IMPACTS OF GLOBAL SEA LEVEL RISE ON CALIFORNIA COASTAL POPULATION RESOURCES[1]

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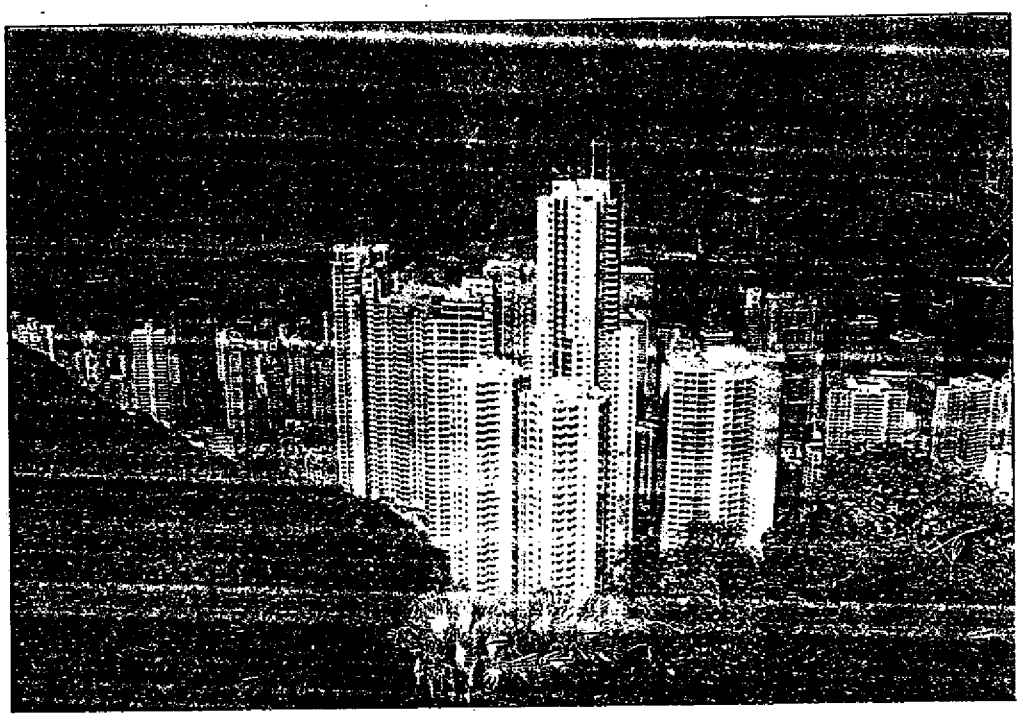

Vue de HONG-KONG

1995

CHAPTER 23

IMPACTS OF GLOBAL SEA LEVEL RISE ON CALIFORNIA COASTAL POPULATION RESOURCES[1]

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1. Objectives

Global effects of human populations, organizations, and technologies upon the environment and subsequent feedbacks to populations now receive attention from demographers (Clarke, 1991). To our knowledge, coastal erosion rates, sea level rise and population changes have yet to be integrated into local resource, risk assessment and social impact models. Our objectives are as follows:

(1) We will describe recent population changes in California counties and projections for California coastal, bay and delta counties from 1990 to 2040.[2]

(2) We will delineate a preliminary enhanced-risk coastal zone on the Oxnard Plain of Ventura County, California, for potential sea level rise related hazards for the years 1990 to 2040.

(3) We will make an initial assessment of potential impacts of sea level rise and identify some possible mitigation measures. We will describe these circumstances for the Oxnard Plain.

(4) We will revise population projections for coastal areas of California to take into account the shrinking land base, including that attributable to a future sea level rise.

(5) We plan to develop a protocol for risk assessment in other coastal, bay, and delta areas in California and elsewhere, and identify potential mitigation measures to reduce impacts of sea level rise on population.

We report our activities to date concerning the first three of these objectives. This is a report of research in progress; our analysis is illustrative rather than definitive. Like other attempts to describe population-environment relations, our preliminary results vary according to the level of aggregation of our questions and data, the perspectives of the disciplines from which they are asked and the time periods under consideration (Heilig, 1993; Keyfitz, 1993).

2. Background

It has been argued that a one meter rise in sea level world-wide could result in more than 50 million environmental "refugees" or displaced persons globally (Jacobson, 1990). The United States, with more than 19,000km of coastline, could be severely affected (Jacobson, 1990), including inundation of both east and west coast wetlands, and beach loss. Early projections of catastrophic sea level rise and widespread coastal inundation are no longer taken seriously. Nevertheless, current projections, at the level of 100cm by 2100, suggest there are many locations where low-lying coastal environments are at risk from even small rises in sea level (e.g. Ellison and Stoddart, 1991).

Population size, as well as production and consumption activities (expressed as gross domestic product per capita), largely determines levels of CO_2 emissions and is described as contributing to global warming (Bongaarts, 1992; Bartiaux and Ypersele, 1993). Global warming may, in turn, lead to sea level rise for two reasons: (1) water expands as it is heated, and (2) glacier and polar ice cap melting could increase the volume of seas (Abrahamson, 1989). Sea level rise decreases the availability of land useful for shelter and subsistence. Natural phenomena may be responsible for some portion of global warming; coastal population increases, however, can exacerbate impacts.

Demographers have recently described population impacts of rising sea level (Nangia and Banerji, 1993). Population-environment connections, including rising sea level, can be expressed as impact = population x affluence x technology, where affluence = consumption/population, and technology = impact/consumption (CICRED, 1992). The Malthusian paradigm suggests that population growth eventually outstrips the ability of the (coastal) environment to provide resources (Malthus, 1798); population increases are assumed to reduce affluence, or reduced affluence is assumed to decrease population (CICRED, 1992). Mitigation includes decreasing levels of consumption and/or technology. Optimists (Simon, 1981) suggest that scarcity limits degradation by driving up (coastal) land prices. Following Boserup (1965), increasing technology such as ocean barriers, may enhance the ability of the coastal environment to support population.

Effects of changes in population and land use "may go in both directions" (Lutz and Holm, 1993). Evaluations of rising sea level-population carrying capacity relationships are hindered by fuzzy concepts, a lack of data, and the fact that definitions of research problems, evaluations of acceptable risks, and specifications and implementation of mitigation measures are all based on social constructions of the reality of risks. The optimist and Boserup paradigms may fit limited (coastal) ecosystems; nevertheless, Malthus correctly anticipated that there are global limits to resources available to support human populations. Following Shaw (1989), we view population growth and affluence-technology determinants of environmental degradation as proximate and ultimate causes, respectively. There appears to be greater resistance to changing the social mechanisms supporting current affluence-technology connections that generate rising sea level than resistance to changing population flows that represent population adaptations (Shaw, 1989). This focuses our attention on the latter.

Two assumptions govern our considerations of impacts of rising sea level on California coastal populations.

First, population growth is a proximate cause of decreasing land availability on the California coast (Koss, Van Arsdol, Jr., and Mongeau, 1987). By 1990, more than 26 million persons, 87 per cent of the state's then 30 million persons, lived in coastal counties (Fig. 1, Table 1). These counties were on the north coast, bay and delta areas, central coast, and south coast. California's coastal county population in 1990 was 20 per cent of the coastal county population of the United States. The sea level rise of perhaps 10–15cm in the past century has had important impacts including beach erosion, recession of wetlands, and salt water intrusion into the bay and delta region, as well as other heavily populated regions (Revkin, 1992).

Second, perceived threats of global warming has raised concerns regarding potential inundation of California coastal areas. Impacts would increase as population increases, and would affect urban and metropolitan areas, which are particularly vulnerable to disaster (Quarantelli, 1987). Redirecting populations away from all affected areas may be unfeasible. Rising sea level is often not perceived as a problem, organizational strategies to mitigate risk are lacking, and land to support relocated populations may not be available. If land is available, an extended time is needed to provide infrastructures, and populations in existing coastal centers must often be accommodated at higher densities and with dwindling resources (Jacobson, 1990).

3. Methods

We consider global sea level rise to be a background (macro) characteristic and describe superimposed local (meso) effects. Our methods are as follows:

We first describe population trends and projections for the State of California and the 29 California coastal or bay counties as defined by the Strategic Environmental Assessments Division of the National Oceanic and Atmospheric Administration (NOAA, n.d.i.a). Seven of these counties are non-metropolitan, the remaining 22 are metropolitan; 5 are on the north coast, 13 on the bay and delta region, 5 on the central coast, 6 on the south coast, and 9 are inland counties classified as coastal by NOAA whose populations affect and are affected by coastal ecology (Fig. 1, Footnote 2). Projections from 1990 to 2040 are based on those of the state's Department of Finance Population Research Unit (1993).[3] Long-term projections are necessary due to the need to plan for long-term disruption of coastal populations and infrastructures that may be occasioned by sea level rise.

Second, we delineate an enhanced risk zone. Outcomes of global sea level rise are typically localized and have been described in anecdotal rather than exhaustive terms (Jacobson, 1990). We evaluate future coastal hazard risks, including horizontal (erosional) and vertical (sea level) changes, for the State of California. We will delineate an enhanced risk zone in three steps. The first step is to describe coastal counties and their populations, including inland counties classified as coastal areas or bays (Fig. 1). The second step is to describe coastal census tracts of coastal counties. The third step is to provide an illustrative description of a potential enhanced risk zone within Ventura County. We describe this zone by using US Bureau of the Census

TIGER/line 1992 files to delineate census tracts and then overlay physical features from digital line graphs, based on an analysis of US Geological Service topographic maps.

Third, we will attempt to meld coastal erosion rates, sea level rise projections, population projections, and organizational factors affecting possible mitigation alternatives into risk assessment and social impact descriptions.

4. Population Trends in Coastal Counties

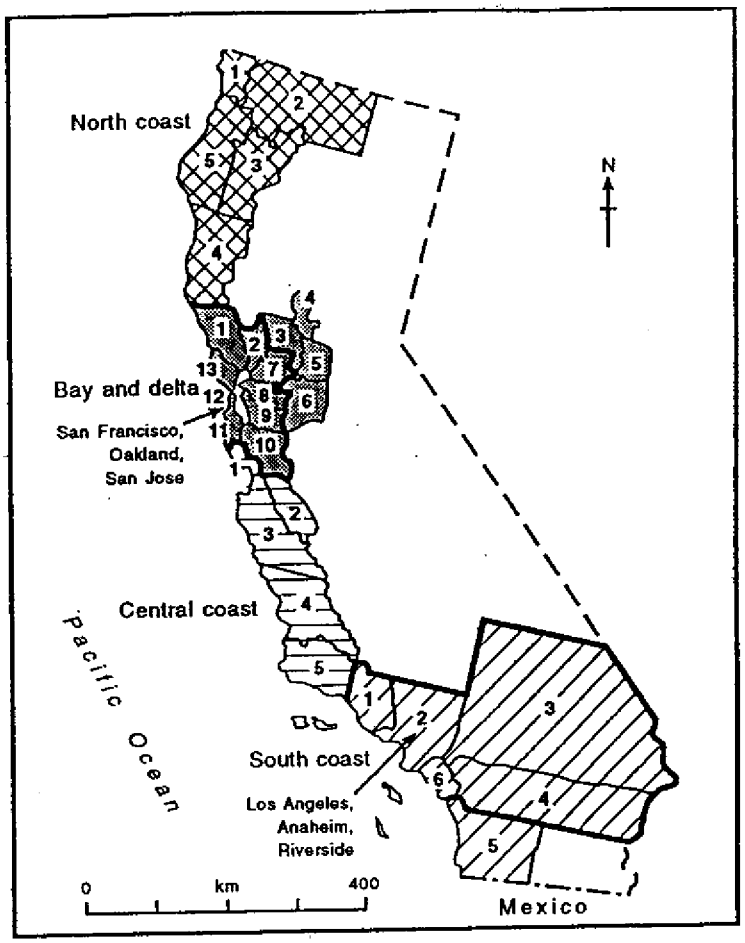
The first step in delineating an enhanced risk zone is to describe California's coastal counties and their populations. California's population historically grew more swiftly than that of the United States as a whole. It increased from less than half a million persons in 1860, when California had one per cent of the nation's population, to nearly 30 million in 1990, 12 per cent of the nation's population. During the 1980s, the state added approximately 6.1 million persons; about 37 per cent from net in-migration and 63 per cent from natural increase.

Population growth in California's coastal counties closely follows that of the state (Fig. 2). High numerical growth occurred in the 1950s, growth was less in the 1960s and 1970s and the highest growth occurred during the 1980s. These trends were apparent in each of the 4 coastal regions.

The total population of the 29 coastal counties (including the 9 inland counties classified as coastal by NOAA) increased by 25 per cent, from 21.0 million in 1980, to 26.3 million in 1990 (Table 1, Fig. 2, Appendix Table 1). Growth for the coastal counties was greatest in the south coast, followed by the bay and delta area. In 1980, the coastal counties contained 89 per cent of the state's population. The land area of these counties accounts for 201,580km^2 or 50 per cent of the state's total land area. The 1990 total populations for the 4 coastal areas were as follows: 280,000 for the north coast, almost 7.8 million for the bay and delta area, 1.2 million for the central coast, and 17.0 million for the south coast.

The share of California population in coastal counties peaked at 90 per cent in 1970, is now decreasing and is projected to continue to decrease. The south coast share was 57 per cent in 1990 and is relatively constant. The bay and delta share was 26 per cent in 1990 and is slowly decreasing. The central coast and north coast shares in 1990 were 4 and less than one per cent, respectively.

California's two largest metropolitan clusters are located on the coast; the San Francisco-Oakland-San Jose Consolidated Metropolitan Statistical Areas (CMSAs) in the bay and delta area and Los Angeles-Riverside-Anaheim (CMSA) on the south coast. Each cluster is integrated into a separate regional economy ranked among the world's largest and each is an economic and social focus for the Pacific Rim, making for metropolitan dominance of the physical ecology of the bay and delta areas and south coast (Fig. 1).



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 Sutter (MSA)*
5 Sacramento (MSA)
6 San Joaquin (MSA)*
7 Solano (PMSA)
8 Contra Costa (PMSA)
9 Alameda (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

1. California coastal counties, by definitions of the U.S. National Oceanic and Atmospheric Administration (NOAA).

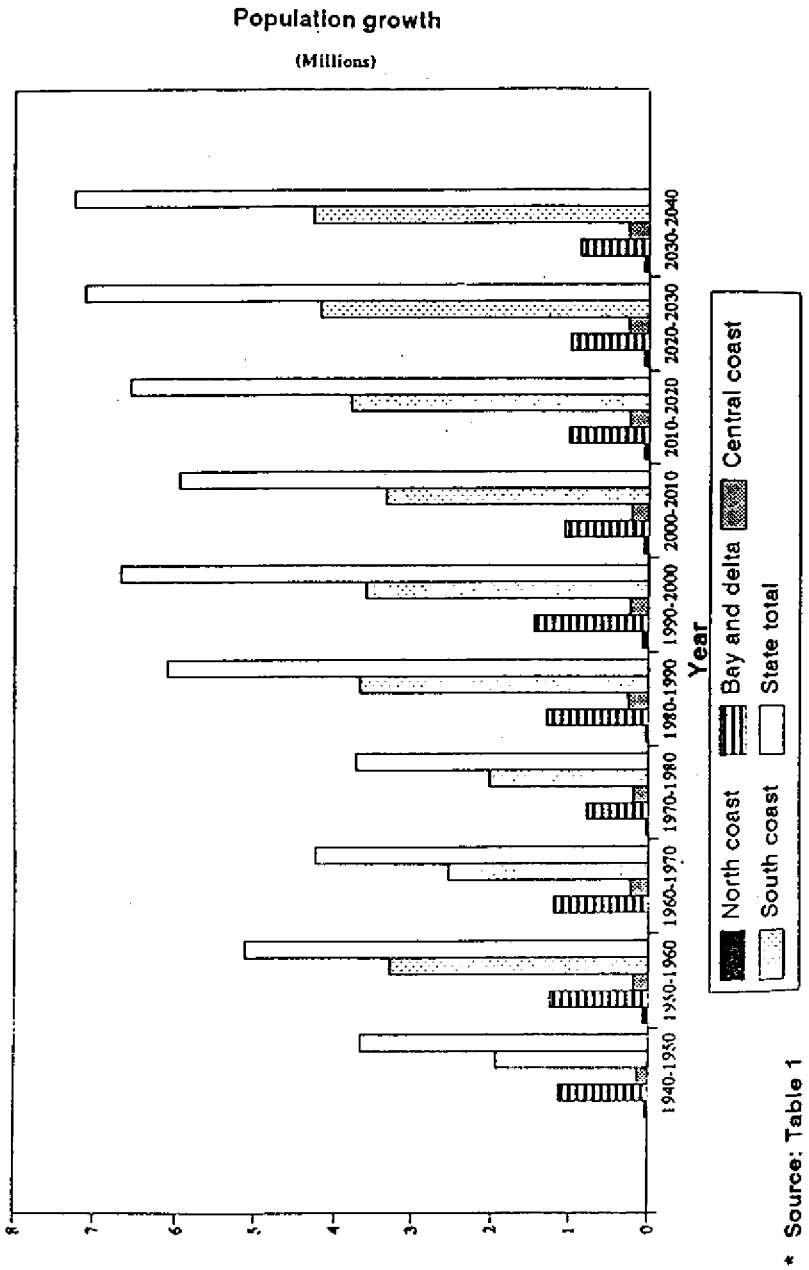


Fig. 2. Decennial population growth of State of California and coastal counties: enumerated 1940–90 and projected 2000–40.

5. Population Changes in the Coastal Strip of Coastal Counties

The second step in designating an enhanced risk zone is to describe coastal census tracts in coastal counties. A preliminary analysis of population and housing changes from 1970 to 1990 was carried out for the coastal strip of census tracts along the shoreline of the 20 NOAA defined coastal counties with a shoreline containing coastal census tracts.[4]

The population on the immediate California coast may now be pressing on the residential resource base. By 1990, 7 per cent of the population of the 20 coastal counties lived in the strip of coastal census tracts compared with 8 in 1980 and in 1970. Nevertheless, between 1970 and 1990, the population of the coastal strip increased by approximately 400,000 persons, 1.3 million to 1.7 million, adding 226 persons/km of shoreline. More than four-tenths (42 per cent) of this growth was concentrated in coastal tracts of the metropolitan south coast. In 1990 the percentage of population in the coastal strip was 32 on the north coast, 7 on the bay and delta, 29 on the central coast, and 5 on the south coast.

There is a lack of public lands in California coastal areas, and local governments are also losing some of their abilities to preserve land. Larger populations are now exposed to the risk of rising sea levels and land loss due to coastal erosion and subsidence. Population activities contribute to coastal environmental instability by increasing seacliff or bluff erosion, lowering water tables in coastal areas through irrigation, blocking sand input into shoreline areas, and by contributing to air, land, and water pollution. Approximately 86 per cent of the 1774km coastline of the state for example, is reported to be eroding (Edgerton, 1991). Future loss in the coastal land base, including inundation, when combined with other growth constraints, can reduce the ability of the coastal zone to support human populations. A scarcity of coastal land and current land use restrictions may drive up housing prices and inhibit growth on the coast. The population of the coastal census tracts of the 20 coastal counties increased less rapidly between 1970 and 1990 (32 per cent) than did the population of the inland census tracts (41 per cent) of these coastal counties. The number of housing units increased more rapidly in coastal tracts (54 per cent) than in non-coastal tracts (49 per cent). The differences between population and housing units were greater in coastal than non-coastal tracts.[5]

Median rent and housing unit values (indexed to 1990) were higher for coastal census tracts than for the remainder of the 20 coastal counties and the coastal counties overall for 1970, 1980, and 1990. The median household income (indexed to 1989) was lower for coastal census tracts than for non-coastal tracts and the coastal counties overall during this period (Fig. 3). The difference in housing unit values and median household income between coastal tracts and the remainder of the coastal counties increased more rapidly during the 1980s than in the 1970s. These trends suggest but do not verify a connection between scarcity of coastal land and inhibited population growth.

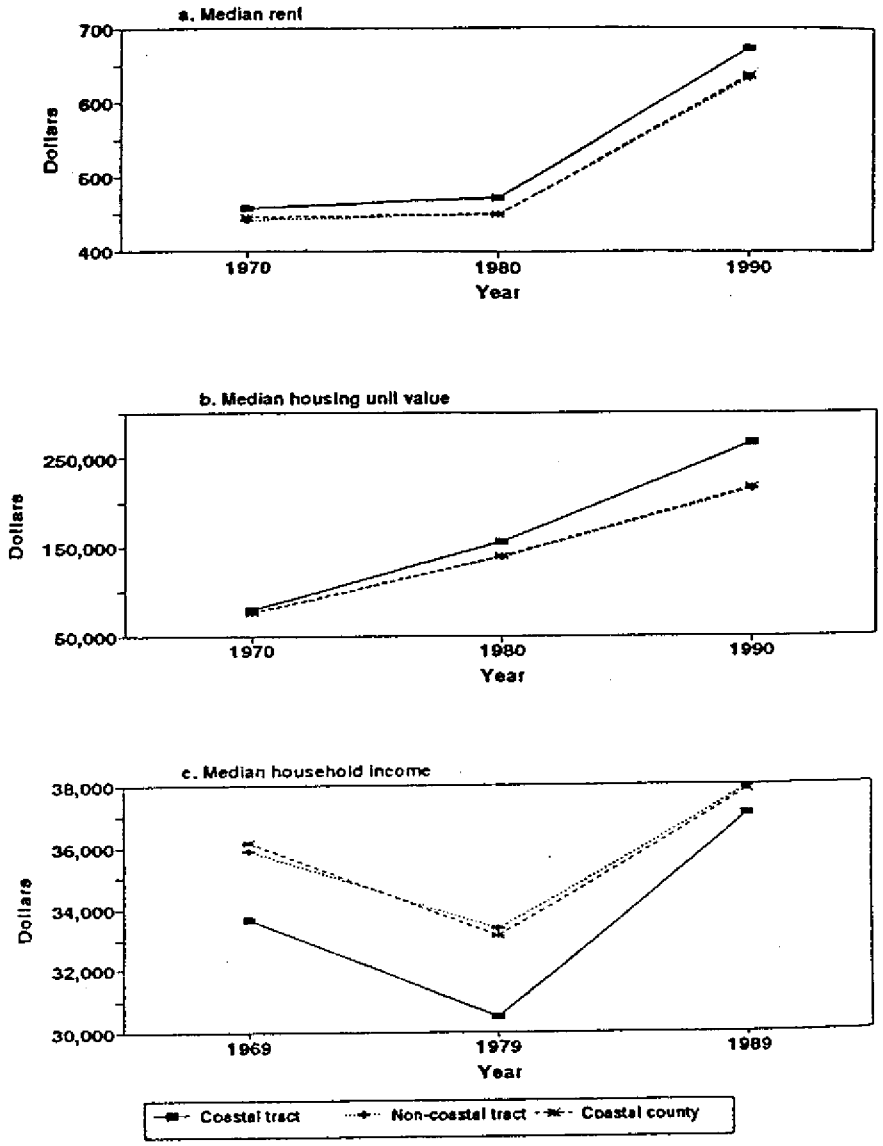


Fig. 3. Median rent and housing unit value, and household income by coastal census tracts, non-coastal census tracts and 20 coastal counties, California, 1970–90.

6. Population Projections for Coastal Counties

Significant future population growth in California is projected after the state recovers from the current economic recession. "The state's demographic underpinnings remain strong" according to Morrison (1993). Recent growth provides demographic momentum, migration to California has global origins, and the economic pull of the state is likely to resume, although it is too soon to determine the future mix of non-skilled versus skilled employment (Koss, Van Arsdol, and Mongeau, 1987; Morrison, 1993). Nevertheless, economic downturns, resource shortages, inadequate infrastructures, environmental and social deterioration, earthquakes and other natural disasters, and community growth limitation policies will eventually constrain growth.

The illustrative projections are to help delineate potential impacts of rising sea level and not to emphasize future human numbers. From 1990 to 2040, California population is projected to increase from 29.8 to 63.3 million persons, an increase of 113 per cent (State of California, Department of Finance, 1993) (Table 1, Appendix Table 1). Coastal counties are projected to increase from 26.2 million in 1990 to 52.2 million in 2040, an increase of 99 per cent. Population could more than double on the south coast, increasing from 17 to 36.2 million. In the bay and delta area, the increase could be from 7.8 to 13.1 million (Fig. 4).

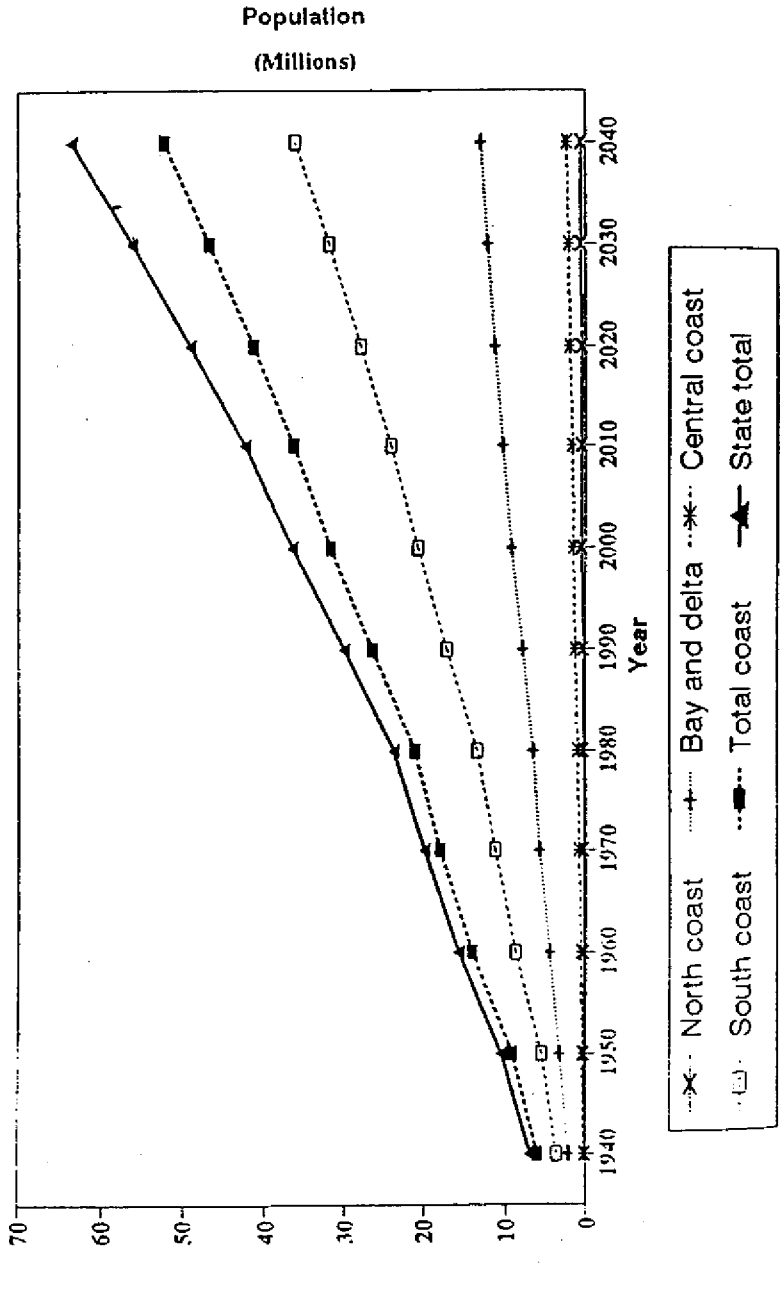


Fig. 4. California coastal population: enumerated 1940–90 and projected 2000–40.

As coastal land becomes more populated, commercial developers and communities attempting to preserve open spaces engage in a conflict over coastal land use restriction. If future population growth saturates the south coast, the bay and delta areas, and the central coast, then further growth is to be expected in inland areas and along the north coast. Urbanization could eventually dominate the entire California coast with the possible exception of the north coast whose timber and canning industries are now too weak to attract newcomers.

7. Ventura County Coastal Impacts

The third step in specifying an enhanced risk zone for sea level rise is to describe such a zone in Ventura County. Our measurements here are preliminary, pending our determination of 1994 mean sea level, which will be used as a benchmark for projecting future sea level rise. Rising sea level affects the Ventura County coastal zone ecosystem in several ways, including reducing fresh water supplies, accelerating beach and cliff erosion, reducing wetlands, dunes, and protective shoreline, and releasing soil bound chemicals on agricultural land. The sandy barrier beach; which advanced by more than 150 m over the last century (Hamblin, 1951), is currently retreating as a consequence of dam and break water construction and sand mining activities. The enhanced risk coastal zone here comprises a broad alluvial lowland area of approximately 405km^2 the Oxnard Plain, with 28km of shoreline between the Ventura River and Point Mugu (Griggs, 1985), including an area overlying a declining aquifer (California Department of Water Resources, 1967) (Table 2).

Due to its low elevation, much of the Oxnard plain would be affected by sea level rise; the census tracts immediately bordering the ocean are considered to be an enhanced risk zone particularly subject to rising tides (Fig. 5). Natural ecosystems are not the only potential casualties of rising sea levels; also threatened are residential structures, sewage treatment plants and other commercial facilities (Griggs and Lauret, 1985). Significant population displacement and property loss could occur in the enhanced risk zone. The coastal census tracts contain high density housing, major resort and hotel complexes, three harbors (Port Hueneme, Channel Island Harbor and Ventura Harbor), and a Marine Corps base at elevations estimated as <3m above sea level, excluding high tide measurements.

Table 2. Summary data for Ventura County, coastal and non-coastal tracts, Oxnard Plain, and preliminary enhanced risk zone, 1990

1990	Total	Coastal tracts	Non-coastal tracts	Oxnard plain	Preliminary enhanced risk zone
Total population	668,666	122,248	546,418	326,871	40,097
Persons per room	0.54	0.64	0.52	0.58	0.47
Occupied housing units	217,298	36,662	180,636	104,324	14,745
Persons per occupied housing unit	3.08	3.33	3.02	3.13	2.72
Vacant housing units	11,180	3,418	7,762	5,786	2,419
Persons in owner-occupied housing units	435,666	63,332	372,334	189,905	18,816
Persons in renter-occupied housing units	219,937	54,968	164,969	128,504	19,024
Owner-occupied housing units	142,262	19,138	123,124	61,624	6,796
Renter-occupied housing units	75,036	17,524	57,512	42,700	7,949

Source: US Bureau of Census enumeration, 1990

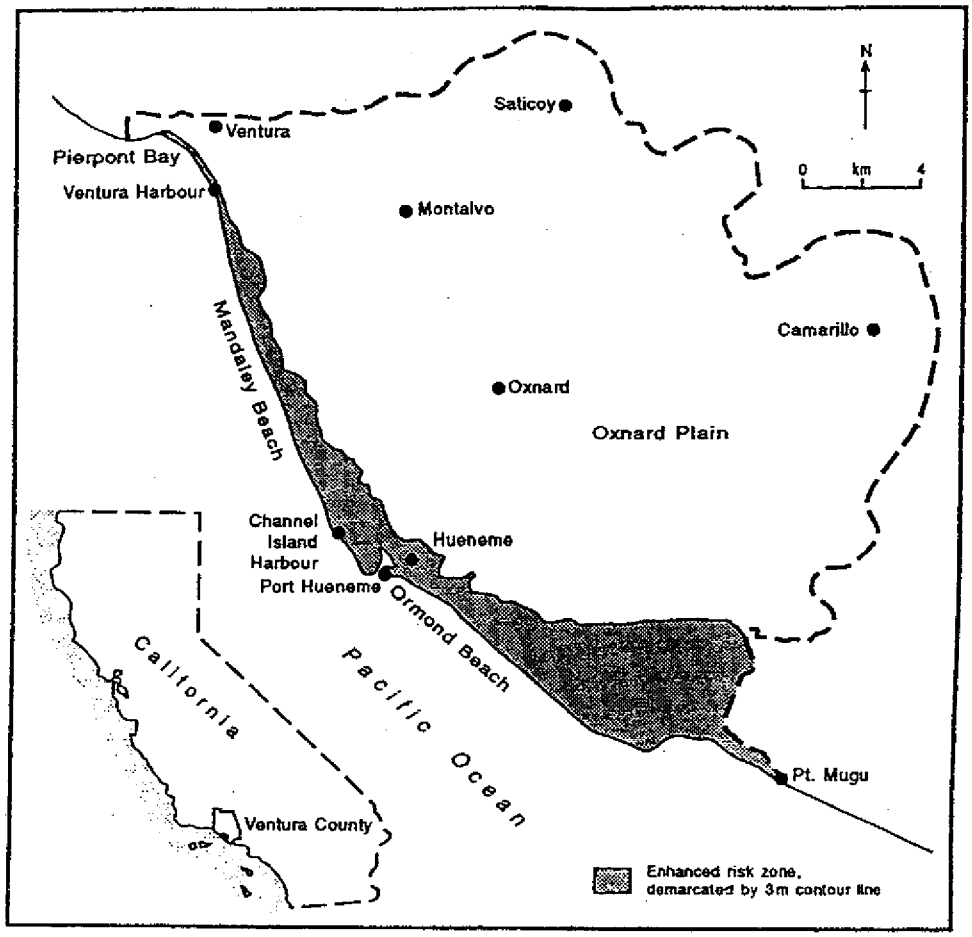


Fig. 5. Enhanced risk zone and Oxnard plain, Ventura County, California, 1994.

The 1990 census enumerated population of Ventura County was 669,000; 18 per cent or 122,248 persons resided in coastal census tracts, and 48 per cent or 326,900 lived within the approximated boundaries of the Oxnard Plain. Of the plain residents, more than 40,100 (13 per cent) dwelled on land estimated as 3m or less above sea level, the area most likely to experience the earliest impacts from sea level rise.

The State of California Department of Finance projections suggest that Ventura County population could reach 1,319,000 persons by 2040 doubling the 1990 population. Population increased 41 per cent during the 1970s or by 152,877 persons. The coastal tracts increased by 27,500, and the Oxnard Plain by almost 71,600. During the 1980s, county population increased 27 per cent or 141,600, and the coastal census tracts by 24,000, while 61,000 persons were added to the Oxnard Plain.

While the coastal tract residents are presently experiencing problems due to chronic beach erosion and periodic storm surges, real estate development continues at a rapid rate. Mounting insurance company concerns could lead to discontinuance of coverage in high risk zones, thus further limiting land resources and development and reducing available government tax sources (Berz, 1991).

8. Organizational Responses

Population impacts of rising sea level in California will be influenced and mitigated by the "social construction" of the hazards, legislation, responses to legislation, actions by relevant government agencies, and the monitoring of regulatory enforcement by "stakeholders" with sometimes opposing interests.[7] These stakeholder groups and their positions are assumed to be as follows:

(1) Groups favoring population and development in coastal and delta zones — business organizations, real estate associations, developers, contractors, fishing interests, and elected officials of some coastal communities.

(2) Groups advocating concentration of commercial and housing development in more central, urban areas -- elected and appointed officials in central city coastal and delta area and their constituencies.

(3) Groups opposed to rapid coastal and delta population growth and to development of the open space of those areas and encouraging low-density housing in the enhanced risk zone -- private sector insurance companies, environmental and neighborhood organizations, farmers affiliations and governmental agencies involved in environmental protection and management.

(4) Groups desiring greenbelts and open spaces for parks particularly in enhanced risk zones -- local, national and international environmental and neighborhood organizations, parks and recreation departments (Koss and Van Arsdol, 1981).

Policy alternatives for distributing growth among regions of the state are limited. First, much of the area of inland counties consists of federal land -- legal mandates and public sentiment tend to reserve these lands for uses that are incompatible with urban development. Second, most private non-urban land in inland counties is devoted to agriculture. Third, many residents of sparsely settled inland areas support local growth limitation ordinances (Koss, Van Arsdol and, Mongeau, 1987). Tax incentives and disincentives may also play a role in population distribution. Local governments--

counties and cities--have at their disposal population growth and distribution control measures but local growth limitation has several negative economic and social consequences, including rising housing prices, increases in homelessness, a contracting economy and increased ethnic segregation (Koss, Van Arsdol and Mongeau, 1987). Enactment and implementation of the policies necessary to distribute and manage population change depends on convincing various "stakeholders" that their interests and the welfare of the community in general will be served by land use policies.

9. Conclusions

Global warming may affect sea level resulting in coastal population impacts. We describe population and social impacts of sea level rise in California. Local sea level rise is expected to decrease the base of California's coastal zone land available for settlement. Coastal population is increasing, and an increasing area is at risk for erosion and flooding.

Rapid population growth is projected for California's coastal counties which now contain nine-tenths of the state's population. For coastal areas in general (excluding the north coast), large population growth is expected. Population increases in California's coastal neighborhoods will exacerbate the instability of the coastline ecology. Population growth in coastal neighborhoods of coastal counties from 1970 to 1990 were not as rapid as in inland neighborhoods of these counties, perhaps reflecting increasing land scarcity and costs. Nevertheless, population increases are likely to stimulate more intense development of coastal lands, and result in the urbanization of much of the California coast. Property loss and population displacement resulting from any sea level rise could be high. In contrast to most past victims of environmental degradation and disasters, future "environmental refugees" from the California coast may be less economically disadvantaged.

Population growth impacts global land use (Jolly and Torrey, 1994). 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. Population phenomena can be regarded as proximate causes of coastal environmental degradation, but not always the most important cause. The nature of population-degradation relationships appears to depend on the level of aggregation of questions and data, disciplinary perspectives, and time frames (Heilig, 1993; Keyfitz, 1993). As our research continues we will attempt to resolve some of these issues.

Footnotes

[1]Support is from the U.S. National Oceanic and Atmospheric Administration (NOAA) grant #NGA36GPO486. The views expressed are the authors and do not represent those of NOAA.

[2]California coastal counties, listed in Figure 1 are as specified in NOAA (n.d.i.a). The 672 coastal counties in the United States (285 on the Atlantic, 142 on the Gulf of Mexico, 87 on the Pacific, and 158 on the Great Lakes) accounted for almost 54 per cent of the Nation's population and 25 per cent of the land area including Alaska in 1990. Excluding Alaska, the proportion of the US land area classified as coastal decreases to 17 per cent. Coastal counties had at least 15 per cent of their land area in the nation's coastal watershed, or, for counties that bisected the coastal watershed, had less than 15 per cent of their total land area in the coastal watershed and accounted for at least 15 per cent of a coastal cataloguing unit. Also see US Bureau of the Census (1991) and NOAA (n.d.i.b).

[3]The projections use a baseline cohort component method, assume a convergence of county race/ethnic-specific fertility rates, and projected increases in life expectancies for race/gender groups, consistent with U.S. Census Bureau expectations. Migration is expected to decline from 1990 to 1995 due to the current economic recession in California, but to increase thereafter and decline again after 2010.

[4]We excluded the 8 inland counties classified as coastal by NOAA, plus Napa county which has no coastal census tracts.

[5]Population in the coastal census tracts in the 20 coastal counties was 1,259,243 and 1,657,025 in 1970 and 1990 respectively. Housing units were 463,307 and 714,807. Population in the non-coastal tracts was 14,981,243 and 21,094,559 in 1970 and 1990, respectively, housing units were 5,218,890 and 7,772,179.

[6]The Ventura Marina (Griggs, 1985:295) was nearly destroyed in a 1969 flood and remains vulnerable to seasonal storms, shoaling and potential sea level rise. The Oxnard Plain contains costly waterfront property with a 1990 average value for the 110,000 housing units of the coastal census tracts of $259,880. This compares with an average housing unit value of $247,983 for the 188,300 housing units in the non-coastal tracts of Ventura County.

[7]We are indebted to Margo Koss for the use of the "stakeholders" concept.

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