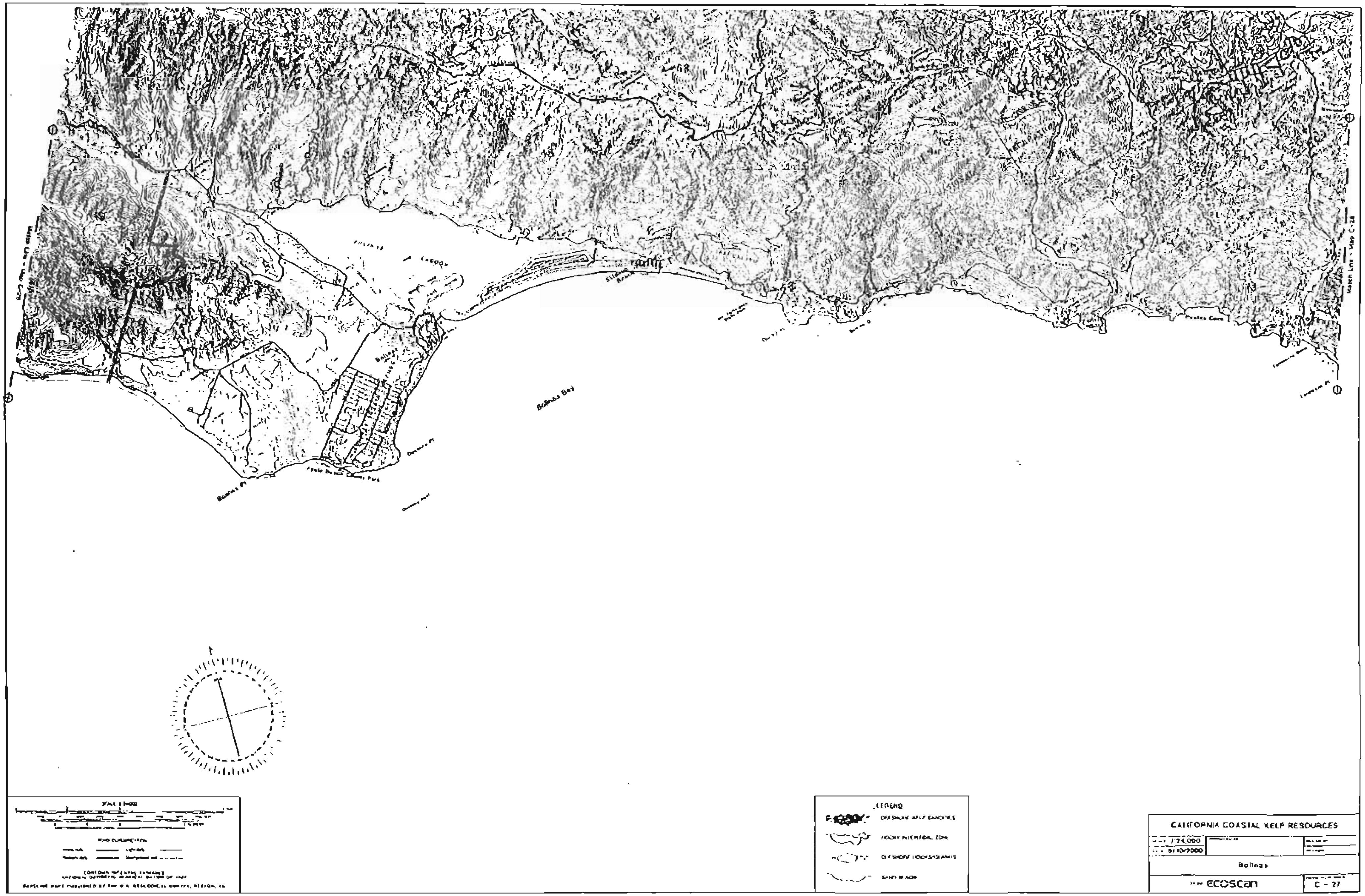
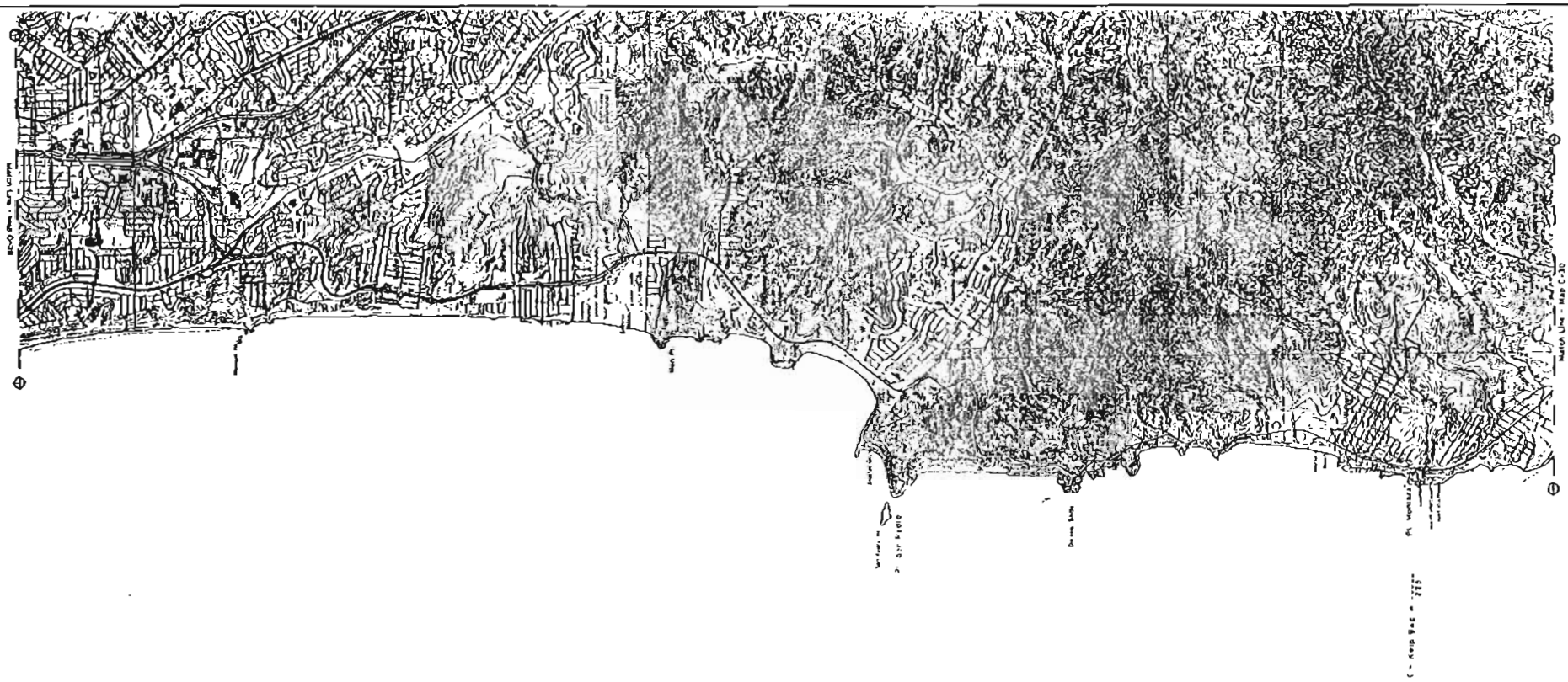
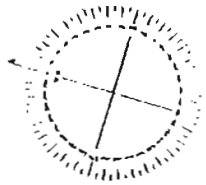
SOUTH HALF
M E X I C O
CALIFORNIA COASTAL KELP RESOURCES
MAP INDEX - 2
ECOSCAN



Match Line - Map C-28
Bolinas Bay
Bolinas
Lagoon
Bolinas Pt
Duxbury Pt
Pastures Cove
LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
8/10/2000
Bolinas
ECOSCAN
C - 27





LEGEND

CALIFORNIA COASTAL KELP RESOURCES

Montara

ecoscan

C - 79

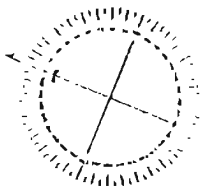
CALIFORNIA COASTAL KELP RESOURCES

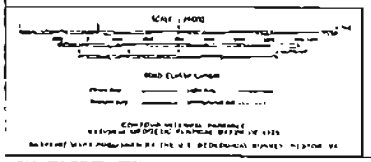
1:24,000

Hallmoon Bay

ECOSCAN

C - 30





LEGEND

CALIFORNIA COASTAL KELP RESOURCES

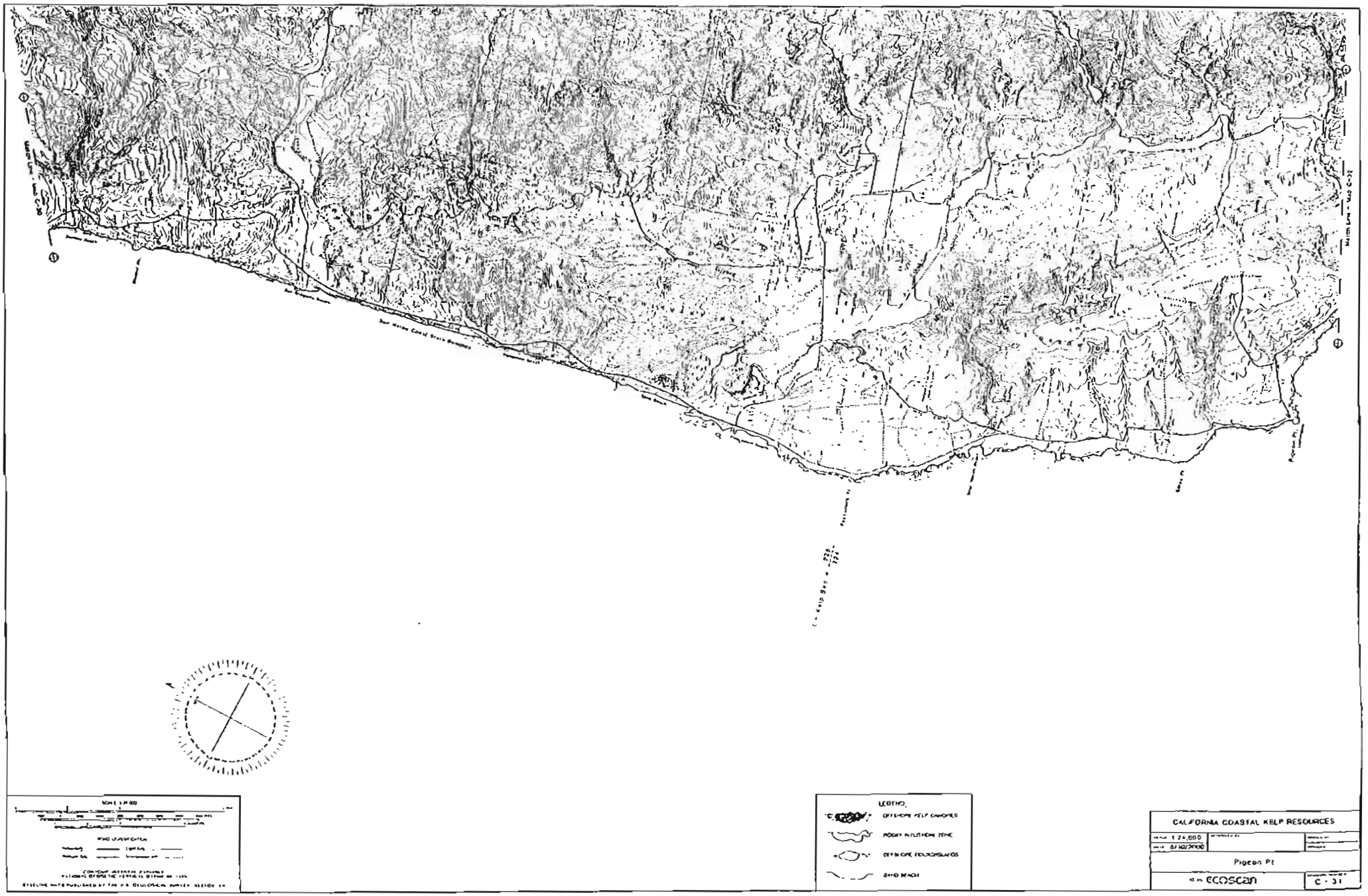
1:24,000

8/10/2000

San Francisco

ECOSCAN

C - 28

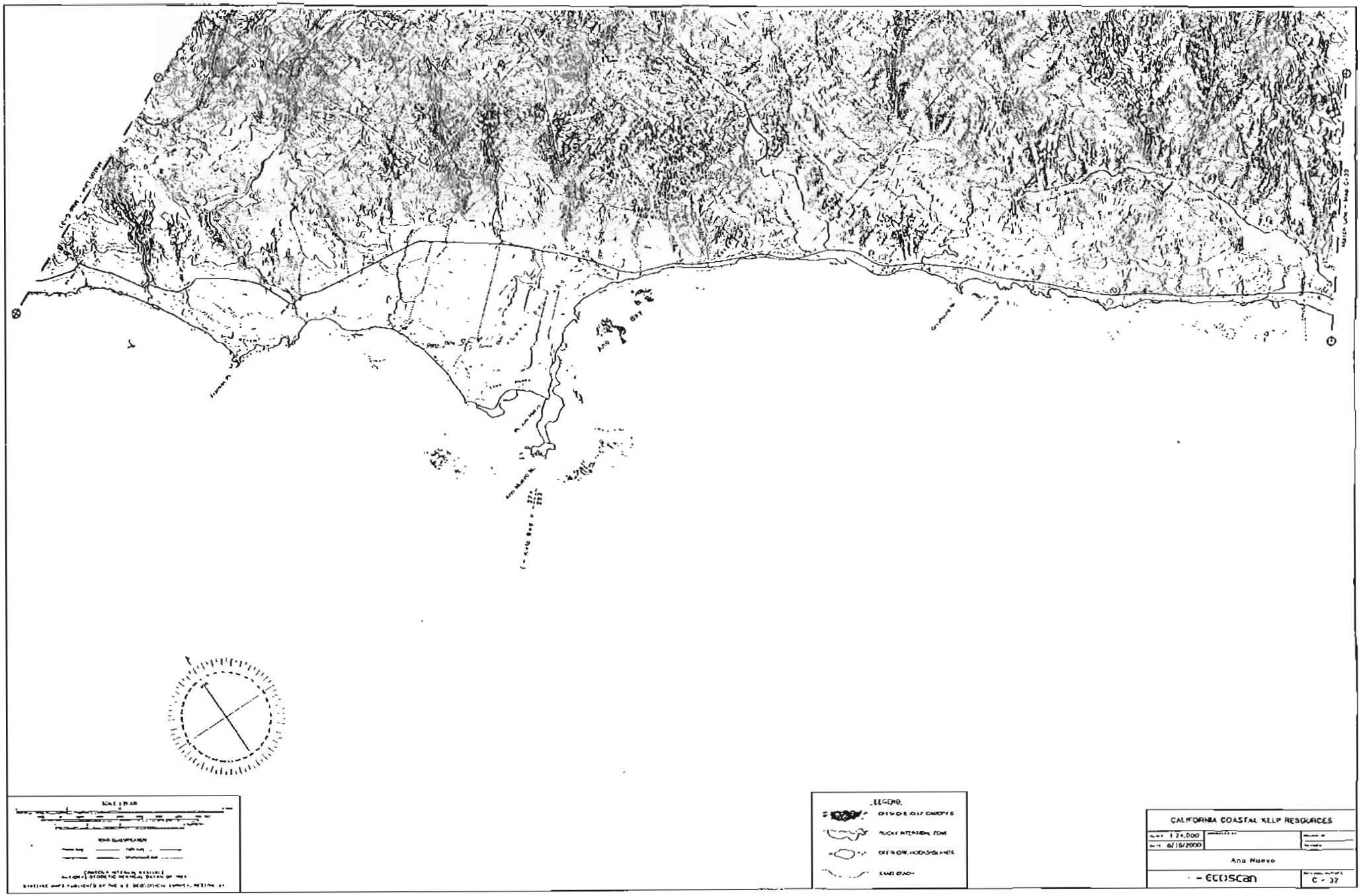


CALIFORNIA COASTAL KELP RESOURCES

Pigeon Pt

ECOSCAN

C - 31



CALIFORNIA COASTAL KELP RESOURCES

1:24,000

07/10/2000

Ano Nuevo

ECOSCAN

C - 32

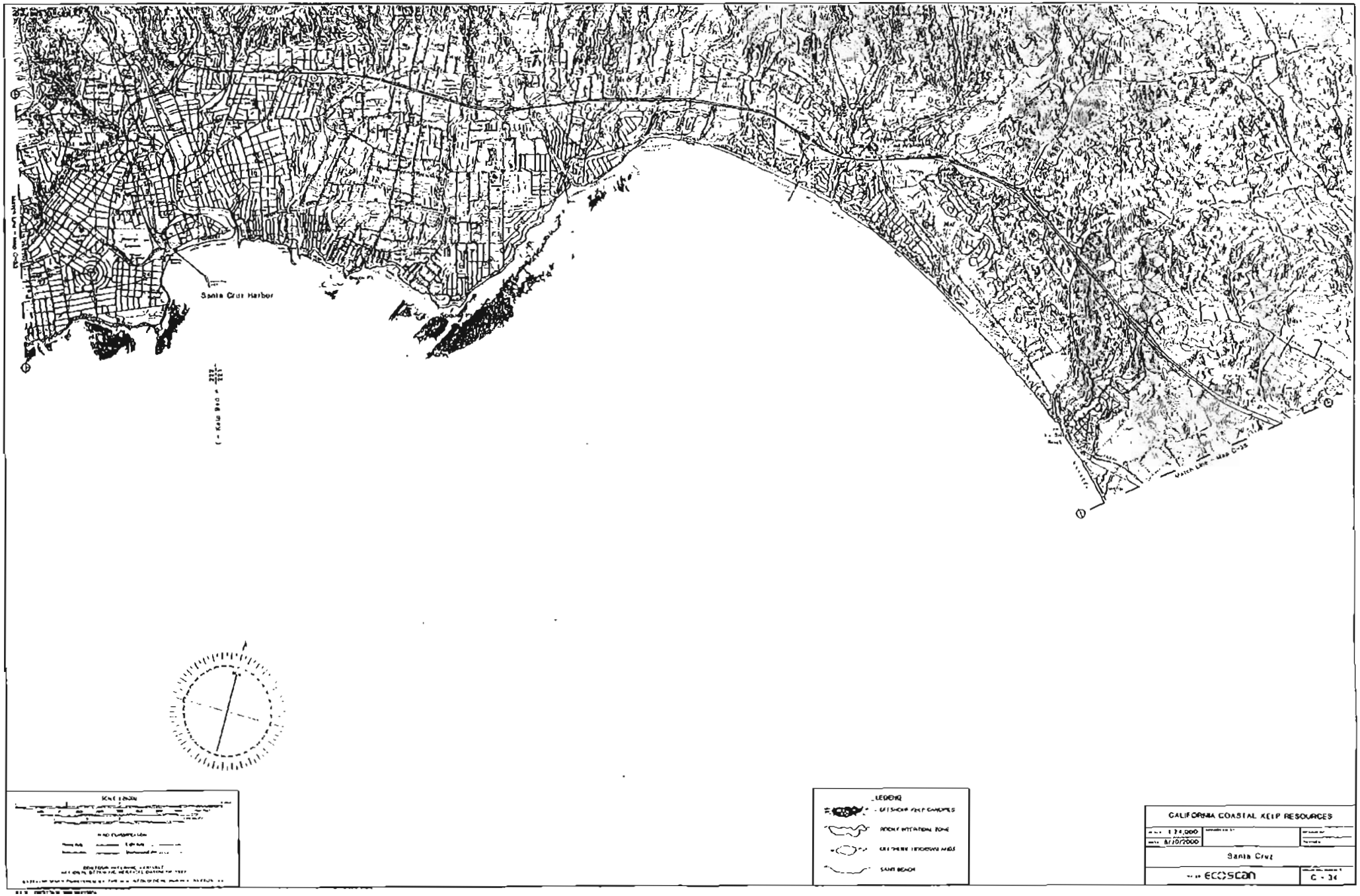
CALIFORNIA COASTAL KELP RESOURCES

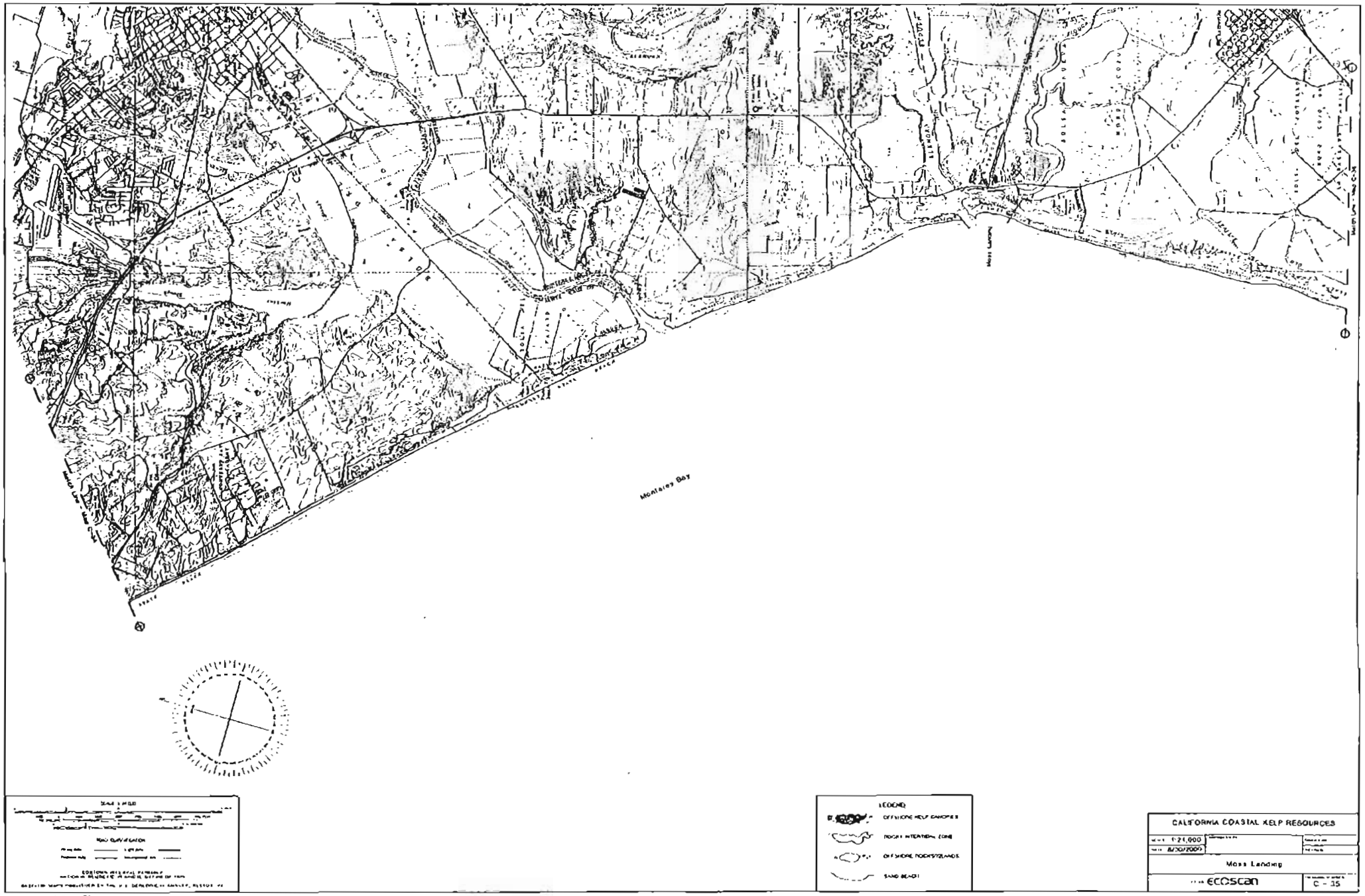
1:24,000

8/10/2000

Davenport

C - 33


Santa Cruz Harbor
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Santa Cruz
ecoscan
C - 34


Monterey Bay
Moss Landing
LEGEND
OFFSHORE KELP CANOPIES
INTERTIDAL ZONE
OFFSHORE ROCK/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:21,000
8/30/2007
Moss Landing
ecoscan
C - 15

SCALE 1:24000

ROAD CLASSIFICATION

Heavy duty — Light duty

Medium duty — Unimproved dirt

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

LEGEND

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

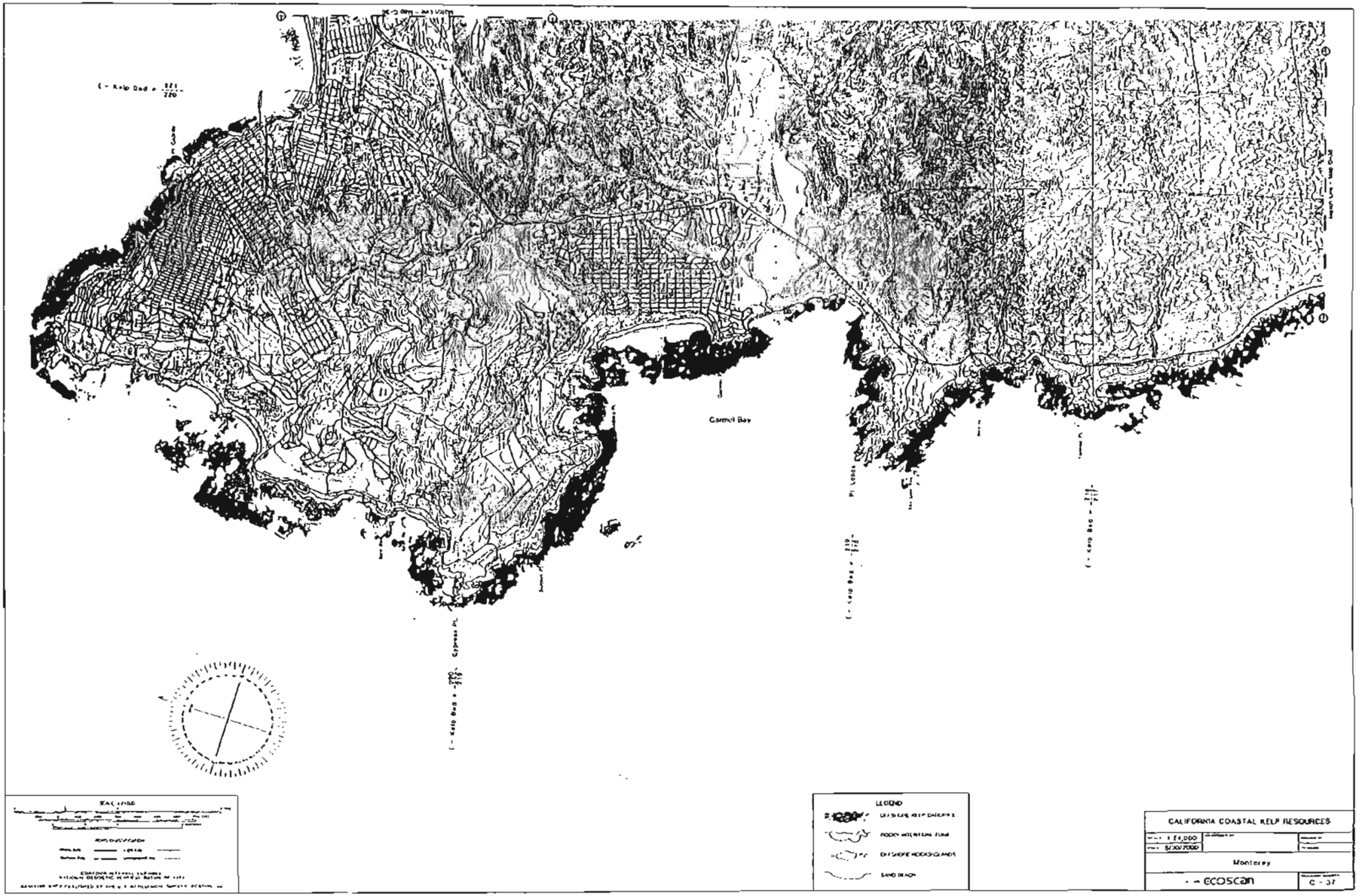
CALIFORNIA COASTAL KELP RESOURCES

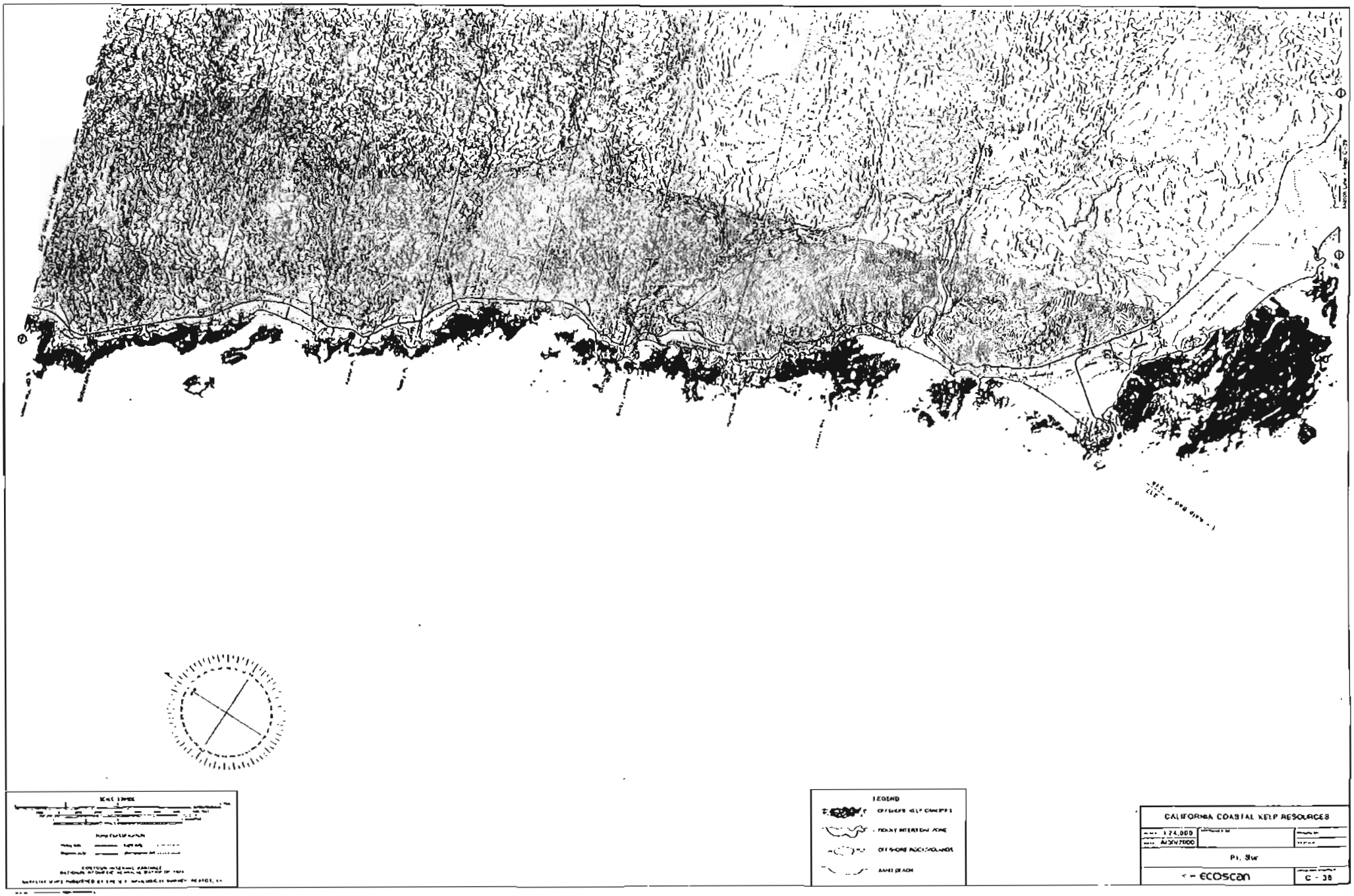
SCALE 1:24,000	APPROVED BY	DRAWN BY
DATE 8/30/2000		REVISED

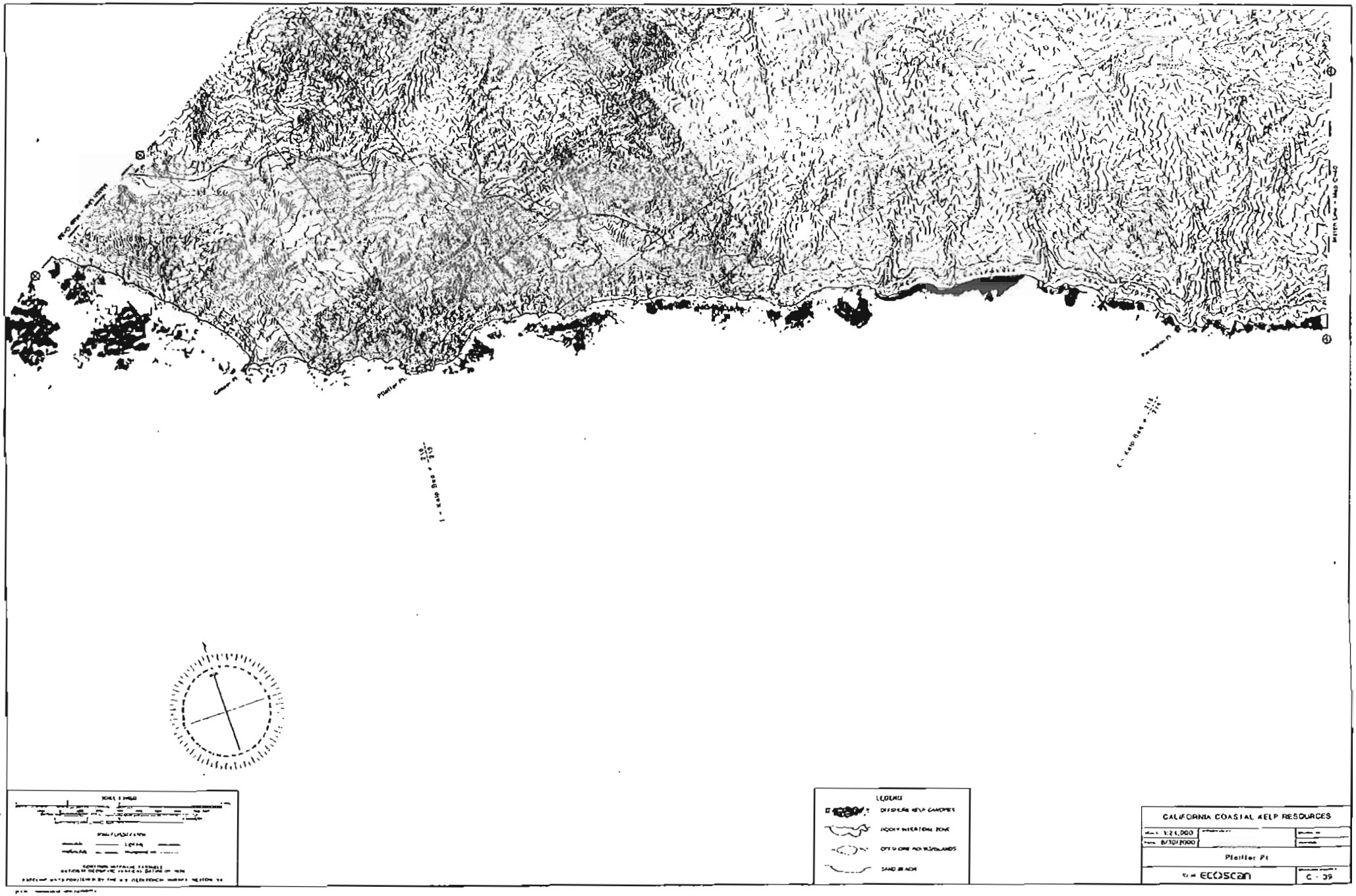
Marina

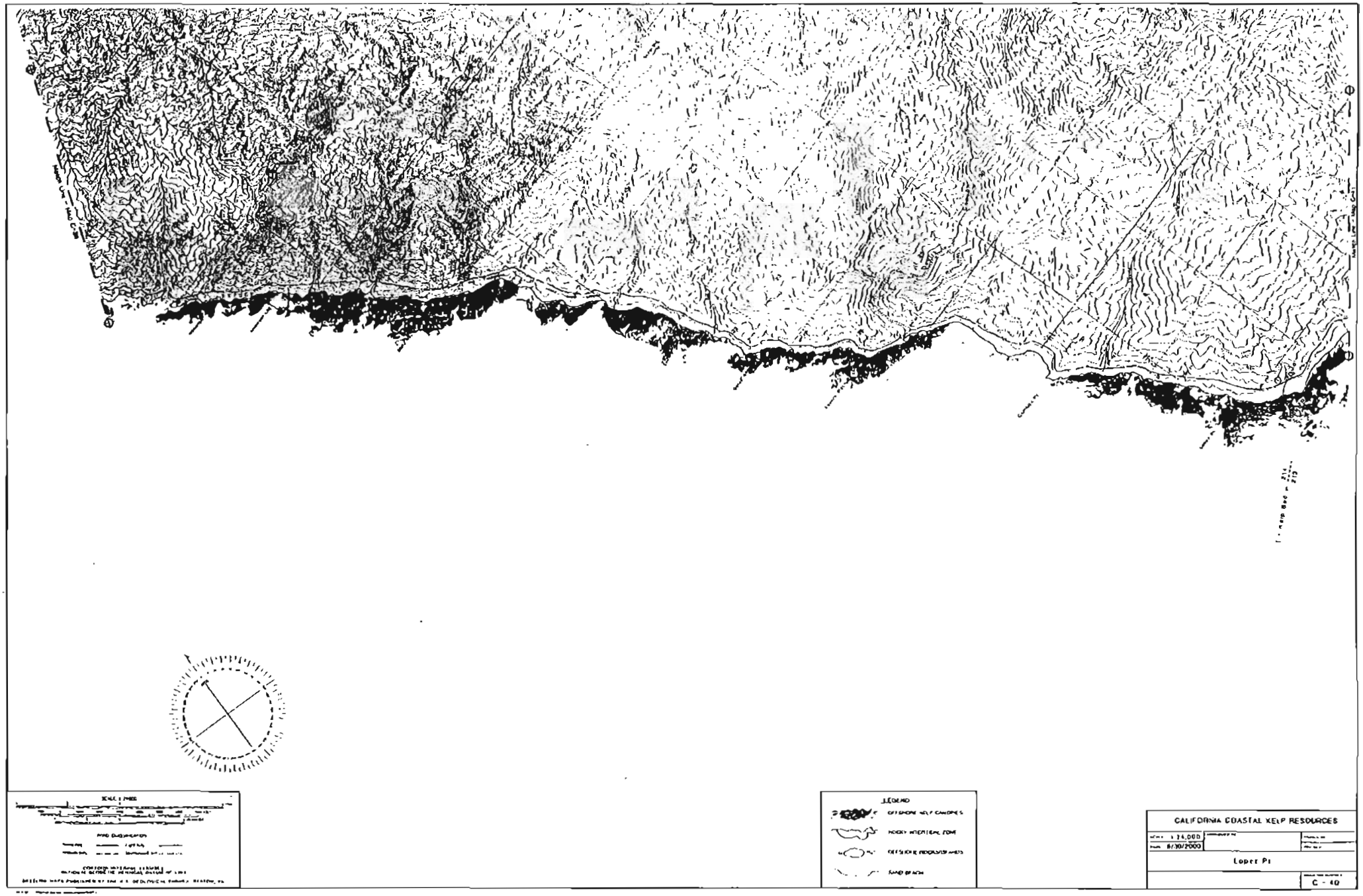
ecoscan

C – 36


Carmel Bay
Pt Lobos
Cypress Pt
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Monterey
ECOSCAN
C - 37


LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Pt. Sur
ecoscan
C - 38

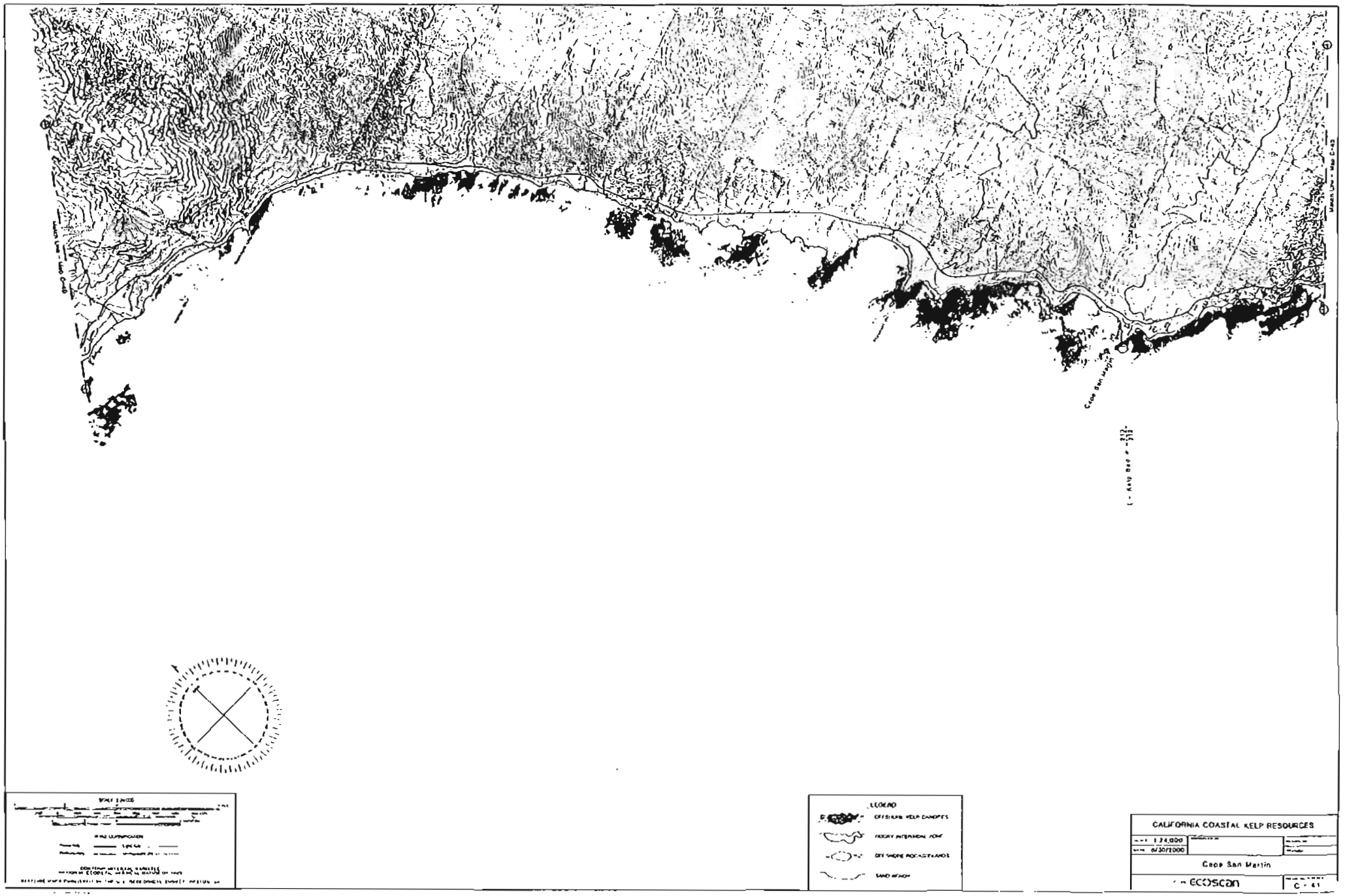

LEGEND
DESERVING KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCK/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
8/30/2000
Pfeiffer Pt
ECOSCAN
C - 39

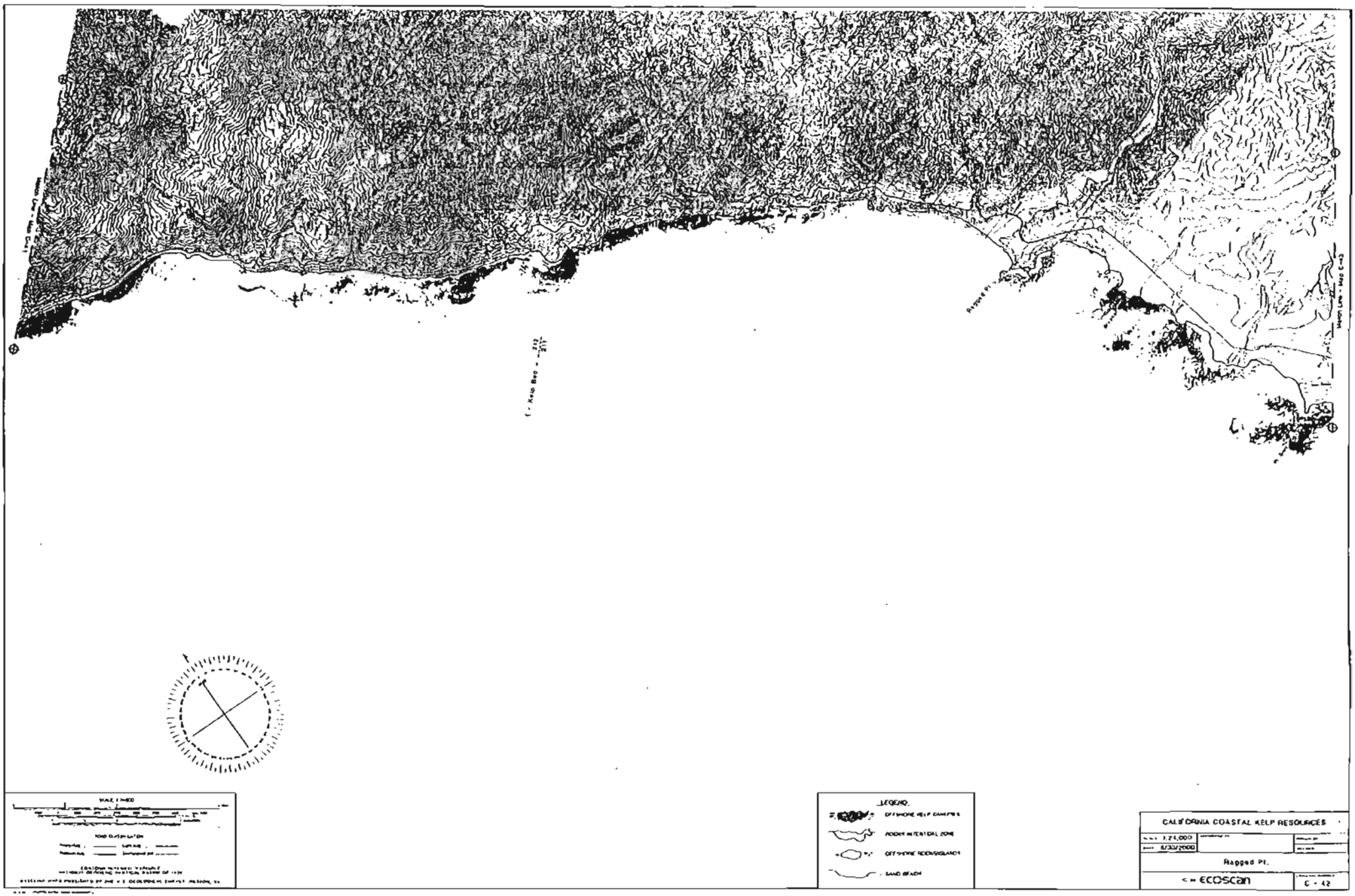


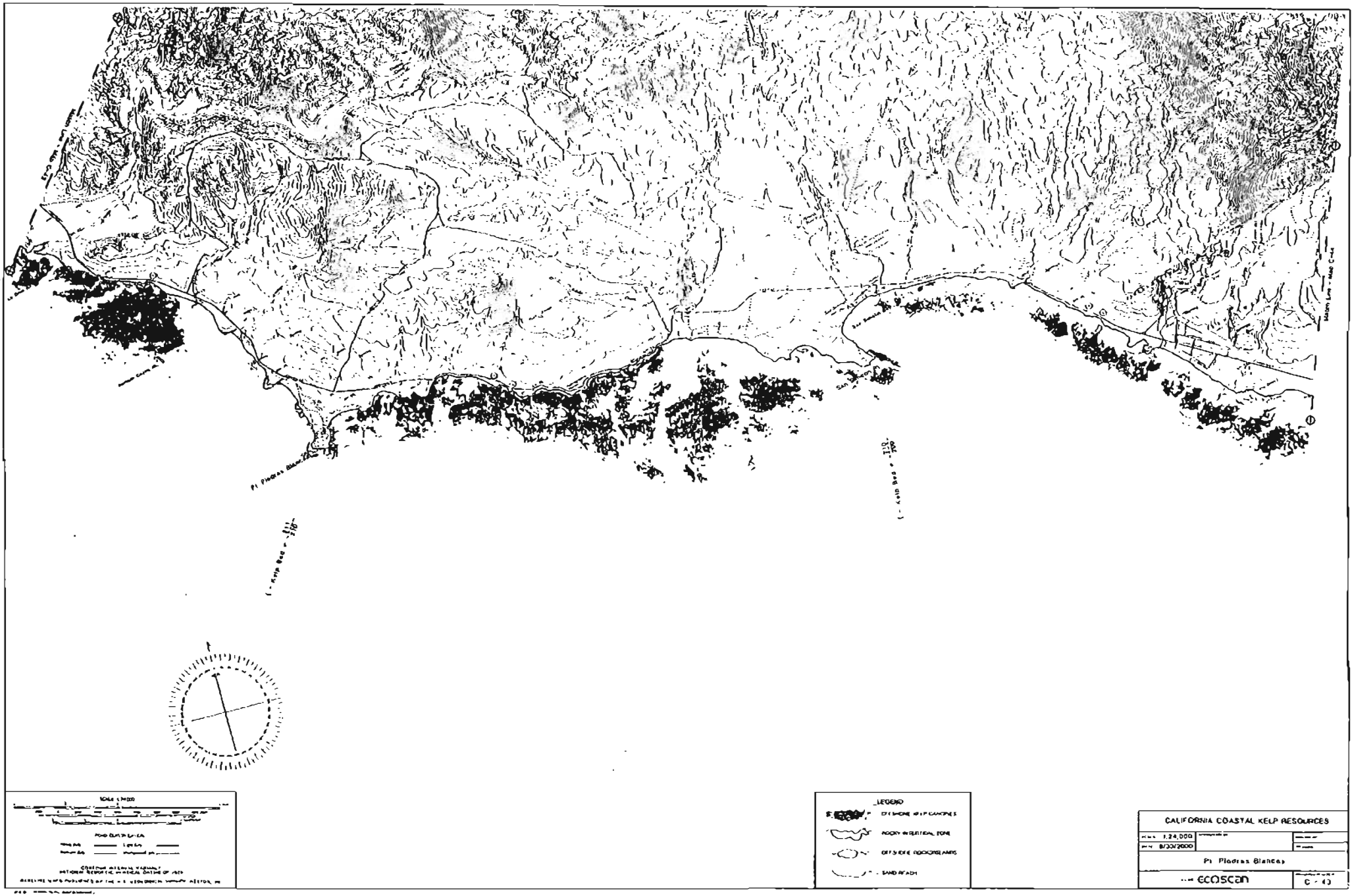
CALIFORNIA COASTAL KELP RESOURCES

Lopez Pt

C - 40


LEGEND
OFFSHORE KELP CANOPIES
NEARSHORE KELP CANOPIES
OFFSHORE ROCK/REEFS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
6/30/2000
Cape San Martin
ECOSCAN
C - 41


LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/ISLANDS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
8/30/2000
Ragged Pt.
ECOSCAN
C - 42


LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCKS/REEFS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
8/30/2000
Pt Piedras Blancas
ecoscan

CALIFORNIA COASTAL KELP RESOURCES

Cambria

ECOSCAN

C - 44

CALIFORNIA COASTAL KELP RESOURCES

Bolinas Lagoon

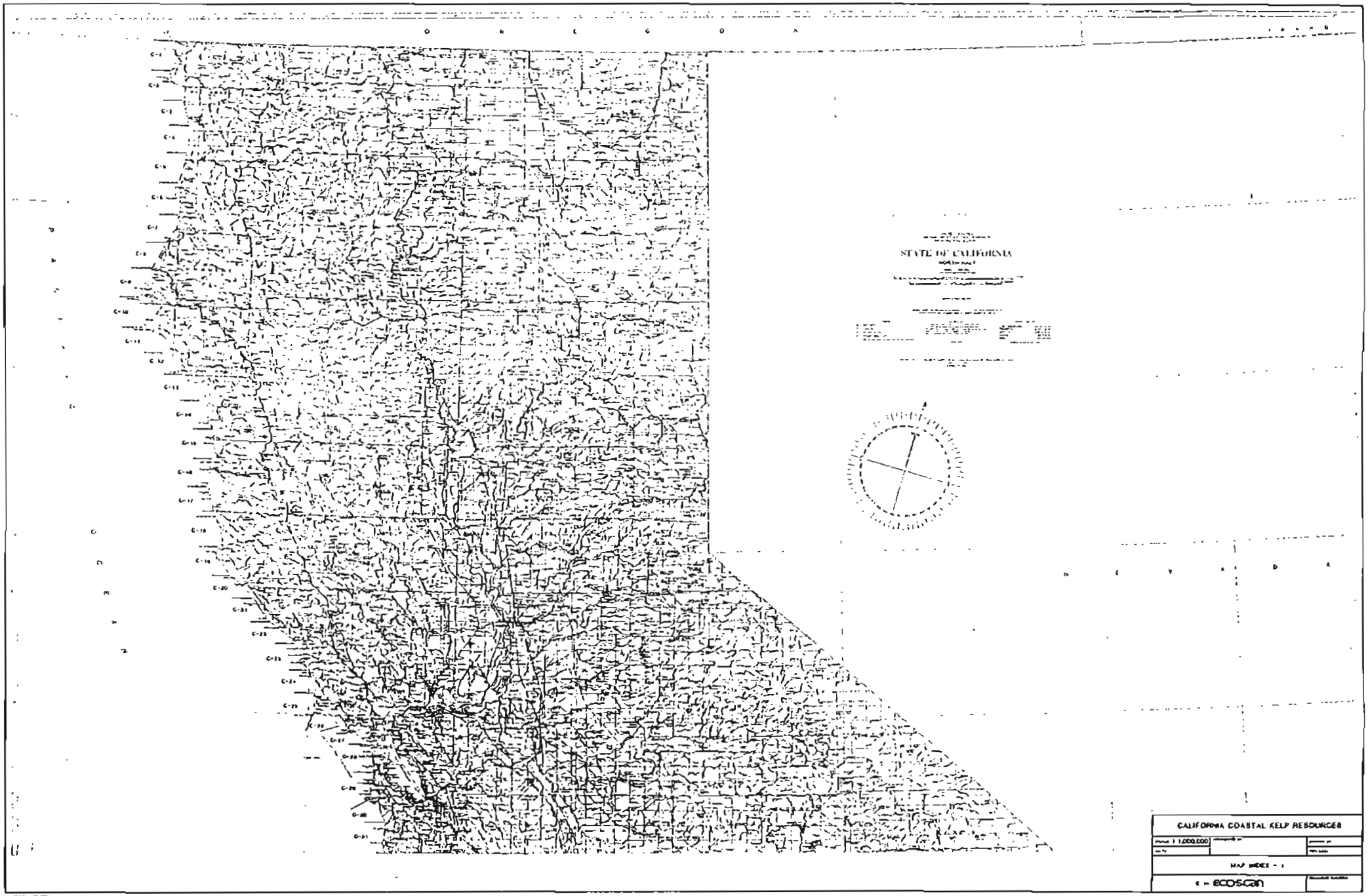
to

Point Estero

Section 5

Kelp Bed Canopy Area Maps: 27-44

October 1999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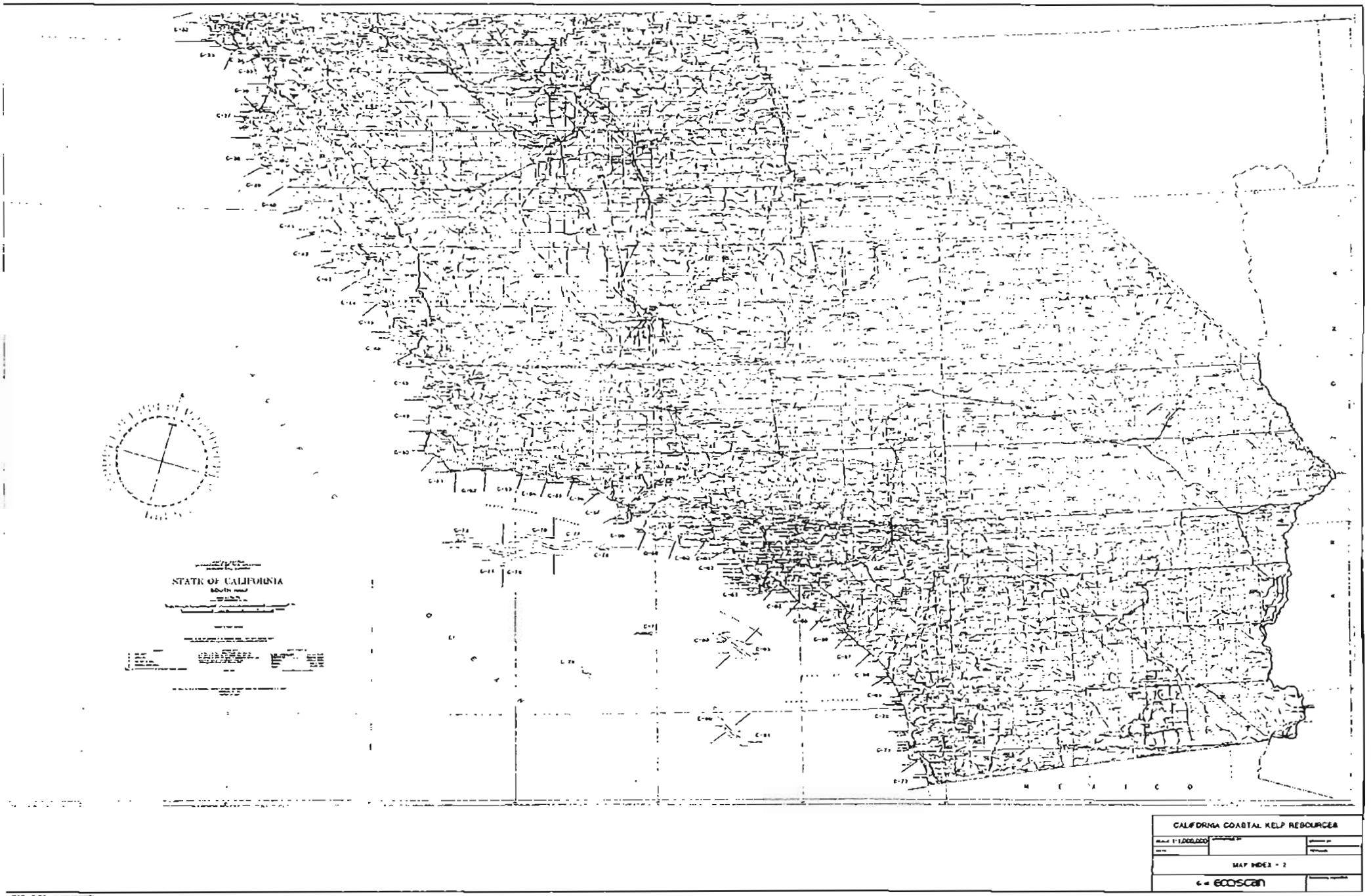
CALIFORNIA COASTAL KELP RESOURCES
MAP INDEX - 1
ecoscan


STATE OF CALIFORNIA
M E X I C O
CALIFORNIA COASTAL KELP RESOURCES
MAP INDEX - 2
ecoscan

LEGEND

CALIFORNIA COASTAL AERIAL RESOURCES

1:24,000

8/30/2000

Marina

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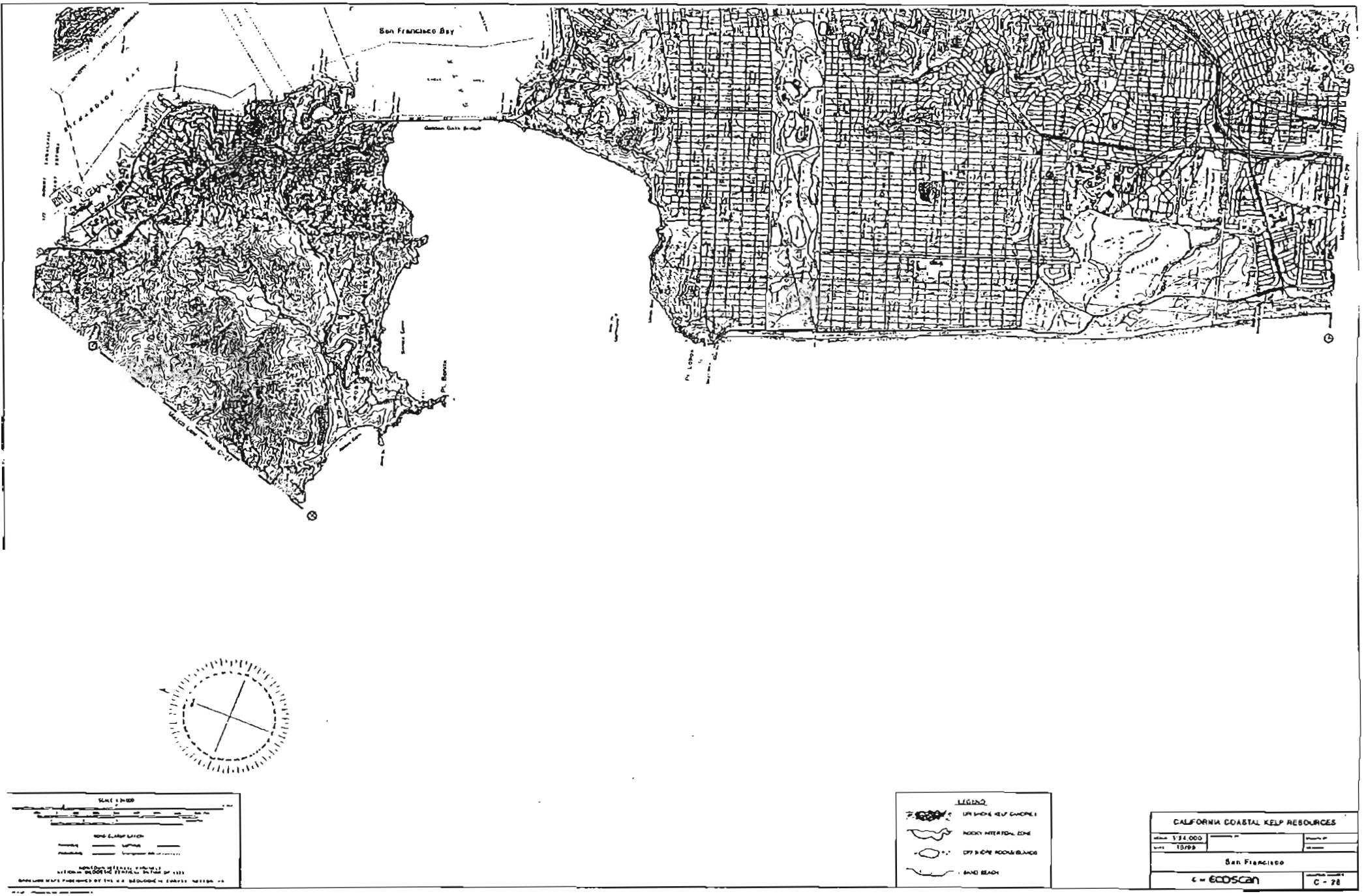
C - 36

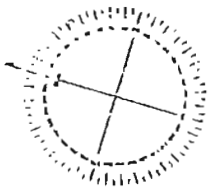

Bolinas Bay
Bolinas Pt.
Duxbury Pt.
Point Reyes
Tomales Pt.
LEGEND
- OFFSHORE KELP CANOPY
- KELP BED
- OFFSHORE ROCK/REEF
- SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
Bolinas
ECOSCAN
C - 27

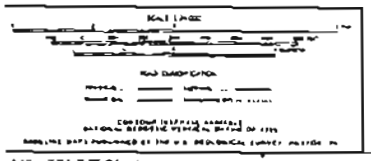


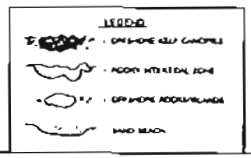
CALIFORNIA COASTAL KELP RESOURCES

San Francisco

C - 28







CALIFORNIA COASTAL KELP RESOURCES

1:24,000		
70/33		

Montara

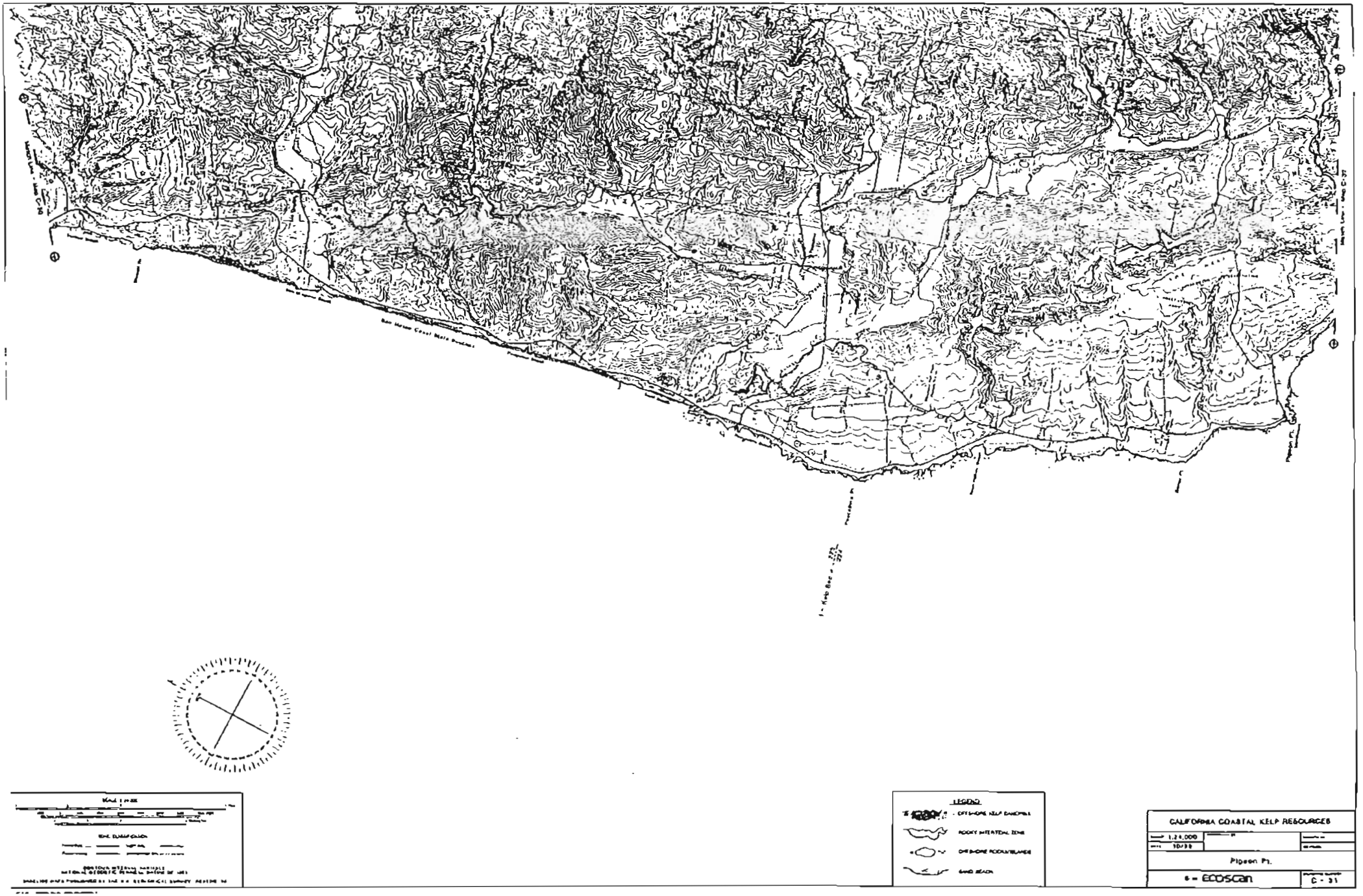
ecoscan

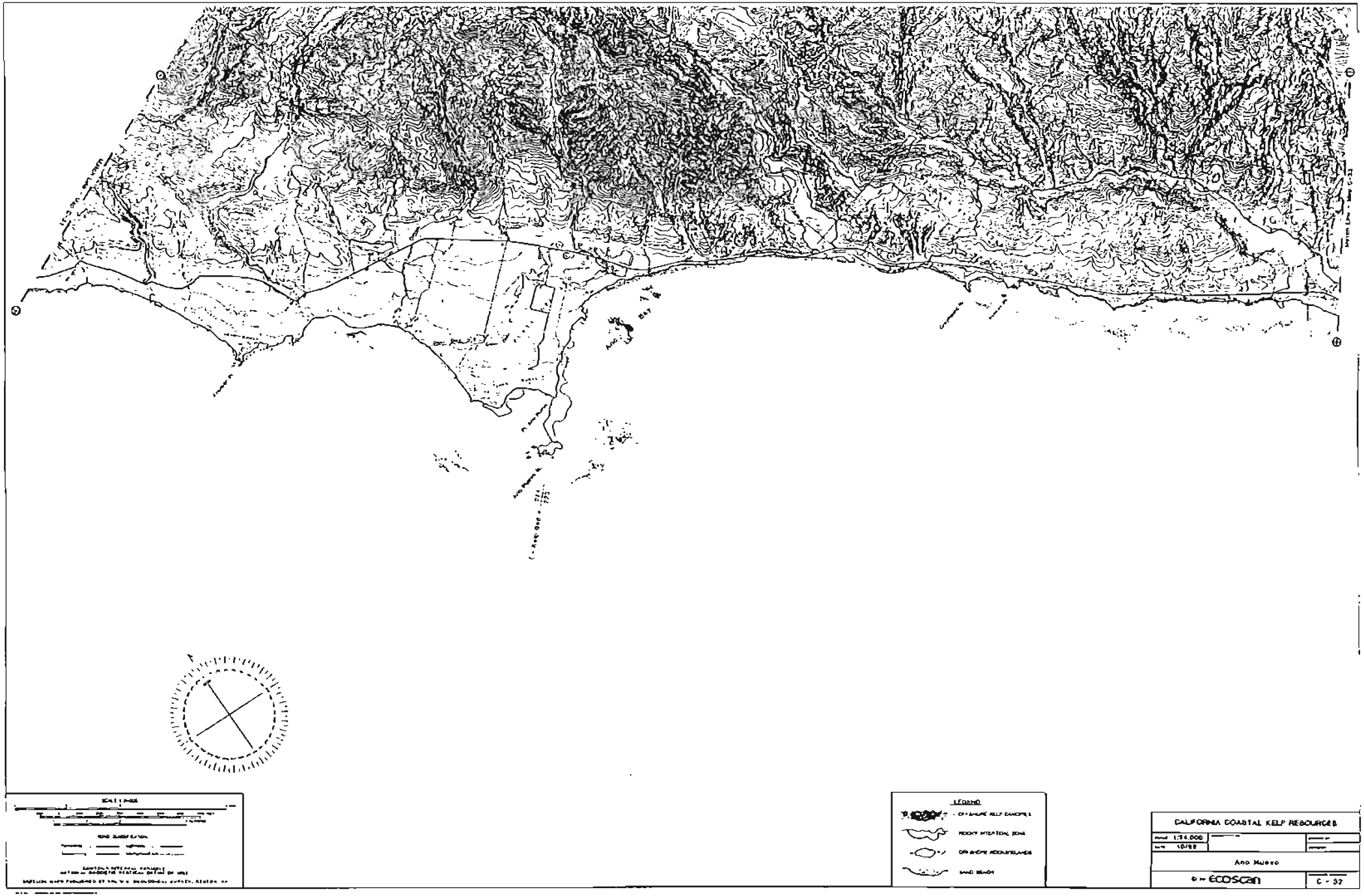
C - 28

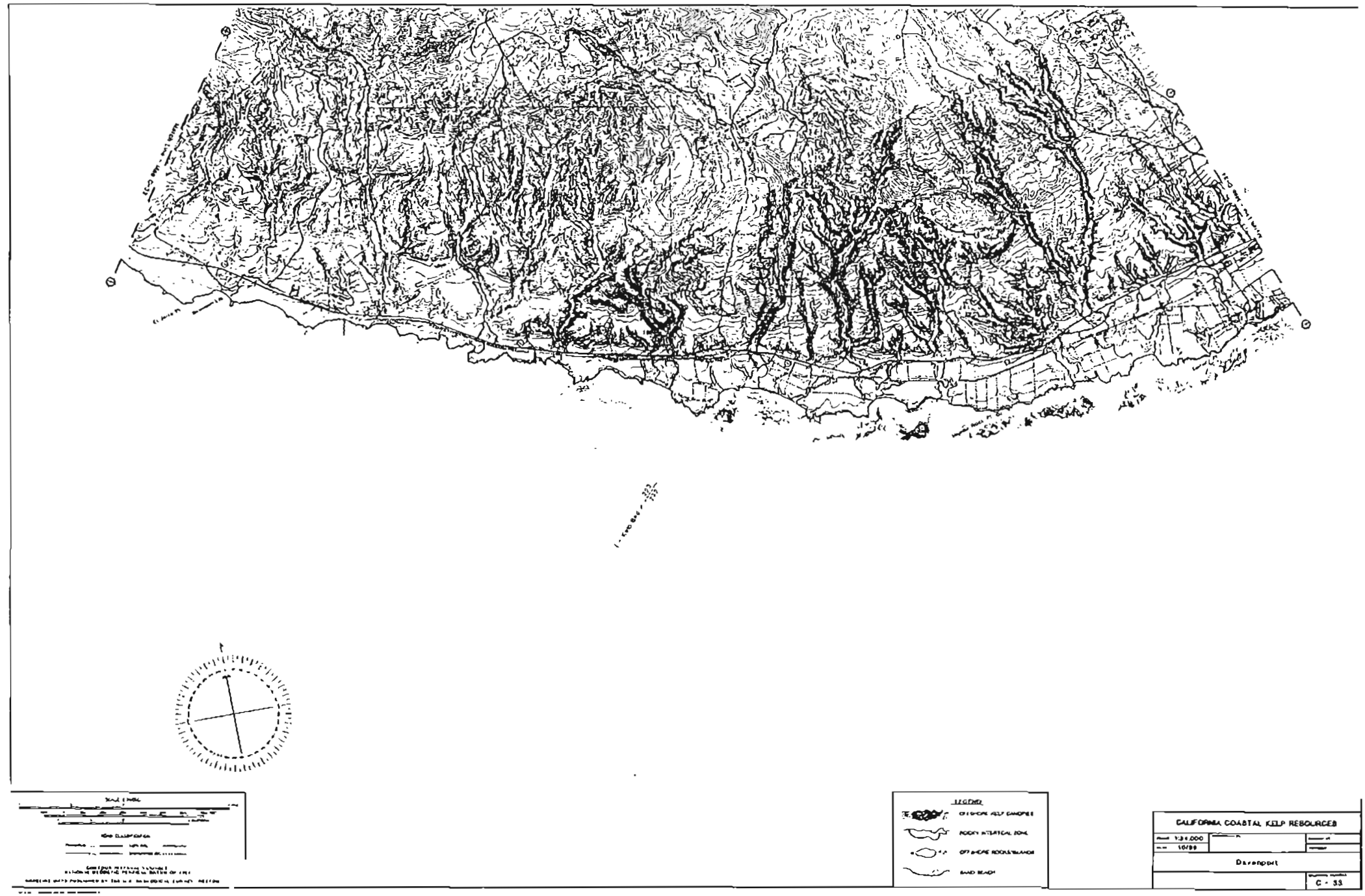
CALIFORNIA COASTAL KELP RESOURCES

Halfmoon Bay

C - 30


LEGEND
OFFSHORE KELP CANOPIES
ROCKY INTERTIDAL ZONE
OFFSHORE ROCK/REEFS
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
10/78
Pigeon Pt.
ECOSCAN
C - 31

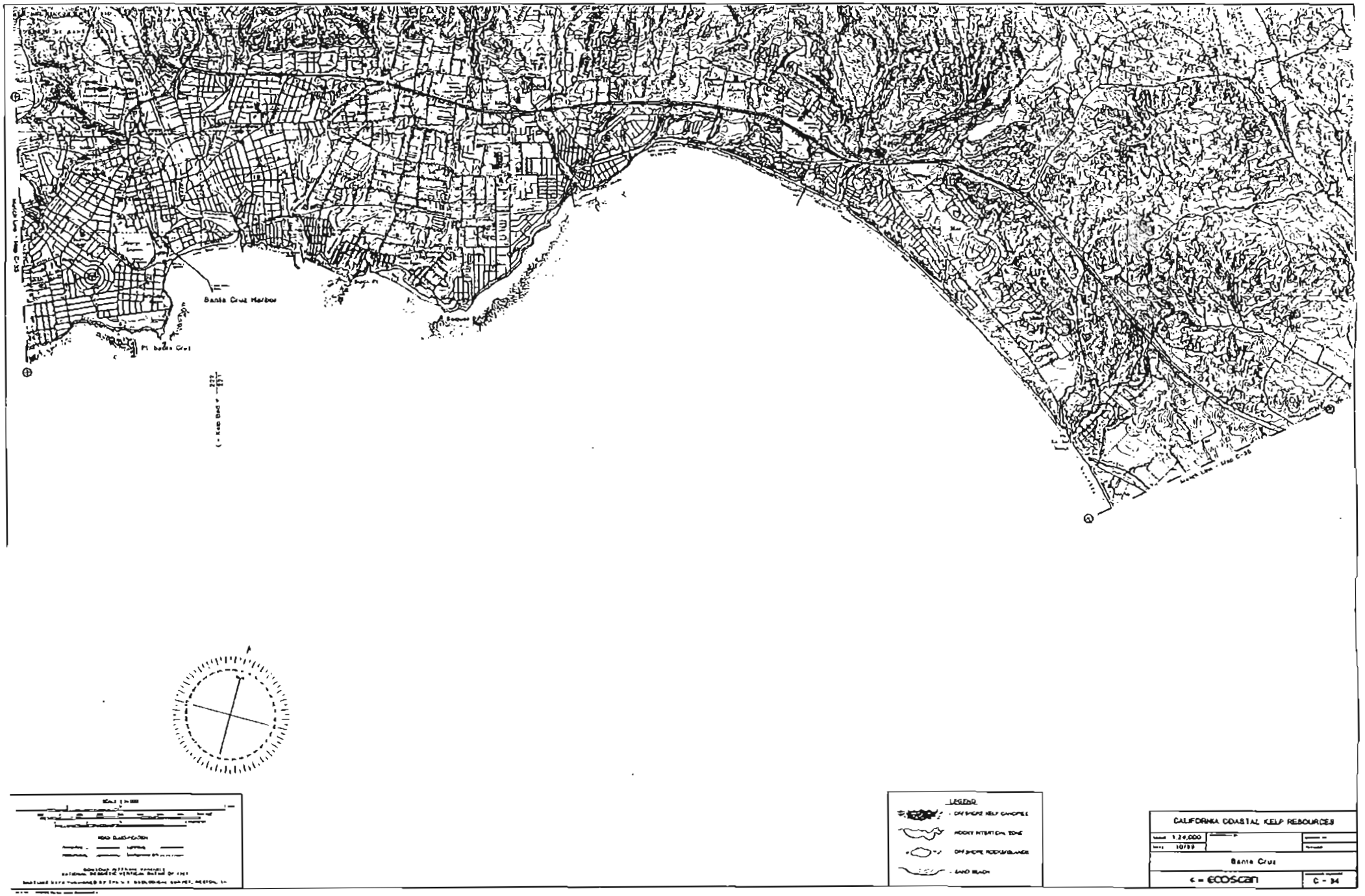

LEGEND
ROCKY INTERTIDAL ZONE
SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
Año Nuevo
© ECOSCAN
C - 32

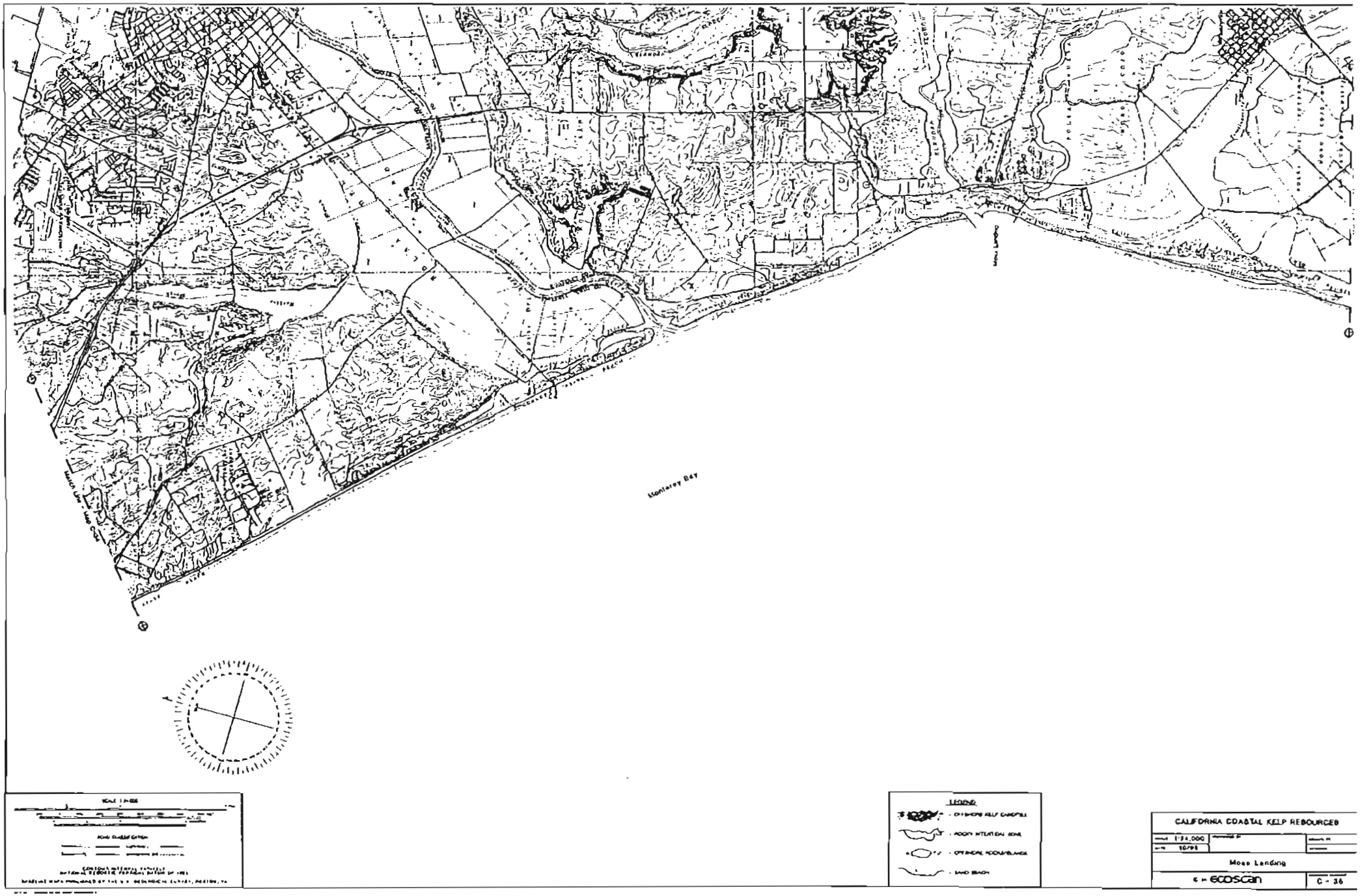


CALIFORNIA COASTAL KELP RESOURCES

Davenport

C - 33

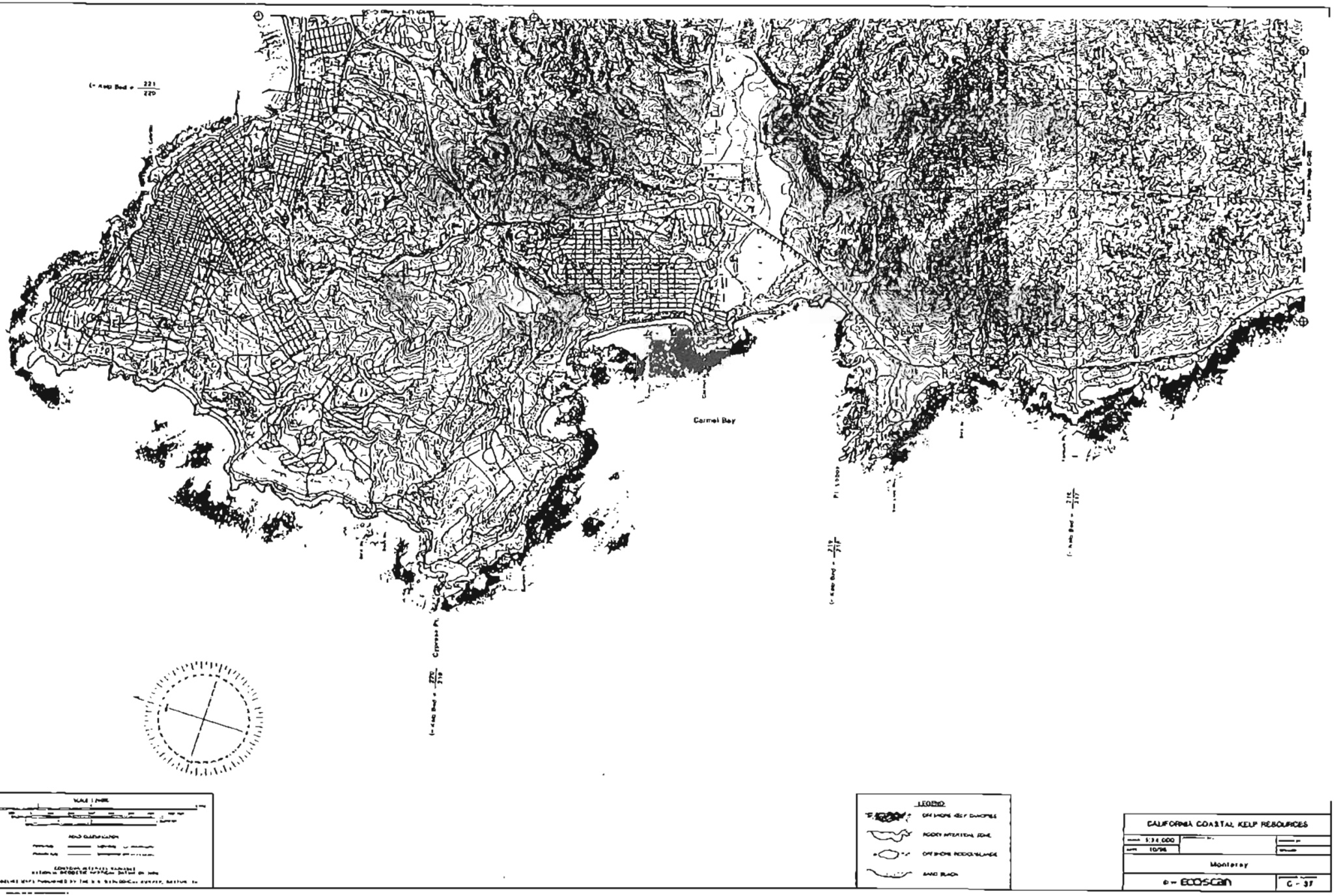

Santa Cruz Harbor
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Santa Cruz
C - 14
ECOSCAN

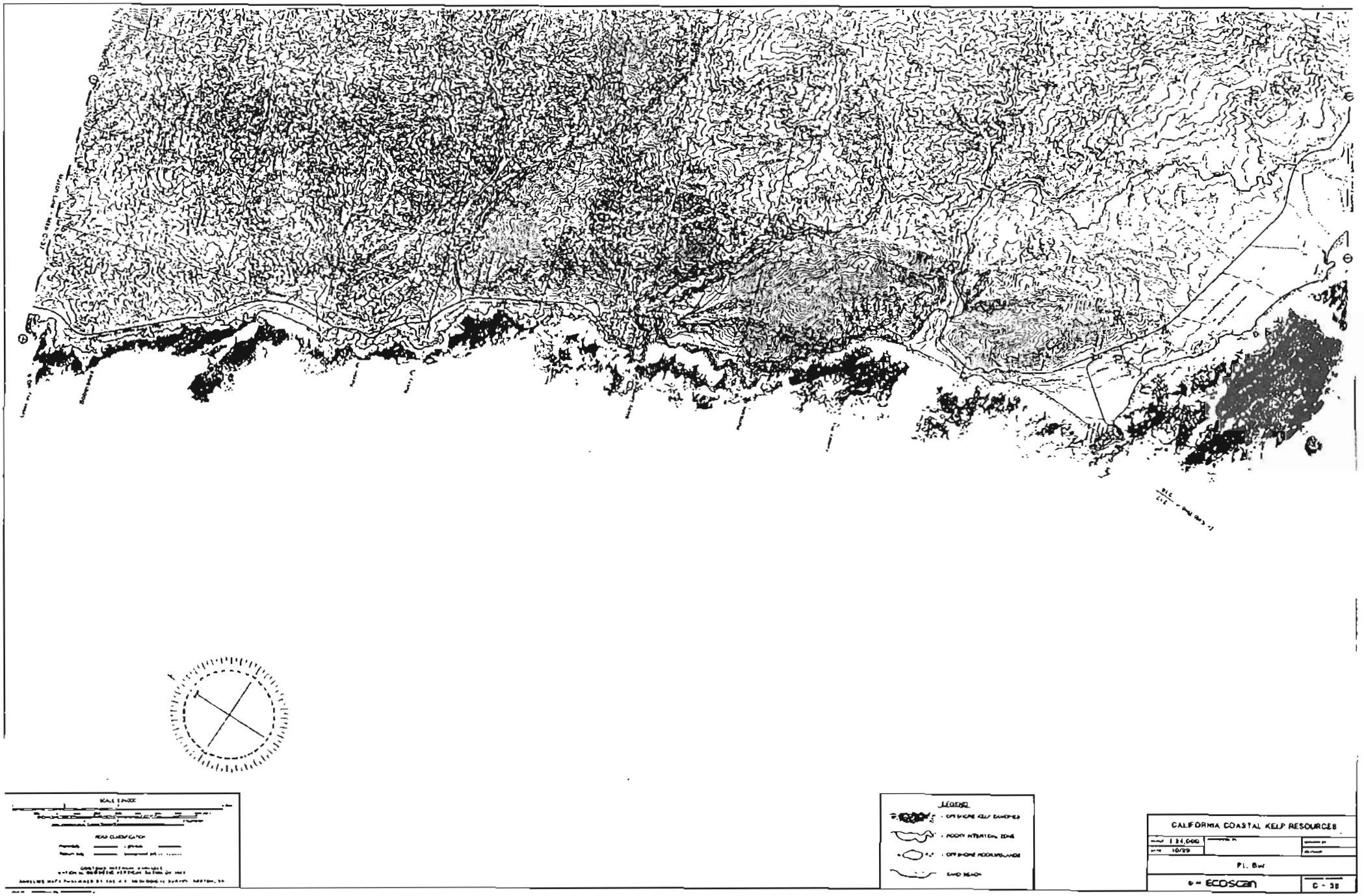

Monterey Bay
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Moss Landing
ecoscan
C - 36

CALIFORNIA COASTAL KELP RESOURCES

ECOSCAN

C - 30


Carmel Bay
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Monterey
ecoscan
C - 37

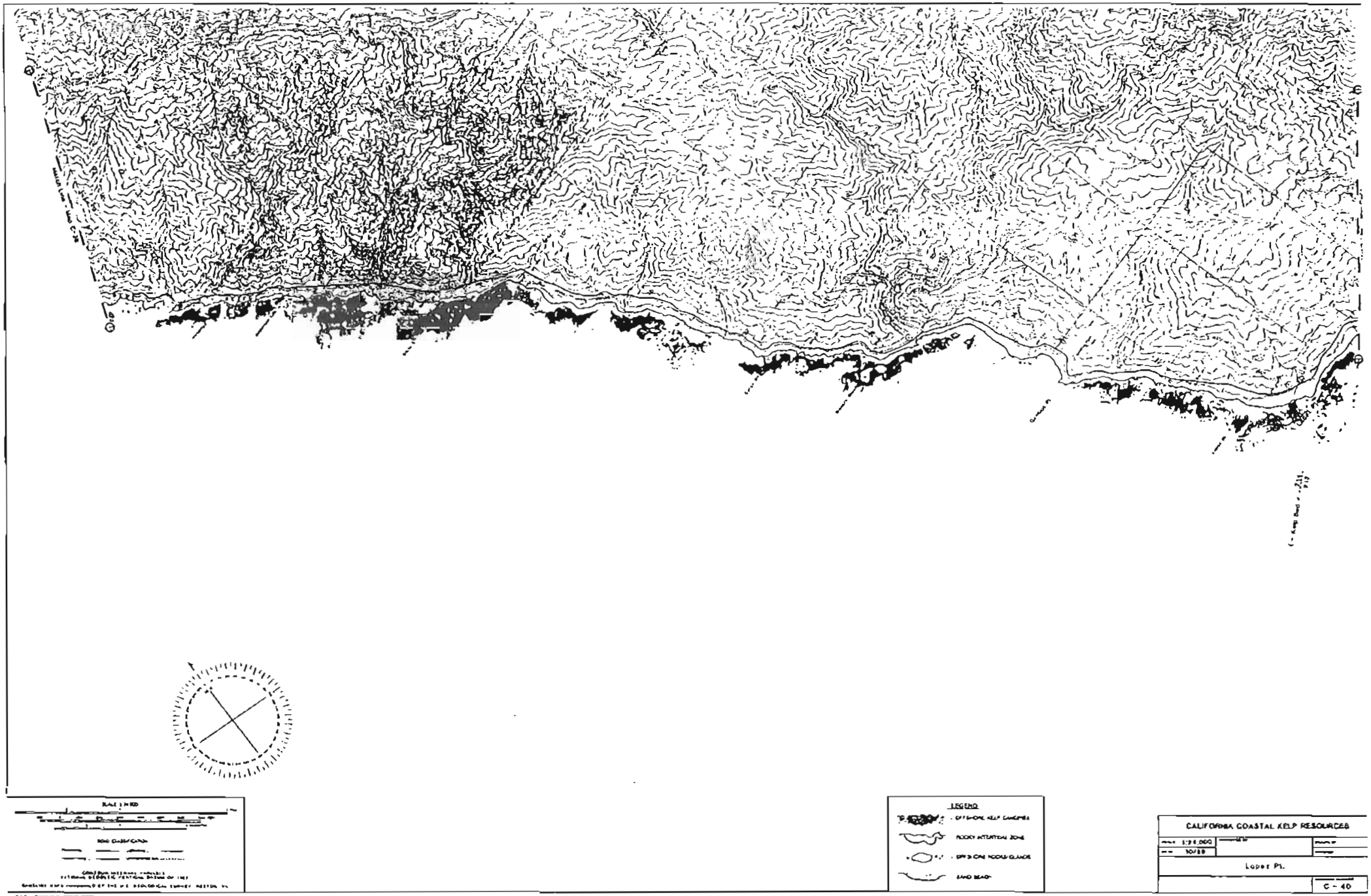


CALIFORNIA COASTAL KELP RESOURCES

ECOSCAN

C - 38


LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Pfeiffer Pt.
ECOSCAN
C - 30



CALIFORNIA COASTAL KELP RESOURCES

Lopez Pt.

C - 40

CALIFORNIA COASTAL KELP RESOURCES

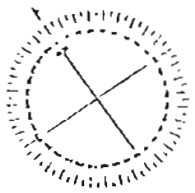
1:24,000

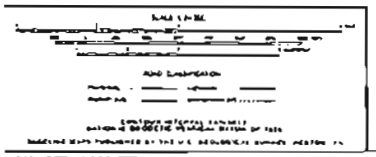
10/99

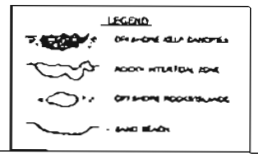
Cape San Martin

ecoscan

C - 41





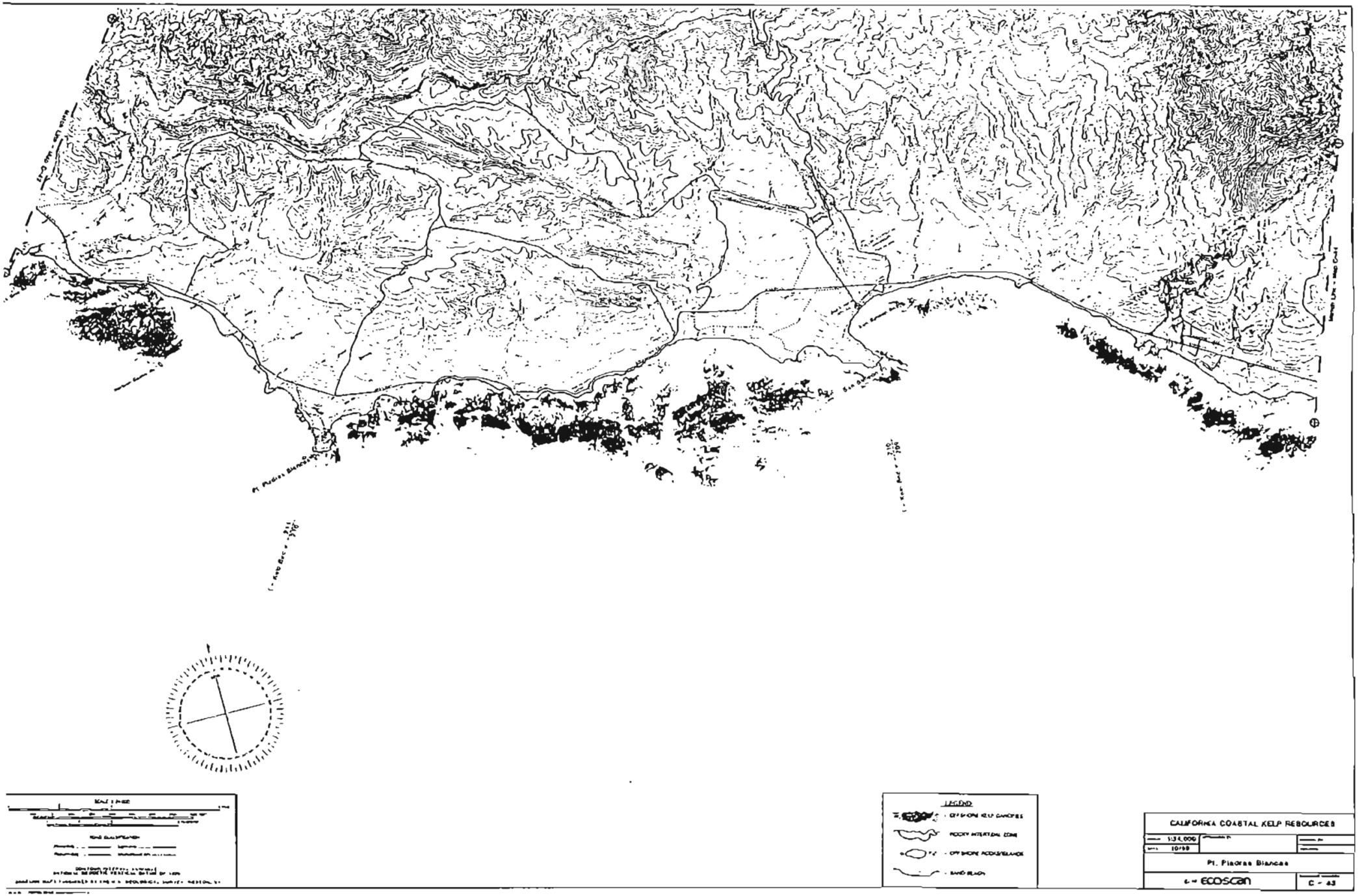


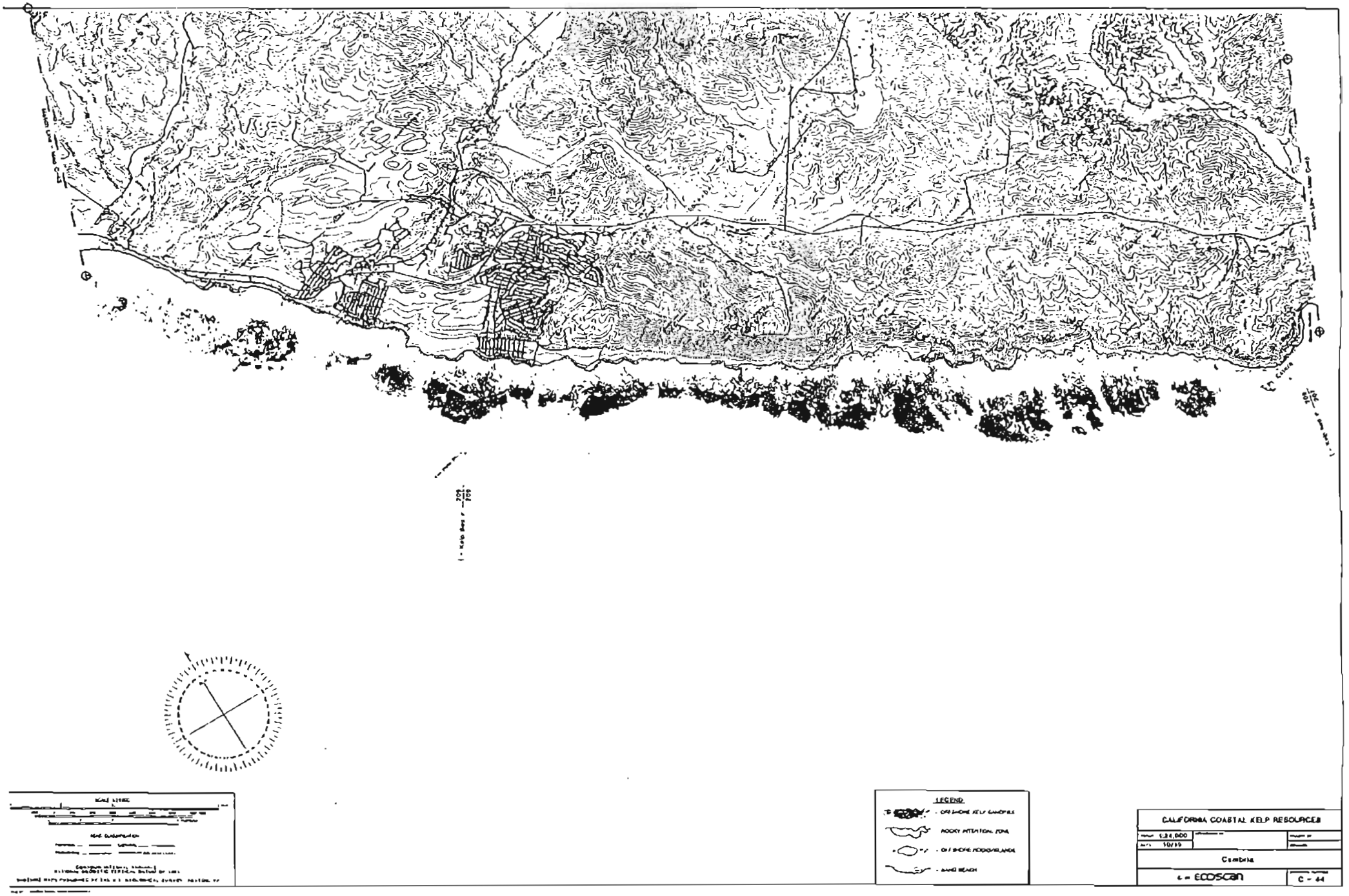
CALIFORNIA COASTAL KELP RESOURCES

Rapped Pt.

ECOSCAN

C - 42


Pt. Piedras Blancas
LEGEND
CALIFORNIA COASTAL KELP RESOURCES
Pt. Piedras Blancas
ECOSCAN
C - 43


LEGEND
- OFFSHORE KELP CANOPIES
- ROCKY INTERTIDAL ZONE
- OFFSHORE FLOODPLAINS
- SAND BEACH
CALIFORNIA COASTAL KELP RESOURCES
1:24,000
10/89
Cambria
ECOSCAN
C - 44