LOCAL POPULATION IMPACTS AND MITIGATION OF SEA LEVEL RISE*

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ABSTRACT

Using sea level rise (SLR) as an example, we describe a protocol to synthesize population/environment case studies that contribute to minimizing local impacts of global environmental change. We delineate areas of potential impact from SLR for the coterminous United States, ascertain and project SLR impacts for selected sandy beach urban sites in South Coast California and South Coast Maine, describe relevant local policy instruments, and summarize responses of local stakeholder populations. Findings are as follows: (1) Storm surges generate cutting edge SLR impacts. (2) Coastal population growth is the overriding proximate determinate of SLR impacts in the areas examined. (3) State and local policy instruments do not fully protect populations at risk. (4) Different stakeholder populations share a common fate from SLR, that may be a basis for developing adaptation and mitigation strategies. Demographers can contribute to protocols that assess impacts of climate change on local populations and develop appropriate responses.

INTRODUCTION

Demographers are now addressing problems of human dimensions of global environmental change (Mageean and Bartlett 1999). Global climate change leads to local environmental impacts of sea level rise (SLR). SLR includes storm surges, erosion, and shoreline recession. We summarize our efforts to identify vulnerable coastal populations and to develop protocols that can be used to synthesize population-environment case studies and minimize local impacts. We emphasize the demography of SLR, appropriate methods for demographers to study SLR, and lessons learned.

We describe coastal areas in the coterminous United States (Alaska and Hawaii are excluded) susceptible to SLR, measure SLR on sandy beach urban areas in south coastal California and south coastal Maine, assess physical impacts for human populations, assess the efficacy and stakeholder acceptability of some mitigation policies, and evaluate stakeholder responses. Our work is an example of how to link emerging properties of global systems to local environmental changes and to synthesize previous studies of relations between population and environmental phenomena.

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BACKGROUND

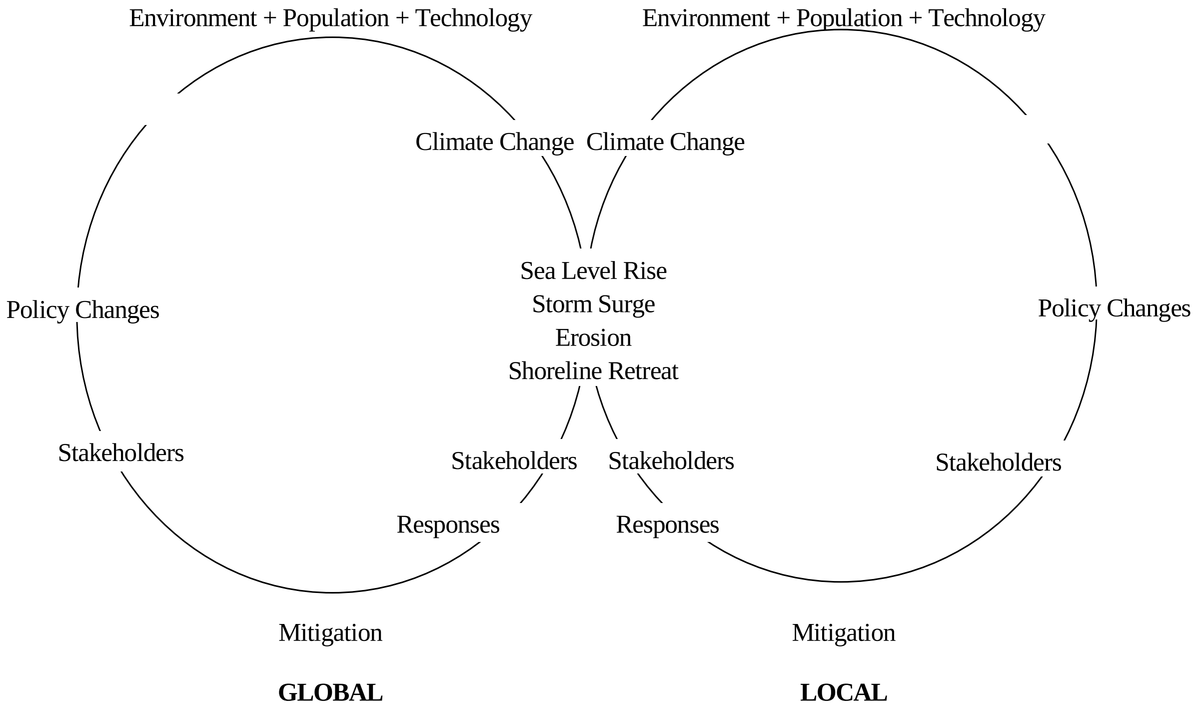
Population, technology-consumption, climate change, and SLR pose interlocking problems (Figure 1). Global warming estimates have recently been revised upwards, and the links between human activities and global warming are now more certain (IPCC, Working Group II 2001), and of increasing policy concern (National Academy of Sciences 2001). Climate change drives SLR, which has global and local consequences. Anthropogenic determinants of climate change, SLR, and related coastal impacts include population growth and increased per capita use of energy (Bongaarts 1992; Bartiaux and Ypersele 1993). Feedback mechanisms link global and local determinants and consequences of climate change, and include SLR, stakeholders, policy changes, and mitigation (Figure 1).

Following Shaw (1989), we view population and technology-consumption determinants of environmental degradation as proximate and ultimate causes, respectively. Coastal areas now contain one half of the Earth's population (Olsen 1998), and are vulnerable to SLR and to weather related storm surges (National Academy of Sciences 2001). Increasing coastal populations are on a "collision course" with climate change that will enhance environmental impacts of SLR (Nicholls and Leatherman 1995). Residential expansion is a threat to coastal ecosystems (Bartlett et al. 2000). We regard population distribution processes to coastal areas that diminish the quantity and quality of coastal resources and increase risk potential as proximate determinants of local SLR impacts. SLR, including storm surges, erosion, and shoreline recession, destabilizes coastline ecology and decreases the supply of coastal land.

We distinguish between "direct," "indirect," "disruption" and "compression" impacts of SLR (Heikkila 1993). Direct disruption impacts of SLR, including hurricanes, typhoons and related storm surges, as well as erosion and coastal flooding, destabilize coastal ecology, displace human populations, and sometimes result in human injuries and mortality (Dean 1999, The H. John Heinz III Center for Science, Economics and the Environment 2000; Noin 1995). Indirect disruption impacts include environmental degradation, natural resource loss, loss of ecosystem services, business/industry interruption costs, loss of tourism revenues, and a variety of social and family impacts and costs (ibid.). Compression impacts of SLR, which include disruption impacts plus decreases in the coastal land supply, induce population redistribution away from the shoreline and further squeeze inland populations and facilities.

Responses to risks of climate change and SLR require decision making under conditions of uncertainty. Population, technology, climate, and SLR have yet to be integrated into local resource, risk assessment and social impact models (Van Arsdol et al. 1995). Both global and local stakeholders influence the adaptation to and mitigation of SLR (Figure 1). At the global/national level candidate policies to reduce climate change (and SLR related impacts) include those that decrease human fertility and population growth, increase energy efficiency, increase use of gas instead of coal, and develop alternative energy sources, technologies and distribution systems.

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



Americans often express their love of the beach by building their homes in harm's way, and at the water's edge. Local populations in the United States adapt to SLR by not moving to the shore or by retreating from the shore, and often attempt to mitigate SLR by adding to, and/or armoring the shore. SLR impacts are eventually exacerbated by infrastructure development, armoring, and attempts at beach stabilization (Pilkey et al.1981).

Current policy decisions will influence the future impacts of climate change and SLR on vulnerable coastal populations (National Academy of Sciences 2001). Evaluations of SLR impacts are influenced by definitions of research problems; risk evaluation, and the adaptation and mitigation measures considered. The increasing momentum of climate change enhances the effects of current failures of governments, businesses and non-government organizations (global/local stakeholders) to interact globally or act nationally to stabilize climate, as well as the importance of stopgap local mitigation by local stakeholders. There may be greater resistance to changing mechanisms supporting technology-consumption connections that generate climate change and SLR impacts than resistance to facilitating population adaptation to SLR or mitigation of SLR impacts (Van Arsdol et al. 1995). To adapt to and mitigate impacts of SLR, communities need scientifically grounded research and action blueprints. We provide some components of such a protocol, which emphasizes local population responses.

METHODS

Most government planning agencies in the United States do not require that SLR be incorporated into planning decisions. Nevertheless, research regarding SLR and mitigation of SLR impacts benefits if local stakeholders are taken into account, and are actively involved in research, planning, policy making, securing policy acceptance and policy implementation. Responses to SLR by local communities may facilitate more effective actions to stabilize climate and SLR by national/global stakeholders. For these reasons we have built stakeholder participation and governance issues into the research.

We examine population impacts of SLR on the Oxnard Plain of Ventura County, California and York and Cumberland Counties, Maine (Constable 1998; Constable et al. 1997; Van Arsdol et al. 1995). Our goals are as follows: (1) Contribute to protocols that measure physical, population, and housing impacts of SLR. (2) Determine responses of local stakeholder populations to SLR. (3) Evaluate the efficacy of state and local policy instruments pertaining to SLR. (4) Determine the acceptability of SLR response strategies among focus groups of local stakeholders. (5) Provide stakeholder populations with impact assessment tools. Given recent government failures to respond to climate change and SLR, we consider responses that can be made available to local communities, and thus decrease local reliance on national research and policy. Our research draws from demography, sociology, human ecology, environmental geography, physical geography, biology, and policy studies. We use a combination of qualitative and quantitative research procedures.

Methods were as follows: (1) We delineated coastal counties, that may contain areas subject to potential harm from SLR, in the coterminous United States. We outlined recent population trends (1960-2000) and summarized population projections (2000-2040) for coastal counties as defined by the Strategic Environmental Assessments Division of the National Oceanic and Atmospheric Administration (NOAA n.d.). We then described these trends for California and Maine. United States census data for 2000 were not used except for Maine; other data for 2000-2040 were obtained from a private source (NPA Data Services, Inc. n.d.). (2) University of Southern California physical geographers developed guidelines for anticipating SLR impacts for sites on the Oxnard Plain of Ventura County, California circa 2000, including measurement and projections of storm surges, erosion, and shoreline recession. The impacts were ascertained in 1993-1994 by using U.S. Census Bureau TIGER/line 1992 files to delineate census tracts and overlay physical features from digital line graphs, that were based on U.S. Geological Service topographic maps. The U.S. Environmental Protection Agency and the Maine State Planning Office prepared SLR guidelines for sites in York and Cumberland Counties, Maine, circa 1990, which differ in climate and sandy beach characteristics from Ventura County, California, and also assessed the numbers of population and housing units affected at that time. No projections were made of future population numbers that would be affected with continued SLR. (3) State and local coastal policy instruments pertaining to SLR in California and Maine and to our local study areas were evaluated according to purpose, objectives, implementation measures and questions relevant to these objectives (Lameka et al. 2000). (4) We use qualitative research procedures, including qualitative interview techniques, to assess responses to SLR by stakeholders, including coastal area residents, casual beach users, environmental activists, elected/appointed officials and real estate agents/developers. We provided summaries of these responses to focus group participants from Ventura County, California, also evaluated potential SLR adaptation and mitigation measures.

POPULATIONS AFFECTED BY SEA LEVEL RISE

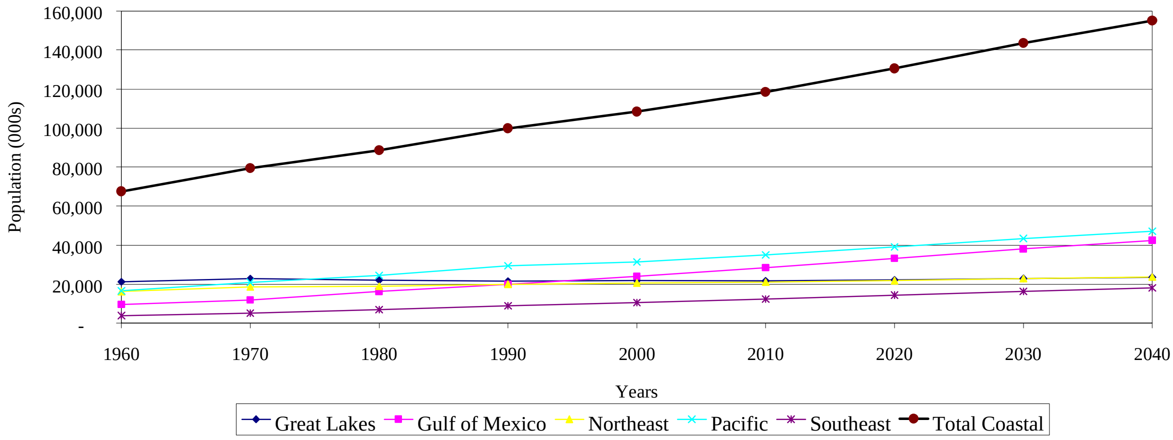
The Coterminous United States

In 2000, 108.4 million persons, or 40 percent of the population of the coterminous United States lived in coastal counties (Figure 2). The largest coastal county populations are on the Pacific Coast (California, Oregon, Washington), followed by the Gulf of Mexico (Florida, Alabama, Mississippi, Louisiana, Texas), the Great Lakes (Illinois, Indiana, Michigan, Minnesota, portions of New York, Ohio, Pennsylvania, Wisconsin), the Northeast (Atlantic Ocean coastal counties in Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, Atlantic Coast New York, Pennsylvania, Rhode Island, Virginia), and Southeast (Atlantic Ocean counties in Florida, Georgia, North Carolina , South Carolina), respectively (Figure 2). Much of the recent coastal population growth in the Northeast, Southeast, and Gulf of Mexico has occurred in dune areas and on barrier islands. The coast from Maine to Texas (comprising the Northeast, Southeast, and Gulf of Mexico coasts) has been described as containing the “longest and best evolved chain of barrier islands in the World” (Godfrey and Leatherman 1979) approximately 4,500 km (USDOI 1982). In contrast, coastal mountains, cliffs, bluffs, and terraces, and some dune lowlands define the Pacific Coast (Griggs 1998).

Recent population growth in the coterminous United States (1990-2000) has been most evident in coastal counties in Gulf of Mexico states, followed by the Pacific Coast, Southeast, Northeast, and the Great Lakes. Illustrative population projections help delineate potential impacts of rising sea level but do not pinpoint future human numbers (NPA Data Services, Inc. n.d.). The coastal population of the Pacific States is projected to increase by 56 percent from 2000 to 2040, from 31.3 to 47.2 million. The Gulf of Mexico coastal population is projected to increase by 77 percent, from 24.0 to 42.4 million. The Southeast coastal population is projected to increase by 75 percent, from 10.6 to 18.1 million. Smaller percentage and numerical increases are projected for the Great Lakes and Northeast (Figure 2).

California and Maine have similar and dissimilar characteristics that make them useful for comparing the impacts of SLR. California’s 2000 population was approximately 33.4 million; Maine’s 2000 population was approximately 1.3 million (NPA Data Services, Inc., n.d.). California and Maine have high coastal population concentrations: 87 and 81 percent, respectively. Population growth in California has focused recently on the South Coast, followed by the Bay and Delta area and the Central Coast (Figure 3). Maine’s recent growth has been most evident on the South Coast, followed by the Central Coast and the East Coast (Figure 4).

FIGURE 2. COTERMINOUS UNITED STATES COASTAL COUNTY POPULATIONS, ENUMERATED 1960-1990, PROJECTED 2000-2040



Source: NPA Data Services, Inc., n.d.

Coastal areas in California and Maine are important destinations for tourists and retirees. Sandy beaches in particular impact coastal tourism, recreation and local economies (U.S.E.P.A./Maine State Planning Office 1995). In high growth areas in both states, sandy beaches, coastal wetlands and eroding bluffs are particularly threatened by continued or accelerated SLR phenomena. California's coastline is 1,774 km, of which 86 percent is reported to be eroding. Maine's mainland coastline of 5,609 km is the longest in the coterminous United States; of which 99 percent appears to eroding. Much of the California and Maine shoreline will not be impacted by SLR due to the relatively steep nature of much of the California shore, and the rocky coast characterizing the East Coast and Mid Coast of Maine. Nevertheless, sandy beach communities on California's South Coast, and Central Coast, and Maine's South Coast are facing pressures due to increasing population and development. Landward migration of the shoreline is inevitable with SLR. Each state has taken action to develop policy instruments and programs to deal with links between coastal population growth and the degradation of coastal ecosystems.

California

In 2000, the population of the 29 California counties defined as coastal by the National Oceanic and Atmospheric Administration (NOAA), including 20 counties with direct shoreline access, was approximately 29.2 million (NPA Data Services, Inc. n.d.), and comprised 87 percent of the total state population, and 27 percent of the total coastal population of the United States (Figure 5). The land area of these counties accounted for 201,580 km^2 or 50 percent of the state's total land area. The 2000 total populations for the four California coastal areas were as follows: 3 million for the north coast, 8.6 million for the Bay and Delta, 1.3 million for the Central Coast,

FIGURE 3. CALIFORNIA COASTAL COUNTIES BY NATIONAL AND ATMOSPHERIC DEFINITIONS

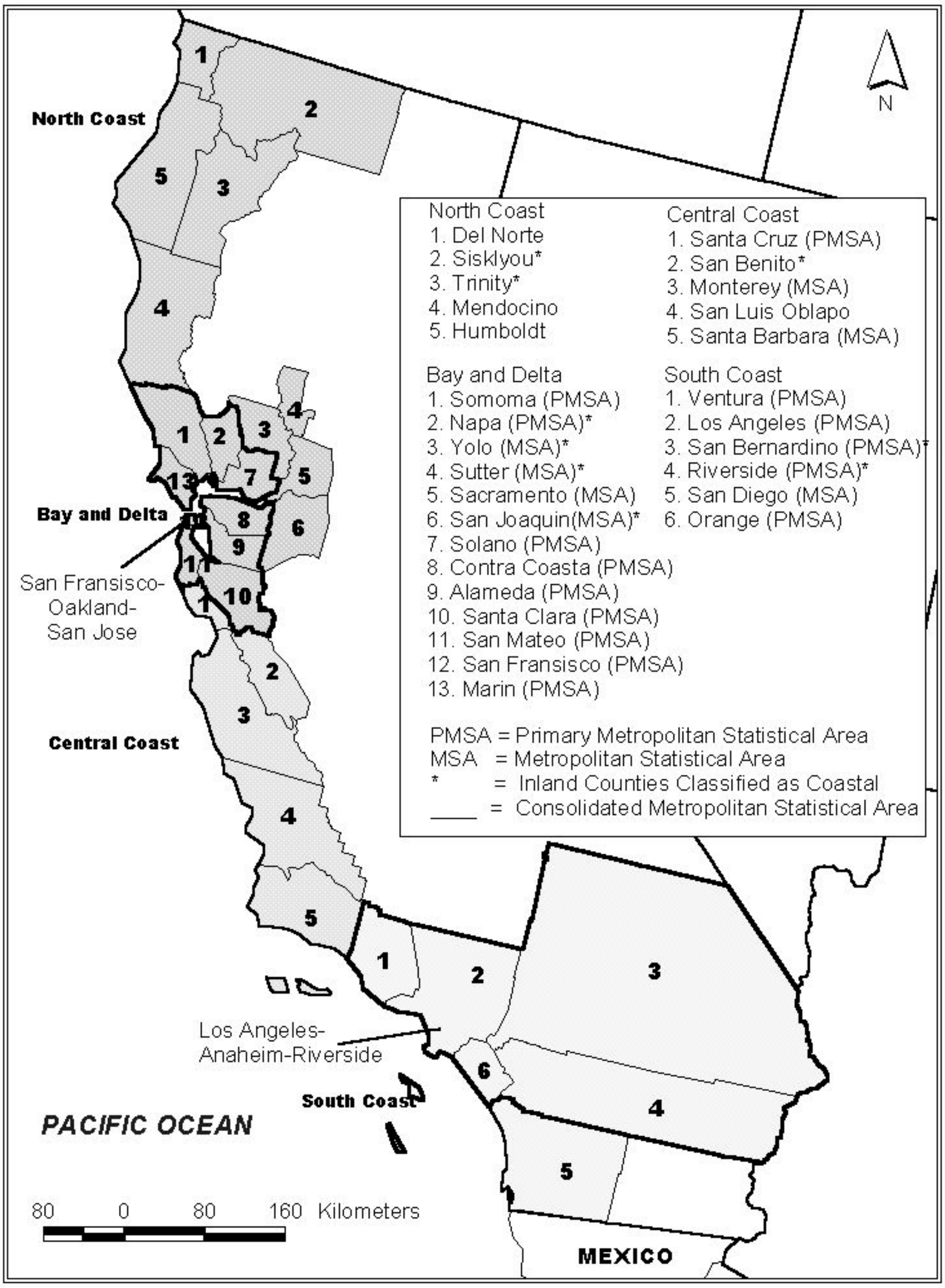
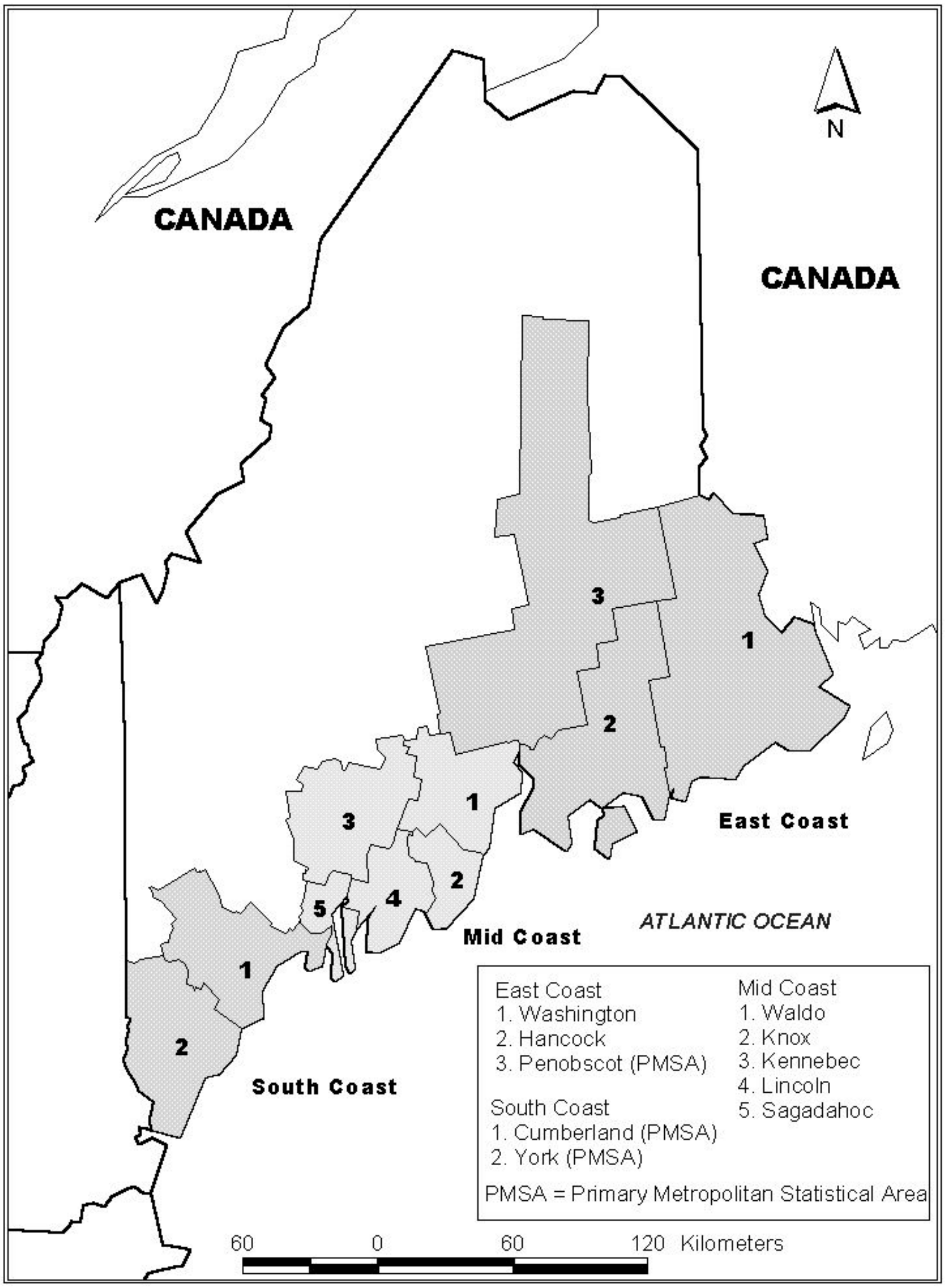
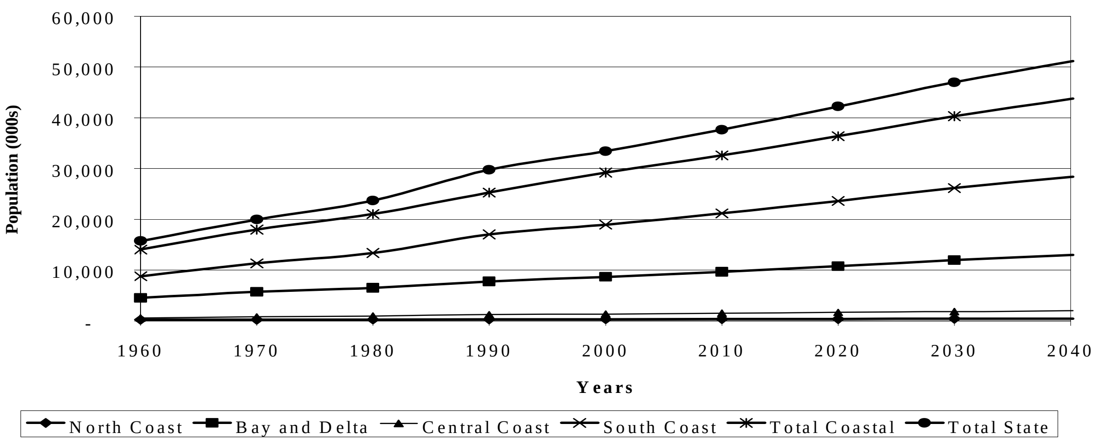


FIGURE 4. MAINE COASTAL COUNTIES BY NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION DEFINITIONS.



and 18.9 million for the South Coast (ibid.) California's two largest metropolitan clusters are located on the coast: the San Francisco-Oakland-San Jose Consolidated Metropolitan Statistical Area (CMSA) in the Bay and Delta area, and the 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 and South Coast (Figure 3, Figure 5).

FIGURE 5. CALIFORNIA COASTAL COUNTY AND TOTAL STATE POPULATIONS ENUMERATED 1960-1990, PROJECTED 2000-2040



Source: NPA Data Services, Inc., n.d.

The growth of California's total coastal population closely reflects that of the state. Total coastal population growth remains high but numerical growth and the rate of growth was less in the 1990s than in the 1980s (ibid.). Increases were greatest in coastal metropolitan areas, the South Coast, Bay and Delta area, Central Coast (Figure 3), and in coastal strip neighborhoods. From 1990 to 2000 growth for California's coastal counties was greatest in the South Coast, followed by the Bay and Delta area.

The population on the immediate California coast may now be pressing on the residential resource base. United States Census 2000 coastal census tract data are not yet available to test this assumption, which is based on our previous analysis of 1980-1990 census data (Van Arsdol et al. 1995). In 1990, 7 percent 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 California's 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 percent) of this growth was concentrated in coastal tracts of the metropolitan South Coast. In 1990 the percentages of coastal county population in the coastal strip was 32 on the North Coast, 7 on the Bay and Delta area, 29 on the Central Coast, and 5 on the South Coast. By 1990 it appeared that a scarcity of coastal land and current land use restrictions could drive up housing prices and inhibit growth on the coastal strip, relative to that of the rest of the state. Between 1970 and 1990, the population of the coastal census tracts of the 20 coastal counties increased less rapidly (32 percent) than did the population of the inland census tracts (41 percent) of these coastal counties (Van Arsdol et al.1995).

Projected coastal population growth could overwhelm the physical ecology of the Bay and Delta, Central Coast, and South Coast regions by the mid 21st century (Figure 5, NPA Data Services, Inc. n.d.). From 2000 to 2040 California population is projected to increase from 33.4 to 55.1 million persons, an increase of 35 percent (ibid.). Coastal counties are projected to increase from 29.2 million in 2000 to 43.8 million in 2040. Population on the South Coast is projected to increase from 18.9 to 28.3 million. In the Bay and Delta area, the increase could be from 8.6 million to 12.9 million. Nevertheless, economic downturns, resource shortages, inadequate infrastructures, social deterioration, earthquakes and other natural disasters, and community growth limitation policies will eventually constrain coastal population growth.

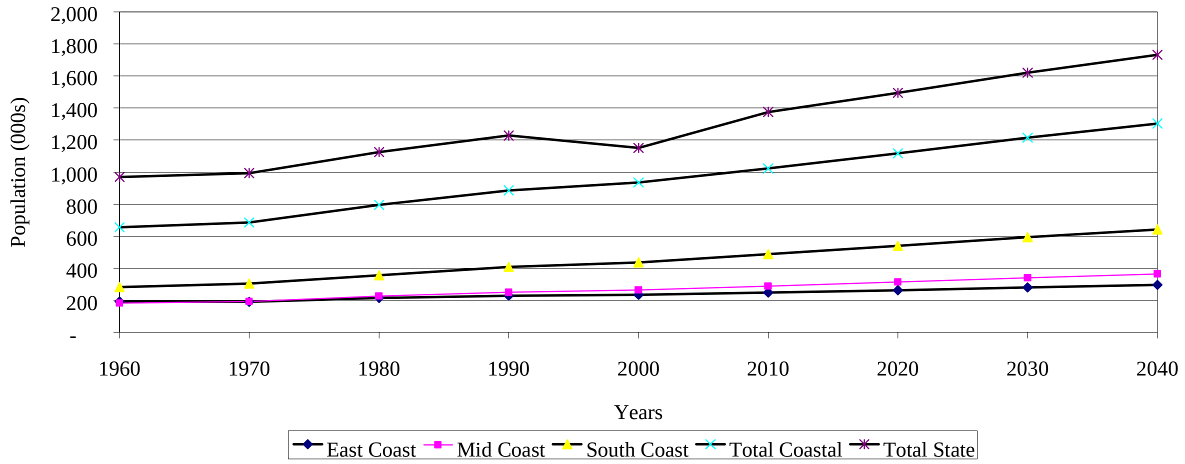
Maine

The total population of Maine in 2000 was approximately 1,275,000 (NPA Data Services, Inc. n.d.). The population of the 10 Maine counties defined as coastal by NOAA, including 9 counties with direct coastal access, was then approximately 945,000 (ibid.) and comprised approximately 74 percent of the total state population, less than one percent of the total coastal population of the United States, about 4 percent of the coastal population of California (Figure 6)**.** The land area of these counties accounted for 31,217 km^2 or 39 percent of the state's total land area (Figure 4). Estimated total populations for Maine's three coastal areas in 2000 were: 231,000 for the East Coast, 262,000 for the Mid Coast, and 452,000 for the South Coast (ibid.). Two of Maine's three Primary Metropolitan Statistical Areas (PMSAs), Cumberland and York, are located on the South Coast (Figure 4).

In 1990 Maine's 144 coastal townships comprised 12 percent of the state's land area but 45 percent of its population**.** In 1990, there were 125 persons/km2 living in coastal communities compared to 55 persons/km^2 in inland communities. Economic growth in Maine since 1990 has been especially evident in coastal areas—fueling population growth—but retirement migration and growth of retirement communities have also contributed to the population increase in coastal communities. Maine's coastal areas also serve as important tourist destinations with fully 80 percent of all tourist-generated dollars in Maine spent at the coast.

Maine's total coastal population growth is disproportionately high, compared to the rest of the state (NPA Data Services, Inc. n.d.). From 1990 to 2000, numerical growth in coastal areas was greatest in the south coast, followed by the mid coast and the north coast. The coastal area shares of Maine's coastal population for the East Coast, Mid Coast, and South Coast were then 24, 28, and 48 percent, respectively (Figure 6). Maine's sand beaches, coastal wetlands and eroding

FIGURE 6. MAINE COASTAL COUNTY AND TOTAL STATE POPULATIONS, ENUMERATED 1960-1990, PROJECTED 2000-2040



Source: NPA Data Services, Inc., n.d.

bluffs are particularly threatened by continued or accelerated sea-level rise phenomena and it is these very areas, located primarily in the Casco Bay/Saco Bay regions of Cumberland and York Counties of the South Coast, which have experienced significant growth in the number of residents and recreational visitors.

Illustrative population projections also help to delineate potential impacts of rising sea level in Maine (N.P.A. Data Services, Inc. n.d.). Significant coastal population growth projected for Maine, which will have negative impacts, particularly in sandy beach urban area on the South Coast Maine. The population of Maine is projected to increase to 1,731,000 in 2040, an increase of 36 percent over 2000. Coastal counties are projected to increase to 1,304,000, an increase of 38 percent. Population on the South Coast is expected increase from 452,000, to 642,000, on the Mid Coast from 262,000 to 296,000, and on the East Coast from 231,000 to 296,000.

SEA LEVEL RISE SCENARIOS

California

Some of the most significant physical changes in California, as a result of SLR, will be on sandy beaches, which are common on the densely populated south coast. We developed physical guidelines for anticipatory SLR on the Oxnard Plain of Ventura County. Surges from El NiZo and other storms here are major determinants of disruption impacts, which 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 (Constable et al. 1997).

The 1990 population of Ventura County was 669,000; 18 percent of which resided in coastal census tracts, which largely comprise the Oxnard Plain (Van Arsdol et al, 1995). Historical analysis of the Oxnard Plain indicates that storm anomalies are leading to significant beach and shore retreat. SLR planning scenarios indicate that SLR, projected at the current rate of 1-2 mm/year (Brunn 1962; Gornitz 1993; IPPC 1996; Constable et al. 1997) combined with beach erosion (Titus 1989), and shoreline retreat could produce an approximate 19-42 m recession by 2040, depending on the frequency of storms and storm surge events (Constable et al. 1997). Storm surges were the major determinants of impacts. This scenario could impact commercial piers in coastal cities, power plants, military bases, and residential areas, and all other near water infrastructures. Mitigation could likely reduce these impacts (Constable et al 1997). Beach retreats > 45 m and > 68 m could be produced by 100 and 200 year storms, respectively.

We estimated that disruption impacts by 2040 could affect an area with 9,080 residents occupying 4,147 housings units with a reported vacancy rate of 23 percent as of April 1990. The 1990 estimated value of owner occupied housing units with a mean housing value of $374,675, was more than $530,000,000, as reported by census respondents. On site inspections circa 2000 indicated that impacts are continuing . Assuming further development, SLR impacts on coastal population could increase significantly by 2040 (Constable et al. 1997) and would be enhanced further by rare storm events. We did not project future population numbers affected by our scenario. Further specification of future impacts would require an integration of local population projections with our SLR scenario.

Maine

Maine's coast is currently experiencing significant local submergence due to lingering effects possibly caused by loading and unloading of receding ice sheets. The state is also vulnerable to the impacts of hurricanes and northeaster storms. Accelerated sea-level rise and storm surges resulting from climate change would exacerbate this situation. Further, 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 of sand beaches in the developed southern part of the state (USEPA/Maine State Planning Office report 1995). Shoreline change resulting from sea level changes of 50 cm, 1 m and 2 m were ascertained. Site-specific vulnerability assessments projected significant changes in two (Old Orchard Beach - a major tourist destination and Camp Ellis, a residential area) of the three beaches. 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 infrastructures. Under the (1 m) scenario, 133 acres . . . with 334 structures would be inundated. The 50 cm scenario projects 71 acres of upland currently developed with 210 structures would be affected (Figure 7). 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 . . .” (USEPA/ Maine State Planning Office 1995).” As is the case with our California example, further projection would require an integration of local site specific population projections with the SLR scenario.

POLICY RESPONSES

Possible Policies

Management of coastal areas experiencing SLR is challenging because the current rate of change of sea level is slow enough to be invisible to most coastal residents during their lifetimes, and the rate of future SLR is uncertain. If coastal residents do notice a change they may attribute it to new shoreline protective structures or attempts at mitigation. Decisions regarding policy responses to SLR can best be guided by policies that recognize the combined pressures of increasing population numbers and SLR on the shore (Daly 1999).

Inhibiting migration to the shore and population retreat from the shore are relevant to the mitigation of SLR, as is armoring the shore, and beach nourishment (G. Griggs n.d.). Armoring is temporary and beach destructive. Beach nourishment is temporary and uncertain. Population retreat from the shore, which can sometimes help to preserve shoreline ecosystems, can be facilitated by "rolling easements," which permits coastal development with the understanding that the owner will abandon the property at some time in the future, and will not build hard protective shoreline structures or otherwise protect the property (Titus,1989). "Relocating …population away from vulnerable coastlines in California and Maine does not prevent shoreline losses; rather, shifting populations away from hazardous areas merely reduces the degree of impact and compresses populations elsewhere" since SLR can still destroy wetlands and shoreline structures (Ricci, et al. 2000). If retreat of shoreline populations is impractical, shoreline mitigation may include sand replenishment and armoring. Complexities of coastal environments require a combination of solutions.

Policy Instruments

The California Coastal Commission is considering the incorporation of SLR into coastal planning (L. Ewing and J. Michaels 1989). Maine has already adopted policies pertaining to SLR based on managed population retreat from the beach through the use of rolling easements (USEPA/Maine State Planning Office 1995). We evaluated the efficacy of relevant policy instruments in these states, but not the effectiveness of the policies they delimit.

Fifteen coastal policy instruments for Maine and California were evaluated according to purpose, objectives, implementation measures, and questions relevant to the objectives. (The evaluation profile was designed by W. Jackson Davis and colleagues; Lameka et al. 2000). A policy strength index measured policy strength based on additive scores for: (1) percentage of the policy document devoted to implementation, (2) provision for funding, (3) plan for ensuring compliance, (4) specification of targets and timetables, (5) the rated scientific effectiveness of the policy in mitigating the problem, (6) provision for organization infrastructure to support the policy, and (7) policy reporting requirements (ibid.). We have not determined the reliability or validity of the policy coding formats.

Seven California coastal policy instruments were assessed, including two state instruments and five local coastal plans in Ventura County (ibid.). The State of California Coastal Commission implements the state's coastal program through (1) the California Coastal Plan of 1975 (California Coastal Commission 1975), and as (2) as the California Coastal Act of 1976 (California Coastal Commission 1976) that establish binding guidelines that local governments must abide by for the formulation of local coastal programs. Some coastal localities have not complied with state requirements to develop coastal plans. California coastal policy instruments are not specifically focused on SLR, but sometimes address coastal issues sometimes relevant to SLR.

Eight Maine state level coastal policy instruments were assessed; The Maine State Planning Office (MSPO) implements the State's coastal zone management programs, which is networked among State agencies. The MSPO has no regulatory authority other than implementing the State Coastal Zone Management Act. Because Maine is significantly smaller than California in geographic size and population, it is able to implement its coastal policy on a state level. Maine coastal policy instruments generally prohibit new shoreline structures, which are allowed through local option in California.

Based on our preliminary analysis of the policy strength index and its components, the most important component of policy instruments in creating strong policies, appears to be a compliance regime, followed by the percentage of the policy document devoted to implementation, provision for organizational infrastructure, provision for funding, and reporting requirements, respectively (Lameka et al. 2000).

The strongest policy instruments are Maine's Natural Resources Protection Act (REF), City of Buenaventura (California) Comprehensive Plan Update (City of Buenaventura 1989), the California Coastal Plan (California Coastal Commission 1975), and the California Coastal Act (California Coastal Commission 1976). The lowest scoring policy instruments are the Maine Coastal Management Policies Act (Maine Legislative Web Site 2001) and three of the four Ventura County, California local coastal programs (Lameka et al. 2000). Policy instruments for both states tended to have more statements favoring environmental protection than protection of private property.

Population Coverage of California Policy Instruments

Feedback loops between SLR and coastal populations and environments suggest that successful coastal policy interventions are those that link human settlements and natural ecosystems. The California Coastal Act of 1976 establishes guidelines for local communities to develop their own local coastal plans (LCPs) that are tailored to fit local human communities and their associated ecosystems. California LCPs do not guarantee protection of coastal populations and ecosystems, as their content is influenced by regional politics and stakeholder conflicts, and the California Coastal Act does not prohibit hard shoreline structures or development on sea front sand dunes. California LCPs do provide forums for tailoring local population distribution coastal policies to local area.

Achieving population coverage with local coastal plans (LCPs) is a time consuming process, even with California's nationally recognized coastal protection act, and an active coastal commission. Table 1 indicates the numbers and percentages of California unincorporated coastal areas, incorporated coastal cities, and populations of incorporated coastal cities that were protected by certified and implemented LCPs as of January 2001. Almost three-fourths of the unincorporated areas, almost two-thirds of the coastal cities, and slightly less than one-half of the coastal city populations were then covered by implemented LCPs, 24 years after the passage of the California Coastal Act. One hundred percent of the cities and city populations of the Bay and Delta area and the North Coast were covered by implemented LCPs. Coverage was lowest for cities and city populations on the densely settled South Coast (60 percent of the cities, and 40 percent of the city populations), but higher on the Central Coast (60 percent of the cities and 71 percent of the city populations).

TABLE 1. CALIFORNIA COASTAL AREAS AND COASTAL CITY POPULATIONS COVERED BY IMPLEMENTED LOCAL COASTAL PLANS: 2000

Area	Unincorporated Areas		Cities		Population	
	N	% with implemented plans	N	% with implemented plans	N	% living in cities with implemented plans
Total	29	72	54	64	8,917,000	48
North Coast	12	34	6	100	59,000	100
Bay Delta	3	100	4	100	958,000	100
Central Coast	4	100	15	60	356,000	71
South Coast	10	40	29	55	7,544,000	40

Source: California Coastal Commission 2001; California Department of Finance 2001.

STAKEHOLDER RESPONSES

The success of policies regarding climate change including SLR often depends on the degree to which they reflect the values and concerns of different stakeholder groups. Adaptation to SLR is influenced by hazard perception, legislation, and actions by government agencies, and of other parties or stakeholders with other opposing interests. There is a public conflict between desires to preserve environmental resources and the need to protect private property from coastal hazards. As SLR impacts increase, coastal properties will be threatened more regularly, and property owners and government officials will be faced with a challenging problem to protect the environment and also to protect private property from coastal hazards (Daly 1999). Mitigation responses to sea level rise are determined partially by the extent that interested parties or stakeholders perceive harm or risk from sea level rise.

The common fates of differing stakeholders impacted by SLR may be a basis for developing acceptance of local SLR response protocols. Nevertheless, “conflict in coastal zone management is the normal state of affairs.” Stakeholder disagreements in California and Maine emphasize the need to negotiate stakeholder agreements (Cicin-Sain 1998).

Five categories of stakeholders who influence organizational responses to SLR were identified and interviewed in California and Maine (Table 2). They are area residents, casual beach users,

TABLE 2. CALIFRONIA AND MAINE STAKEHOLDER RESPONSES

Stakeholder Categories	Oxnard Plain, Ventura County, California	South Coast of Maine
Area residents	Want government to mitigate SLR impacts	Want government to mitigate SLR impacts
Casual beach users	Want beach access, and Want government to mitigate Beach erosion/retreat	----
Environmental activists	Perceive benefits from lack of development	Perceive benefits from lack of development
Real estate agents/developers	Want government to mitigate beach erosion and beach retreat, and to armor shore	Want government to mitigate beach erosion and beach retreat and to armor shore
Elected/appointed officials	Split between activists and real estate agents/developers	Split between activists and real estate agents/developers
Hazard concerns	Earthquakes are first concern, but SLR is a considered risk	Storm surges, “north-easters” are first concern, but SLR is a considered risk

environmental activists, elected/appointed officials, and real estate agents/developers. Respondents were few in number, were selected by purposive or “snowball sampling,” and are not necessarily representative of the population studied. Risk perceptions were assessed through questions regarding hazard circumstances and views regarding development.

Perception and acceptance of risk from SLR are influenced by personal response and choice, as well as the realities of risk. Although subtly intertwined, realities and perceptions of risks are not bound together. Explication of these differences rests on perceptual processes, and past experiences, including those regarding property damage or loss. We assume that perceived amenities from coastal living can sometimes override the perceived costs.

California

Sixty-six interviews were carried out during the fall of 1997 with 27 Ventura County and city elected/appointed offices, 5 developers, 13 residents of coastal census tracts directly adjacent to or on the shoreline, 10 recreational beach users, and 11 environmental activists (Constable 1998). Respondents ranked the potential risk to the Oxnard Plain of SLR and expressed their views regarding coastal development and insurance. Some politicians shared the views of environmental activists and others sided with developers. Environmental activists perceived benefits from less development. Area residents and beach users cited either the climate or quality of life as benefits of living in the community. Most area residents and beach users wanted more restrictions on residential construction in coastal areas, stating that homes on the beach would be damaged from storm surges or SLR. Area residents and beach users did not favor continued development in the coastal zones.

Casual beach users wanted public access to the beach. The majority of respondents supported additional property taxes to mitigate beach erosion or retreat. Real estate agents/developers perceived financial gain from coastal development to exceed the costs or risk from SLR or storm surge events. Most would support a special tax to maintain area beaches, some indicated support for restrictions on residential construction in the coastal areas, and all stated it was necessary to armor the shore.

In ranking issues that they considered to be most important in development planning, casual beach users ranked the “environment” as having the highest priority, followed by “habitat” and “beach.” Area residents ranked “habitat” as the most important and elected/appointed officials gave priority to the “environment” followed by planning for “hazards.” Activists ranked the environment as the most important consideration for planning criteria and “habitat” ranked second. Elected/appointed officials ranked “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. Developers selected the “environment” as most important followed by the “beach” and planning for “hazards.”

The five stakeholder categories considered earthquake as the primary hazard risk and fire as the second most important hazard. There was little concern with storm surge or SLR.

California Focus Groups

Analysis of some current policy responses was provided to stakeholders in focus group interviews in Ventura County, California. Stakeholders were asked their opinion of the current policies and how SLR strategies can be improved. We conducted two sets of focus group interviews in September 2000 with environmental activities and public officials. 6-8 stakeholders participated in each focus group interview session.

Most focus group participants had serious concerns regarding SLR. Responses of Ventura County focus group participants were as follows: (1) Coastal problems were described as erosion, sand loss and sand accretion, pollution, human health problems and lack of communication between stakeholders. (2) Reasons attributed to these problems were described as lack of concern from public officials, pressures from developers, lack of education of the public regarding coastal problems, and inconsistent federal policies that encourage coastal development as well as preservation. (3) Methods proposed to preserve the coast included education of the public and public officials, new national policies to discourage rebuilding of structures after storm surge and erosion impacts, to treat public beaches as public property rather than as private property, and to develop the "political will" to emphasize that beaches are public property. (4) There was support for rolling easements or managed retreat from the coast in principle in principle but rolling easements in Ventura County were not considered to be possible due to the already high coastal population densities and rapid population growth.

Maine

Twenty-five resident stakeholders in coastal areas in southern Maine were interviewed during Fall-Winter 1998. They were 11 elected/appointed officials, 5 area residents, 4 real estate agents/developers, and 9 environmental activists. (No recreational beach users were contacted due to Maine winter conditions.) The majority of respondents were aware of local concerns regarding beach maintenance and beach degradation.

Most of the Maine respondents stated that the government should pay to replenish beach sand and to mitigate beach erosion damage. While two of the respondents maintained that private parties should be financially responsible for beach damage, eight respondents listed both government and private parties as agencies to effect coastal zone integrity.

In response to questions regarding the need for insurance coverage, three-fourths of the Maine respondents argued that insurance companies should cover homeowners in the event of casualty loss from natural disasters. This suggests some area residents were willing to accept the uncertainty of living in a hazard zone for the benefits of beach living, provided that other parties assumed some of the financial risk.

When asked whether respondents were worried or concerned about sea level rise, storm surge, erosion or "northeasters" (winter storms) the area residents, realtors and elected officials were more likely to view erosion as a problem than the environmental activists. Activists viewed northeasters as a more significant risk than storm surge or beach erosion. However, all of the

Maine respondents saw storm surge as a considerable problem and it was listed as the second most risky event by all the respondents who did not list storm surge as the primary risk to coastal zone living.

The Maine respondents were presented data regarding Maine=s susceptibility to sea level rise as were the California respondents. Four of the Maine respondents felt that SLR had the maximum potential of risk to the Maine coastal zone; ten listed SLR as a serious risk, six selected SLR as a moderate risk and four members of the Maine groups cited SLR as minimal risk. This coincides with the California sample where the majority (30) listed SLR as a serious risk.

Maine elected officials prioritized planning criteria equally between planning for the benefit of the environment and planning for hazards. These responses concur with the data from the California sample. Habitat planning was the second most important concern for the Maine respondents followed by planning for private residents. Again these responses agree with those from California respondents.

Storm surge was listed by one-half (3) of the Maine elected officials as the risk posing the most personal threat; realtors cited northeasters as the worst possible risk; area residents were equally divided among which hazard posed the greatest threat; and three environmental activists selected erosion as the greatest hazard, two chose flooding, two fire, two storm surge, two northeasters and one selected SLR as the greatest risk. (The California respondents overwhelmingly chose earthquakes as the most serious risk followed by fire. The differences in perception of risk between the samples lie in their geographic proximity to specific natural hazards. Flooding is the most common risk to residents of coastal zones.)

DISCUSSION

Population grown in coastal areas is the overriding proximate determinant of SLR impacts in the coterminous United States. Significant portions of the population of the coterminous United States are vulnerable to SLR phenomena. Within or without future SLR coastal population increases will increase human numbers subject to current levels of SLR impacts. Our case studies yield the following results: (1) By 2040 disruption impacts from storm surges, erosion and beach retreat in Ventura county, California could affect the residents of more than 4,000 units of the April 1990 housing stock. SLR is also expected to impact South Coast Maine during this century, destroying housing and other beach structures even at a minimal SLR scenario. (2) Storm surges are cutting edge SLR impacts; SLR requires adaptation and disaster mitigation. (3) Physical mitigation of SLR impacts includes armoring the shore, beach replenishment, and establishing bulkheads, but each measure has negative environmental consequences. Rolling easements—or abandoning structures severely damaged by SLR—is an established response to SLR in Maine, but populations retreat merely reduces the degree of impact and compresses population inland. The most effective mitigation is not to build on the shoreline. (4) State and local coastal policy instruments applicable to SLR in California and Maine are covering increasing numbers of coastal residents but vary in their efficacy. The "strength" of these policy instruments appears to be a function of a compliance regime, followed by provisions for implementation, organizational infrastructures, funding provisions, and reporting requirements, respectively. The California experience has shown that obtaining full population coverage of coastal policy instruments is a time consuming process. (5) Resident populations of both Ventura County and South Coast Maine, and casual beach users in Ventura county want government mitigation of SLR impacts, environmental activists perceive benefits from a lack of development, developers want to build, and elected/appointed officials are split between the positions of developers and environmental activists. (6) Ventura County focus group participants viewed SLR impacts as being exacerbated by a lack of response by public officials, a lack of public education regarding coastal problems, and inconsistent federal policies that encourage both development and preservation. Focus group participants rejected abandoning structures damaged by SLR because they perceive adjacent inland areas as being built up and therefore unable to accommodate displaced populations. (7) Coastal stakeholders have differing interests, but some share a common fate from SLR, which may be a basis for developing SLR response strategies acceptable to local populations.

LESSONS LEARNED

Demographers can increase their social relevance by contributing to protocols with which governments, NGOs, businesses and citizens can assess population impacts of climate change and SLR on populations, and consider appropriate responses. Assessments of the determinants, consequences and potential effectiveness of adaptation to and mitigation of SLR require multi-disciplinary teamwork. Data sets will not always be available to link environmental and population changes through time and at different levels of aggregation. Procedures must be developed to assess relevant policy instruments. Qualitative interviews of selected stakeholders are a useful tool. Focus group interviewers contribute to research and policy strategies.

An understanding of the linkages of affected populations, stakeholder positions, and policy options will facilitate more successful adaptations and mitigations of SLR impacts, and contribute to the development of integrated approaches and theories of demographic and environmental change.

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