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By Nathan Wood

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FRONT COVER—The cities of Manzanita (left) and Seaside (right) on the Oregon coast, shown with the internationally adopted tsunami-evacuation sign (Intergovernmental Oceanographic Commission, 2003). (USGS photographs by Nathan Wood.)

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Abstract

Evidence of past events and modeling of potential future events suggest that tsunamis are significant threats to Oregon coastal communities. Although a potential tsunami-inundation zone from a Cascadia Subduction Zone earthquake has been delineated, what is in this area and how communities have chosen to develop within it have not been documented. A vulnerability assessment using geographic-information-system tools was conducted to describe tsunami-prone landscapes on the Oregon coast and to document city variations in developed land, human populations, economic assets, and critical facilities relative to the tsunami-inundation zone. Results indicate that the Oregon tsunami-inundation zone contains approximately 22,201 residents (four percent of the total population in the seven coastal counties), 14,857 employees (six percent of the total labor force), and 53,714 day-use visitors on average every day to coastal Oregon State Parks within the tsunami-inundation zone. The tsunami-inundation zone also contains 1,829 businesses that generate approximately $1.9 billion in annual sales volume (seven and five percent of study-area totals, respectively) and tax parcels with a combined total value of $8.2 billion (12 percent of the study-area total). Although occupancy values are not known for each facility, the tsunami-inundation zone also contains numerous dependent-population facilities (for example, adult-residential-care facilities, child-day-care facilities, and schools), public venues (for example, religious organizations and libraries), and critical facilities (for example, police stations). Racial diversity of residents in the tsunami-inundation zone is low, with 96 percent identifying themselves as White, either alone or in combination with one or more race. Twenty-two percent of the residents in the tsunami-inundation zone are over 65 years in age, 36 percent of the residents live on unincorporated county lands, and 37 percent of the households are renter occupied. The employee population in the tsunami-inundation zone is largely in accommodation and food services, retail trade, manufacturing, and arts and entertainment sectors.

Results indicate that vulnerability, described here by exposure (the amount of assets in tsunami-prone areas) and sensitivity (the relative percentage of assets in tsunami-prone areas) varies considerably among 26 incorporated cities in Oregon. City exposure and sensitivity to tsunami hazards is highest in the northern portion of the coast. The City of Seaside in Clatsop County has the highest exposure, the highest sensitivity, and the highest combined relative exposure and sensitivity to tsunamis. Results also indicate that the amount of city assets in tsunami-prone areas is weakly related to the amount of a community's land in this zone; the percentage of a city's assets, however, is strongly related to the percentage of its land that is in the tsunami-prone areas. This report will further the dialogue on societal risk to tsunami hazards in Oregon and help identify future preparedness, mitigation, response, and recovery planning needs within coastal cities and economic sectors of the state of Oregon.

Introduction

The 2004 Sumatra-Andaman earthquake and tsunami devastated communities throughout the Indian Ocean and demonstrated to the world how tsunamis are significant threats to the safety, security, economic well-being, and natural resources of many coastal communities. Historical and geologic evidence suggest that the Oregon coast has experienced similar large-magnitude tsunamis and is likely to experience more (Heaton and Snavely, 1985; Heaton and Hartzell, 1987; Lander and Lockridge, 1989; Atwater and others, 1995; Satake and others, 1996; Atwater and Hemphill-Haley, 1997; Clague, 1997; Jacoby and others, 1997; Peters and others, 2001; Priest and others, 2001; McMillan and Hutchinson, 2002; Leonard and others, 2004; Atwater and others, 2005).

The Oregon coast is susceptible to two types of tsunamis —those generated by distant earthquakes on the seismically active Pacific Ocean margin and those generated by local earthquakes within the Cascadia subduction zone. A distant-earthquake example is the tsunami associated with the 1964 magnitude 9.2 earthquake in the eastern Aleutian-Alaska subduction zone that inundated the Oregon coast approximately 4 hours after initial ground shaking in Alaska (Landers and Lockridge, 1989). A more significant tsunami threat for coastal communities is associated with local earthquakes emanating along the Cascadia Subduction Zone (CSZ), the interface of the North America and Juan de Fuca tectonic plates that extends more than 1,000 kilometers from northern California to southern British Columbia (Rogers and others, 1996;

fig. 1). Based on geologic evidence, the CSZ has ruptured and created tsunamis 13 times in the past 7,600 years and has a considerable range in recurrence intervals, from as little as 140 years between events to more than 1,000 years (Atwater and others, 1995; Atwater and Hemphill-Haley 1997; Goldfinger and others, 2003; Kelsey and others, 2002; Witter and others, 2003; Kelsey and others, 2005). The last CSZ-related tsunami is believed to have occurred on January 26, 1700 (Satake and others, 1996; Atwater and others, 2005), and researchers predict a 10 to 14 percent chance that another could occur in the next 50 years (Petersen and others, 2002). Future CSZ-related earthquakes have been predicted to be magnitude 8 or greater and could subject Oregon coastal communities to intense ground shaking, subsidence, landslides, and liquefaction of unconsolidated sediments. In addition, a series of tsunami waves possibly 8 meters or higher are predicted to inundate the Oregon coast in tens of minutes after initial ground shaking in a magnitude 8 or larger earthquake (Myers and others, 1999; Priest and others, 2001; Geist, 2005; Cascadia Regional Earthquake Workgroup, 2005).

To reduce tsunami risk in Oregon and other western States, the U.S. National Tsunami Hazard Mitigation Program, a State-Federal partnership, has supported several hazard assessment, warning guidance, and mitigation efforts (Bernard, 2005). Oregon hazard assessments include a series of tsunami-inundation maps and tsunami-evacuation brochures (Oregon Department of Geology and Mineral Industries, 2007) created with modeling support provided by the Tsunami Inundation Mapping Effort (TIME) Center (Gonzales and others, 2005b). Tsunami-warning efforts include a network of deep-ocean tsunami detection stations (Gonzales and others, 2005a), enhancements to existing tsunami-warning centers (Darienzo and others, 2005; McCreery, 2005; Titov and others, 2005), evacuation signage (Priest and others, 1996), and use of the National Oceanic and Atmospheric Administration (NOAA) Weather Radio "All-Hazards Alert Broadcast" warning system (Crawford, 2005). Mitigation efforts include educational materials to raise awareness of the potential of CSZ-related tsunamis (Priest and others, 1996; Connor, 2005), to improve evacuation procedures (Dengler, 2005), and to promote land-use strategies that reduce tsunami risk (Eisner, 2005; Jonientz-Trisler and others, 2005).

Although much has been done to improve our understanding of tsunami hazards and to develop regional warning systems and awareness programs, less has been done to understand community vulnerability to these hazards, specifically the potential impacts on people and infrastructure (U.S. Government Accountability Office, 2006). Community vulnerability, defined as the attributes of a human-environmental system that increase the potential for hazard-related losses or reduced performance, is primarily determined by how communities occupy and use hazard-prone land. Along the Oregon coast, use of tsunami-prone land varies considerably, including low-density residential development (fig. 2*A*), commercial ports (fig. 2*B*), industrial warehouses (fig. 2*C*), and high-occupancy hotels (fig. 2*D*). These land-use variations influence

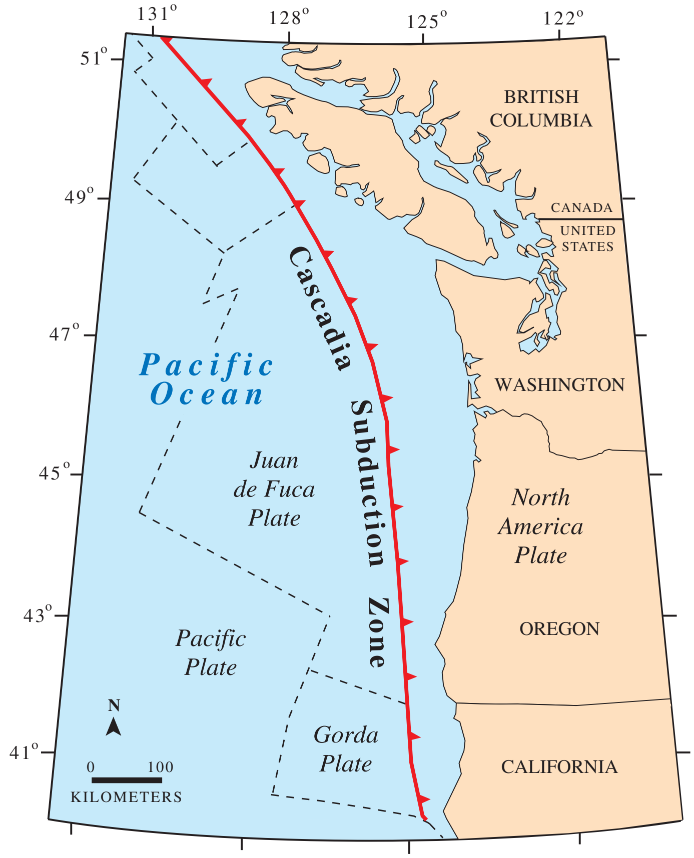


Figure 1. Map of the Cascadia Subduction Zone (adapted from U.S. Geological Survey, 2007).

vulnerability, often characterized by the exposure, sensitivity, and resilience of a community and its assets in relation to hazards (Turner and others, 2003). A tsunami may cause damage to buildings or injure people, but the cumulative choices a community makes with regards to land use and its willingness to develop risk-reduction strategies (for example, education programs and evacuation training) before an extreme event occurs set the stage for these losses (Mileti, 1999; Weichselgartner, 2001; Wisner and others, 2004). The risk of future tsunami disasters is therefore a function of predicted hazards and the vulnerable human systems that occupy hazardous areas (fig. 3).

Although not as extensive as research on past and potential tsunamis, some research has been done to understand societal vulnerability to CSZ-related tsunami hazards in Oregon. Charland and Priest (1995) indicate that many critical facilities in Oregon coastal communities are at significant risk of collapse should a CSZ-related earthquake and tsunami occur. Wood and Good (2004) show that residential populations are low in tsunami-prone areas of one Oregon port and harbor community; whereas the high number of major employers and tourist attractions indicate a tsunami could result in high employee and tourist fatalities. Countering the traditional emphasis on engineering-based approaches to assess vulnerability, Wood and others (2002) show that non-spatial aspects of

Figure 2. Photographs of (*A*) the City of Manzanita, (*B*) the Port of Garibaldi, (*C*) the Port of Astoria, and (*D*) the City of Seaside. (USGS photographs by Nathan Wood.)

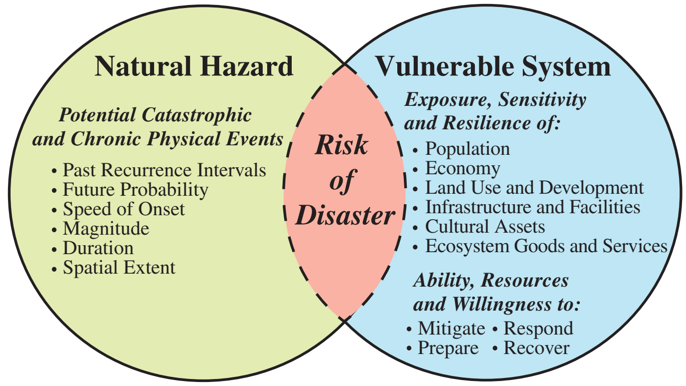


Figure 3. Conceptual diagram of societal risk to disasters.

community vulnerability, such as poor interagency communication and low hazard awareness of residents, were of greater concern to members of an Oregon port and harbor community than the loss or damage of any specific structure that could be mapped or studied. Results of a 2001 perception study of Oregon and Washington coastal communities indicate that comprehension of earthquake and tsunami hazards and of societal vulnerability to these threats varied considerably among survey participants and that few local risk-reduction actions had been implemented (Wood and Good, 2005). Finally, a statewide seismic needs assessment indicates that there are numerous Oregon education and emergency-services buildings (for example, fire and police stations) in areas of high tsunami risk (Lewis, 2007).

To complement these efforts, research describing the communities that occupy tsunami-prone land along the Oregon coast is needed. Although all communities here are vulnerable to predicted tsunami hazards, the extent of the vulnerability in each community will vary, depending on the distribution of socioeconomic assets. Determining how communities currently vary in their vulnerability to tsunami hazards will help community members, emergency managers, and private relief organizations understand potential societal impacts of CSZ-related tsunamis. This knowledge will help them determine if regional mitigation, preparedness, response, and recovery strategies need to be augmented with site-specific efforts that reflect local conditions and needs, such as targeted education programs, evacuation procedures for special-needs populations, or continuity planning for particular business sectors. Land-use planners and coastal resource managers will find this information valuable in their efforts to manage the use of tsunami-prone land.

Purpose and Scope

The purpose of this report is to describe tsunami-prone landscapes and document how cities vary in vulnerability to CSZ-related tsunamis on the Oregon coast. Data presented in this report include city-level descriptions and comparisons of the amount and percentage of assets in tsunami-prone areas, based on the distribution of developed land, human populations, economic assets, and critical facilities relative to a CSZ-related tsunami-inundation zone. Variations in city vulnerability to tsunamis are based on the presence of assets in tsunami-prone areas; results are not engineering-based loss estimates for any particular facility.

Certain vulnerability aspects were considered outside the scope of this report, including potential ecosystem impacts, risk perceptions, social capital (Alwang and others, 2001; Pelling, 2002) and resilience, defined as the ability to withstand, absorb, adapt to, and recover from losses (Turner and others, 2003). It also does not seek to identify the underlying determinants of the variations in community vulnerability (Wisner and others, 2004). The report focuses exclusively on tsunamis on the Oregon coast and does not discuss the additional hazards associated with a CSZ earthquake, including ground shaking, liquefaction, subsidence, and landslides.

To understand the potential impacts of future tsunamis in Oregon, policymakers, managers, and private citizens must understand the current vulnerability of communities that occupy tsunami-prone land. This analysis is intended to serve as a foundation for additional risk-related studies and to help community members and public-sector managers to develop mitigation, preparedness, response, and recovery strategies that are tailored to local needs. This information will also help county, State, and Federal policymakers (either in the emergency-management or land-use arena) decide where and for whom to prioritize risk-reduction strategies.

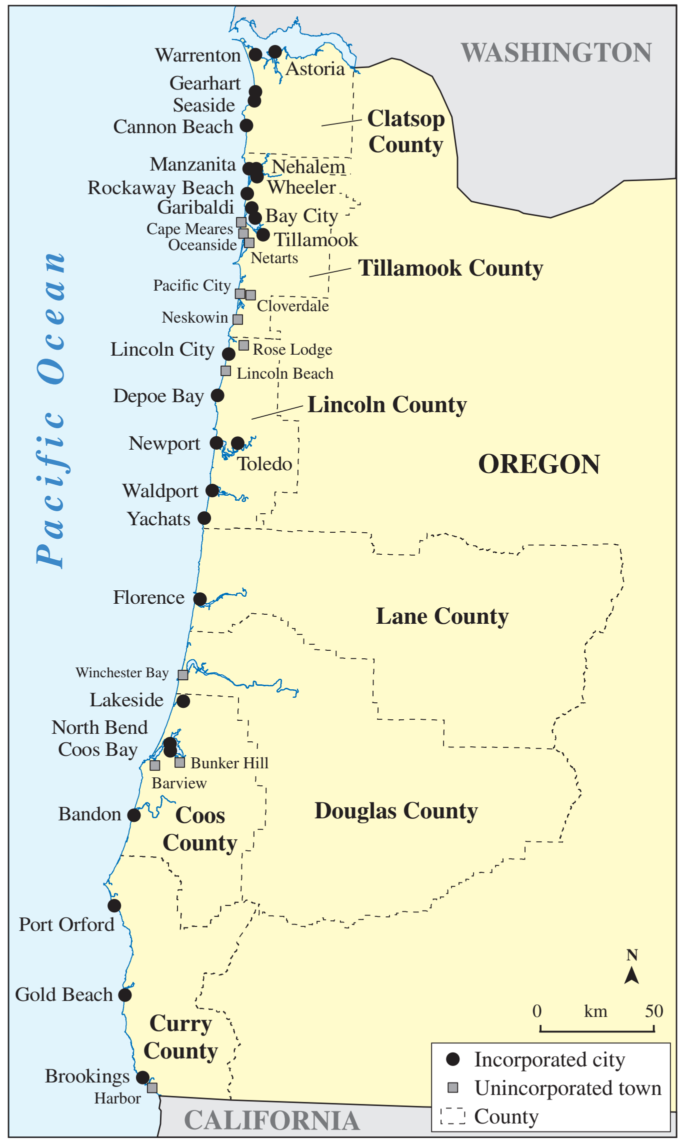


Figure 4. Map of counties and communities on the Oregon coast with land in the tsunami-inundation zone.

Study Area

This study focuses on the seven coastal counties of Oregon, including Clatsop, Tillamook, Lincoln, Lane, Douglas, Coos, and Curry, and the 26 incorporated cities (based on 2003 city-limit boundaries) within them that intersect a statewide tsunami-inundation zone (Oregon Geospatial Enterprise Office, 2007) (fig. 4). There are also 12 unincorporated towns along the Oregon coast, as delineated by census-designated-place boundaries (U.S. Census Bureau, 2007a), that intersect the tsunami-inundation zone (fig. 4); however, because emergency services and land-use planning for these towns are performed by county offices, results related to unincorporated towns are reported at the county level.

The tsunami-inundation zone was developed by the Oregon Department of Geology and Mineral Industries (DOGAMI) to support Oregon Revised Statutes (ORS) chapter 455, sections 446 and 447, which are provisions passed in 1995 to limit the construction of essential facilities in tsunami-inundation zones (Priest, 1995; Olmstead, 2003). Based on geologic evidence of past events and tsunami-propagation modeling, this tsunami-inundation zone delineates the upper limit of area expected to be covered by flood water from a tsunami caused by a magnitude 8.8 CSZ earthquake (Priest, 1995). The maximum run-up estimated in Priest (1995) was considered a reasonable inundation boundary for implementation of ORS 455 but new modeling coupled with improved understanding of earthquake sources and the role of local splay faults and areas of concentrated fault slip in amplifying tsunami heights suggest worst-case inundation scenarios that exceed the ORS 455 zone (Witter and others, 2007; Zhang and others, 2007; Priest, written communication, 2007). Higher-resolution inundation models and zones have been developed for select Oregon estuaries (for example, Wong and others, 2006); however, the ORS 455 tsunami-inundation zone is used here because it is a regional study. The impacts of a CSZ-related tsunami described in this report are based on the ORS 455 inundation zone and are therefore conservative estimates.

Methods and Data

To describe tsunami-prone landscapes and compare city vulnerability to tsunamis on the Oregon coast, geographic-information-system (GIS) tools were used to integrate publicly available hazard and socioeconomic data. Vulnerability calculations and comparisons consider city exposure and sensitivity based on the distribution of developed land, populations (residential, employee, and tourists), economic assets, and critical facilities. These assets are chosen based on the data U.S. jurisdictions are encouraged to collect as they develop State and local mitigation plans (Federal Emergency Management Agency, 2001), a requirement to qualify for funds under the U.S. Hazard Mitigation Grant Program in accordance with the Disaster Mitigation Act of 2000, Public Law 106-390. Exposure is based on the amount of an asset (for example, the number of residents) within a tsunami-inundation zone of a city. Sensitivity is defined as the relative impact of losses to an entire community (for example, the percentage of a community's workforce in a tsunami zone) and is calculated by dividing the amount of an asset in a tsunami-inundation zone by the total amount of that asset in a city. For example, if community A has 100 businesses in a tsunami-inundation zone (representing 10 percent of the local economy) and community B has 30 businesses in a tsunami- inundation zone (representing 90 percent of the local community), then community A has a higher economic exposure because it has more businesses in the tsunami zone, but community B is more economically sensitive because it has a higher proportion of its businesses in the tsunami zone. Exposure and sensitivity values based on various socioeconomic assets are reported for each city and then combined to create overall indices of city exposure and sensitivity to tsunami hazards. Prior to analysis, all geospatial data were processed to share the same datum (North American Datum of 1983) and projection (Oregon Lambert) of data within the Oregon Geospatial Data Clearinghouse (2007). Spatial analysis of vector data (for example, business points and tax-parcel polygons) focused on determining if points or polygons are inside the tsunami-inundation-zone polygons. Slivers of polygons that overlap administrative boundaries and tsunami zones are taken into account during analysis and final values are adjusted proportionately.

Land Data

The first step in understanding societal vulnerability is to determine the type of land-use and land-cover (LULC) in the tsunami-inundation zone. County-level descriptions of land use in the tsunami-inundation zone are based on regional zoning and land-ownership data (Oregon Geospatial Enterprise Office, 2007); local land-use information is not digitally available for all segments of the study area. Land-cover descriptions of the tsunami-inundation zone are based on data compiled in 2001 by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (C-CAP). C-CAP land-cover data is nationally standardized for the coastal regions of the United States (NOAA CSC, 2007; Dobson and others, 1995) and is part of the National Land Cover Database (NLCD) effort through the interagency Multi-Resolution Land Characteristics (MRLC) Consortium (Homer and others, 2004; Loveland and Shaw, 1996). NLCD products, including LULC, percent impervious cover, and percent canopy cover, are automatically derived from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM) digital satellite imagery, which is produced at a 30-meter horizontal resolution. C-CAP data generated before 2005 have 22 land-cover classes and have a reported accuracy standard of 85 percent (Dobson and others, 1995).

One set of societal vulnerability indicators assessed in this study is the amount and percentage of developed land relative to the tsunami-inundation zone in each incorporated city and for the unincorporated portions of each county. Vulnerability is assumed to increase with greater amounts and percentages of developed land in tsunami-prone areas. Developed land is represented by low-intensity developed and high-intensity developed classes in C-CAP data generated before 2005. Low-intensity developed cells contain 50 to 79 percent of constructed surfaces, are a mix of constructed and vegetated surfaces, and typically represent small buildings, streets, and cemeteries. High-intensity developed cells contain more than 80 percent of constructed surfaces, have little or no vegetation and typically represent heavily built-up urban centers, large buildings, and large paved surfaces, such as runways and interstate highways (Dobson and others, 1995). Since 2005, a medium-intensity developed class was added; however, the pre-2005 classification scheme is used to allow for comparisons to tsunami assessments already completed in other States (Wood and others, 2007). Based on the distribution of land-cover cells classified as high- and low-intensity developed in relation to the tsunami-inundation zone, the majority of developed land is outside of the zone in the cities of Lakeside (fig. 5*A*) and Newport (fig. 5*B*), but inside the zone in the City of Seaside (fig. 5*C*).

Population Data

Another aspect of community vulnerability is the size of local populations (including residents, employees, and dependents) and tourist populations that may be at risk from tsunamis (fig. 6). The number and type of residents in the tsunami-inundation zone were determined using demographic data from census blocks (a geographic unit) of the 2000 U.S. Census (U.S. Bureau of Census, 2000). In addition to total population and households, demographic information for each city is summarized relating to ethnicity (Hispanic or Latino), race (American Indian and Alaska Native, Asian, Black or African American, Native Hawaiian and other Pacific Islander, and White—all alone or in combination with one

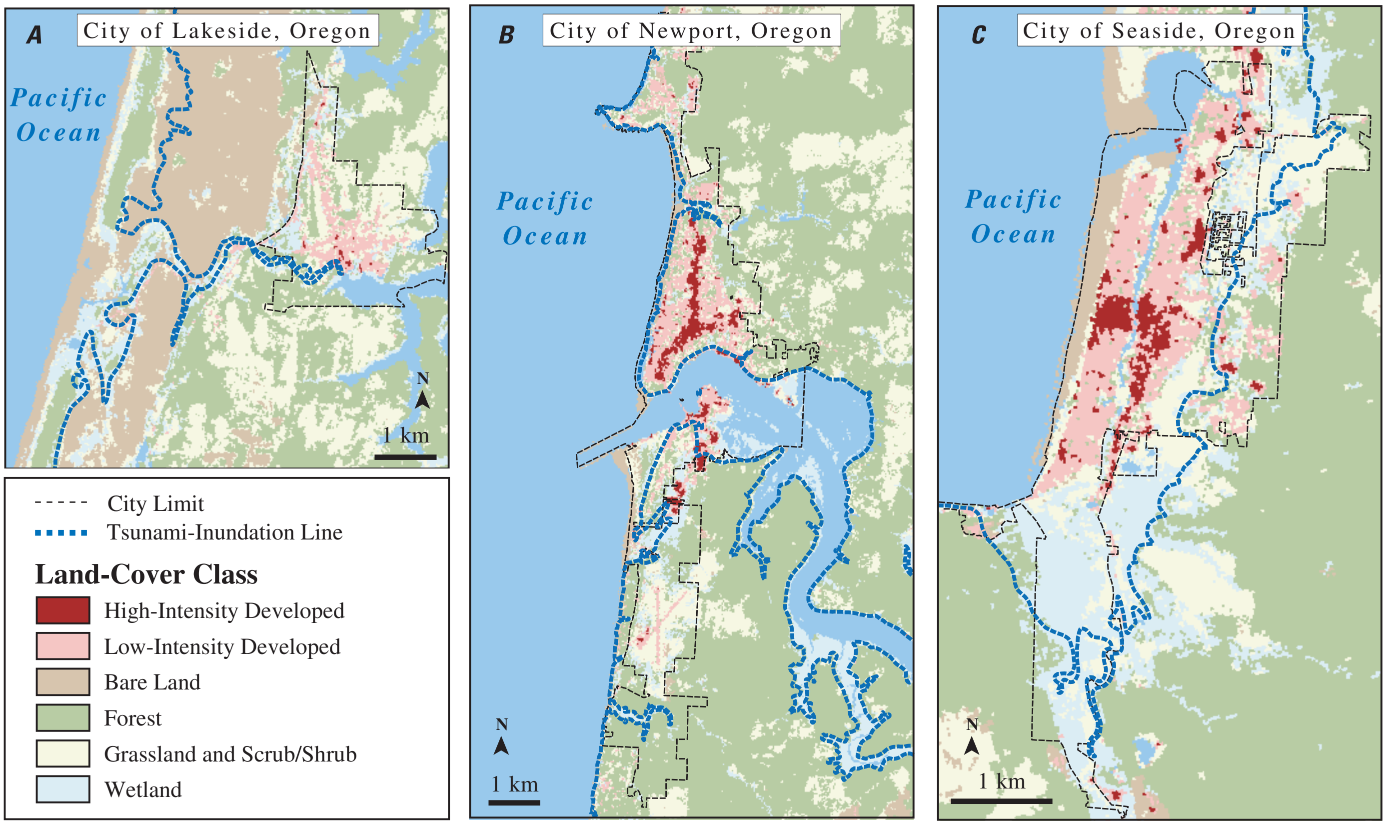


Figure 5. Maps of 2001 NOAA C-CAP land-cover data for the (*A*) City of Lakeside, (*B*) City of Newport, and (*C*) City of Seaside, Oregon.

or more other races), age (populations under 5 and over 65 years in age), gender (female population and female-headed households with children and no spouse present), and tenancy (renter-occupied households). Census block-group and tract data are summarized at the county level, regardless of the tsunami-inundation zone, to provide additional insight on local conditions if a disaster were to occur and not at the hazard-level due to the size differences between inundation polygons and the larger census units.

Other local at-risk populations include employees and dependents. The number and types of employees in the study area (excluding seasonal labor) were determined using the 2005 InfoUSA Employer Database. Because no fieldwork was conducted to verify business locations, results based on the Employer Database throughout this report should be considered first approximations and developed to generate discussions for additional, more-detailed studies. Dependent populations are defined as individuals who temporarily reside in facilities and would require assistance to evacuate and recover. North American Industry Classification System (NAICS) codes for businesses in the InfoUSA Employer Database (appendix A) were used to identify the following dependent-population facilities:

- Medical facilities, including hospitals, psychiatrics and substance abuse hospitals, mental health services and psychiatric treatment facilities, pregnancy counseling, clinics, and physician offices;
- Adult residential care, including adult care facilities, hospices, nursing homes, rest homes, retirement communities, adult homes, senior citizens services, residential care homes, group homes, foster care, and adult day care centers;
- Child day care, including large babysitting facilities, childcare centers, pre-schools and nursery schools (both public and private);
- Schools, including religious schools, public and private schools, schools with special academics, and home-schooling centers; and
- Correctional facilities, including State and Federal facilities.

Tourists are another significant population in coastal communities and can often outnumber residents and employees in tsunami-prone areas (Wood and Good, 2004). Because no consistent census count for tourists exists, public venues and Oregon State Park visitor data are used. Businesses that likely attract nonresidents are considered public venues and are identified using NAICS codes for businesses in the 2005 InfoUSA Employer Database (appendix A). Public venues include aquariums, botanical gardens, casinos, colleges and universities, historical places, libraries, museums, parks, religious organizations, shopping centers and malls, sporting facilities, theaters (including live and cinematic), and zoos. Data on the annual-average number of visitors from 1998 to 2003 for Oregon State Parks

(Oregon State Parks, 2005, unpublished data) are also used to approximate the number of visitors along the Oregon coast that may be in the tsunami-inundation zone. To gauge the potential impact to communities in the event of a tsunami, coastal parks are coded by the incorporated city closest to them (based on road distance). The number of annual visitors to nearby parks is summed for each city and a relative percentage is calculated for each city based on the overall sum of annual visitors to parks on the Oregon coast. These calculations are done to approximate which cities and their services (for example, police and hospitals) could be most impacted by high casualties in nearby parks. This approach also indicates the number of day tourists that may be in or near a city should a tsunami occur; for example, visitors to a State park may have lunch or shop in a nearby town.

Economic Data

Economic analyses for this study focus on two elements of the coastal economy—tax base and business community. Tax base, as represented by county parcel values, is an attribute of societal vulnerability because cities and counties rely on property taxes for local services. Communities can typically expect disaster-relief aid from State and Federal sources, as well as from nonprofit organizations and private donations, but funds for longer-term recovery and the restoration of county services typically come from revenue generated by property taxes. If an extreme event destroys property, land values will be reassessed at some point and likely lowered, the city tax base will shrink, and a city may have a harder time with disaster recovery. Tax-parcel databases were provided by all seven counties in 2006 and parcel-polygon attributes include property value and content value (both in 2006 U.S. dollars).

Potential impacts to the business community in each city and county are determined by calculating the amount and percentage of businesses, employees, and generated sales volumes in the tsunami-inundation zone using data from the InfoUSA Employer Database. Businesses in the tsunami-inundation zone with "P.O. box" mailing addresses (four percent of the database) were counted in the city- and county-totals, because point locations were for the P.O. box and not the actual business. Economic conditions, such as the dominance of specific sectors, are based on employee distributions, an indicator routinely used by the private and public sector to evaluate economic health and market trends (Marshall, 1989; Bureau of Labor Statistics, 2007a).

Critical-Facilities Data

Certain facilities are considered critical for short-term response and others are considered essential for long-term recovery of a community following a disaster. As a starting point for discussing critical and essential facilities along the Oregon coast, certain facilities were identified using NAICS codes in the InfoUSA Employer database (appendix A). Critical facilities include those used for public safety purposes (civil-defense facilities, fire stations, national-security facilities, police stations, and radio and television stations), medical services (ambulances, hospitals, outpatient-care centers, and physician offices), and infrastructure maintenance (electric, public-works, natural-gas, waste-water, and water

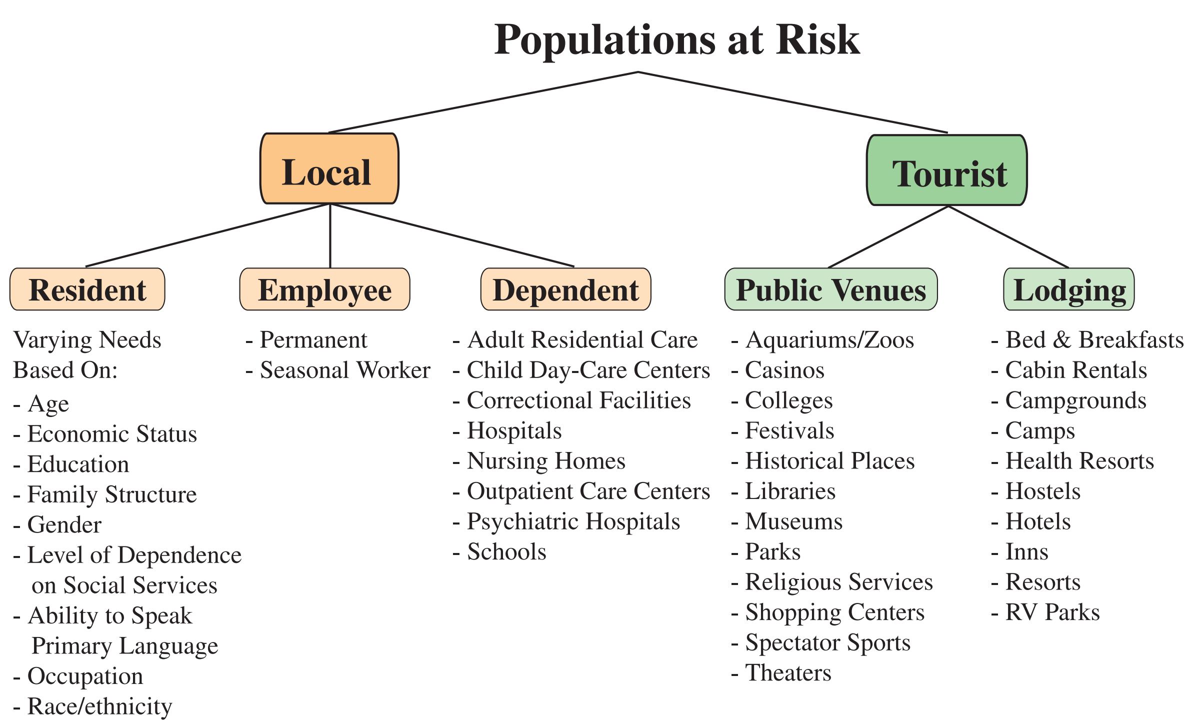


Figure 6. Conceptual diagram of populations at risk from natural hazards.

and sewer facilities). Essential facilities include those that provide for basic necessities (banks and credit unions, gas stations, and grocery stores) or serve government functions (courts and legal offices, government offices, international-affairs offices, and U.S. Post Offices).

Composite Indices of Exposure and Sensitivity

To compare city and county vulnerability, composite exposure and sensitivity indices were developed for the 33 geographic units (26 incorporated cities and the unincorporated land in the 7 counties) and are based on the amounts and percentages, respectively, of five categories–developed lands, residents, employees, public venues and hotel facilities, and total tax-parcel values. Composite indices of exposure and sensitivity were developed by first normalizing values in the five categories to the maximum value found within that category. Normalizing data to maximum values creates a common data range of zero to one for all five categories and is a simple approach for enabling comparisons among disparate datasets. The five normalized values are then summed, resulting in one final score ranging from zero to five for each of the 33 geographic units. These are relative scores developed to compare the 33 geographic units and have no stand-alone meaning for an individual city or county. A final score integrating the composite exposure and sensitivity values is determined for each of the 33 geographic units by first normalizing each of the composite scores to maximum values, creating common data ranges of zero to one for each of the indices and minimizing any weighting bias between the indices. Normalized values are then added with no additional weighting, resulting in a final combined score ranging from zero to two.

Statistical Methods

Descriptive statistics are used to summarize general trends and identify extremes in city exposure and sensitivity. Several datasets have non-normal distributions, based on Shapiro-Wilk (W) normality tests at $\alpha = 0.05$ (Zar, 1984); therefore, median and third-quartile (75th percentile) values are reported instead of mean values and their standard errors, which are commonly used to describe normal distributions. One hypothesis that arises in the process of documenting these variations is that the amount of city assets and the amount of city land in the tsunami-inundation zone are related; that is, more community land in the tsunami zone means there are more community assets in the zone. To test this hypothesis, a series of linear-regression analyses were conducted between land-area data and several city assets, including developed lands (lands classified as either low- or high-intensity developed), residents, employees, total parcel values, and public venues and hotels. Linear regressions were conducted for exposure values (the amounts of city land and assets in the tsunami-inundation zone) and for sensitivity values (the percentages of city land and assets in the tsunami-inundation zone) to determine if the amount and percentage of city land in tsunami-prone areas are significant factors in the distribution of city and county assets. The independent variable was the amount or percentage of land, regardless of land-cover class, within city and county limits. The dependent variables were the amount or percentage of assets within city and county limits. The null hypothesis in each of the analysis-of-variances tests is that no statistically significant relationship exists. Significance is assumed if calculated Fisher (F) values comparing the mean squares of the linear regression and residuals are greater than 4.17, which represents the critical F-value for a one-tailed test at $\alpha = 0.5$ and 31 degrees of freedom (Zar, 1984). Tests are done with an assumption of normality in the distribution of residuals (or homoscedasticity), based on a graphical examination of residual plots (Zar, 1984). In addition to F-values, the Pearson product-moment-correlation coefficient (r), the square of the Pearson product-moment correlation (r^2), and p-values are calculated. A significant statistical relationship between land area and the specific asset is assumed if a p-value is less than 0.05. A p-value of greater than 0.05 suggests that differences in the variances of the populations being compared (for example, land-area and number of residents) are too large to propose that a relationship exists.

Results

Descriptions of tsunami-prone landscapes in Oregon focus on land use and land cover, populations, economic assets, and critical and essential facilities. Third quartiles, also known as 75th-percentiles, are noted on bar-graphs in each section so that readers can easily identify which cities are in the top 25 percent of exposure and sensitivity calculations and, therefore, can be considered the most vulnerable in a category. Data on cities and counties are also provided in an accompanying database (appendix B).

Land Cover

The distribution of land-cover types (by area) in the tsunami-inundation zone was determined for the entire Oregon coast (fig. 7*A*) and for land just within the 26 incorporated cities (fig. 7*B*) by integrating 2001 C-CAP data, city and county boundaries, and the ORS 455 boundary. Results indicate that 95 percent of the land in the tsunami-inundation zone along the Oregon coast is classified as undeveloped (neither high- nor low-intensity developed) (fig. 7*A*). Wetland-related classes were the most common type of land-cover found in the tsunami-inundation zone (56 percent), followed by grasslands (15 percent) and bare land (14 percent). For land just in the 26 incorporated cities (fig. 7*B*), seventy-eight percent of land is classified as undeveloped, with most land classified as wetland (44 percent) or grassland (14 percent).

Although the majority of tsunami-prone land in Oregon is not classified as developed, these undeveloped areas can attract recreationists (both local residents and tourists) who could be impacted by a CSZ-related tsunami. Past studies

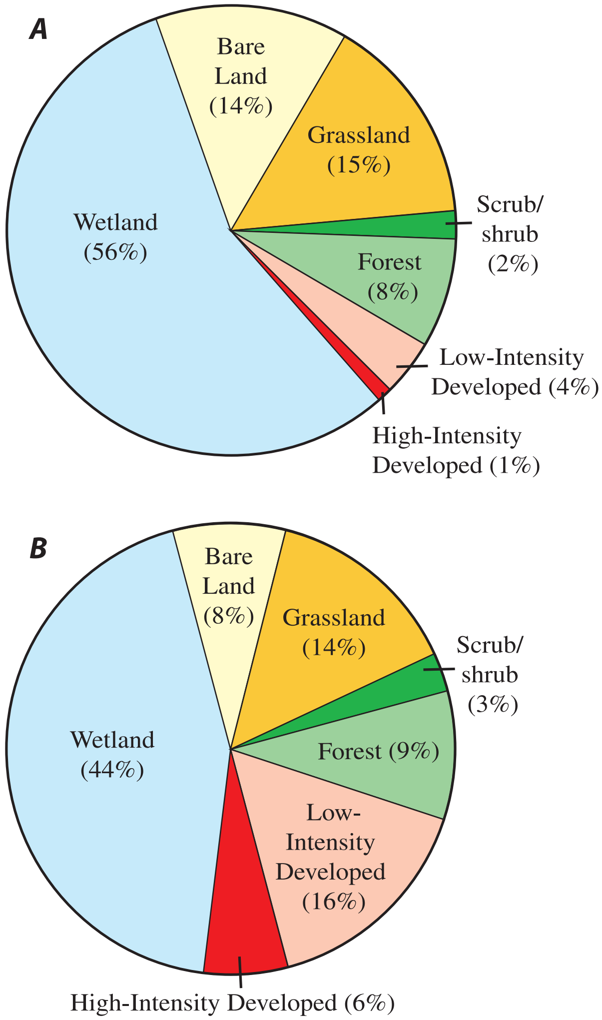


Figure 7. Distribution of land-cover classes (by area) in the tsunami-inundation zone for (*A*) the entire Oregon coast, and (*B*) the 26 incorporated cities.

(Wood and others, 2002; Wood and Good, 2004) have shown that tourists can dominate the daily population of coastal communities and represent a significant tsunami vulnerability issue. In addition, damage or loss of natural areas due to a tsunami could have societal consequences because these areas provide natural resources, critical habitats, and ecosystem services. For example, tsunami-related deposition of sediment and debris in coastal wetlands could impact ecosystem functions in these areas, which are critical habitats for juvenile fish. The subsequent losses to fisheries could impact the Oregon fishing industry, an industry that contributed $283 million to the Oregon economy in 2003 (Radtke and Davis, 2004).

Focusing on the distribution of developed land, results indicate that the amount (fig. 8*A*) and percentage (fig. 8*B*) of C-CAP landcover cells classified as either low- or high-intensity developed in the tsunami-inundation zone vary within the cities and unincorporated county lands along the Oregon coast (note: jurisdictions on the y-axis are arranged in descending geographic order from the City of Astoria in the north to the unincorporated land of Curry County in the south). Third quartiles for the amount and percentage of developed land in cities and the unincorporated county lands are 0.73 km^2 and 27 percent, respectively, suggesting that most jurisdictions have low amounts and percentages of developed land in the tsunami-inundation zone. Certain cities are well above the third quartile in both categories, such as the City of Seaside with 2.57 km^2 of developed land in hazard-prone areas, representing 87 percent of its developed land. The next highest amount of developed land in tsunami-prone areas is in the rural sections of Tillamook County, indicating potential impacts to the unincorporated towns of Cape Meares, Cloverdale, Oceanside, Neskowin, Netarts, and Pacific City (fig. 4).

Results indicate that cities either have high exposure (amounts) or high sensitivity (percentages), but rarely both. Some cities, such as Newport and North Bend, have relatively high amounts of developed land in the tsunami-inundation zone (0.83 km^2 and 0.86 km^2, respectively) that represent a small percentage of total city land (15 and 16 percent, respectively). Other cities, such as Gearhart, Cannon Beach, Waldport, and Yachats, have relatively low amounts of developed land in tsunami-prone areas (less than 0.5 km^2), but this land represents the majority of their development (greater than 50 percent in the four cities). Only the cities of Warrenton and Seaside exceed third-quartile values in both exposure and sensitivity.

Land Use

The distribution of land uses (by area) in the tsunami-inundation zone was determined for the seven coastal counties using zoning and ownership data to provide county, State, and Federal officials additional context on potential response and recovery issues. For example, tsunami-prone land zoned for nonurban uses (for example, parks and recreations, forestry, coastal, natural resources) suggest that initial response efforts will likely center on tourist populations in undeveloped areas and not on damaged infrastructure or buildings. This may be the case in Lane and Douglas Counties, where 69 and 91 percent, respectively, of the tsunami-prone land is zoned parks and recreation (fig. 9*A*). The highest percentages of tsunami-prone areas zoned as urban, and therefore greater development, are in the northern half of the Oregon coast, including Clatsop County (48 percent), Lincoln County (34 percent), and Tillamook County (21 percent).

The majority of tsunami-prone land along the Oregon coast is privately owned (fig. 9*B*), with the highest values in Curry County (96 percent), Lincoln County (93 percent), and Clatsop County (91 percent). In counties with high private land ownership, public officials will have to balance county and State needs with the rights of private land owners during the recovery process. Douglas County is the only county where the majority of tsunami-prone land is not privately owned; the small amount of its coastal shoreline (approximately 28 kilometers from north to south) is owned primarily by the Federal Government (70 percent) or the State of Oregon

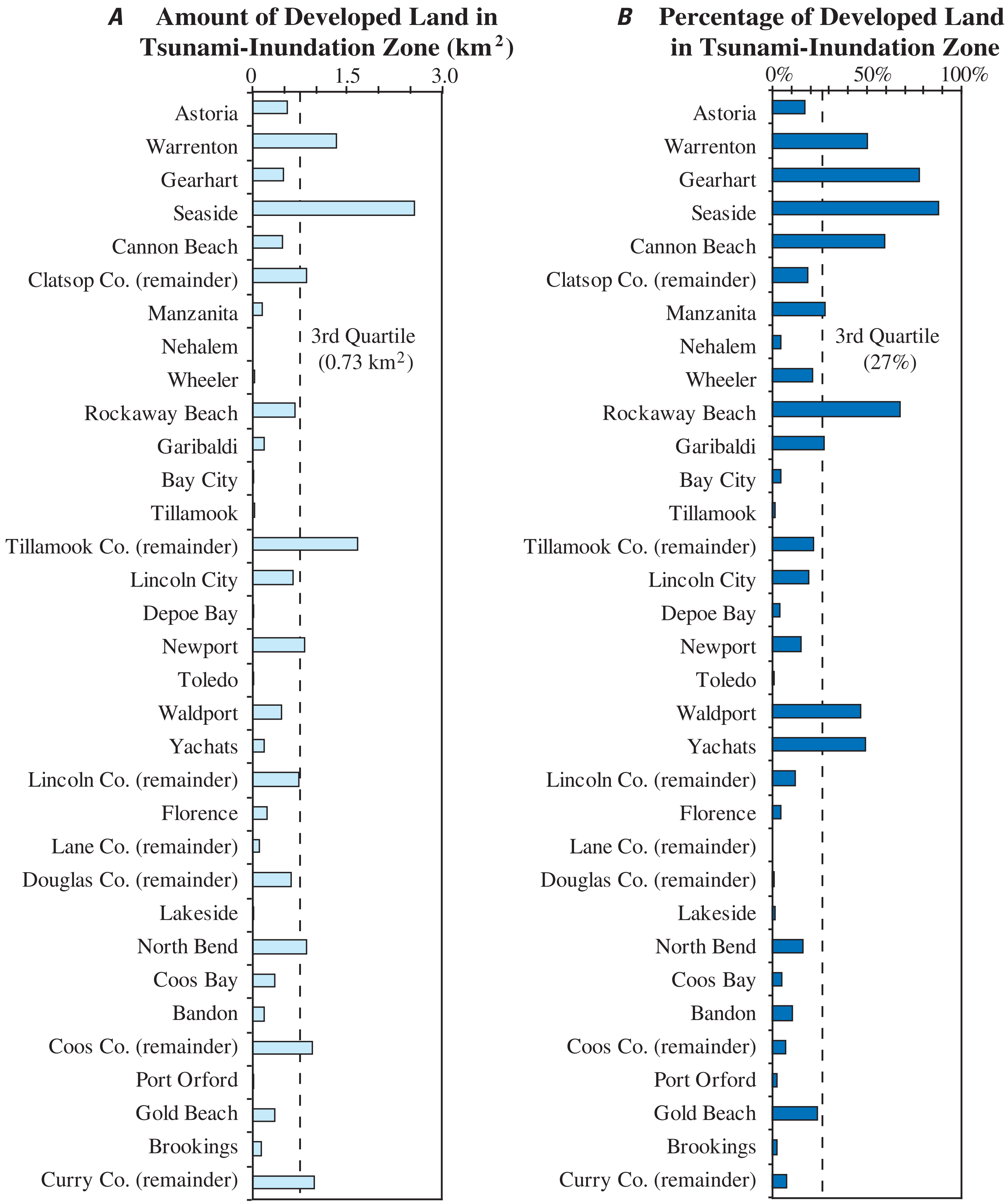


Figure 8. Amount (*A*) and percentage (*B*) of developed land in the Oregon tsunami-inundation zone.

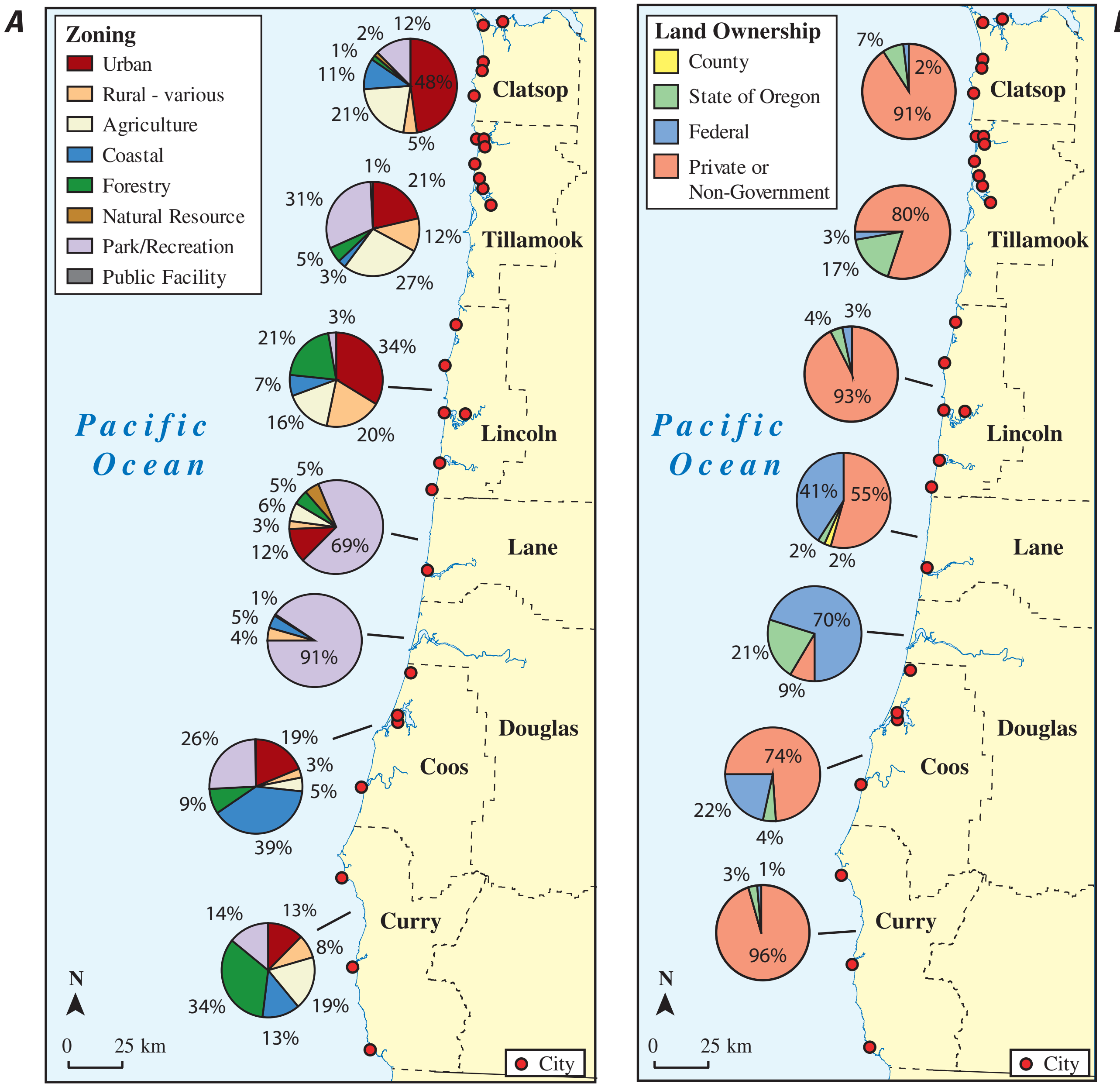


Figure 9. County-level distributions, by area, of (*A*) zoning and (*B*) land ownership for tsunami-prone land in Oregon.

(21 percent). In the event of a tsunami that impacts Douglas County, recovery of damaged lands (for example, State park facilities) will take place largely within the public sector.

Population

Residents

The tsunami-inundation zone contains 22,201 residents and 10,201 households (table 1), both representing 4 percent of totals in the seven counties. These study-area percentages, and all subsequent study-area percentages reported in this report, are low because the major population centers for Lane and Douglas Counties (Eugene and Roseburg, respectively) are not along the coast, unlike the other five counties, and are the biggest cities in the study area. The number (fig. 10*A*) and percentage (fig. 10*B*) of residents in the tsunami-inundation zone varies across the seven counties, with the highest values in the northern section of the coast. The City of Seaside has the highest number of residents (4,790) in the tsunami-inundation zone, while the City of Gearhart has the highest percentage (85 percent) of its residents in the tsunami-inundation zone. Some cities, such as Lincoln City, have a high number of residents in the tsunami-prone area (1,321) but these residents represent a low percentage (18 percent) of the town's total population. The reverse is true in other cities (for example, Cannon Beach, Rockaway Beach, Waldport, and Yachats) where low numbers represent high percentages. Results also indicate that 7,912 residents are in tsunami-prone areas outside of the 26 incorporated cities (representing 36 percent of all residents in the tsunami-inundation zone) and are primarily in the unincorporated portions of Lincoln (2,175), Clatsop (1,828), Tillamook (1,641) and Coos (1,014) Counties. Residents in the tsunami-prone areas of unincorporated lands within Tillamook County are primarily located in the unincorporated town of Pacific City (estimated population of 1,027 residents in the 2000 Census).

Any individual occupying tsunami-prone land is vulnerable to some extent, but social-science research has demonstrated that demographic factors like age, race, gender, and socioeconomic status can amplify this vulnerability, thereby increasing the potential for losses, present unique response needs, or slow recovery after an extreme event (Morrow, 1999; Ngo, 2003; Cutter and others, 2003; Laska and Morrow, 2007). Results characterizing demographic attributes of residents in the study area (table 1) do not imply that all individuals of a certain demographic group will exhibit identical behavior during or after a tsunami. Variations in local cultures and situations, as well as individual and community resilience, will influence the extent of these demographic sensitivities.

Race and ethnicity influence individual sensitivity to stressors, as studies have shown that households of racial and ethnic minorities tend to be more vulnerable to extreme natural events (Morrow, 1999). This reflects not characteristics of the individual but of historic patterns of racial and ethnic inequalities within a society that result in minority communities which are more likely to have inferior public services, infrastructure, and building stock (Laska and Morrow, 2007) and that may be excluded from disaster planning efforts (Morrow, 1999). Minorities that speak a language other than the primary language of an area are also more vulnerable, as language barriers could hinder the effectiveness of awareness campaigns, evacuation procedures, and post-disaster recovery opportunities. Racial and ethnicity diversity is low for the tsunami-prone areas of the Oregon coast, where 96 percent of all residents in the Oregon tsunami-inundation zone identified themselves in the 2000 Census as White, either alone or in combination with one or more other races (table 1), and the percentage of this demographic group ranges from 91 to 100 percent within the cities and the unincorporated county lands. Other reported races for residents in tsunami-prone areas of the Oregon coast include Black or African American (1 percent), American Indian and Alaska Native (3 percent) and Native Hawaiian and Other Pacific Islander (less than 1 percent). The percentage of Hispanic populations in the tsunami-inundation zone is also low (4 percent). Race percentages do not sum to 100 percent because individuals were able to report multiple races in the 2000 Census. Comparisons of the race and ethnicity of

Table 1. Block-level demographic characteristics for residential populations in the Oregon tsunami-inundation zone, based on the 2000 Census.

Population	Tsunami-Inundation Zone	Study Area Total	Tsunami-Zone Percentage[1]	Study Area Percentage[1]	Maximum City Percentage
Total Population	22,201	611,645	4%	n/a	85%
Hispanic or Latino Population	827	26,011	4%	4%	8%
Race—White alone or in combination with one or more other races	21,236	578,171	96%[2]	95%[2]	100%
Race—Black or African American alone or in combination with one or more other races	118	5,594	1%[2]	1%[2]	6%
Race—American Indian and Alaska Native alone or in combination with one or more other races	610	19,392	3%[2]	3%[2]	7%
Race—Asian alone or in combination with one or more other races	322	12,552	1%[2]	2%[2]	3%
Race—Native Hawaiian and Other Pacific Islander alone or in combination with one or more other races	62	2,202	0%[2]	0%[2]	2%
Population under five years old	975	33,476	4%	5%	8%
Population over 65 years	4,867	97,518	22%	16%	45%
Female population	11,400	310,830	51%	51%	58%
Number of Households	10,201	250,229	4%	n/a	86%
Renter-Occupied Households	3,795	86,201	37%	34%	56%
Single-Mother Households	559	15,671	5%	6%	12%

[1]In-hazard percentages refer the percentage of individuals (or households for the last two rows) in the tsunami-inundation of a specific demographic category. Study-area percentages refer to the percentage of individuals (or households for the last two rows) in the seven coastal counties of a specific demographic category.

[2]The sum of percentages by race will not sum to 100%, as individuals are able to report multiple race categories in U.S. Census Bureau reports.

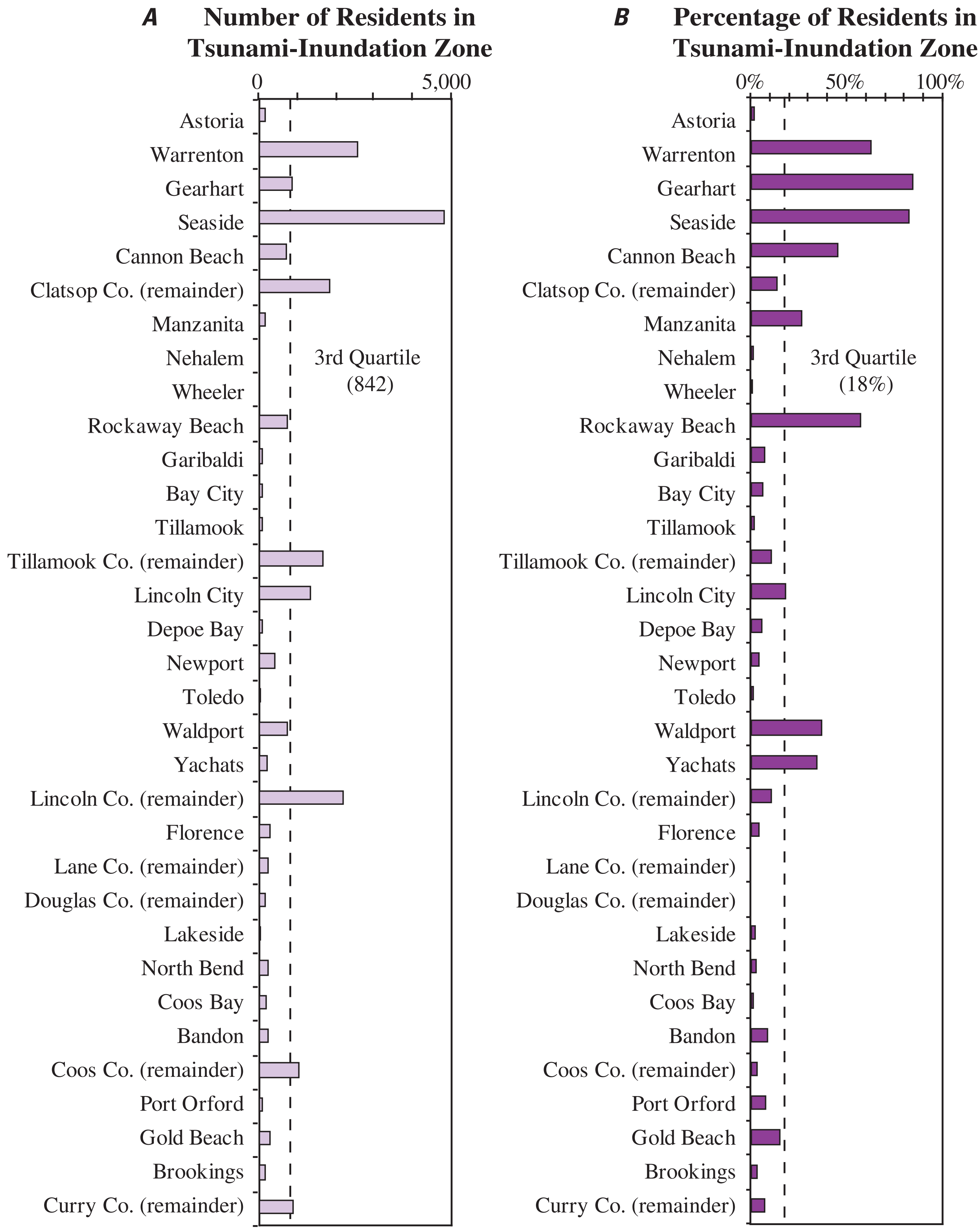


Figure 10. Number (*A*) and percentage (*B*) of residents in the Oregon tsunami-inundation zone.

residents in tsunami-prone areas to that of the entire study-area population indicate that no group is disproportionately represented in tsunami-prone areas (table 1).

Another demographic characteristic that influences an individual's sensitivity is age (Morrow, 1999; Ngo, 2001; Balaban, 2006; Laska and Morrow, 2007; McGuire and others, 2007). For example, a survey of Indonesian households impacted by the 2004 Sumatra-Andaman tsunami demonstrated that mortality was highest for the youngest and oldest age groups (Rofi and others, 2007). Younger populations, defined here as less than 5 years in age, often require direction and assistance to evacuate due to their immaturity and size. They are also prone to developing post-traumatic stress disorders, depressions, anxieties, and behavioral disorders as a result of their inability to comprehend and process effects of a disaster (Balaban, 2006). Results indicate that 4 percent of individuals in the Oregon tsunami-inundation zone are younger populations, approximately equal to the State percentage, and the percentage of younger populations in the hazard-prone areas of the 26 cities and 7 unincorporated county lands ranges from 0 to 8 percent (table 1).

Older populations, defined here as residents over 65 years in age, may also have special needs during and after a tsunami. Research suggests the older populations may require assistance in evacuation due to potential mobility and health issues or a reluctance to evacuate, may require special medical equipment at shelters (McGuire and others, 2007), and are more apt to lack social and economic resources to recover (Morrow, 1999; Ngo, 2001). Results indicate that 22 percent of individuals in the tsunami-inundation zone are older populations, higher than the 16 percent for the entire study area. The percentage of older populations in tsunami-prone land of the 26 cities and 7 unincorporated county lands varies considerably in this study area, ranging from 10 percent in Bay City to 45 percent in Bandon (fig. 11*A*). It may be difficult to quickly evacuate older populations from tsunami-prone areas, given their potential health and mobility issues and the limited time between earthquake ground-shaking and tsunami inundation (30 minutes in some communities). If a tsunami were to occur in the winter months, emergency shelters may not adequately protect older populations from exposure to low air temperatures and high precipitation (common during winter months on the Oregon coast), causing further health complications for older populations. Therefore, communities with high percentages of older populations in tsunami-prone land (for example, Manzanita, Yachats, Bandon, and Port Orford) may need special evacuation and relief procedures for this demographic group.

Gender differences also influence an individual's sensitivity to a stressor (Enarson and Morrow, 1998; Bateman and Edwards, 2002). Preliminary work by Oxfam (2005) in the wake of the 2004 Sumatra-Andaman tsunami indicates that women had a disproportionately higher mortality rate. Research of gender differences to natural hazards indicates that women tend to have higher risk perceptions, demonstrate higher preparedness planning, and are more likely to respond to warnings than men but also are more likely to be single parents or primary care givers, have special medical needs, have lower incomes, and less autonomy than males. Research also indicates that there are more documented reports after natural disasters of women with post-traumatic stress (Ollenberger and Tobin, 1998) and of abuse against women (Enarson, 1999). The heightened vulnerability of women to extreme events is believed to be a reflection of broader cultural, political, and economic inequalities within a society and not due to physical differences of the sexes (Morrow, 1999; Bateman and Edwards, 2002). Results indicate that 51 percent of residents in the tsunami-inundation zone are women, identical to the study area percentage. For the individual jurisdictions, the percentage of residents in the tsunami-inundation zone that are female ranges from 42 percent (unincorporated Douglas County) to 58 percent (City of Bandon). Results also indicate that 5 percent of households in the tsunami-inundation zone are single-mother households, slightly lower than the 6 percent for the study area. Single-mother households may have unique evacuation and recovery issues, as they are more likely to have limited mobility and fewer financial resources (Laska and Morrow, 2007). The percentage of single-mother households in tsunami-prone land ranges from zero percent in Wheeler to 12 percent in Waldport and Nehalem (fig. 11*B*), although the high percentage in Nehalem reflects a small number of households in its hazard zone.

Tenancy is another factor that influences individual sensitivity to stressors, as studies have shown that renters are less likely than homeowners to prepare for catastrophic events (Morrow, 1999; Burby and others, 2003). Theories on why this is the case include (1) higher turnover rates for renters that may limit their exposure to hazard information, (2) preparedness campaigns may pay less attention to renters, (3) renters typically have lower incomes and fewer resources to prepare, and (4) renters may lack the motivation to invest in mitigation measures for rented property (Burby and others, 2003). After a disaster, renters also have little control over the speed with which rental housing is repaired or replaced (Laska and Morrow, 2007). Results indicate that 37 percent of households in the tsunami-inundation zone are renter-occupied (table 1), and values within the jurisdictions range from 10 percent (City of Wheeler) to 56 percent (City of North Bend) (fig. 11*C*).

Demographic characteristics germane to societal vulnerability that are available at census block-group and tract levels (Cutter and others, 2003) are summarized for each county in the study area (fig. 12). Following the disaster pressure and release model (Wisner and others, 2004), vulnerability is the characteristics of a group that influences their ability to anticipate and cope with the impacts of a natural hazard; attributes summarized in figure 12 are pre-event characteristics that could attenuate or amplify the societal impact of a tsunami, or any natural hazard for that matter. Results indicate that the seven counties are below Oregon and National averages in terms of households earning more than $75,000, slightly above Oregon and National averages in the percent-

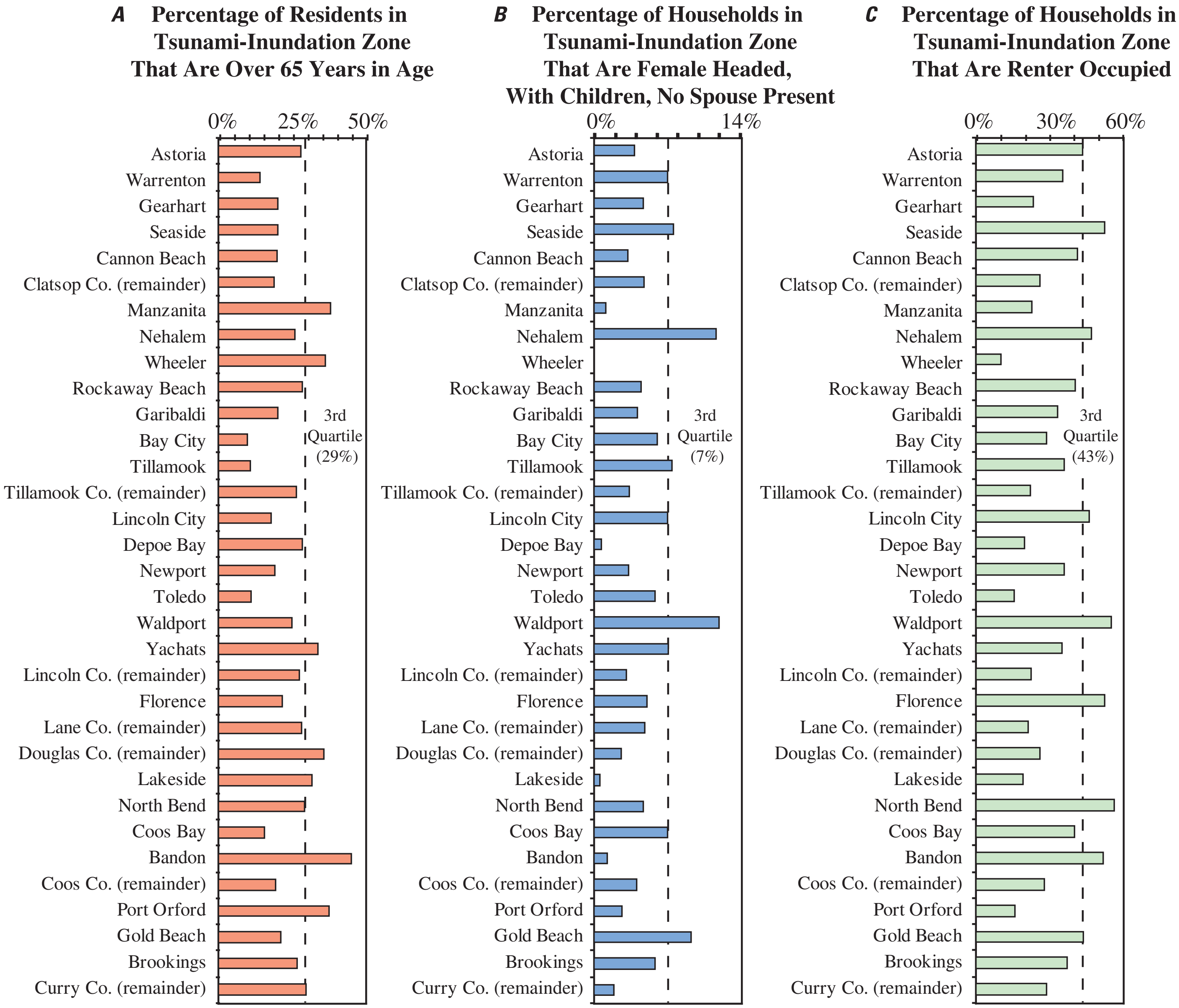


Figure 11. Percentage of residential population in the tsunami-inundation zone that is (*A*) residents over 65 years in age, (*B*) female-headed households, with children, no spouse present, and (*C*) renter-occupied households.

age of population for whom poverty status is determined and in the percentage of civilian labor force unemployed, and are greatly above Oregon and National averages in the percentage of housing units that are mobile homes and in the percentage of households receiving Social Security benefits. The percentage of population 25 years or older with no high school diploma in the 7 counties fall between the Oregon (14.9 percent) and National (19.6 percent) averages. Overall, these socioeconomic indicators suggest that post-tsunami recovery could be slow on the Oregon coast, considering the relatively low income levels, the high dependence on Federal benefits, and the high number of residents living in mobile homes.

Employees

The tsunami-inundation zone contains 14,857 employees at 1,829 businesses, representing 7 percent of the businesses and 6 percent of the employees in the seven counties (table 2). Third-quartile values for the amount and percentage of employees working in the tsunami-inundation zone of the 26 cities and 7 counties are 455 employees and 31 percent of a jurisdiction's workforce. Similar to residential populations, the amount (fig. 13*A*) and percentage (fig. 13*B*) of employee populations in the tsunami-inundation zone vary considerably in the study area, with higher amounts and percentages in the more-northern cities. Some cities, such as Seaside and Warrenton, have high

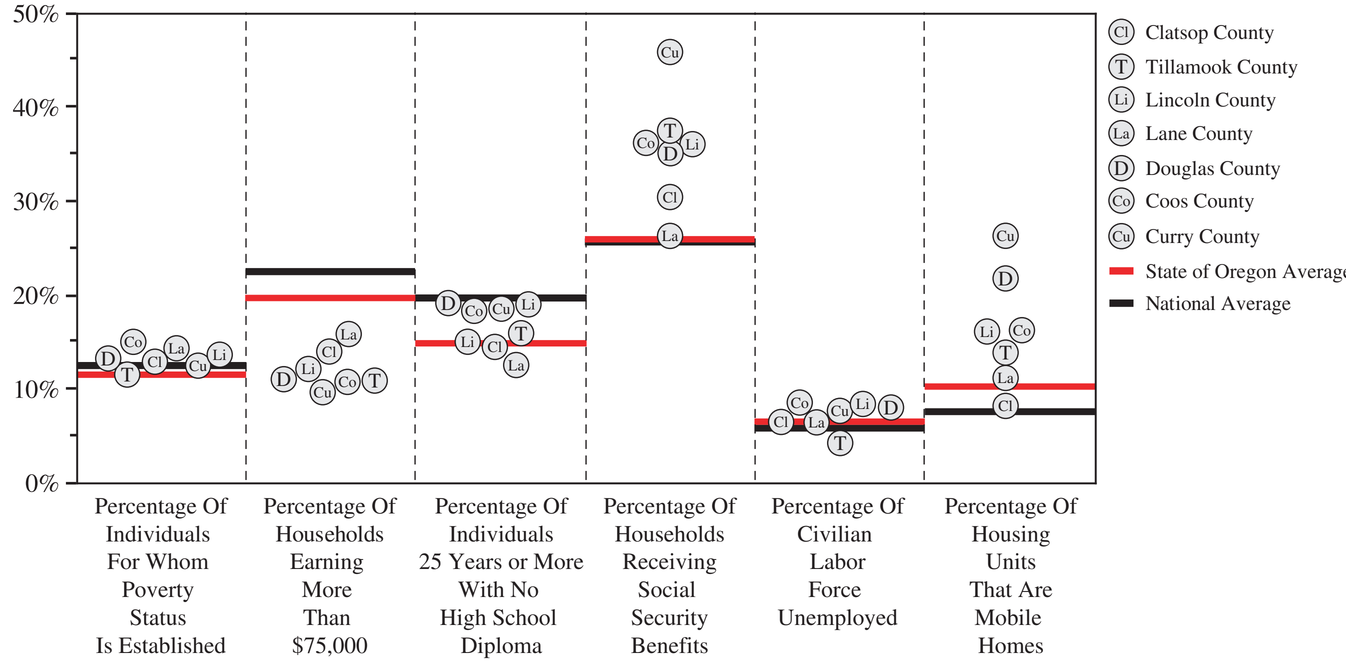


Figure 12. Blockgroup- and tract-level demographic characteristics for residential populations in Oregon coastal counties, based on the 2000 Census.

Table 2. Amount and percentage of economic assets in the Oregon tsunami-inundation zone.

Economic Asset	Inundation Zone	Study Area Total	Percentage
Businesses	1,829	26,775	7%
Employees	14,857	251,227	6%
Sales volume (in U.S. dollars)	$1,881,774,000	$38,000,598,000	5%
Total tax-parcel value (in U.S. dollars)	$8,158,045,904	$68,343,196,747	12%

numbers of employees in the tsunami-inundation zone (3,446 and 1,764, respectively) that represent high percentages of their total workforce (89 percent and 64 percent, respectively). Other cities have much lower numbers of employees in the tsunami-inundation zone, including Gearhart (365) and Rockaway Beach (355), but these amounts represent the majority of the local workforce (73 percent and 68 percent, respectively). Unlike the residential data, there are not large numbers of employees in the tsunami-prone portions of unincorporated county land.

Dependents

Several dependent-population facilities are in the tsunami-inundation zone (table 3), including 14 schools, 10 adult-residential-care centers, 9 outpatient-care facilities and 7 child-day-care centers, and many of these facilities are in northern cities (fig. 14). Additional evacuation planning may be required in communities with high dependent populations (for example, the City of Seaside) due to the limited mobility of certain groups, such as those in schools and nursing homes. Traditional relief efforts may need to be augmented if a community has a significant adult residential care population due to potential health complications after a disaster. In addition to unique evacuation and relief issues, many dependent-population facilities represent critical social services that, if lost, could slow community recovery following an extreme event. For example, the loss of child-day-care facilities or schools could keep some parents from returning to their jobs until suitable arrangements can be made for their children and, in smaller communities, this delay

Table 3. Amount and percentage of dependent-population facilities in the Oregon tsunami-inundation zone.

Facility	Inundation Zone	Study Area Total	Percentage
Adult-residential-care facilities	10	213	5%
Child-day-care facilities	7	139	5%
Correctional facilities	1	16	6%
Hospitals	0	18	0%
Outpatient-care facilities	9	420	2%
Psychiatric and substance abuse hospitals	2	22	9%
Schools	14	412	3%

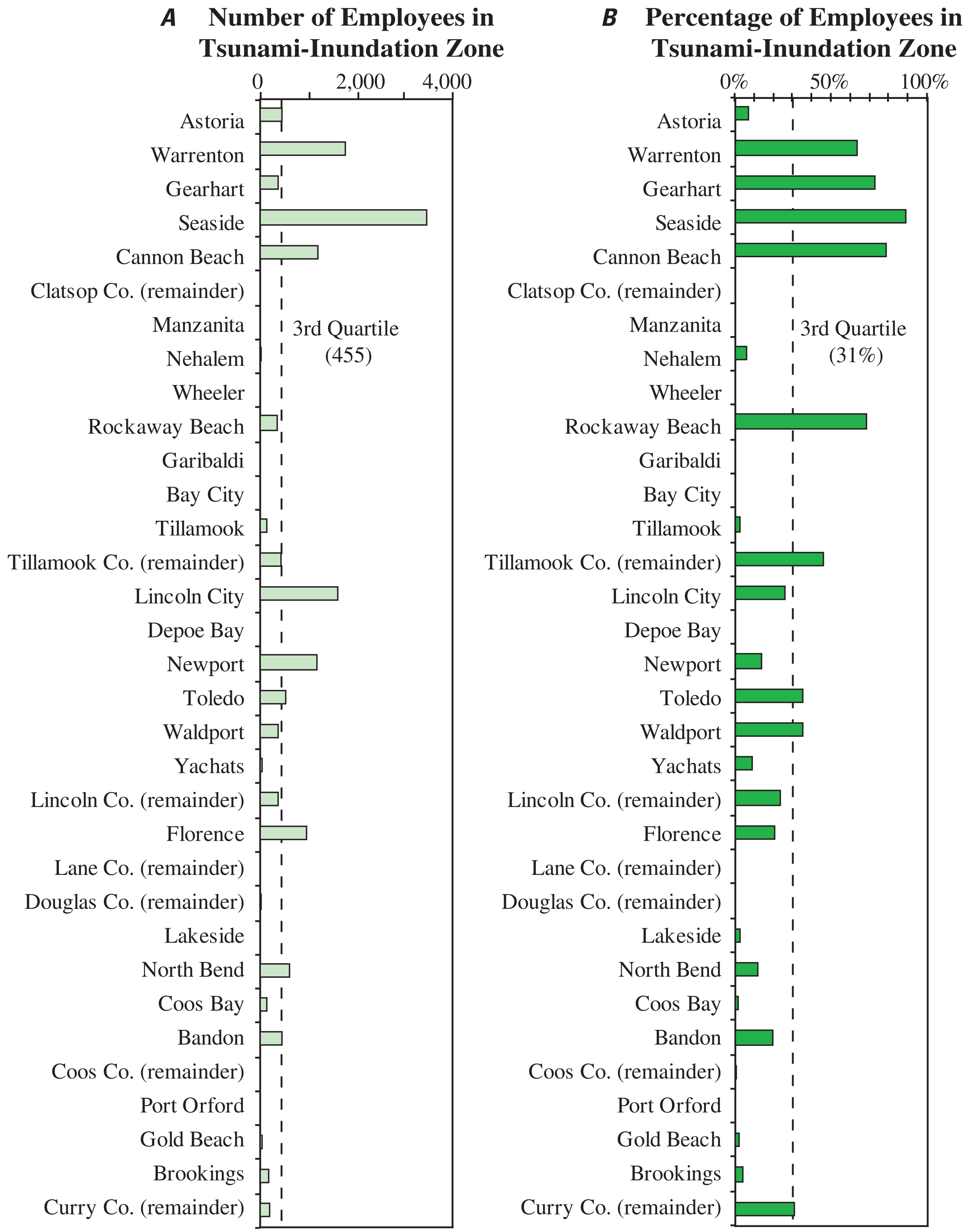


Figure 13. Number (*A*) and percentage (*B*) of employees in the Oregon tsunami-inundation zone.

could take weeks. Therefore, although a business may escape debilitating physical damage from the original earthquake or tsunami, it may suffer economic damages as a result of staffing challenges associated with the loss of community services.

Public Venues

There are several public venues in the tsunami-inundation zone that likely attract high numbers of local populations and tourists, including 34 religious facilities and 8 libraries (table 4). Similar to dependent-population facilities, the highest numbers of public venues in the tsunami-inundation zone are in the City of Seaside and other northern cities (fig. 15). The high numbers of public venues in the tsunami-inundation zone present both challenges and opportunities for the emergency-management community. An obvious challenge is the large number of individuals that would be in the tsunami-inundation zone if an event were to occur during a high-occupancy time (for example, during a religious service). The presence of public venues in the tsunami-inundation zone, however, also presents an outreach opportunity for county and State emergency managers to work with owners and employees of these public venues to further educate local populations and to reach tourist populations.

The tsunami-inundation zone contains 171 overnight-tourist facilities (including bed and breakfasts, cabins, camps, campgrounds, health resorts, hostels, hotels, inns, resorts, and tourist accommodations), representing 25 percent of all such facilities in the seven coastal counties and 43 percent of these facilities are in the City of Seaside (fig. 16). Five overnight-tourist facilities is the regional third-quartile value, indicating that most cities do not have many of these businesses in the tsunami-inundation zone. Most overnight-tourist facilities in the tsunami-inundation zone are clustered in only a few cities, such as Seaside (43), Lincoln City (28), Cannon Beach (24),

Table 4. Amount and percentage of public venues in the Oregon tsunami-inundation zone.

Public Venue	Inundation Zone	Study Area	Percentage
Aquariums	2	3	67%
Botanical gardens	0	1	0%
Casinos	2	5	40%
Colleges and universities	3	29	10%
Libraries	8	66	12%
Museums	3	33	9%
Parks	1	43	2%
Religious organizations	34	817	4%
Shopping centers and malls	1	9	11%
Sporting facilities	0	4	0%
Theaters	6	46	13%
Zoos	0	0	0%

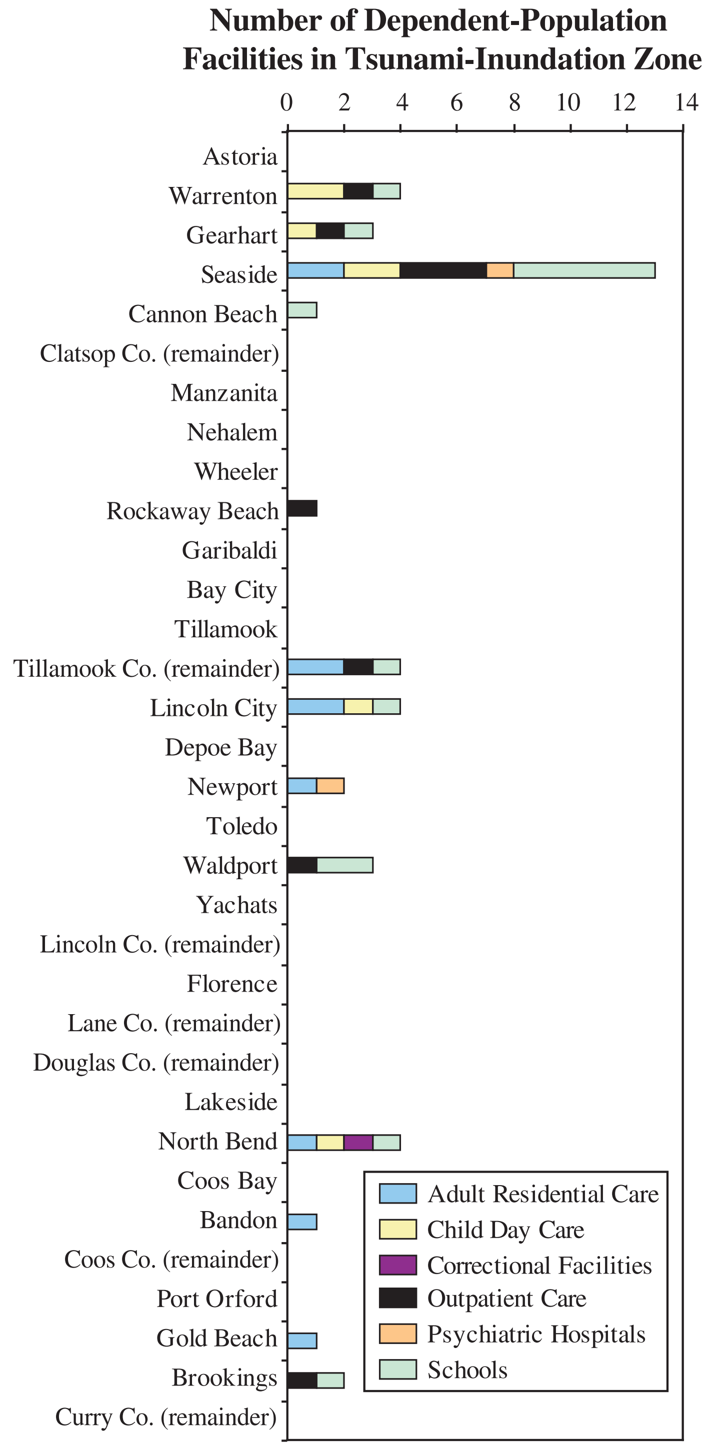


Figure 14. Number of dependent-population facilities in the Oregon tsunami-inundation zone.

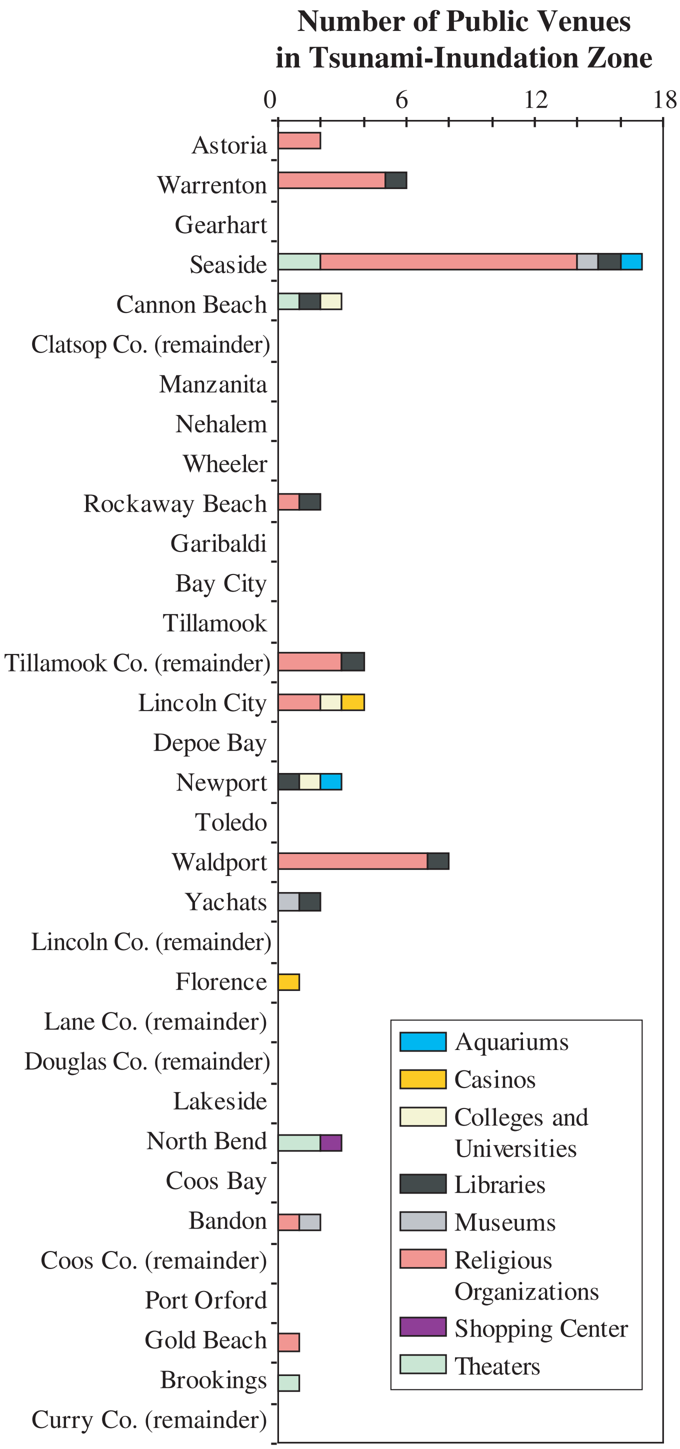


Figure 15. Number of public venues in the Oregon tsunami-inundation zone.

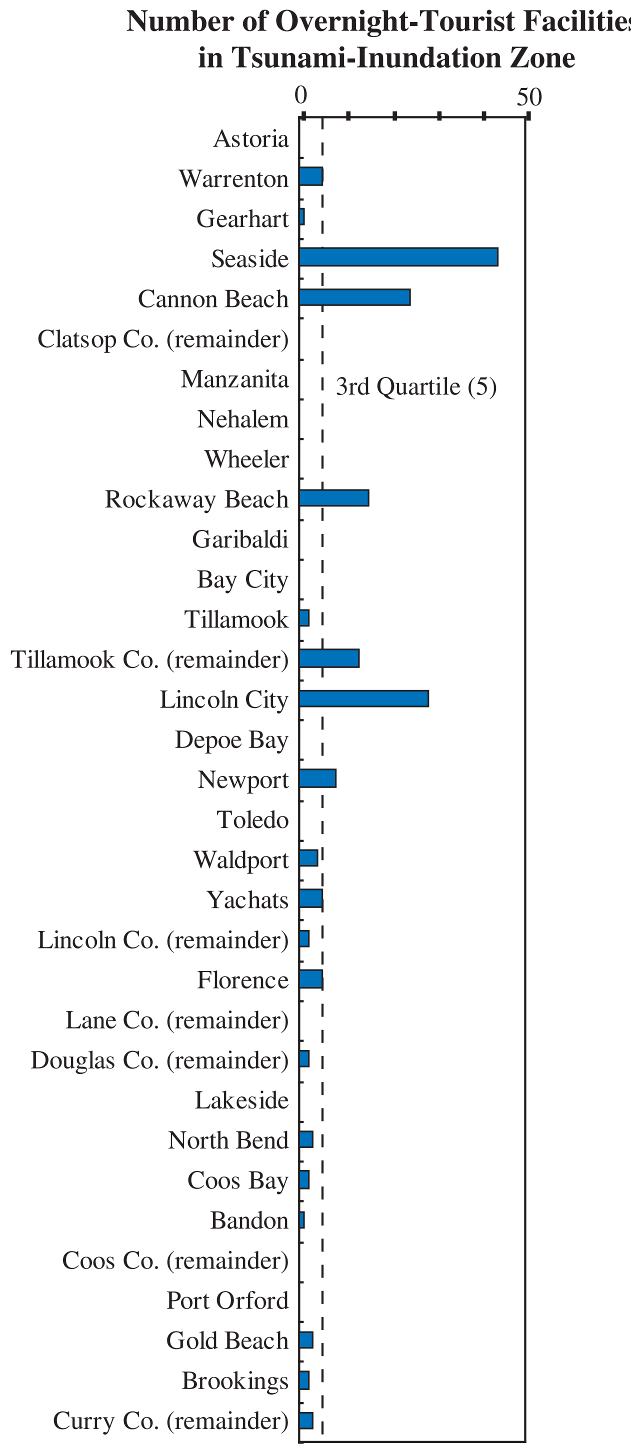


Figure 16. Number of overnight-tourist facilities in the Oregon tsunami-inundation zone.

and Rockaway Beach (15). Although tourist-related lodging in tsunami-prone areas provides some insight on tourist exposure, the number of tourists at risk is likely much greater, due to the number of unaccountable individuals staying with friends and family and those who go to the coast during the day but stay at hotels outside of the tsunami-inundation zone.

The sum of the annual-average number of visitors (1998–2003) to 66 Oregon State Parks in the tsunami-inundation zone is 19,605,770 people per year. Assuming an equal distribution of visitors on every day of the year, this corresponds to 53,714 day-use visitors to Oregon State Parks on average every day. In reality, this number is low because attendance is not equally distributed throughout the year; there will be seasonal peaks in park attendance (for example, summer months and holidays). The highest annual average number of day-use visitors for the 66 parks are for D River State Recreation Site (1,175,581 visitors per year and near Lincoln City) and Yaquina Bay State Recreation site (1,135,584 visitors per year and near Newport) (fig. 17*A*). After adding the number of day-use visitors at parks based on nearby incorporated cities, it is clear that the majority of visitors are going to parks in the central Oregon coast (fig. 17*B*); for example, 44 percent of the Oregon State Park visitors are going to parks in Lincoln County. The highest percentages are for parks near the cities of Newport (19 percent) and Lincoln City (11 percent). Coastal parks in southern Oregon, specifically those in Curry County, also see a significant number of park visitors; an interesting finding because coastal cities in this area have otherwise low amounts of assets in the tsunami-inundation zone.

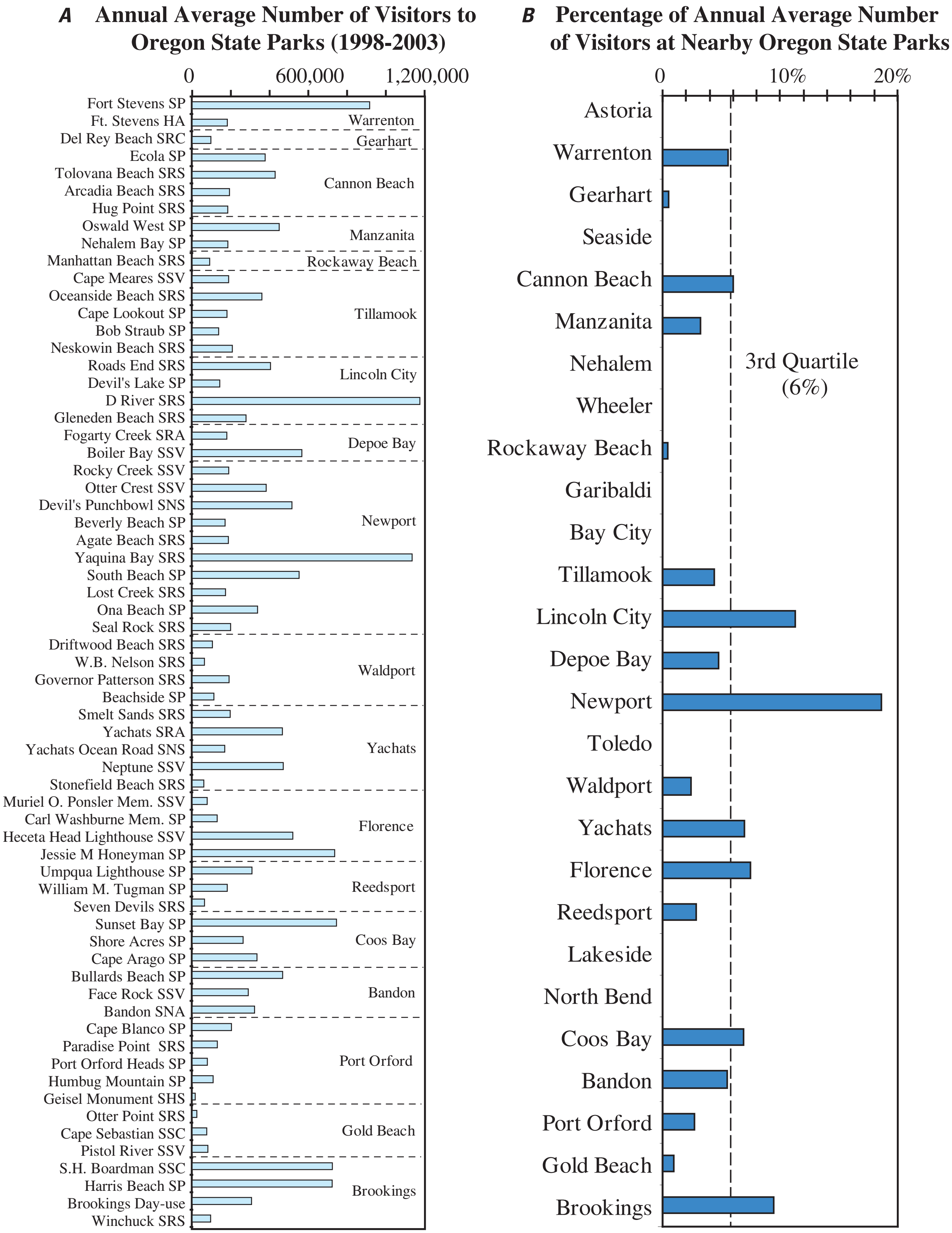
Economic Assets

The tsunami-inundation zone contains parcel values collectively assessed at approximately $8.2 billion, representing 12 percent of the total tax-parcel value in the seven counties (table 3). The amount (fig. 18*A*) and percentage (fig. 18*B*) of total tax parcel value in the tsunami-inundation zone varies significantly across the study area. The third-quartile value for total tax-parcel value in the tsunami-inundation zone among the 26 cities and 7 unincorporated county lands is approximately $361 million. The highest total exposed tax parcel values in the incorporated cities are in Seaside ($843 million) and Cannon Beach ($605 million), representing 90 percent and 69 percent, respectively, of the total tax base in these cities. The highest total exposed parcels value for the region is the rural portion of Tillamook County (approximately $1.2 billion), reflecting the unincorporated towns of Cape Meares, Cloverdale, Oceanside, Neskowin, Netarts, and Pacific City. The unincorporated portions of the other counties, specifically Clatsop and Lincoln, also have high total parcel values in the tsunami-inundation zone. As is the case with residential and employee distributions, some cities (for example, Gearhart, Toledo, and Yachats) have relatively low amounts of tax parcel value in the tsunami-inundation zones but the exposed parcels represent a high percentage of a city's total tax base. Building damages due to CSZ-related tsunamis, as well as from the preceding earthquake, could significantly lower the content value of individual properties, thereby lowering the tax base of a community after a tsunami disaster, and reducing the funds available for long-term recovery.

Results indicate that there are 1,829 businesses with 14,857 employees that generate over $1.9 billion in sales volume in the Oregon tsunami-inundation zone, representing seven percent of all businesses, six percent of employees, and five percent of generated sales volume in the seven coastal counties (table 2). High percentages of employees in tsunami-inundation zone represent economic fragility for a community, as unemployment could increase dramatically overnight if a tsunami injures or kills employees or if it damages or destroys businesses. Even if a business escapes damage or physical disruption due to an extreme event, it may still experience significant customer and revenue loss if the neighborhood and other businesses around it are damaged, leading customers to shop elsewhere. Neighborhood effects have been found to be especially important for retailers that rely on foot traffic (Chang and Falit-Baiamonte, 2002), a potentially significant issue for tourist-related retail and food services within Oregon coastal communities. Therefore, knowing where there are high numbers and percentages of employees can help identify potential economic recovery issues.

Results indicate that cities on the northern Oregon coast have the highest percentages of their employees in the tsunami-inundation zone (fig. 13*B*), including Seaside (89 percent), Cannon Beach (79 percent), Gearhart (73 percent), and Rockaway Beach (68 percent). Some cities have high numbers of employees in tsunami-inundation zones but these numbers represent a small proportion of the local economy; for example, there are 1,185 employees in the tsunami-inundation zone in the City of Newport, but these employees only represent 14 percent of the city's workforce. Smaller cities, such as Gearhart and Rockaway Beach have much smaller numbers of employees in their tsunami-inundation zones (365 and 355 employees, respectively), but face relatively larger economic threats from a tsunami than Newport because of the larger employee percentages (73 percent and 68 percent, respectively).

Societal vulnerability is also influenced by the types of businesses in the tsunami-inundation zone. If the dominant business sectors in the tsunami-inundation zone are accommodations and food services, then a primary concern for local responders is the high number of tourists likely in danger. If the businesses are primarily manufacturing facilities, response issues may center instead on employees and the potential for hazardous-material spills. The highest numbers of employees in the seven Oregon coastal counties (fig. 19) are in retail trade (16 percent), accommodation and food services (12 percent), health care and social assistance (11 percent), and manufacturing (11 percent). Employee distributions for businesses in the tsunami-inundation zone are similar to the entire study area, except for an increase in the accommodation and food



Historical Area = HA; State Natural Area = SNA; State Park = SP; State Recreation Area = SRA; State Recreation Site = SRS; State Scenic Viewpoint = SSV.

Figure 17. Annual average number of visitors to coastal Oregon State Parks (1998-2003) illustrated (*A*) by the amount per State park and (*B*) as a percentage related to nearby incorporated cities.

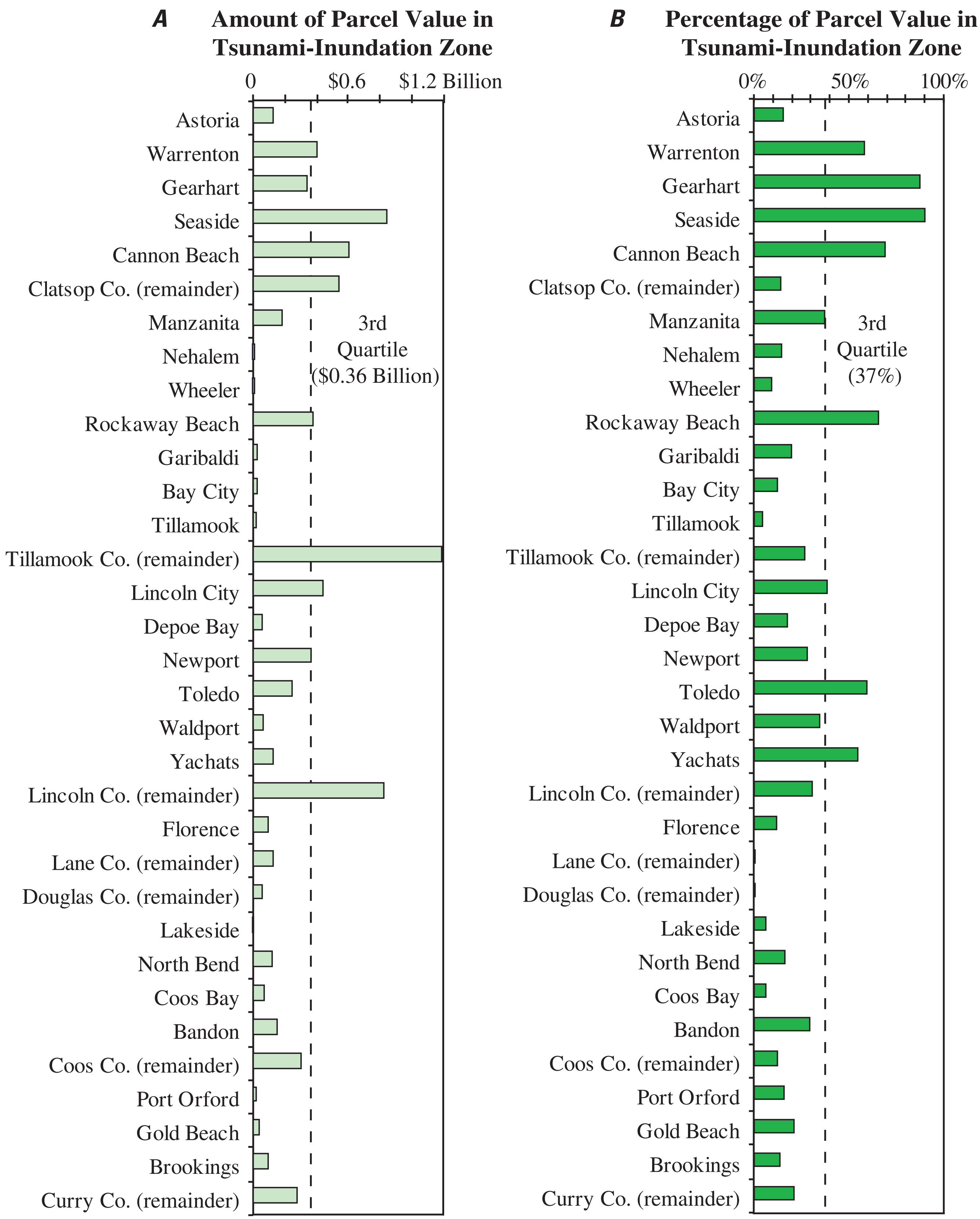


Figure 18. Amount (*A*) and percentage (*B*) of total tax-parcel value in the Oregon tsunami-inundation zone.

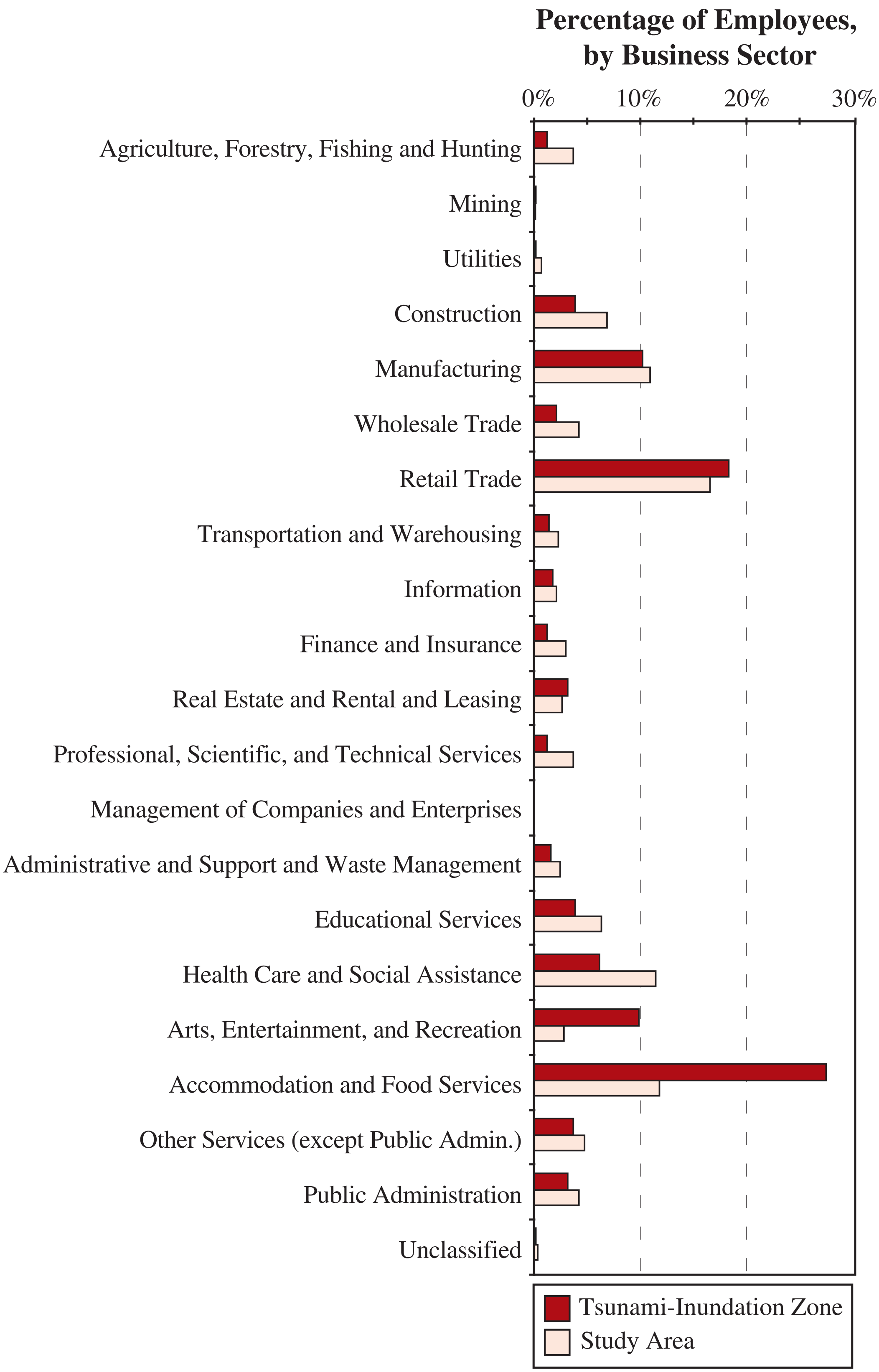


Figure 19. Percentage of employees, by business sector, in the Oregon tsunami-inundation zone.

services businesses (from 12 percent for all businesses to 27 percent for those in the tsunami zone), an increase in the arts, entertainment and recreation businesses (from 3 percent to 10 percent), and a decrease in health care and social assistance businesses (from 11 percent down to 6 percent).

The percentage of employees in the accommodation and food services sector for businesses in the tsunami-inundation zone (27 percent) is over three times the national average of 8.3 percent (2005 value) for the same industry sector (Bureau of Labor Statistics, 2007b), reflecting the dominance of the tourism sector along the Oregon coast (fig. 19). This dominance is also reflected in the high percentage of employees in the arts and entertainment sector for businesses in the tsunami-inundation zone (3 percent), a percentage twice the national average of 1.4 percent (Bureau of Labor Statistics, 2007b). The fourth highest employee percentages in the tsunami-prone areas are in the manufacturing sector (10 percent), demonstrating that many Oregon port and harbor communities are not simply tourist destinations but are also working ports with significant seafood- and timber-processing businesses. The high percentage of retail trade, accommodations and food services, and arts and entertainment sectors indicate that the tsunami-inundation zone likely contains significant tourist populations. The high percentage of manufacturing facilities indicate that the tsunami-inundation zone also likely contains hazardous material and heavy machinery (both commonly found in industrial zones) that could be dispersed and transported throughout an estuary during a tsunami. In addition to providing emergency managers with estimate of potential impacts from a tsunami, this information also helps economic planners determine the type of business continuity planning needed before a disaster and recovery assistance after a disaster. A mixed economy with strong retail, accommodations and food services, and manufacturing sectors indicate that economic recovery along the Oregon coast will be multifaceted, with each sector having different needs.

Critical and Essential Facilities

Several critical and essential facilities are in the Oregon tsunami-inundation zone (table 5). The low number of exposed hospitals (0) and outpatient-care centers (1), but high number of exposed physician and dentist offices (27), indicates that hospitals may be able to handle casualties and injuries during the immediate response phase of a disaster but some communities may experience difficulties in maintaining medical services during the longer-term recovery phase if they lose a significant number of doctor offices. Long-term community recovery also may also be hampered by the potential loss of the numerous essential facilities in the tsunami-inundation zone, including government offices (21), banks and credit unions (16), grocery stores (15) and U.S. Post Offices (12). Information on types of facilities within each city and whether they are in the tsunami-inundation zone is available in the accompanying database (appendix B).

In most cases, the percentages are low for most categories when comparing critical and essential facilities in the tsunami-inundation zone to the entire study area (table 5). Therefore, local populations could be inconvenienced by the loss of specific facilities in their communities but may be able to find the services elsewhere. A next step for analysis is to determine the redundancy of facility functions in a city or across the region. For example, results indicate that several police stations (8) are in the Oregon tsunami-inundation zone. If neighboring communities both lost their police stations, then the ability to maintain order for that area is compromised even more. However, if one town loses a station and the other does not, resources could possibly be shared between communities. Facility access is another area for further research. For example, results indicate that the hospital in the City of Seaside is not in the tsunami-inundation zone. However, assuming the hospital in Seaside escapes damage from the CSZ-related earthquake and associated tsunamis, neighboring communi-

Table 5. Amount and percentage of critical and essential facilities in the Oregon tsunami-inundation zone.

	Tsunami-Inundation Zone	Study Area Total	Percentage
Critical facilities			
Civil-defense facilities	0	3	0%
Fire stations	5	58	9%
National-security facilities	4	31	13%
Police stations	8	65	12%
Ambulance services	0	13	0%
Hospitals	0	18	6%
Outpatient-care centers	1	53	2%
Electrical facilities	2	14	14%
Public-works facilities	2	43	5%
Gas facilities	0	11	0%
Radio and television facilities	3	53	6%
Waste-water facilities	1	15	7%
Water and sewer facilities	1	41	2%
Essential facilities			
Banks and credit unions	16	270	6%
Courts and legal offices	1	40	3%
Physician/Dentist Offices	27	648	4%
Gas stations	7	115	6%
Government offices	21	406	5%
Groceries	15	255	6%
International-affairs offices	0	0	0%
U.S. Post Offices	12	110	11%

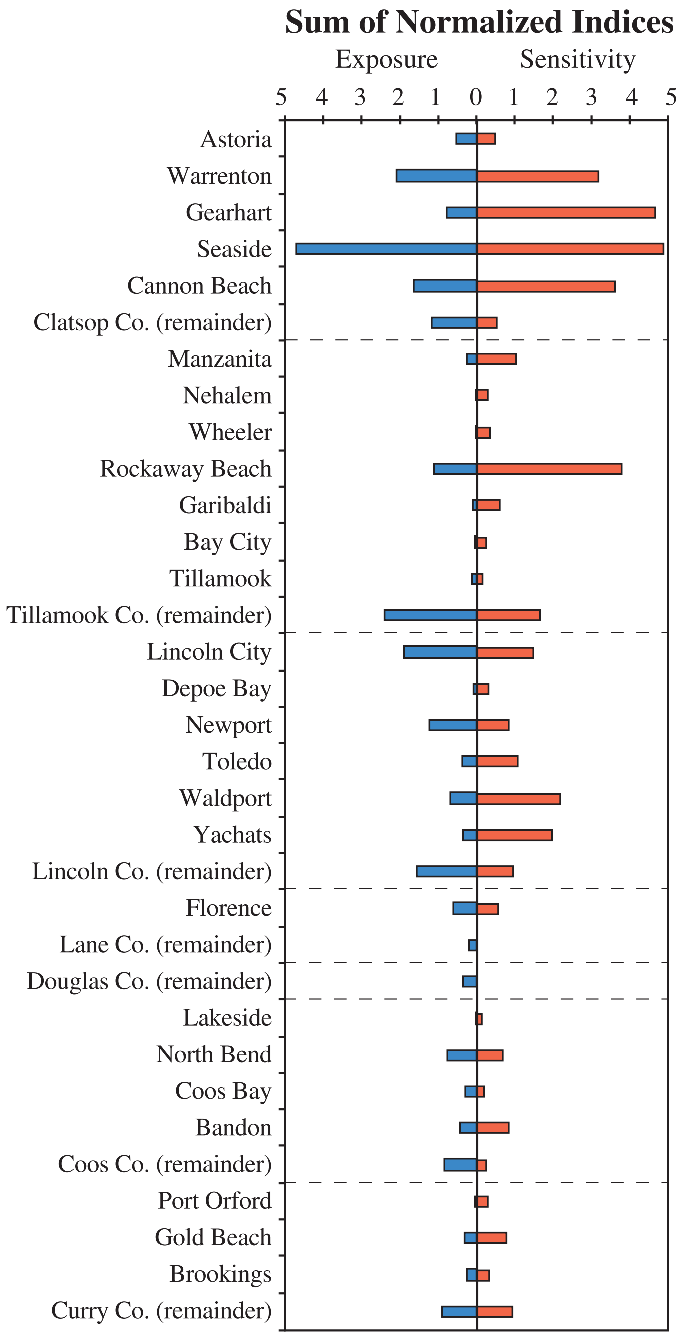


Figure 20. Comparison of normalized exposure and sensitivity indices for incorporated cities in the Oregon tsunami-inundation zone.

ties that rely on this hospital for medical services may have difficulty accessing the functioning facility on blocked or impaired roads, due to earthquake-related ground deformation and landslide debris or tsunami-related debris and deposition. For example, the City of Seaside was temporarily isolated from neighboring communities due to storm-related damage and flooding of access roads after a winter storm struck the region on 12/2/07 (Trappen, 2007). Therefore, although the percentage of critical and essential facilities in the Oregon tsunami-inundation zone is low, the ability to access these facilities on impaired roads and the level of dependency on critical facilities between communities are topics that require further analysis.

Composite Indices of Exposure and Sensitivity

Composite indices of exposure (based on amounts) and sensitivity (based on percentages) for each of the 26 cities and the 7 rural county areas are the sums of normalized data in 5 categories–developed land, residents, employees, public venues, and total parcel value. Table 6 summarizes the composite exposure and sensitivity values (each with a range from 0 to 5) for the 26 cities and 7 unincorporated county lands where higher values indicate higher relative exposure or sensitivity. Figure 20 provides the same information in graphical form with the exposure scale vertically mirrored to facilitate visually comparisons of exposure and sensitivity values for individual cities. The City of Seaside has the highest composite exposure value (4.7) and composite sensitivity value (4.9), indicating that this city consistently has the highest amount and percentage of assets in the tsunami-inundation zone (fig. 20). Results indicate that some cities (for example, Lincoln City) have higher relative exposure than sensitivity values, while others (for example, Rockaway Beach) have higher relative sensitivity than exposure (fig. 20).

A frequency histogram depicting the distribution of composite exposure and sensitivity values indicates that the City of Seaside is somewhat of an outlier of city vulnerability (fig. 21). The x-axis shows the composite values in 0.5 increments and the y-axis notes the number of jurisdictions. Most cities and unincorporated county lands have composite exposure values less than 1.0, indicating that they have considerably fewer assets in tsunami-prone areas than the City of Seaside. Although many communities also have composite sensitivity values less

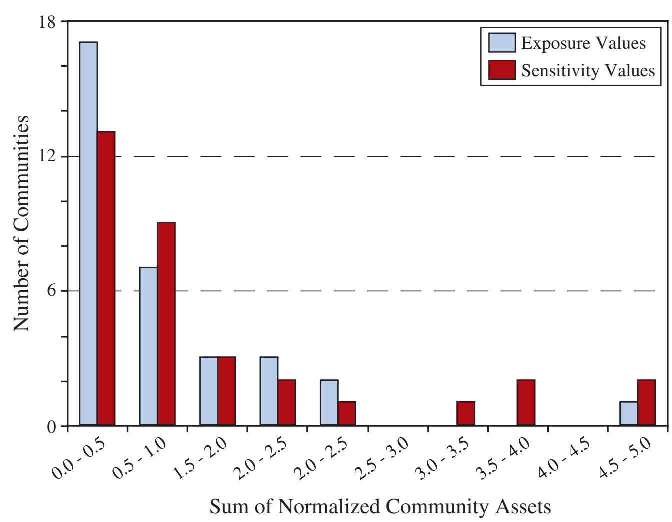


Figure 21. Frequency histogram of the sum of normalized exposure and sensitivity indices for incorporated cities in the Oregon tsunami-inundation zone.

Table 6. Composite exposure and sensitivity values for cities in the Oregon tsunami-inundation zone.

Range	Composite Exposure Values	Composite Sensitivity Values
4.0 to 5.0	- Seaside	- Seaside - Gearhart
3.0 to 3.9		- Rockaway Beach - Cannon Beach - Warrenton
2.0 to 2.9	-Unincorporated Tillamook County (including Cape Meares, Cloverdale, Oceanside, Neskowin, Netarts, and Pacific City) - Warrenton	- Waldport
1.0 to 1.9	- Lincoln City - Cannon Beach - Unincorporated Lincoln County (including Lincoln Beach and Rose Lodge) - Newport - Unincorporated Clatsop County - Rockaway Beach	- Yachats - Unincorporated Tillamook County (including Cape Meares, Cloverdale, Oceanside, Neskowin, Netarts, and Pacific City) - Lincoln City - Toledo - Manzanita
0 to 0.9	- Unincorporated Curry County (including Harbor) - Unincorporated Coos County (including Barview and Bunker Hill) - Gearhart - North Bend - Waldport - Florence - Astoria - Bandon - Toledo - Unincorporated Douglas County (including Winchester Bay) - Yachats - Gold Beach - Coos Bay - Brookings - Manzanita - Unincorporated Lane County - Tillamook - Garibaldi - Depoe Bay - Bay City - Port Orford - Wheeler - Nehalem - Lakeside	- Unincorporated Lincoln County (including Lincoln Beach and Rose Lodge) - Unincorporated Curry County (including Harbor) - Unincorporated Coos County (including Barview and Bunker Hill) - North Bend - Florence - Unincorporated Clatsop County - Astoria - Bandon - Unincorporated Douglas County (including Winchester Bay) - Gold Beach - Coos Bay - Brookings - Unincorporated Lane County - Tillamook - Garibaldi - Depoe Bay - Bay City - Port Orford - Wheeler - Nehalem - Lakeside

than 1.0, four cities have sensitivity values between 3.0 and 5.0 (Gearhart, Rockaway Beach, Cannon Beach, and Warrenton), indicating relatively high sensitivity to tsunamis similar to that of Seaside.

To provide some insight on which cities have the highest combined exposure and sensitivity to tsunamis, composite exposure and sensitivity values are normalized to maximum values found in each category and then added to create a combined exposure and sensitivity value (fig. 22). The City of Seaside has the highest combined exposure and sensitivity value of 2.0, indicating that it is the highest in both categories. The next highest combined values are for the cities of Gearhart, Warrenton, Cannon Beach, and Rockaway Beach, where high relative vulnerability is primarily due to high sensitivity. The unincorporated portion of Tillamook County has the sixth highest combined value.

Exposure and sensitivity comparisons are only first approximations of societal vulnerability because they do not include variations in resilience, the third component that influences vulnerability (Turner and others, 2003). The ability of a community to withstand, absorb, adapt to, and recover from losses defines its resilience, and—with other conditions

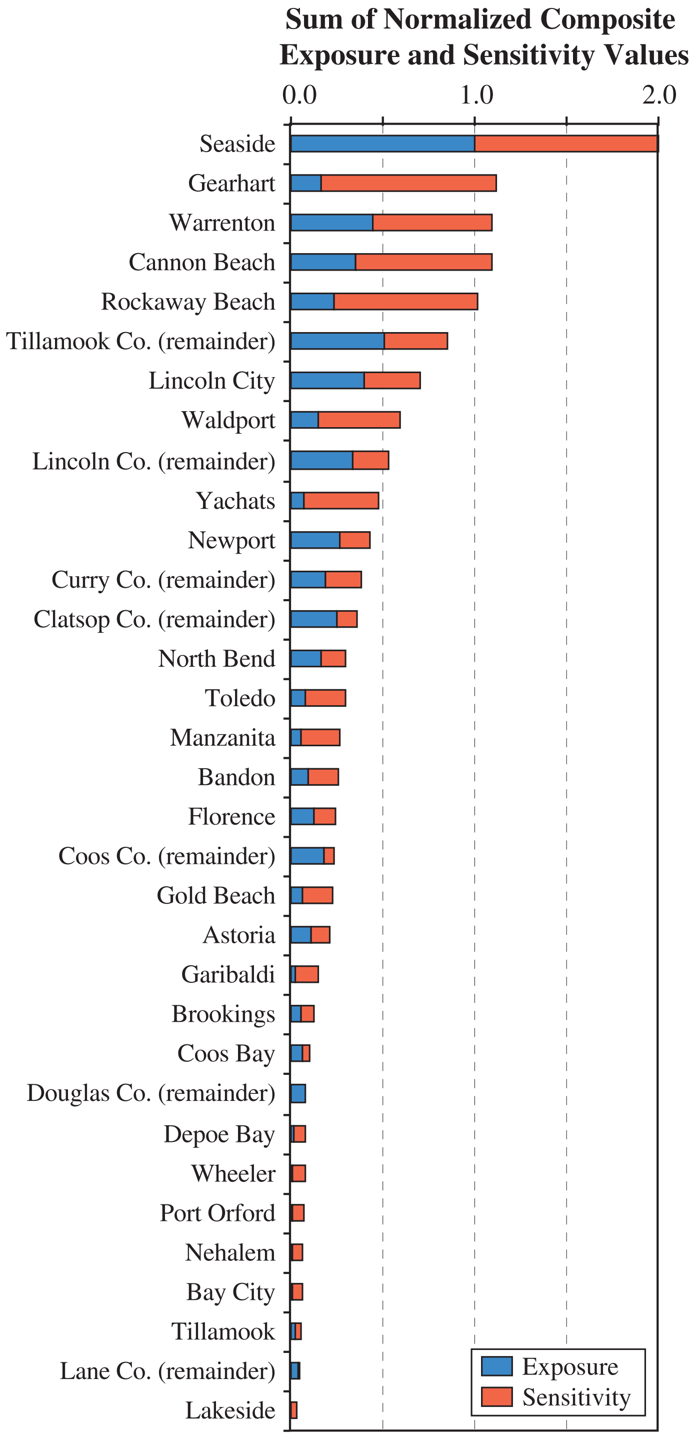


Figure 22. Sum of normalized exposure and sensitivity indices for incorporated cities in the Oregon tsunami-inundation zone.

remaining the same—greater resilience lowers a community's vulnerability to extreme events. For example, if two communities have identical community assets in tsunami-prone land, but one has a tsunami education program, a well-rehearsed evacuation plan, redundant critical infrastructure, and a holistic post-disaster recovery plan and has met the criteria for certification as a TsunamiReady community (National Weather Service, 2007), then that community is assumed to have greater resilience, resulting in more-efficient response operations and shorter recovery times after the extreme event. Despite similar asset distributions, the same extreme natural event may create a short-term crisis in the more resilient community and a longer-term disaster in the less-resilient community. Follow-up studies to document variations in potential community resilience would complement this report, providing the State of Oregon with a more complete understanding of societal vulnerability to tsunamis.

Statistical Relationship to Land Cover

Linear regression analyses were performed to test the hypothesis that distributions of city assets correlate to the distribution of city land (regardless of land-cover class) and were done for values of exposure (the amounts of land compared to the amounts of various assets in tsunami-inundation zones) and of sensitivity (the percentages of land compared to the percentage of various assets in tsunami-prone areas). Based on criteria of $p < 0.05$, results indicate that some, but not all relationships are significant (table 7). For exposure values, the relationships between the amount of tsunami-prone land in a city and the amounts of employees ($p = 0.52$) and tourist facilities ($p = 0.69$) in these areas are not statistically significant. Relationships are significant between the amount of land and the amount of developed land ($p = 0.01$), residents ($p = 0.03$), and total parcel value ($p < 0.01$); however, low explained variance (r^2) values for these assets (0.19, 0.15, and 0.27, respectively) suggest that the relationships, although statistically significant, are not strong. For sensitivity values, relationships are statistically significant between the percentage of city land in the tsunami-inundation zone and the percentage of city assets in the zone (all $p < 0.01$). Unlike the significant exposure relationships, r^2 values for sensitivity comparisons are strong, ranging from 0.64 for employees to as much as 0.87 for residents.

Two graphs are provided to help visualize the differences between the nonsignificant and significant relationships reported here. Figure 23*A* is a scatter-plot comparing the amount of city land in tsunami-inundation zones with the amount of employees in tsunami-inundation zones (both normalized to maximum values for comparison purposes) for the 33 geographic units. No significant relationship exists between the two datasets ($p = 0.52$, $r^2 = 0.01$) and the graph shows little discernible trend in the points. Figure 23*B* shows the percentage of city land compared to the percentage of employees, in which a statistically significant relationship is present and the

Table 7. Statistical results comparing land data and societal assets in the Oregon tsunami-inundation zone.

Regression significance between landcover with:	Exposure Values				Sensitivity Values			
	R	R^2	F*	P	R	R^2	F*	P
Developed Land	0.44	0.19	7.26*	0.01	0.92	0.85	174.35*	< 0.01
Residents	0.38	0.15	5.32*	0.03	0.93	0.87	212.19*	< 0.01
Employees	0.12	0.01	0.43	0.52	0.80	0.64	55.19*	< 0.01
Tourist facilities	0.07	0.01	0.17	0.69	0.87	0.76	99.03*	< 0.01
Total Parcels Value	0.52	0.27	11.27*	0.00	0.88	0.77	101.66*	< 0.01

*A regression relationship is considered significant at $p < 0.05$ if $F > 4.17$, as $F_{0.05(1),1,31} = 4.17$.

r^2 value of 0.64 is reflected in a distinct clustering of points around the regression line.

Results indicate that the amount of city assets in tsunami-inundation zones does not have a strong correlation with the amount of city land in these areas. In other words, two cities with the same amount of tsunami-prone land have made different land-use decisions on the amount of development in these threatened areas. Strong relationships between the percentages of city assets in the tsunami-inundation zone and the percentage of city land in this zone indicate that although there are few common patterns of asset distribution in the tsunami-inundation zone among cities, there is consistency within individual cities. Consequently, knowing the amount of tsunami-prone city land does not indicate the level of city exposure to tsunamis. However, knowing the percentage of city land in tsunami-prone areas can approximate how sensitive a city may be to a tsunami.

Summary

This report describes the landscape in the ORS 455 tsunami-inundation zone and compares city exposure and sensitivity to tsunamis. Based on a geospatial analysis of the distribution of developed land, populations, economic assets, and critical facilities relative to the Oregon tsunami-inundation zone, the following conclusions can be made:

(1) The majority of tsunami-prone land (95 percent) is classified as undeveloped, although these areas likely attract recreationists and provide ecosystem services to the region;

(2) A significant portion of the 22,201 residents in the tsunami-inundation zone is 65 years in age or older (45 percent in one city) or a renter (37 percent of the all households in the tsunami zone), indicating a need for unique preparedness, response, and recovery procedures in some cities;

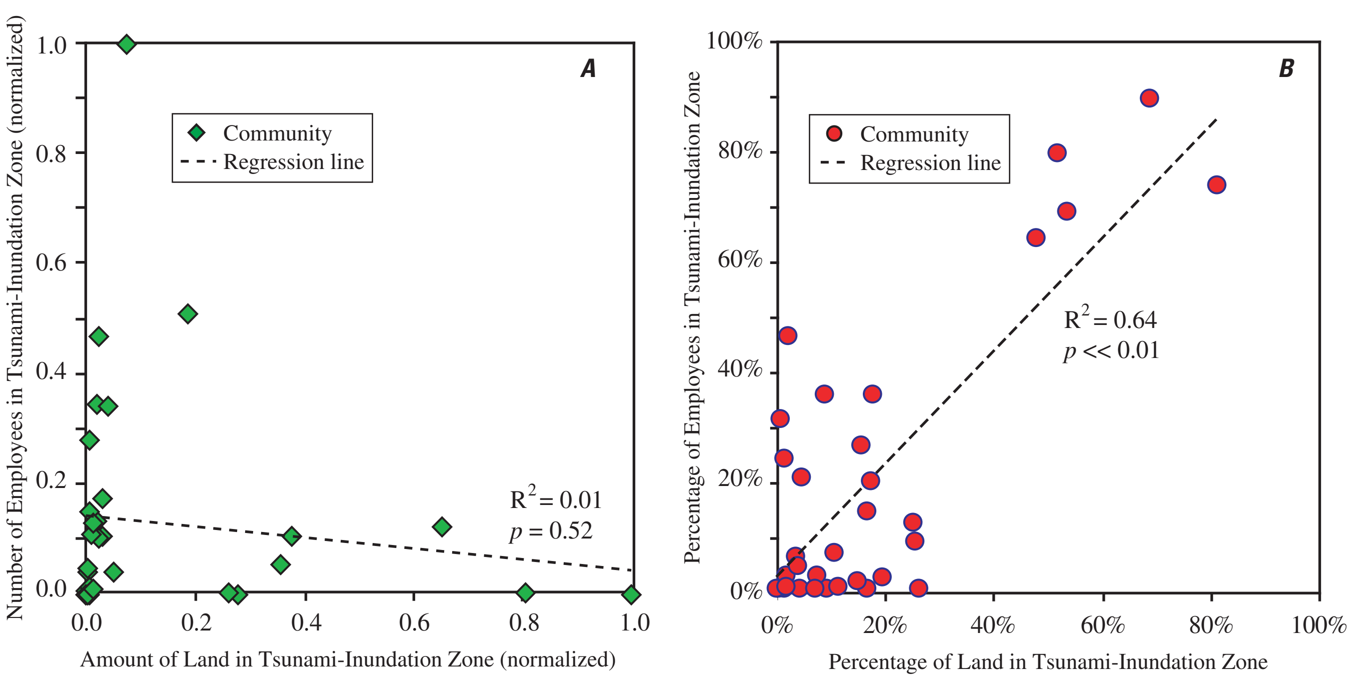


Figure 23. Scatter-plots comparing the amounts (*A*) and percentages (*B*) of land and of employees for incorporated cities in the Oregon tsunami-inundation zone.

(3) Thirty-six percent of the residents in the tsunami-inundation zone are in the unincorporated portions of the seven counties, indicating the importance of awareness programs and evacuation planning in rural communities;

(4) Nonresidential populations in the tsunami-inundation zone are significant, including 14,857 employees, 53,714 day-use visitors on average per day to Oregon State Park, and a high number of dependent-population facilities (for example, child- and adult-day care facilities), overnight-tourist accommodations, and public venues (for example, religious organizations);

(5) The 1,829 businesses in the tsunami-inundation zone are primarily retail trade, accommodation and food services, health services, or manufacturing, indicating variations in the amount of on-site customers and tourists that businesses must deal with in the event of a disaster and variations in the type of business continuity planning needed to facilitate post-disaster recovery;

(6) Economic recovery needs will vary across the region, with some cities potentially experiencing no direct business impact (Port Orford) and others possibly losing 89 percent of their workforce (Seaside);

(7) City exposure and sensitivity to tsunamis vary across the region with some cities having high amounts but low percentages of assets in the tsunami-inundation zone (for example, employees in Lincoln City and Newport) and others having low amounts that represent high percentages (for example, residents in Cannon Beach and Rockaway Beach);

(8) The City of Seaside has the highest amounts and percentages of developed land, residents, employees, dependent-population facilities, public venues, overnight facilities, and total parcel values of the 26 cities and seven counties with land in the tsunami-prone land; and

(9) Knowing the amount of tsunami-prone city land does not indicate the level of city exposure, but knowing the percentage of city land in the tsunami zone is an indicator of sensitivity.

Information presented in this report will further the dialogue on understanding societal risk to tsunami hazards in Oregon. Results can be used by public officials to determine where site-specific risk assessments and more-detailed tsunami-inundation modeling efforts may be warranted to further detail the threats posed by tsunamis to coastal communities in Oregon. Results can also be used by communities, private relief organizations, and emergency and land-use managers to augment regional mitigation, preparedness, response, and recovery strategies with site-specific efforts that reflect local conditions and needs. It is up to managers, policymakers, and private citizens to determine where to allocate limited risk-reduction resources and attention—to the communities with high loss potentials, to communities that may be incapable of adapting to the loss of significant percentages of their assets, or to a specific demographic or economic sector.

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Glossary

dependents Individuals who temporarily reside in facilities where they would be dependent on external assistance to evacuate and recover, including adult residential care, child day care, correctional facilities, hospitals, outpatient-care centers, psychiatric and substance-abuse hospitals, and schools.

exposure The first component of vulnerability, focusing on the amount of an asset (for example, the number of residents of a town) within a tsunami-evacuation zone.

resilience The third component of vulnerability, focusing on a community’s ability to withstand, absorb, adapt to, and recover from losses.

sensitivity The second component of vulnerability, focusing on the relative impact of losses to an entire community (for example, the percentage of a community’s workforce in a tsunami zone); for population data, it refers to differential impacts between demographic groups (for example, differences based on age of individuals or race).

vulnerability The attributes of a human-environmental system that increase the potential for hazard-related losses or reduced performance; characterized by the exposure, sensitivity, and resilience of a community and its assets in relation to stressors, either chronic or sudden (Turner and others, 2003).

Appendix A. North American Industry Classification System

The North American Classification System (NAICS) is used to classify economic activity in Canada, Mexico, and the United States (U.S. Census Bureau, 2007b). The eight-digit code is read from left to right with the first two digits noting the business sector, the third and fourth digits noting the subsector and industry group, the fifth and sixth digits noting particular industries, and the seventh and eighth digits (if needed) noting the jurisdictional level (for example, county, State, or Federal). The following table summarizes the sector descriptions for the two-digit 2007 NAICS codes.

Sector number	Description
11	Agriculture, Forestry, Fishing and Hunting
21	Mining
22	Utilities
23	Construction
31-33	Manufacturing
42	Wholesale Trade
44-45	Retail Trade
48-49	Transportation and Warehousing
51	Information
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific, and Technical Services
55	Management of Companies and Enterprises
56	Administrative and Support and Waste Management and Remediation Services
61	Education Services
62	Health Care and Social Assistance
71	Arts, Entertainment, and Recreation
72	Accommodation and Food Services
81	Other Services (except Public Administration)
92	Public Administration

Appendix A—Continued.

In addition to classifying economic activity, the NAICS codes can be used to extract information on critical and essential facilities, public venues, and dependent-population facilities. The following is a list of facilities that can be extracted from the infoUSA Employer Database. Numbers refer to the eight-digit code of the North American Industry Classification System (NAICS) code (U.S. Census Bureau, 2007b).

Critical Facilities	Essential Facilities
Public Order Police stations Federal: 92212002 Police departments: 92212003 Sheriff: 92212004 State Police: 92212005 Fire stations County Fire: 92216001 Local Fire: 92216003 State Fire: 92216004 Civil Defense Civil Defense: 92219001 County: 92219003 National Security Federal: 92811003 State: 92811007	Gas stations: 44719005 Banks and Credit Unions: Banks: 52211002 Credit Unions: 52213003 Retail Grocers: 44511003 Courts and legal counsel (group the following) Municipal courts: 92211001 County courts: 92211001 Federal Courts: 92211004 State Courts: 92211006 City Legal Counsel: 92213001 County Legal Counsel: 92213002 State Legal Counsel: 92213004 U.S. Post Offices: 4911101
Medical Services Hospitals: 62211002 Outpatient care centers: Childbirth education: 62141003 Pregnancy counseling: 62141005 Clinics: 62149301 Physician offices: 62111107, 62121003 Ambulance services: 62191002	Government offices: City government offices: 92111001, 92112006, 92113001, 92119001 County government offices: 92112007, 92111002, 92113002, 92119002 State government offices: 92112008, 92113005, 92119006 Federal government offices: 92112009, 92119003 Government weather offices: 92119000
Utilities Wastewater treatment: City: 92613001 County: 92613002 Water and sewage companies: 22131003 Gas companies: 22121002, 22121007 Electric companies: 22112202 Public works: 23731004, 23731007 Radio and TV Broadcasting: 51511203, 51512001	

Appendix A—Continued.

<table>
<tr><th>Public venues</th><th>Dependent Populations</th></tr>
<tr><td>Libraries
City: 51912001, 51912002
Federal: 51912003
Institutional: 51912005
Public: 51912006
State: 51912011, 51912010
Shopping centers and malls: 53112008
Colleges: 61131009
Museums: 71211001
Casino: 71329002
Historical Places: 71212001
Botanical Gardens: 71213003
Aquariums: 71219001
Zoos: 71213006
Parks: 71219004
Theaters: 51213101, 71111007
Spectator Sports: 71121203, 71121204
Religious Organizations
Christian Science: 81311005
Church Organizations: 81311006
Churches: 81311008
Clergy: 81311009
Convents and Monasteries: 81311010
Mediation Organizations: 81311011
Mosques: 81311015
Religious Organizations: 81311021
Retreat Houses: 81311023
Spiritualists: 81311025
Synagogues: 81311026
Places of Worship (non-theistic): 81311031</td><td rowspan="3">Hospitals:
Hospitals: 62211002
Mental Health Services: 62221001
Psychiatric treatment facilities: 62221003
Outpatient Care Centers (group the following)
Childbirth education: 62141003
Pregnancy counseling: 62141005
Clinics: 62149301
Offices of physicians: 62111107
Adult residential care
Adult care facilities: 62311001, 62311002, 62311008
Hospices: 62311011
Nursing homes: 62311016
Nursing home services: 62311018
Rest homes: 62311020
Retirement communities: 62331101
Homes – adult: 62331203
Senior citizens services: 62331205
Residential care homes: 62331206
Sheltered care homes: 62399000
Group homes: 62399007
Foster care: 62399013
Day care centers – adult: 62412002
Child day care
Babysitters: 62441001
Childcare centers: 62441002, 62441003
Pre-schools: 62441005
Nursery schools: 62441006
Schools
Religious schools: 61111004
Schools: 61111007
Schools with special academics: 61111010
Home schooling: 61111016
Colleges: 61131009
Correctional Facilities
City: 92214001
State: 92214002
Federal: 92214003
County: 92214004</td></tr>
<tr><th>Overnight Tourists</th></tr>
<tr><td>Hotels: 72111002
Bed and Breakfasts: 72119101
Inns: 72119102
Cabin Rentals: 72119903
Health resorts: 72119907
Resorts: 72119909
Tourist accommodations: 72119911
Campgrounds: 72121101
Camps: 72121403
Hostels: 72131006
Student housing: 72131009</td></tr>
</table>

Appendix B. Overview of Project Database

Additional data on the distribution of assets within specific cities is provided in the database that accompanies this report.

Database Worksheets—Land Cover, Population, Economy, and Facilities

Information on the amount and percentage of various assets are summarized in four worksheets—land cover, population, economy, and facilities. In these four worksheets, rows 3–35 refer to the 26 incorporated cities that have land in the tsunami-inundation zone, as well as the unincorporated portions of the seven coastal counties. Rows 36–42 are county-level summaries and rows 43–48 provide descriptive statistics for the region, including study area totals, third quartiles, and maximum values.

In these worksheets, the first four columns identify the city name, a geographic identifier, and the county name. The geographic identifier is a number assigned to each jurisdiction, starting at 1 with the City of Astoria and ending with 33 for the unincorporated portions in Curry County. Sorting and graphing information by the geographic identifier allows one to graph and visualize information in a consistent fashion based on geographic location. The remaining columns in the four note the following for each jurisdiction:

- The amount of an attribute located in the tsunami-inundation zone of a city ("Inundation Zone");
- The total amount within a city, regardless of the hazard zone ("City Total"); and
- The percentage of an attribute in the tsunami-inundation zone of a city ("City %"), which is derived by dividing the "Inundation Zone" amount by the "City Total."

Land-cover data refer to the number of 30-meter cells, residential and employee data refer to the number of individuals, parcel data refer to 2006 U.S. dollars, and facility data refer to the number of facilities. Demographic data includes an additional attribute noted as "% of Total Population in Inundation Zone." While "City %" notes the percentage of a demographic category of a community in the hazard-prone area, "% of Total Population in Inundation Zone" notes the percentage of residents in the inundation zone of a city that are a certain demographic group. For example, a "City %" value of 34 in the Hispanic or Latino population category indicates that 34 percent of the Hispanic population of a city is in the tsunami-inundation zone. A "% of Total Population in Inundation Zone" value of 34 in the Hispanic or Latino population category indicates that 34 percent of the residents in the inundation zone are Hispanic.

Database Worksheet—Business Types

The distribution of business types are summarized in the database worksheet "Business Types." Rows in this worksheet are the 21 industry types, based on the first two digits of the North American Industry Classification System code attached to each business in the InfoUSA Employer Database. Information on businesses, employees and sales volume are each sorted by business type.