SCU-R-98-004 C2

Reprinted from

EMERGING TRENDS IN BEACH EROSION AND SAND RIGHTS LAW

PROCEEDINGS
JUNE 3-5, 1998
SOUTH SEA PLANTATION

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and M. D. Van Arsdol, Jr.

USCSG-R-04-2003

University of Southern California
Los Angeles, CA 90089-0373

Reprint

Reprinted from

Emerging Trends in Beach Erosion and Sand Rights Law

Proceedings

June 3 - 5, 1998
South Seas Plantation
Captiva Island, Florida

Sponsored by:
American Society of Civil Engineers
The Coastal Zone Foundation
Florida Shore & Beach Preservation Association

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Impacts of Rising Sea Level on Coastal Populations in California and Maine*

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Introduction

Sea level rise is a global phenomenon with local effects that affect and influence such stakeholders as property owners, recreational users, and municipal and state authorities. Sea level rise includes storm surges, erosion, shoreline recession, subsidence and other phenomena. The magnitude of the problem of sea level rise facing communities is growing as the United States experiences urbanization with resulting coastal population growth and economic development. The United States National Oceanic and Atmospheric Administration projects that in the United States, approximately 15 million people will be added to the coastal zone population base by 2010. The United States, with more than 19,000 km of coastline, contains many locations where low-lying coastal environments are at risk from even small rises in sea level and beach erosion (IPCC 1996).

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*Support for this research is from the United States National Oceanic and Atmospheric Administration grant #NGA 36GPO486 to USC Sea Grant Program, USC Sea Grant Program # M-298 and to University of Maine Sea Grant Program.
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Coastal beach erosion results from attempts to block or divert material from the beach system and from the effects of storm surges, wave action and other weather phenomena. Population, technology, climate change and beach erosion are interlocking problems. As shown in Figure 1, erosion is one aspect of sea level rise which in turn, may be a consequence of climate change. Global and local determinants of climate change (and global warming) include population growth and increased use of technology reflecting increased per capital energy consumption.

Sea level rise is expected to exacerbate the instability of coastline ecology and to decrease the available land at a time when coastal population and demand for coastal development is rising, and areas at risk for storm surge, erosion and flooding are increasing. Population increases are likely to continue to stimulate development of coastal lands, and result in the urbanization of much of the coastal US. Rising coastal land, values may eventually limit degradation, but there also appear to be limits in the ability of the coastal environment to support populations. Impacts from property loss, population displacement, and mitigation will be substantial.

Much of the most recent coastal population growth in the United States, has occurred in dune areas and on barrier islands, (Figure 2) (Mageean and Bartlett, In Press). Sandy beaches backed by dunes, beach ridges, or "other sandy depositional terrain" comprise approximately 20 percent of the world's coastline and 70 percent of these are being eroded (Bird 1985). Barrier beaches comprise 13-15 percent of the world's coastline and the conterminous US coastline from Maine to Texas is the "longest and best evolved chain barrier islands in the world" (Godfrey and Leatherman 1979), approximately 4500 KM (USDOI 1982). Coastal barrier islands are rich in natural resources but extremely vulnerable to human development (Clark 1976).

In the United States, recent population growth (1980-1990) has been especially evident in coastal counties along the Pacific, California's south and central coasts, the Gulf Coast and much of the Atlantic Coast (Figure 3). In the Gulf and Atlantic coast barrier island and coastal dune areas most forms of reserve status inhibited settlement but designation as Coastal Barrier Reserve units denied developers access to most forms of government subsidies or insurance without actually prohibiting development and actually resulted in larger, more intensely developed schemes (Bartlett, Mageean and O'Connor, In Prep.)

Coastal beach erosion will not go away even in the absence of climate change. Only some portions of coastal areas are affected by sea level rise. Nevertheless, human population growth and use of technology on the shoreline will increase the impacts of storm surges and further contribute to erosion even without warmer temperatures. "Disruption" impacts reflect disturbance of the land by sea encroachment. "Compression" impacts include disruption plus a decrease in coastal land supply.

What can we do to mitigate coastal beach erosion? Both global and local stakeholders who respond to sea level rise from differing positions may influence mitigation. (Stakeholders are individuals or organizations with vested interests regarding coastal erosion and other aspects of sea level rise.) At the global and national level, we can develop policies to reduce erosion impacts. This includes policies to decrease human fertility and population growth and to decrease per capita energy consumption. Responses to sea level rise impacts include individual actions by local stakeholders as well as actions by state and national organizations, but such responses are often ineffective in the absence of local research and action blueprints. At the local level, local response protocols based on "no regrets" strategies can include not armoring the beach and retreating from the beach at the appropriate time.

We report work developing protocols for planning for sea level rise by teams at the University of Maine and the University of Southern California. Our goals are as follows: (1) Develop protocols with national and international utility for assessing impacts of sea level rise, including storm surges, erosion, shoreline retreat, and; (2) Develop "no regrets" strategies to mitigate impacts that will be cost effective in the absence of sea level rise; (3) Provide local area "stakeholders" who have vested interests in planning for sea level rise, with impact assessment tools. We are integrating the efforts of our teams in order to increase the scope of our protocols.

We selected several sites in coastal Maine and coastal Ventura County, California to serve as guidelines for anticipatory planning for sea level rise. We integrated coastal erosion rates, sea level rise and population changes into local resource, risk assessment and social impact models. Differences in and similarities between coastal Maine and coastal Ventura, County, California exist in the areas of beach access, governmental control, insurance coverage, and shoreline protection measures as well as the nature of the stakeholders.

The work we report on has the following components: (1) describe populations affected by coastal beach erosion and other sea level rise phenomena, (2) specify beach erosion scenarios, (3) describe the positions of stakeholders who may support or oppose policies related to beach erosion, and (4) outline policies which may be used to obtain the support of stakeholders. As this is work in progress, our conclusions are tentative.

Populations Affected by Beach Erosion

Only a portion of California's and Maine's counties and townships will be affected by future erosion. Nevertheless, much of the eroding coastline in California and Maine is in urban and metropolitan areas and affects residential neighborhoods and area infrastructures. In 1990, California's coastal populations consisting of 29 counties defined as coastal by NOAA, including 20 counties with shoreline access, was nine-tenths of the total state population and two-fifths of the total coastal population of the United States (Figure 4). There are large population concentrations in the coastal strips subject to sea level rise impacts in the 20 coastal counties in California with shoreline census tracts. Populations of these areas are increasing significantly, particularly in the metropolitan portion of the south coast, bay and delta areas and central coast.

In 1970, 7 percent of the total population of coastal counties lived on the coastal strip of shoreline census tracts, compared with 6 percent in 1990. Between 1970 and 1990, California's population of the coastal strip increased by 32 percent, or from approximately 1.3 million to 1.7 million persons, adding 226 persons km2 of shoreline census tracts. Forty-two percent of this growth was in coastal tracts of the metropolitan south coast. In 1990, the percentages of coastal strip populations in the coastal census tracts were 32 on the north coast, 7 in the bay and delta region, 29 on the central coast, and 5 on the south coast (Van Arsdol et al., 1994) (Figure 5).

Ten of Maine's 16 counties are designated as coastal by NOAA, comprising 92 per cent of the total population but less than 1 per cent of the U.S. coastal population. There are 144 coastal townships in the state, comprising 12 percent of the state's land area but 45 percent of its population. California's coastline is 1774 km of which 86 percent is reported to be experiencing erosion. Maine's mainland coastline of 7,352 km is the longest in the United States and 99 percent of its coast is reported to be experiencing significant erosion.

In order to delimit areas subject to potential disruption from sea level rise impacts; we use coastal census tracts (coastal neighborhoods) to approximate the ecotone between sea and terrestrial ecosystems.

Maine's population of 1.2 million in 1997 is located disproportionately in its southern and coastal communities. Over half of the population resides in the communities which range in size from the most populated city in Maine - Portland (64,000) - to the least populated of Perkins Township on Swan's Island (six people at last count). In 1990, there were 125 persons per square kilometer living in coastal communities compared to 55 persons per square kilometer in inland communities. After a period of significant population growth in the 1980s when the state's population grew by 9 percent overall and the coastal counties grew by up to 18 percent, growth is now slow - 1.2 percent overall between 1990 and 1997 - and five counties have actually experienced population decline. Conversely, the experience of the coastal counties in the last seven years has been of steady growth (3 to 9 percent change). Economic development has occurred predominantly in these areas - fuelling population growth - but the movement of people to the scenic coastal areas and the growth of retirement communities have also contributed to the increase in population. These areas also serve as important tourist destinations with fully 80 percent of all tourist-generated dollars spent at the coast.

While Maine's immediate coastline has a "rock-solid reputation" some areas consist of bluffs of clay, sand or gravel beaches which may erode a foot per year. Rocky shorelines are not particularly vulnerable to a change in sea level. However, sand beaches, coastal wetlands and eroding bluffs are particularly threatened by continued or accelerated sea-level rise and it is these very areas, located primarily in the Casco Bay/ Saco Bay region of southern Maine which have experienced very significant growth in the number of residents and recreational visitors.

SEA LEVEL RISE SCENARIOS

Maine

Sea level varies significantly in both its vertical and spatial position over time. Much of this is caused by the tides and causes no change in the position of the shoreline. However, during the last fifty years geodesists have observed tide gages record a rise of sea level. In the New England region, this has averaged 2.4 mm/yr. The Maine Geological Survey has used National Ocean Survey tide-gauge readings to estimate that Maine's rate of sea-level rise between 1940 and 1980 ranged from 1.1. mm per year in Kittery (on the Maine-New Hampshire border), to 2.3 mm per year in Portland (Maine's largest city) to 3.2 mm per year to Eastport (in the Eastern most part of Maine). A 1995 report, Anticipatory Planning for Sea-

Level Rise Along the Coast of Maine, notes that if that rate remains unchanged into the future, it translates into increases per century of 11 cm in Kittery, 23 cm in Portland, and 32 cm in Eastport (U.S.E.P.A./Maine State Planning Office 1995). The authors note that Maine's coast is currently experiencing significant local submergence due to lingering effects possibly caused by loading and unloading of receding ice sheets. Accelerated sea-level rise as a result of climate change would exacerbate this situation.

Maine's sand beaches will probably experience the most profound changes as a result of sea-level rise. This is of particular concern in Maine because sand beaches are scarce in the state. Sand and cobble beaches comprise less than 10 percent of the state's shoreline and the areas adjacent to them tend to be intensely developed. Inland movement of the shoreline might result in the loss of the dry sand portion of the beach and have a very significant impact on coastal tourism, recreation and the local economy (U.S.E.P.A./Maine State Planning Office 1995).

In a 1989 study, Kelley (1989) showed that Maine's coastal sand dune systems, coastal wetlands, and coastal eroding bluffs face the prospect of significant coastal erosion even without accelerated sea-level rise but simply based on historic rates of change. In the research conducted for anticipatory planning for such sea-level rise a range of sea-level rise scenarios were used to assess vulnerability to projected changes in shoreline position. The report described four physical impacts likely to be experienced in Maine: change in shoreline position, accelerated erosion/inundation of dunes and beaches, inundation of wetlands and lowlands and loss of natural coastal protection. Researchers mapped and evaluated the impact of shoreline change resulting from sea levels of 0.5 m, 1.0 m, and 2.0 m greater than today. They examined study sites within Casco Bay and Saco Bay which best represented three types of environmental settings, namely salt marshes, bluffs and sand beaches (U.S.E.P.A. /Maine State Planning Office 1995). The findings of projected change in shoreline position by 2001 under the different scenarios for these sites are shown in

Table 1. The site specific vulnerability assessment projected significant changes in two (Old Orchard Beach - a major tourist destination and Camp Ellis, a residential area) of the three beaches. Impact at one, Pine Point (a residential community) was minimal because it is currently accreting. Under the projections Old Orchard Beach and Camp Ellis are expected to experience major impacts, even at the 50-cm scenario.

> "Of the three sand beaches ...the Camp Ellis/Ferry Beach case study contained the most quantitative" assessment of anticipated impacts. Under the worst case scenario, 260 acres of upland would be inundated along with more than 350 structures and public roads, utility lines, a municipal service facility, and heavily used state and municipal recreational beaches. Under the 100cm scenario, 133 acres of upland currently developed with 334 structures would be inundated. The 50 cm scenario projects 71 acres of upland currently developed with 210m structures would be affected. The level of private investment at risk in Camp Ellis/Ferry Beach ranges from almost 38 million to over $61 million, depending on the sea-level scenario (Figure 6).
>
> For central Old Orchard Beach, projections based on the 50 cm sea-level scenario indicate a loss of 80 acres of upland, including beachfront development and development... landward. This area includes an amusement park, arcades, retail shops, motels, restaurants, highly residential structures, sewer lines and a new stormwater outfall. Since 1991, about $3.9 million has been channeled into public improvements in waterfront and downtown areas which are potentially at risk, and other significant investments are planned in this area as part of ongoing revitalization efforts " (U.S.E.P.A. / Maine State Planning Office, 1995).

In the face of such scenarios, analyzed possible adaptive response strategies were analyzed which might be adopted to mitigate the negative impacts of a change in shoreline position and associated impacts of global climate change. These responses were then analyzed from several different perspectives:

- the relative costs and benefits of selected preliminary response strategies for one specific case study area

- the responsiveness of existing State and federal laws and policies to address the most significant negative impacts on coastal resources identified by the vulnerability assessment

- the legal considerations for Maine's policy response including potential legal challenges to regulatory tools; and

- approaches already adopted or evaluated by other states for coastal erosion or coastal hazard mitigation

Four different response strategies were evaluated two of which represented protection and two of which used rolling easements. The first protection strategy involved a combination of beach nourishment along sand beaches, maintenance of existing bulkheads and construction of new bulkheads along wetlands to prevent inland migration. The second strategy was a variant on one, namely the addition of an initial buy-out and abandonment of the structures that are most valuable, to the protection strategies. Strategies three and four were retreat strategies. Strategy three assumed that regulations would prohibit all new development within the area expected to be affected by a change in shoreline position within the next 100 years. It also assumed that any existing development would be subject to a "rolling easement" which would require removal of development and restoration of the site to its natural condition as the shoreline moved in to affect development. The final strategy assumed that rolling easements would apply to both existing and new development. New development would be allowed on sites expected to be affected by projected sea-level rise but it would have to be removed if the sites became inundated by the sea. (U.S.E.P.A./Maine S.P.O., 1995)

A cost-benefit analysis of these respective strategies was conducted on the Camp Ellis study site and revealed that the two retreat strategies (3 and 4) were more cost-effective, with benefits exceeding costs for all sea-level rise scenarios. This cost-benefit analysis, along with the mapping, vulnerability assessment, evaluation of existing State and federal laws, and legal assessment of strategic policy response options led the researchers to conclude that the recommended course of action is to retreat from the shoreline in the face of sea-level rise. The main reason for such a recommendation is that in present value terms, it is far less costly to allow development to occur, and then remove structures and infrastructure which would be affected by sea-level rise over the next 100 years than it would be to incur the continual annual expense of beach nourishment and bulkheading.

The policies already in place for Maine's sand dune systems, established by the Sand Dune Rules of the Natural Resources Protection Act (Appendix 1) can form the base for the recommended adaptation strategy.

As the authors note there might be atypical sites in Maine where this strategy may not be appropriate because the current level of development or a heavily engineered shoreline (for instance along the Portland Harbor waterfront) might justify reactive protection as a more cost-effective strategy. Another area, which might test the State's determination to adhere to its retreat policy and current ban on construction of seawalls, is in intensely developed tourist resorts such as Old Orchard Beach. Ironically this area probably faces the greatest potential impacts of sea-level rise, with threats to the local economy and the very culture and identity of the community, but there is a considerable level of public and private investment. Regular meetings of the Sand Dune Stakeholders Group (comprised mainly of town planners, D.E.P and the Maine Audubon Society as well as other interested parties) continue to discuss the issues. Further analysis of a broad range of stakeholders' perceptions and reactions will be conducted this summer.

California

As in Maine, some of the most significant changes as a result of seal level rise will be on sand beaches, which are most common on the densely populated south coast. Within California, we developed guidelines for anticipatory sea level rise in Ventura County on the Oxnard Plain (Figure 7). The Oxnard Plain comprises a broad alluvial lowland area of approximately 405 sq. km, with 28 km of shoreline between the Ventura River and Point Mugu (Griggs, 1985). Rising sea level effects on the Oxnard Plain include reduced fresh water supplies, accelerated beach and cliff erosion, reductions in wetlands, dunes, and protected shoreline, and the release of soil bound chemicals from agricultural land.

The population of Ventura County is increasing rapidly (Table 2). The 1990 census enumerated population was 669,000 person; 122, 248 people (18 percent of the total county population) resided in coastal census tracts, which largely comprise the Ventura Plain. Population increased 41 percent during the 1970s and in coastal tracts by 27,5000. During the 1980s county population increased by 27 percent or by 141,600; and 24,000 in the coastal census tracts. Projections (State of California Department of Finance, 1993) suggest that Ventura County population could reach 1,319,000 persons by 2040, twice that of the 1990 population.

Historical analysis of the Oxnard Plain indicates that storm anomalies are leading to significant beach and shore retreat. Hurricanes off the coast of Mexico have driven storm surges northward and have caused erosion on south facing beaches (Griggs 1985). Wave heights normally range from < 1 m – 1 m, but spring storm surges can force < 1 m – > 3 m swells (Orme 1985:281). Port Hueneme is currently losing significant volumes of sand to offshore canyons and depends on complex systems of sand renoursihment to maintain its beaches (Orme 1985; Liu 1991). Sand transport is influenced by sand mining in the Santa Clara River, construction of piers and groins, and the creation and operation of three harbors. (Liu 1991).

We developed our sea level rise planning guidelines with respect to the following four sea level rise scenarios: (1) low, sea level rise only; (2) moderate, sea level rise adding erosion; (3) high, sea level rise, combined with erosion and storm surges; and (4) a Waterworld© case of maximum sea level rise (<3 meter enhanced risk zone). As is the case in our Maine example, inland movement of the shoreline can result in the loss of dry sand portions of beaches and significantly impact coastal tourism and the local economy as well as residential areas.

In scenario one, sea level rise is projected beginning at the current rate of between 1-2 mm per year (Gornitz 1993; IPPC 1996), and accelerating to reach a height of 60 cm by the year 2040; all other factors such as beach slope remain constant (Wang 1996). Some beaches would be submerged, and beach retreat would be maximum at Pierpont Bay, Ventura Harbor, and Ventura Pier (Wang, 1996; Constable et al., 1996:22). Commercial piers in Ventura County, and at Port Hueneme, Ventura, and Oxnard, and power plants in Ventura and Oxnard, as well as the military base and some residential areas such as the Silver Strand could be affected. Mitigation could likely reduce thee impacts (Constable, et al. 1996) (see Table 3).

Scenario two depicts the same sea level rise (60 cm by 2040) as scenario one, but adds beach erosion according to the Brunn model (Titus 1989:177). The Brunn model demonstrates how sea level rise contributes to shoreline erosion. Shoreline recession could reach 26 meters in some areas and intensify local impacts of scenario one (Wang, 1996; Constable, et al. 1996).

The third scenario adds beach retreat to the same sea level rise and erosion rates of cases one and two. Beach retreat would be approximately 19-42 meters depending on the frequency and severity of storms and storm surge events (Wang 1996; Constable, et al. 1996:7). This maximum case of sea level rise would particularly impact the lower lying areas of Silver Strand, Mandalay and Hollywood Beaches, and all other near-water infrastructures. For a one hundred-year storm, beach retreat could surpass 45 meters, and a two hundred-year storm could produce a retreat greater than 68 meters (Constable, et al. 1996).

Using data provided from 1990 census respondents, a snapshot assessment can be made of some of the potential disruption impacts from scenario three sea level rise. The enhanced risk zone contains 9,080 residents occupying 4147 housings units, with a reported vacancy rate of 23 percent as of April 1990 (Constable, et al. 1996). The estimated value of owner occupied housing units with a mean housing value of $374,675 by census respondents in the enhanced risk zone in 1990 was more than $530,000,000 (Table 4).

The fourth scenario is described as a Waterworld© maximum case. This improbably example was configured using a topographical map and determining a <3 meter contour line excluding high tide measurements. This case assumed a 60 cm rise in sea level over 50 years, accelerating erosion, loss of protective shoreline barriers, continued development patterns including sand mining, and increasingly violent storms (Constable, et al. 1996). Scenario four would potentially impact over 40,000 of the Oxnard Plain residents (Table 2).

Assuming that development continues over the next 50 years, impacts could increase significantly. We therefore interviewed stakeholders on the Oxnard Plain in order to gain information regarding possible response strategies. Vested interests of stakeholders may evolve from ownership and/or residence on land, power from control of regulations, from acting as agents to preserve the land, or from recreational user of the land in coastal Ventura County.

Stakeholder risk perceptions influence coastal land-use decisions and response strategies to mitigate impacts of sea level rise. Adaptations to perceived risk are assumed to be based on cost/benefit analysis i.e.; an acceptance of risk in exchange for perceived benefits. Risk perceptions were assessed by interviewing potentially affected stakeholders regarding hazard circumstances. Interviews were with 27

Ventura County and city elected/appointed officials, 5 developers, 13 residents of coastal census tracts directly adjacent to or on the shoreline, 10 recreational beach users, and 11 environmental activists. Respondents ranked the potential risk to the Oxnard Plain of sea level rise and expressed their views regarding coastal development and insurance.
Some politicians share the views of environmental activists and while others side with developers. Activists perceived benefits from the absence of or less development of coastal zones. Area residents and beach users cited either the climate or quality of life as benefits of living in the community. Many cited a decline in the environment and "development" as negative aspects of the shoreline community.

Most area residents and beach users opted for more restrictions on residential construction in coastal areas. Most stated that homes on the beach would be damaged from storm surges or sea level rise. Area residents and beach users did not favor continued development in the coastal zones. Beach users appeared to perceive a benefit of public access to the beach coupled with additional property taxes to mitigate beach erosion or retreat. The majority of the other respondents would also support additional taxes.

Developers perceived financial gain from coastal development to exceed the costs or risk from sea level rise or storm surge events. Most would support a special tax to maintain area beaches, and some indicated support for restrictions on residential construction in the coastal areas and all stated it was necessary to armor the shore. Flooding is the most common natural hazard. (Burton 1993:12) in the United States and in the beach area, but was considered to be less salient by beach users and residents than other hazards particularly earthquakes. Storm surges, sea level rise, landslides, and mudslides were rated as the least likely events by all categories of respondents. Environmental activists, elected/appointed officials and developers ranked the hazards of sea level rise above the risk of storm surge.

The respondents were then asked to rank the issues that each considered to be most important in developmental planning. Beach users ranked the "environment" as having the highest priority in developmental planning followed by "habitat" and "beach." Area residents ranked "habitat" as the most important consideration commissioners followed by "environment" and "hazards."

Environmental activists ranked the environment as the most important consideration for planning criteria and "habitat" ranked second. Elected/appointed officials were the only group to rank "hazard planning" as second in order of importance, and they elevated to third place the importance of "private property" over the "beach" and "habitat," but assigned "commercial property" the lowest preference. The developers selected the "environment" as most important followed by the "beach" and planning for "hazards."

Summary

In the absence of local action, global considerations of environmental problems are of limited interest. Continued coastal area urbanization requires development of "no regrets" local response strategies to contend with sea level rise. As urbanization is severely affecting coastal areas, such strategies are necessary whether climate change or sea level rise occurs. Local communities can measure and project sea level rise, assess populations affected by sea level rise, or assess the positions of local stakeholders and put in place appropriate responses.

Our research in California suggests that shoreline stakeholders, while representing different economic interests do share a common fate which can be a basis for developing workable local strategies to measure, assess and respond to shoreline loss. The Maine experience suggests that, while some highly developed or engineered shorelines might justify reactive protection or further armoring, the best long term protection is to retreat from the shoreline in the face of sea level rise. Thus shoreline development may not be warranted until the "life expectance" of "natural" and armored shores are first ascertained. We have described some of the tools needed to evaluate the consequences of shoreline development whether sea levels rise or not.

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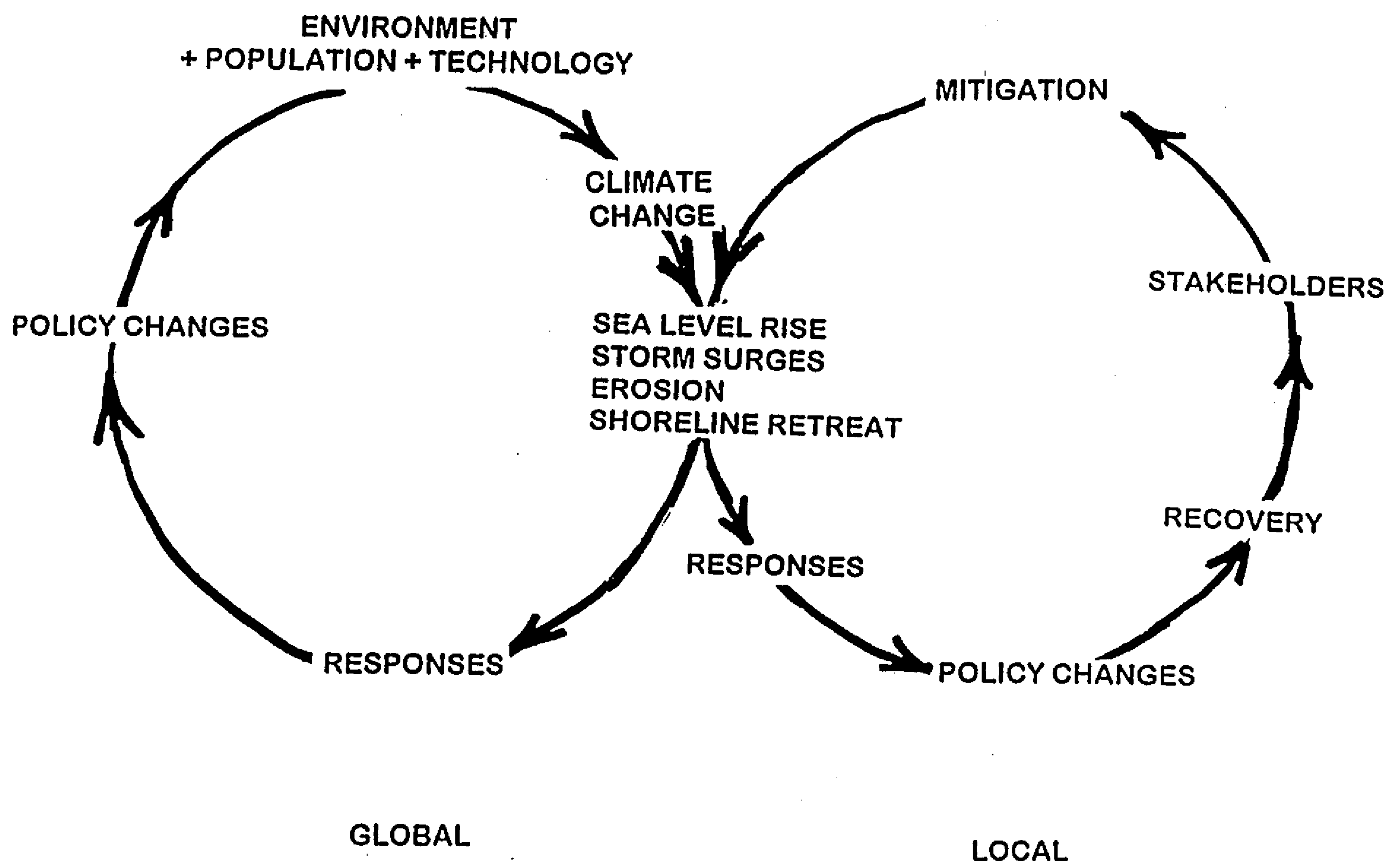
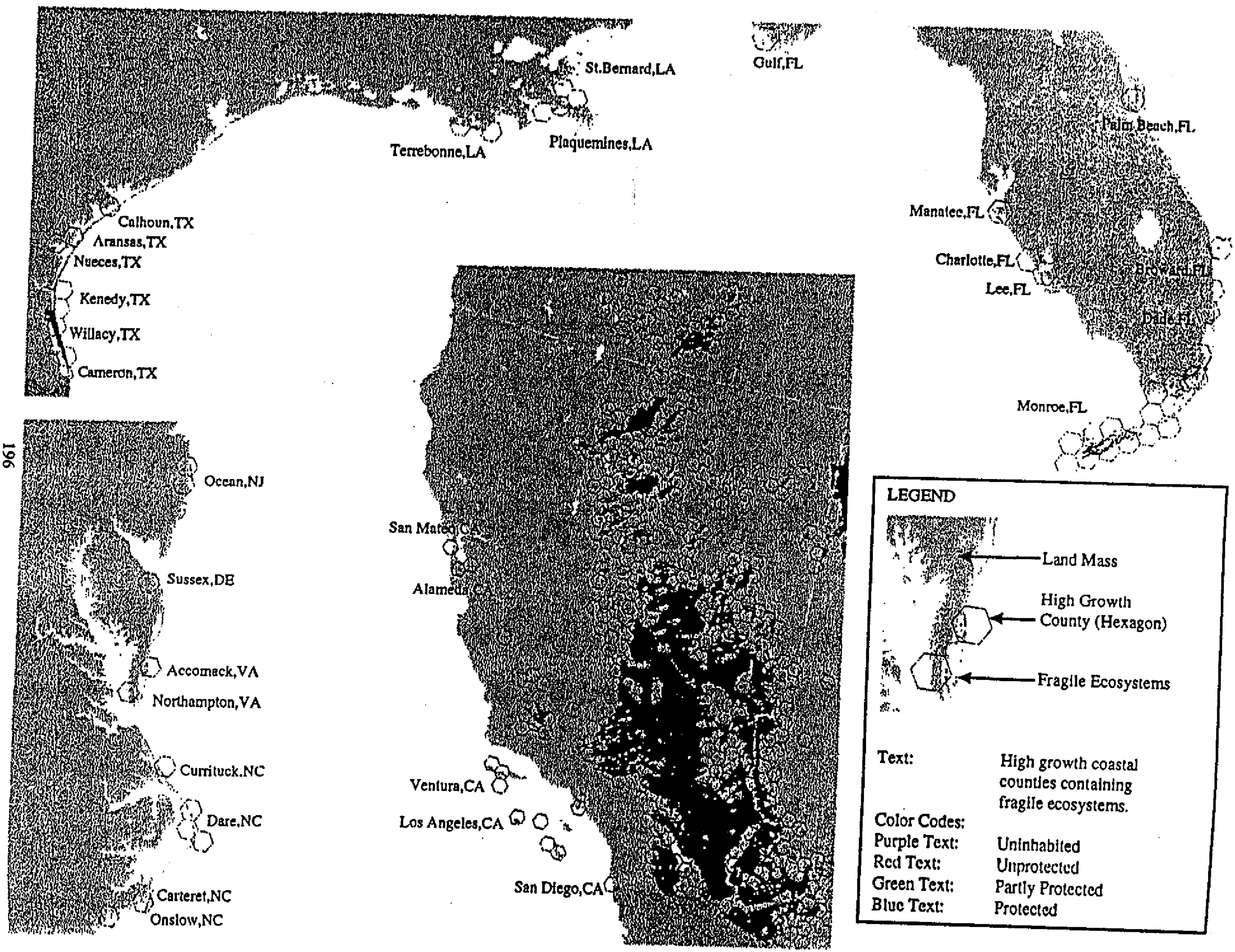
FIGURE 1 GLOBAL AND LOCAL DETERMINANTS AND CONSEQUENCES OF SEA LEVEL RISE

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Cameron,TX
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Charlotte,FL
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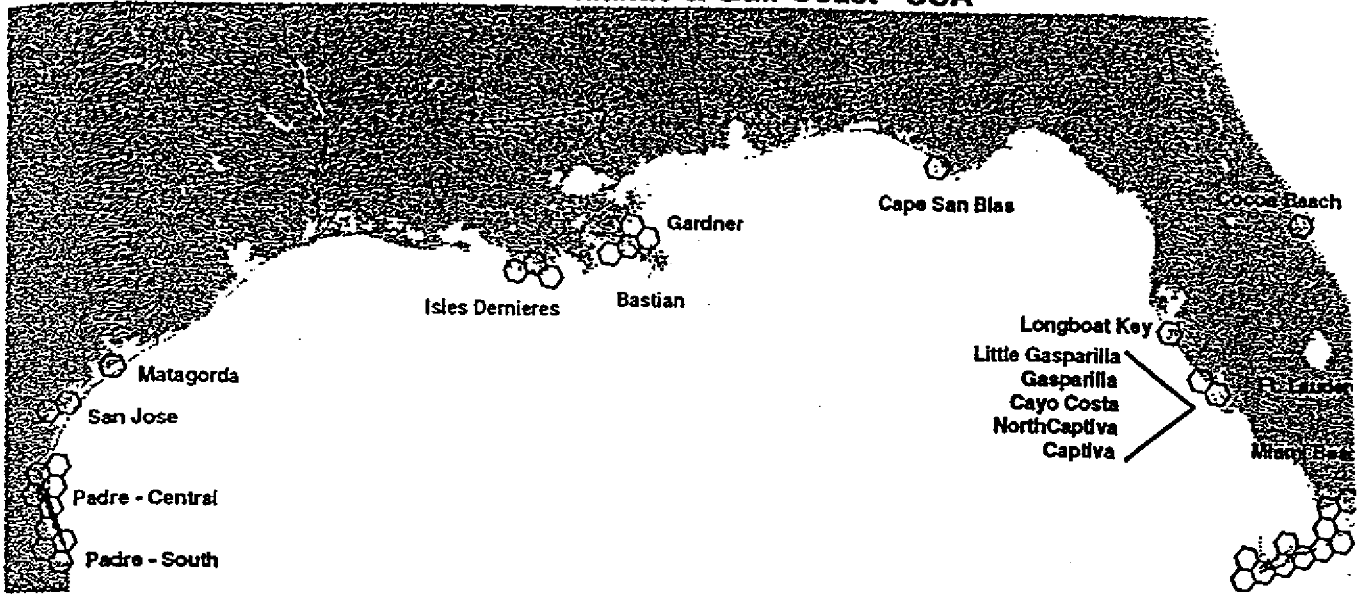
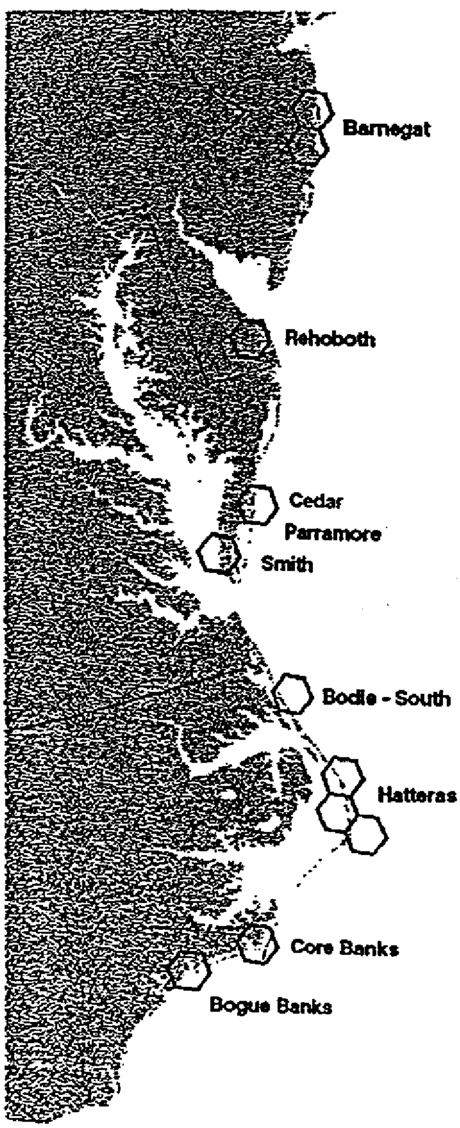
Ocean,NJ
Sussex,DE
Accomack,VA
Northampton,VA
Currituck,NC
Dare,NC
Carteret,NC
Onslow,NC
San Mateo,CA
Alameda,CA
Ventura,CA
Los Angeles,CA
San Diego,CA
LEGEND
Land Mass
High Growth County (Hexagon)
Fragile Ecosystems
Text: High growth coastal counties containing fragile ecosystems.
Color Codes:
Purple Text: Uninhabited
Red Text: Unprotected
Green Text: Partly Protected
Blue Text: Protected

FIGURE 3

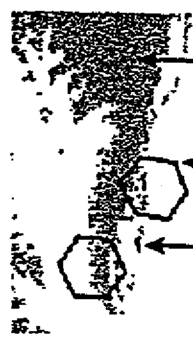
South Atlantic & Gulf Coast - USA



Central Atlantic Coast - USA



LEGEND

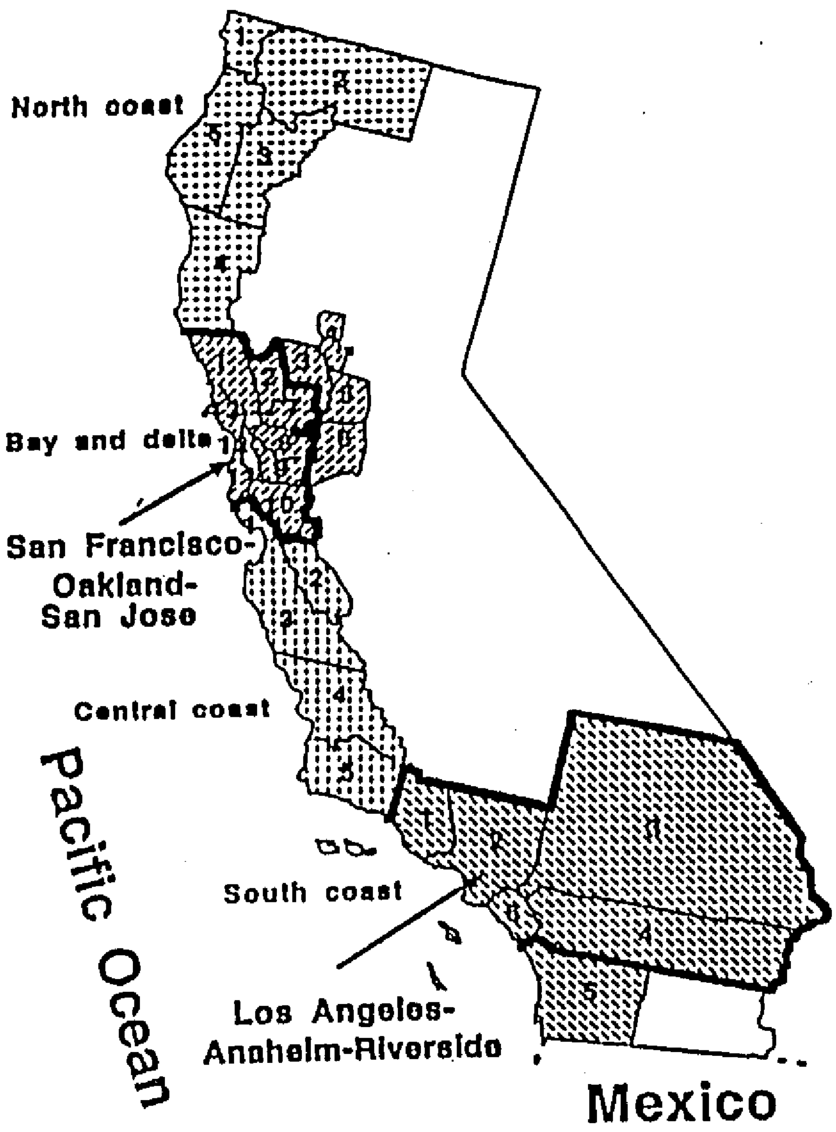


Text: Coastal Barriers in High Growth Counties.

Color Codes for Barrier Ownership:

Red Text:	Private
Green Text:	Private & Public
Blue Text:	Local, State, Fed, and/or Nature Conserv.
Magenta Text:	Coastal Barrier Reserve Units (CBRS)
Brown Text:	Private & CBRS
Orange Text:	Public & CBRS

FIGURE 4 **California coastal counties (by NOAA definitions)**



North coast

1. Del Norte
2. Siskiyou *
3. Trinity *
4. Mendocino
5. Humboldt

Bay and delta

1. Sonoma (PMSA)
2. Napa (PMSA) *
3. Yolo (MSA) *
4. Suttor (MSA) *
5. Sacramento (MSA)
6. San Joaquin (MSA) *
7. Solano (PMSA)
8. Contra Coasta (PMSA)
9. Alamoda (PMSA)
10. Santa Clara (PMSA)
11. San Mateo (PMSA)
12. San Francisco (PMSA)
13. Marin (PMSA)

Central coast

1. Santa Cruz (PMSA)
2. San Benito *
3. Monterey (MSA)
4. San Luis Obispo
5. Santa Barbara (MSA)

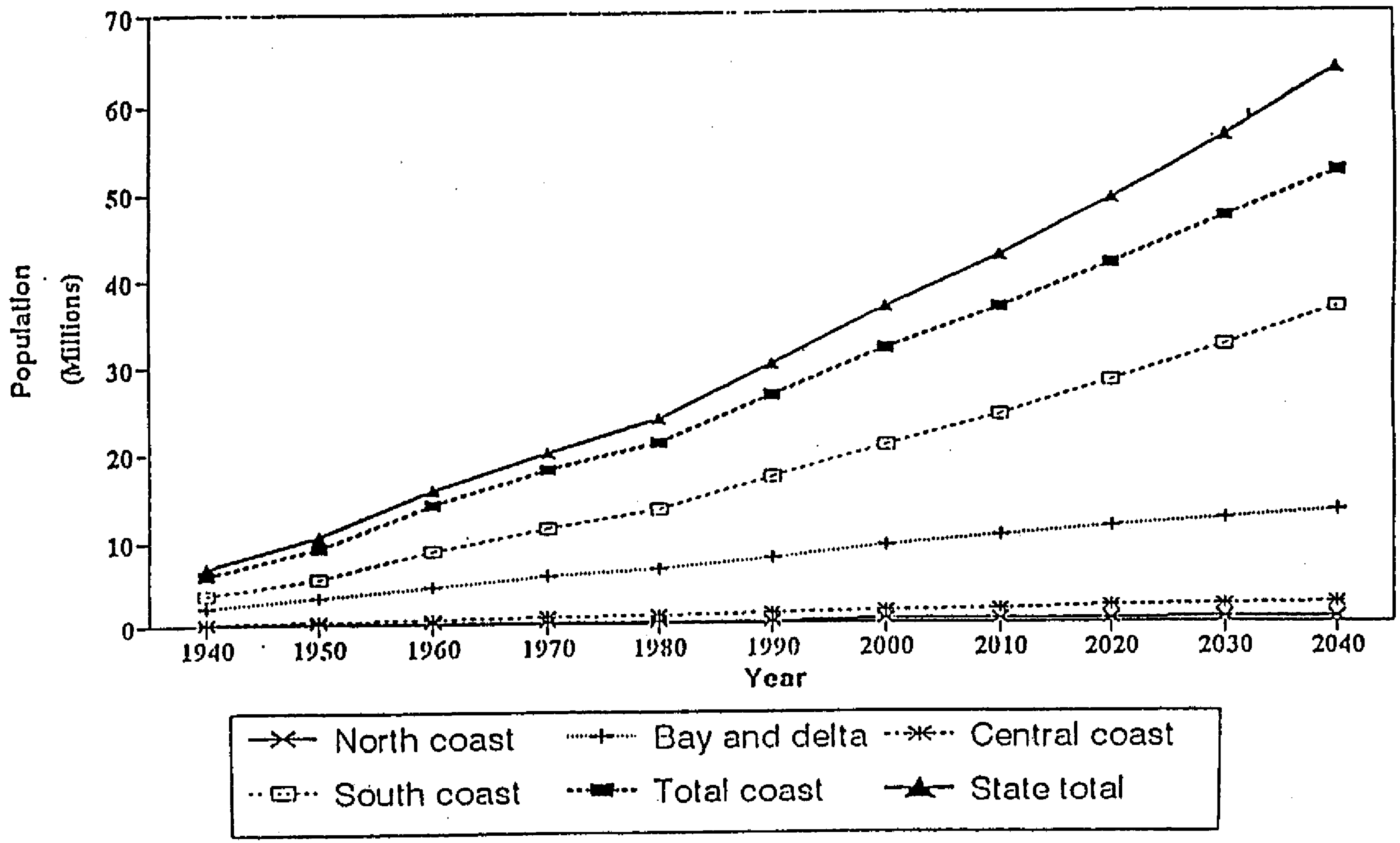
South coast

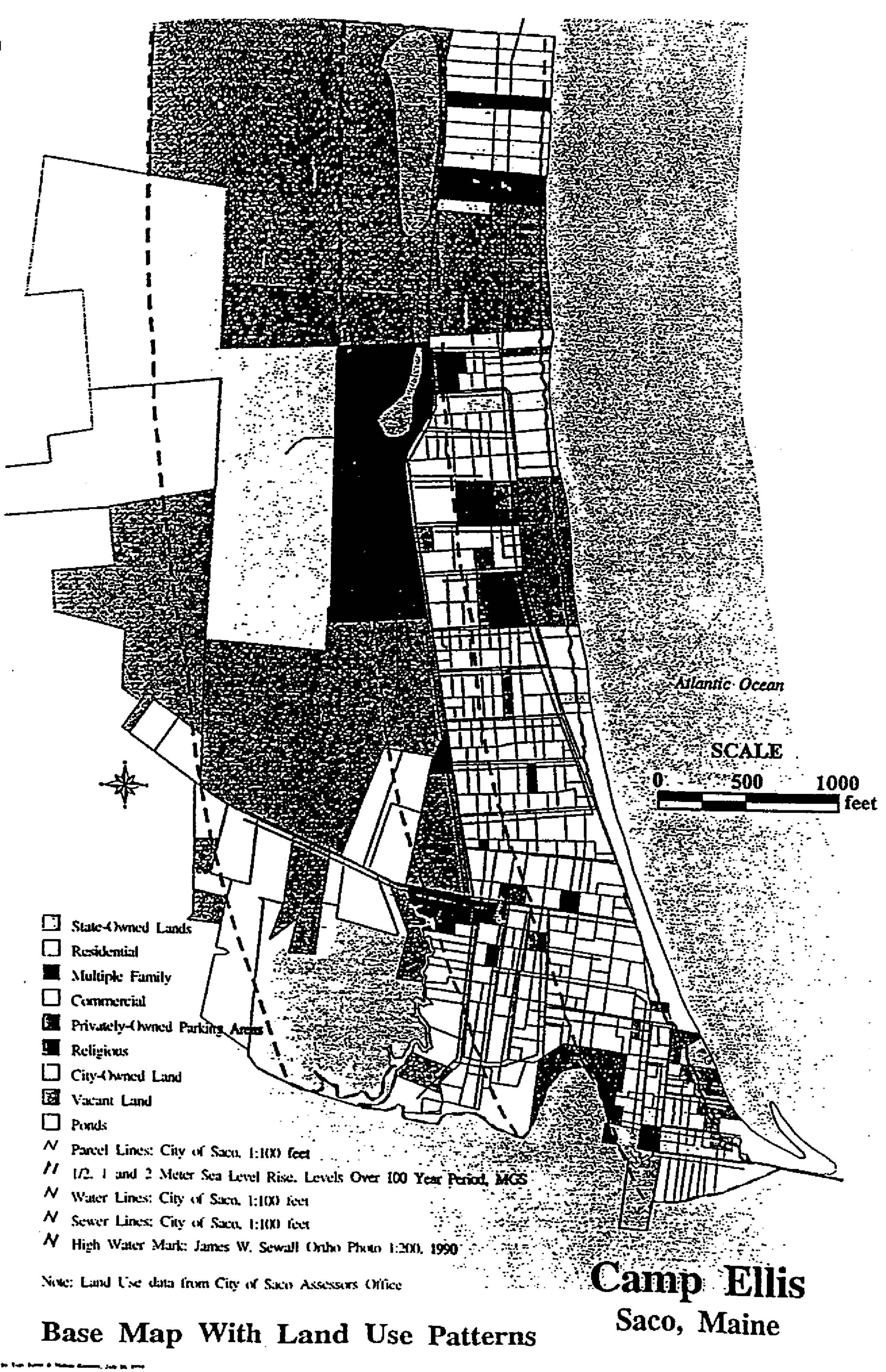
1. Ventura (PMSA)
2. Los Angeles (PMSA)
3. San Bernardino (PMSA) *
4. Riverside (PMSA) *
5. San Diego (MSA)
6. Orange (PMSA)

PMSA = Primary Metropolitan Statistical Area
MSA = Metropolitan Statistical Area
▬ = Consolidated Metropolitan Statistical Area
* = Inland counties classified as coastal

Km

FIGURE 5 California coastal population: enumerated 1940-1990, and projected 2000-2040





ure 3.5 Camp Ellis, Saco, Maine. Settlement patterns and wetlands.