ASSESSING SOCIETAL VULNERABILITY OF U.S. PACIFIC NORTHWEST COMMUNITIES TO STORM-INDUCED COASTAL CHANGE

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Abstract

Progressive increases in storm intensities and extreme wave heights have been documented along the U.S. West Coast. Paired with global sea level rise and the potential for an increase in El Niño occurrences, these trends have substantial implications for the vulnerability of coastal communities to natural coastal hazards. Community vulnerability to hazards is characterized by the exposure, sensitivity, and adaptive capacity of human-environmental systems that influence potential impacts. To demonstrate how societal vulnerability to coastal hazards varies with both physical and social factors, we compared community exposure and sensitivity to storm-induced coastal change scenarios in Tillamook (Oregon) and Pacific (Washington) Counties. While both are backed by low-lying coastal dunes, communities in these two counties have experienced different shoreline change histories and have chosen to use the adjacent land in different ways. Therefore, community vulnerability varies significantly between the two counties. Identifying the reasons for this variability can help land-use managers make decisions to increase community resilience and reduce vulnerability in spite of a changing climate.

Introduction

Extreme winter storms are capable of causing widespread damage to coastal communities of the U.S. Pacific Northwest (PNW). During these storms, dune-backed beaches tend to respond episodically whereby large portions of the foredune are eroded, potentially threatening property. The frequency and magnitude of coastal change hazards in the region has been linked to increasing extreme wave heights in the eastern North Pacific (Allan and Komar, 2006). If these trends continue to enhance coastal hazards, communities in the PNW need to know where and how to respond to best protect lives, livelihoods, infrastructure, and resources. Reducing risk requires an understanding of the vulnerability of human-environmental systems to these hazards (Wood, 2009). To demonstrate how exposure and sensitivity to coastal hazards varies, we present a case study of two PNW counties and their vulnerability to storm-induced coastal change.

Study Area

This case study focuses on communities within Pacific County in southwest Washington (Figure 1A) and Tillamook County in north-central Oregon (Figure 1B) that have land within coastal change hazard zones. Our analyses in Pacific County focus on the Long Beach Peninsula where low-density development tends to be set back from the coast a few hundred meters. In contrast, land use near the coast in Tillamook County is more intensive, with development often present within tens of meters of the primary foredune.

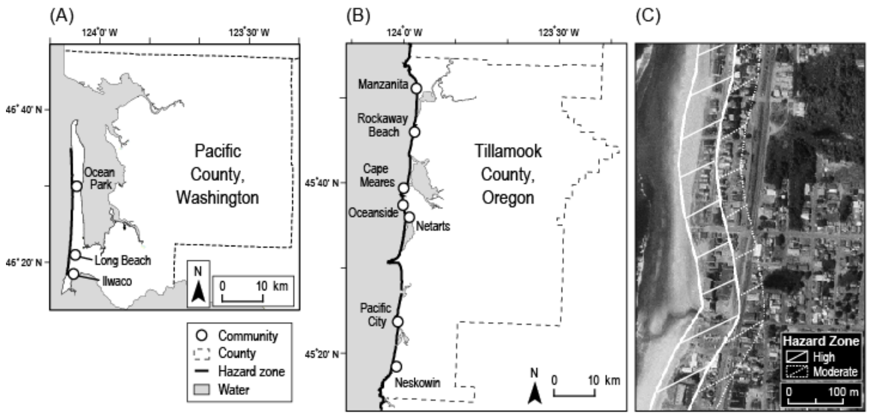

Figure 1. Maps showing the communities with land in storm-induced coastal change hazard zones of (A) Pacific County, Washington and (B) Tillamook County, Oregon. (C) Close-up of high and moderate hazard zones in Rockaway Beach, Oregon.

Methods

The potential impacts of extreme storms to PNW coastal communities were characterized by first assessing the physical hazards and then the exposure and sensitivity of communities. The simple geometric dune erosion model developed by Komar et al. (1999) was used to determine the maximum potential erosion of dune-backed beaches during a given extreme storm event. This conservative model predicts the landward retreat of a foredune when the total water level associated with a storm (a combination of tidal elevation, wave runup, and storm surge) exceeds the elevation of the dune toe (the junction between the dune and beach). Dune erosion distances were calculated by comparing LIDAR-derived morphological variables (i.e., foreshore beach slope and dune toe elevation) to predicted total water levels for two different extreme storm scenarios. The resulting hazard zones are classified as “high” or “moderate” according to their likelihood of occurrence (Figure 1C; Allan and Priest, 2001).

Consistent with Allan and Priest (2001), the scenario adopted for defining a high hazard zone involves a large storm (wave height = 14.5 m, wave period = 17 s, storm surge = 1.0 m in Tillamook and 1.4 m in Pacific) occurring in winter during an above-average high tide and is similar to the most extreme storms experienced in the PNW over the period of quantitative measurements. This zone represents the area at high risk to storm-induced coastal change. The storm associated with the moderate hazard zone (analogous to a 100-year storm) is considered less likely than first scenario because it is more extreme (wave height = 16 m, wave period = 20 s, storm surge = 1.7 m in Tillamook and 2.0 m in Pacific). This latter scenario also accounts for a (potentially non-conservative) projected 100-year estimate of sea level rise of 0.4 m. The moderate hazard zone represents only a moderate risk due to its lower probability of occurrence.

The exposure and sensitivity of communities in Tillamook and Pacific Counties to the extreme storm scenarios were calculated using geographic information system (GIS) software (ArcMap 9.3, ESRI) to overlay geospatial data showing 2000 Census Bureau block-level population counts, land-cover classifications of the 2001 National Land Cover Database, 2001 administrative boundaries, and the two coastal change hazard zones. Exposure is defined as the amount of an asset in the hazard zones, whereas sensitivity is defined as the percentage of that asset in the zones relative to the entire community. Following methods outlined in Wood (2009), we focus on developed land and residents in our discussion.

Results

The width of the high (moderate) hazard zones for the two counties varies considerably from 80 m (130 m) wide in Tillamook County to 200 m (300 m) wide in Pacific County. The zones in Pacific are more than double that of Tillamook because it has a significantly lower beach slope and higher storm surge values for the two scenarios. The amount and relative percentage of developed land (Figure 2) and residents (Figure 3) in the hazard zones varies between the two counties and their communities. Despite the difference in hazard zone width, the two counties have a similar amount of exposed developed land. Tillamook County, however, has a higher number of residents in the hazard zones than Pacific County (550 vs. 370) indicating that development is much more intense. Several communities in Tillamook County (e.g., Manzanita, Cape Meares, Oceanside, and Neskowin) have low exposure but high sensitivity to coastal change hazards with regards to both developed land and residents. Therefore, although there are a small number of residents or low amount of developed land within the hazard zones, the loss of these individuals or development could represent significant community impacts.

Discussion

To explain the variations in exposure and sensitivity observed between the two counties, it is necessary to compare and contrast both the physical and social factors that may be controlling their vulnerability. The dune geomorphology is comparable and therefore provides a similar vertical barrier to storm waves. However, with more intense development close to the dunes, communities in

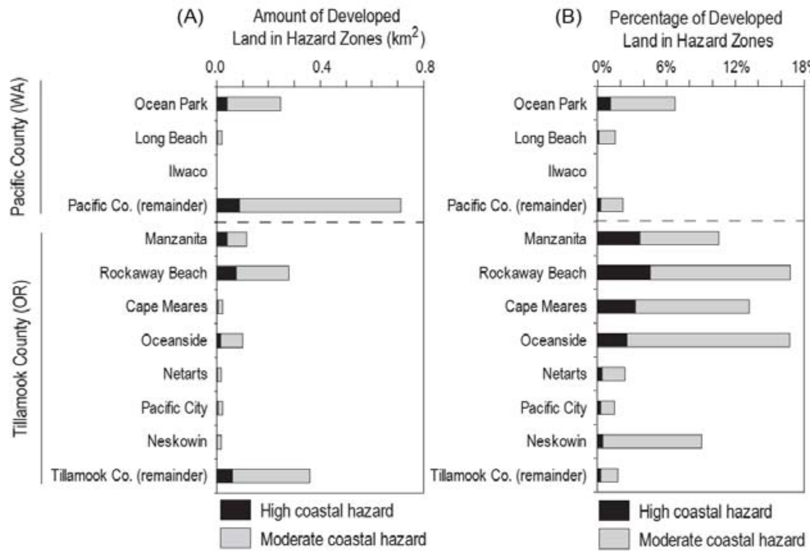

Figure 2. Amount (A) and percentage (B) of developed land within coastal change hazard zones in Pacific and Tillamook Counties.

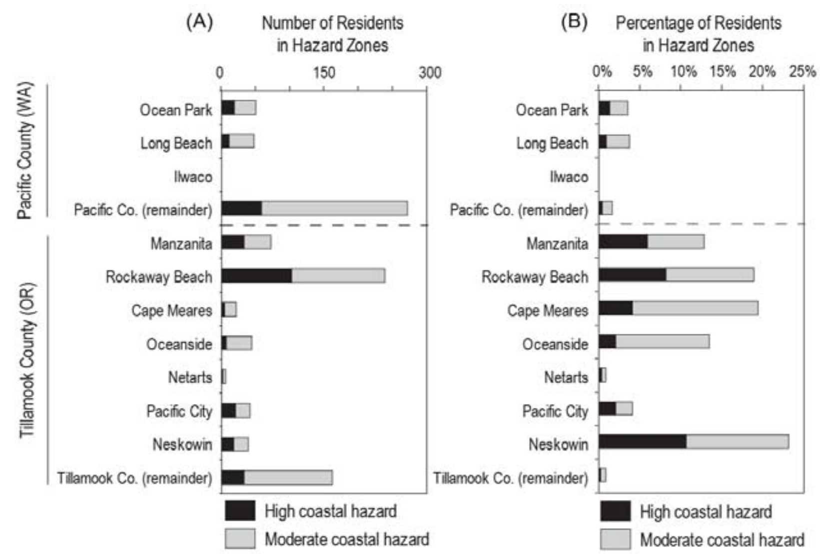

Figure 3. Number (A) and percentage (B) of residents within coastal change hazard zones in Pacific and Tillamook Counties.

Tillamook County is more susceptible to landward retreat. Differences could also result from a combination of social factors such as development pressures, coastal planning strategies, or variability in local knowledge about natural hazards. However, much of Pacific County's coastline has experienced a substantial trend of beach progradation over the last several decades (Kaminsky et al., in press) while Tillamook County beaches have been either erosional or stable. Future work will attempt to quantitatively distinguish between these physical and social factors in determining community vulnerability.

The relatively low percentage of each asset in the hazard zones suggests that episodic coastal change is an issue that may be more likely dealt with at a local scale rather than by the county as a whole. While this approach begins to quantify vulnerability and assess reasons for its variability, the next step is to develop improved hazard models that probabilistically incorporate long-term environmental trends and develop information for effective land-use, hazard-mitigation, and emergency-management plans.

Acknowledgements

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