Measuring Tsunami Planning Capacity on U.S. Pacific Coast

Zhenghong Tang[1]; Michael K. Lindell[2]; Carla S. Prater[3]; and Samuel D. Brody[4]

Abstract: The U.S. Pacific coastal states are at risk from both locally and distantly generated tsunamis. This vulnerability can be reduced by effective hazard management plans, but no studies have been conducted to determine how local jurisdictions have incorporated tsunami hazard management into their planning frameworks. This paper analyzes the quality of hazard management plans from 43 coastal counties in these states. Plan quality was measured by a plan evaluation protocol defined by five components and 37 indicators. The results show that few Pacific coastal counties have prepared well for tsunamis. Most plans have a weak factual basis, unclear goals and objectives, weak policies, and few coordination and implementation mechanisms. The average plan quality score is 12.25 out of 50 points and 10 counties never mention tsunami risks in their local plans at all. This evaluation suggests that these jurisdictions need to build a solid factual basis about tsunami hazards, set appropriate goals and practical objectives, expand the array of tools used by planners, enhance interdisciplinary and interorganizational coordination mechanisms, and improve their mechanisms for plan implementation.

DOI: 10.1061/(ASCE)1527-6988(2008)9:2(91)

CE Database subject headings: Hazards; Tsunamis; Coastal environment; Planning; United States.

Introduction

On December 26, 2004, a massive 9.0 magnitude earthquake under the Indian Ocean generated a tsunami that caused great destruction and loss of life. The disaster struck more than 10 countries, killed at least 283,000 people, and displaced a further 1.1 million in the countries bordering the Indian Ocean (Greenhough et al. 2005). Studies of the tsunami concluded that there is a need for more effective warning and preparedness to evacuate threatened populations (Cyranoski 2005; Kintisch 2005; Bhattacharjee 2005; Kerr 2005; Danielsen et al. 2005; Krishna 2005; Levy and Gopalakrishnan 2005; Lorch 2005; Marris 2005). In addition, better hazard mitigation practices could have prevented development of the most highly hazardous locations and required construction of more hazard-resistant structures such as steel-reinforced concrete buildings.

The U.S. Pacific coastal states—Alaska, California, Hawaii, Oregon, and Washington—are at risk both from distantly and locally generated tsunamis. In the past two centuries, all five states have been struck by tsunamis which caused significant casualties and damage (see Table 1).

To reduce tsunami risks, the National Tsunami Hazard Mitigation Program (NTHMP) was initiated in 1996 to improve tsunami detection and warning systems, produce tsunami evacuation maps, increase awareness of tsunami hazards and appropriate household hazard adjustments, and incorporate tsunami hazard planning into state and federal mitigation programs. In addition, the five Pacific coast states have established their own programs for tsunami hazard management (Bernard 2005; Dengler 2005; Gonzalez et al. 2005; Johnston et al. 2005; McCreery 2005; Oppenheimer et al. 2005; Tsunami Hazard Mitigation Federal/State Working Group 1996), but they are in different phases of completion (see Table 2).

Before the 2004 Indian Ocean tsunami, tsunami hazard management was a low priority for local governments and not likely to be addressed in local plans. In part, this neglect was due to lack of public concern. For example, Johnston et al. (2005) surveyed 300 residents and visitors in 2001 to assess their perceptions of tsunami hazards in coastal Washington and found the levels of preparedness were low to moderate. However, the Connor (2005) evaluation of a tsunami hazard awareness program in Oregon documented significant increases in coastal residents' knowledge about tsunami behavior and appropriate protective actions attributable to news media coverage of the 2004 tsunami. Since the Indian Ocean tsunami, some studies have begun to address tsunami hazard management (Darienzo et al. 2005; Jonientz-Trisler et al. 2005; Ramirez and Perez 2004), but none of them have empirically examined local jurisdictions' existing tsunami hazard planning. This is unfortunate because there is extensive literature on methods for plan evaluation. Early work in this area concentrated on substantive topics (e.g., land use, housing, transportation) and functional attributes (Boyce 1970; Hill 1968; Masser 1983). Later, Alexander and Faludi (1989) proposed five criteria for a comprehensive evaluation of plan quality: Conformity, rational process, optimality ex ante, optimality ex post, and utilization. Kent and Jones (1990) contended that the key characteristics in plan quality measurement are clear policies and strong maps with spatial intent of policies or land-use design. Later researchers adopted an evaluation framework of fact basis, goals, and policies to analyze the influence of state planning mandates on

[1]Research Assistant, Hazard Reduction and Recovery Center, Texas A&M Univ., College Station, TX 77843-3137.

[2]Professor, Hazard Reduction and Recovery Center, Texas A&M Univ., College Station, TX 77843-3137 (corresponding author). E-mail: MLindell@archmail.tamu.edu

[3]Research Scientist, Hazard Reduction and Recovery Center, Texas A&M Univ., College Station, TX 77843-3137.

[4]Associate Professor, Hazard Reduction and Recovery Center, Texas A&M Univ., College Station, TX 77843-3137.

Note. Discussion open until October 1, 2008. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on October 30, 2006; approved on June 8, 2007. This paper is part of the ***Natural Hazards Review***, Vol. 9, No. 2, May 1, 2008. ©ASCE, ISSN 1527-6988/2008/2-91–100/$25.00.

Table 1. Main Historical Tsunamis Striking the U.S. Pacific Coast

Date	Location
December 1812	Santa Barbara, California
April 1, 1946	Aleutian Islands, Hawaii
March 9, 1957	Aleutian Tsunami, Hawaii
July 9, 1958	Lituya Bay, Alaska
March 27, 1964	Great Alaska Tsunami (Alaska, Washington, Oregon, California, and Hawaii)
November 29, 1975	Hawaiian Islands
April 25,1992	Cape Mendocino Tsunami, California
November 3, 2002	King County, Washington

Note: Data sources: ⟨http://www.drgeorgepc.com/index.html⟩ and ⟨http://www.metrokc.gov/prepare/docs/RHMP/BasicPlanAug2004.pdf⟩.

local plan quality (Berke and French 1994; Kaiser and Godschalk 1995). Brody (2003b, c) extended this conception of plan quality by adding two components, interjurisdictional coordination and plan implementation, to further measure the ability of local plans to manage environmental hazards.

These previous studies of plan quality have mainly analyzed the quality of local land use plans (Brody 2003a; Brody et al. 2003,Burby 1998, 2000; Nelson and French 2002; Olshansky 2001). Moreover, they have focused on relatively frequent hazards such as floods (Burby et al. 1985, 1998) and coastal storms (Godschalk et al. 1999), as well as earthquakes (Berke and Beatley 1992; Burby et al. 1998; Nelson and French 2002; Olshansky 2001). The Pacific coast states vary in their requirements for hazard management (Burby 2005), but all emphasize natural hazards in their guidance on local land use planning. In general, these states allow local jurisdictions to choose between two approaches to tsunami hazard planning. The first approach is to develop a stand-alone hazard mitigation plan, whereas the second approach is to integrate hazard management concepts and strategies into local comprehensive plans, emergency operations plans, or coastal management plans. None of the studies evaluating plan quality have examined the degree to which local plans address tsunami risks. This neglect is important because tsunamis are such rare events that they are more likely to have been overlooked in hazard management plans than more frequent events such as floods and coastal storms.

It is important to recognize that coastal counties vary significantly in their governmental capacity and commitment, so the quality of their hazard management plans is also likely to vary. For example, a number of studies have documented the influence of state mandates on hazard mitigation plan quality (Burby and Dalton 1994; Berke and French 1994; Berke et al. 1996; Burby and May 1998; Deyle and Smith 1998). Other research has analyzed the effects of additional contextual characteristics such as population (Burby and May 1998; Brody 2003c), wealth (Brody et al. 2004), and education (Guagano and Markee 1995; Brody et al. 2004). In addition, research has examined the effects of interorganizational relations and individual planners' characteristics on plan quality (Berke et al. 1989; Berke and French 1994; Dalton and Burby 1994).

Studies examining emergency operations plans have found that communities with a history of emergency evacuation tend to produce better emergency planning outcomes (Kartez and Lindell 1987; Lindell and Whitney 1995). Such studies have also found characteristics of the planning process substantially mediate the relationship between the community context and planning outcomes (Kartez and Lindell 1990; Lindell and Brandt 2000; Lindell et al. 1996a,b, Lindell and Meier 1994). These include technical guidance from federal and state agencies, community support, and linkages with other jurisdictions.

It is also possible that the type of plan might affect the quality of hazard management plans. A stand-alone mitigation plan is almost certain to ignore emergency preparedness and response, whereas an emergency operations plan is likely to suffer from the reverse bias. A coastal management plan seems likely to provide the most thorough examination of tsunami hazards, but is likely to provide only superficial linkage to other community issues. A comprehensive plan seems likely to link tsunami hazard management with other community issues such as land use, housing, and

Table 2. Major Federal and State Tsunami Mitigation Programs

Region	Program	Status
Federal	National Tsunami Hazard Mitigation Program (NTHMP)	In progress
	Tsunameter Project	In progress
Alaska	State's Tsunami Inundation Mapping Program	In progress
	Tsunami Ready Community Program	Almost completed
	Tsunami Sign Program	Completed
	Quake Cottage Program	Completed
California	State Tsunami Steering Committee for Inundation Program	Completed
	California Geological Survey's Hazard Mapping Program	In progress
	State's Standardized Emergency Management System	In progress
	State's Local Emergency Planning Guidance	In progress
	Designing for Tsunamis Program	In progress
	Redwood Coast Tsunami Work Group	In progress
Hawaii	Operational NOAA Tsunami Wave Forecast Program	In progress
Oregon	GIS-Based Tsunami Evacuation Maps	Completed
	Tsunami Signs Program	Completed
Washington	Washington State/Local Tsunami Work Group	In progress
	Tsunami Warning/Evacuation Cycle	Completed
	Washington Tsunami Alert and Notification System	In progress

Note: Sources: (Jonientz-Trisler et al. 2005; Gonzalez et al. 2005; McCreery 2005; Bernard 2005; Titov et al. 2005; Darienzo et al. 2005; and Johnston et al. 2005).

transportation but lack depth in its treatment of tsunami hazards.

In summary, previous research on plan evaluation yields five specific research questions about the degree to which the coastal counties of the Pacific states have adequately addressed tsunami risk in their local hazard management planning. These questions are: (1) to what extent do NTHMP program goals correspond to the plan evaluation components identified by planning scholars; (2) to what extent do local hazard management plans effectively address tsunami risks; (3) what are the plan components and indicators that receive the greatest attention; (4) do the contextual characteristics of these jurisdictions affect the quality of local hazard management plans; and (5) does the type of plan used for hazard management affect its quality?

Evaluation Criteria

Factual Basis

Berke and French (1994) point out that the factual basis of a local land use plan should identify existing local conditions and needs for community physical development. Deyle et al. (1998) further define the factual basis as identifying potential hazards, mapping hazardous areas, and analyzing past disasters for lessons that can be applied in future decisions about development. Determining the likelihood of a disaster is often considered a key component of hazard assessment (Geist and Parsons 2006). This is particularly important for events whose catastrophic consequences are likely to offset their very low probability.

Thus, tsunami hazard management plans should assess hazard exposure by identifying the regional and local geology that can initiate seismic activity and locally generated tsunamis. Planners can use this information together with records of historic tsunamis to identify tsunami inundation zones. Once they identify which areas are at risk and which are safe, they can designate which roads should be used for evacuation. A hazard management plan should also identify which buildings are likely to be physically vulnerable and which population segments are socially vulnerable because of their limited hazard knowledge or limited resources for hazard mitigation, emergency preparedness, emergency response, or disaster recovery (Lindell et al. 2006). The quality of a plan's factual basis can be greatly improved by maps, videos, checklists, or tables describing a tsunami's physical and social impacts, but it is important to be aware of some people's limited ability to comprehend such information (Arlikatti et al. 2006). Additionally, tsunami hazard management plans need to identify any issues that require further investigation (e.g., the management of transient populations).

Goals and Objectives

A hazard management plan should create a vision of hazard resilience and specify goals and objectives for its realization (Burby 2005). The plan's goals and objectives should reflect the needs and desires of local residents as well as identify the means by which the envisioned future will be achieved (Berke and French 1994). Goals and objectives that are thorough, long term, consistent, and clear lead to the formulation, adoption, and implementation of effective strategies in hazard management plans (Burby 2005; Nelson and French 2002). Specifically, the goals should seek to protect population safety, reduce property damage, minimize socioeconomic impacts, and preserve the natural environment. In turn, objectives should be specific, measurable, achievable, and acceptable, as well as identify actions necessary to move toward the stated goals.

Policies, Tools, and Strategies

Policies, tools, and strategies represent the heart of a plan because they are the means for realizing the plans' goals and objectives (Berke and French 1994; Brody 2003c). Olshansky and Kartez (1998) catalogue a variety of land-use management tools, which include building standards, development regulations, critical and public facilities policies, land and property acquisition, taxation and fiscal policies, and information dissemination. Policies, tools, and strategies should be worded so their implementation can be monitored. The policies, tools, and strategies component of a plan sets forth specific principles of land use design and development management (Kaiser and Godschalk 1995). Each policy, tool, and strategy may only pertain to one particular aspect of a goal or it may be one of several successive steps toward goal achievement.

Tsunami hazard management can be divided into mitigation, preparedness, response, and recovery, with each of these functions being promoted by regulations, incentives, and risk communication (Lindell and Perry 2004). Regulations can take a variety of forms—land use permits, seismic or coastal zoning, subdivision regulations, and building codes—that restrict households' and businesses' land use and building construction practices (Lindell et al. 2006). Site assessment and tsunami hazard review procedures can be used as regulatory tools in the posttsunami recovery phase. Tsunami legislation can provide a legal support for local regulatory efforts (Jonientz-Trisler et al. 2005).

Incentives can also take a variety of forms that induce households and businesses to adopt hazard-resistant mitigation, emergency preparedness measures, and recovery preparedness actions. Such incentives include tax abatements, density bonuses, low interest loans, and technical assistance to community groups.

Risk communication can address both short-term and long-term reduction of tsunami risks by households, businesses, and nongovernmental organizations. Education and public participation programs are crucial components of tsunami hazard management that promote hazard awareness (Dengler 2005; Johnston et al. 2005). Specific awareness of tsunami risk areas (e.g., signs designating tsunami inundation zones) and specific guidance for tourists and visitors (e.g., signs indicating evacuation directions) are critical elements of the risk communication process. Effective tsunami risk communication also depends on a practical tsunami information exchange network with multiple agencies for tsunami warning, response, and evacuation. Furthermore, local tsunami mitigation plans should address alternative mechanisms for tsunami information dissemination (e.g., posting tsunami information on a local government website).

Interorganizational Coordination

Interorganizational coordination is a key component in defining local plan quality to manage transboundary environmental issues (Brody 2003c). Tsunami risk reduction is complex, dynamically dispersed, and multiple scale, so the local planning process needs a wide range of expertise to understand tsunami risks, and an even wider range of agencies to find solutions and implement them. Accordingly, a coordination component in tsunami hazard management plans ensures systemic cooperation among different

Table 3. Tsunami Hazard Management Plan Coding Protocol

Category	Indicators
Factual basis (eight indicators)	Tsunami risk identification and probability estimation
	Regional/local geologic and seismic settings
	Records of historical tsunami experiences
	Delineation of tsunami risk areas
	Tsunami inundation maps
	Affected vulnerable populations
	Affected vulnerable infrastructure and facilities
	Need for further investigation (tourists estimated)
Goals and objectives (four indicators)	Protect safety of population
	Reduce property damage
	Minimize socioeconomic impacts from tsunamis
	Preserve the natural and built environment
Policies, tools, and strategies (17 indicators)	Land use permits
	Seismic/coastal zoning and subdivision
	Buffer zones
	Building code controls
	Organizational tsunami response procedures
	Tsunami monitoring and warning systems
	Emergency evacuation system
	Critical facilities preparedness
	Environmental hazard review for tsunamis
	Tsunami legislation
	Volunteer/community groups for tsunamis
	Initiate and encourage tsunami insurance
	Tsunami education program
	Tsunami guidance for tourists and visitors
	Posting of tsunami signs
	Tsunami information exchange network
	Effective accessibility, notification, and dissemination for tsunami information (e.g., webpage)
Coordination (three indicators)	Coordinate with neighboring/state/federal agencies
	Coordinate tsunami monitoring, warning, response
	Link science, technology, and policy
Implementation (five indicators)	Designation of responsibility
	Clear timetable for implementation
	Necessary technical assistance
	Identify reliable financial support
	Incorporate tsunamis into all-hazard planning

levels of government, as well as among neighboring jurisdictions. Coordination policies can enhance hazard mitigation, emergency preparedness, and recovery preparedness by systematically linking science, technology, and policies into an integrated whole.

Plan Implementation

The plan implementation component should translate a plan's policies, tools, and strategies into specific tasks and assign each task to a designated agency (Brody 2003c). Next, it should set a clear schedule for performing those tasks, and allocate for the required resources (e.g., human, material, and financial). Finally, the implementation component should establish a framework for evaluating how well the plan is meeting its goals and objectives, and identify opportunities for improving the performance of policies, tools, and strategies.

Research Methods

Coding Protocol

The preceding conceptualization of plan quality supports the development of a plan coding protocol. Each element of a hazard management plan is evaluated by scanning it to determine whether it has addressed any of the 37 indicators of the five plan components: (1) factual basis; (2) goals and objectives; (3) policies, tools, and strategies; (4) interorganizational coordination; and (5) plan implementation (see Table 3). Within these five components, each indicator is scored on a 0–2 scale. A score of "0" means the indicator is not mentioned in the plan, a score of "1" means that an indicator is considered but not thoroughly, and a score of "2" means the indicator is fully considered.

Since this study focuses on tsunami hazard management, rec-

Table 4. Counties Included in This Study and Their Plan Types

State	Number of coastal counties	Number of available plans	Plan type A[a]	Plan type B[b]	Plan type C[c]	Plan type D[d]	Number of unavailable plans
Alaska	26	9	5	2	0	2	17
California	20	20	20	0	0	0	0
Hawaii	5	3	3	0	0	0	2
Oregon	7	2	2	0	0	0	5
Washington	15	9	5	0	2	2	6
Total	73	43	35	2	2	4	30

[a]Plan type A: Comprehensive plan.
[b]Plan type B: Coastal management plan.
[c]Plan type C: Emergency management plan.
[d]Plan type D: Stand-alone hazard plan.

ognition of tsunami hazard exposure is a critical element of any plan. If the word "tsunami" is never mentioned, the entire plan was given a score of 0 even if some other indictors (e.g., buffer zones, land use permits, or building code controls) were addressed.

Total and Component Scores

Based on previous research (Brody 2003a,c), total plan quality and plan component quality can be calculated by the following equations:

$$\mathrm{PC}_j = \frac{10}{2m_j}\sum_{i=1}^{m_j} I_i$$

and

$$\mathrm{TPQ} = \sum_{j=1}^{5} \mathrm{PC}_j$$

where PC_j=quality of the jth plan component (ranging 0–10); m_j=number of indicators within the jth plan component; I_i represents the ith indicator's score (ranging 0–2); and TPQ=total scores of a whole plan (ranging 0–50).

Sample Selection

The population of this study comprises the hazard management plans from all coastal counties in the states of California, Hawaii, Oregon, Washington, and all boroughs in Alaska. The dataset was constructed by first searching each county's (borough's) web site to find its local comprehensive plan, coastal management plan, emergency operations plan, or stand-alone hazard mitigation plan. Some counties were not scored because they either did not make their plans available on a web site, made no response to a written request, were still updating plan elements, or simply had no hazard management plan. This selection process yielded 43 plans from the 73 coastal counties in these five states. These 43 plans cover 62% of the coastal counties in these states, including nine of the 26 (35%) Alaska coastal counties, all 20 (100%) California coastal counties, three of the five (60%) Hawaii coastal counties, two of the seven (28%) Oregon coastal counties, and nine of the 15 (60%) Washington coastal counties. Of the 43 plans, 35 (81.5%) were comprehensive plans, two (4.6%) were coastal management plans, two (4.6%) were emergency operations plans, and four (9.3%) were stand-alone mitigation plans (see Table 4).

The data for the contextual variables were collected from the U.S. census fact sheet. Population was measured as the number of people in a jurisdiction. Education was calculated by the percentage of the population 25 years or over who have a bachelor's degree or higher. Income was measured by the median family income in 1999.

Results

Correspondence of NTHMP Goals with Plan Evaluation Criteria

The NTHMP set five major goals to build tsunami-resilient communities: (1) Understand the nature of the tsunami hazard; (2) have the tools needed to mitigate tsunami risk; (3) disseminate information about tsunami hazard; (4) exchange information with other at-risk areas; and (5) institutionalize planning for a tsunami disaster (Dengler 1998; Jonientz-Trisler et al. 2005). These five goals are systematically related to the five components of a high quality plan indicated in Fig. 1. Specifically, the NTHMP's first program goal, understanding the tsunami hazard, is achieved by a strong factual basis that identifies existing local conditions related to tsunami vulnerability. This understanding is clarified by setting appropriate goals and objectives for reducing hazard vulnerability. The second program goal, having adequate tools, is achieved

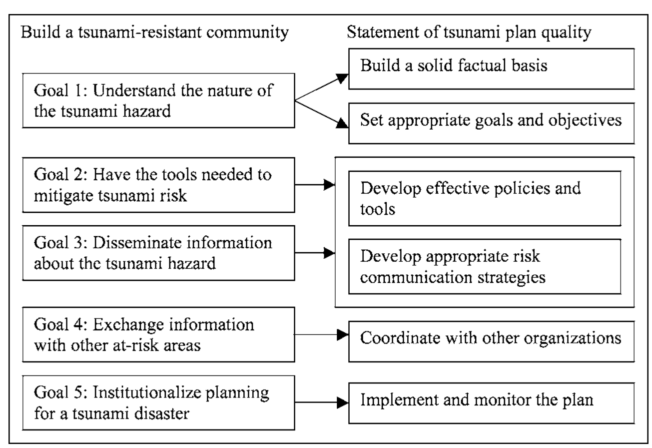

Fig. 1. Relationship between NTHMP goals and plan quality components

Table 5. Descriptive Statistics on Tsunami Plan Quality

Plan Components[a]	N	Mean	Standard deviation	Minimum	Maximum
Factual Basis	43	3.16	2.66	0.00	8.75
Goals and objectives	43	4.04	3.13	0.00	10.00
Policies, tools, strategies	43	1.53	1.84	0.00	6.47
Coordination	43	2.51	3.17	0.00	10.00
Implementation	43	0.95	1.75	0.00	6.00
Total[b]	43	12.25	11.56	0.00	37.22

[a]Maximum score for each plan component is 10.00.

[b]Maximum score for total plan quality is 50.00.

by policies, tools, and strategies that are integrated into the hazard management plan. The third program goal, disseminating information, is achieved by an effective risk communication program that constitutes one of the strategies by which hazard management is achieved. The fourth program goal, exchanging information with other at-risk areas, is achieved by coordinating with other agencies. The fifth program goal, institutionalizing tsunami planning, is broader than plan implementation and monitoring, but certainly includes it. In summary, the NTHMP's program goals have a reasonable correspondence with the evaluation criteria identified in previous planning research.

Total Quality and Component Quality of Local Plans

As Table 5 indicates, the mean total score for the 43 hazard management plans is only 12.25 out of a maximum score of 50. Ten of the 43 counties never mentioned tsunami risk in their plans, so they received a score of 0. If the calculation is restricted to the plans that addressed tsunamis, the mean score only increases to 15.96. Thirty-seven counties received less than half of the total points, meaning these jurisdictions do not have well-organized, thoroughly-prepared plans that will significantly reduce their tsunami risks. Only five counties' total scores are above 30 points and the highest score was 37.22.

Of the five plan components, goals and objectives received the highest score of the five plan components, meaning jurisdictions do best at setting goals to protect themselves from tsunami hazards. Nonetheless, the quality of these goals is poor (mean $=4.04$ on a 0–10 scale). Factual basis has a slightly lower score ($M=3.16$) than the goals and objectives component, demonstrating a lack of knowledge about tsunami hazard and its impacts. Interorganizational coordination ($M=2.51$) is lower yet, indicating these plans lack mechanisms to coordinate tsunami hazard management actions with other organizations. Policies, tools, and strategies ($M=1.53$) is the second lowest plan component, demonstrating these plans have limited mechanisms for reducing tsunami vulnerability. Finally, implementation ($M=0.95$) is the lowest scoring plan component, indicating weak mechanisms for plan implementation and monitoring.

To assess the effects of contextual factors on plan quality, plan quality total and component scores were correlated with population size, education, and income, as well as with plan type (comprehensive, coastal, emergency operations, stand alone). The correlation results show that none of the contextual variables or plan types were significantly correlated with tsunami plan quality.

Indicator Quality

The results of the indicator evaluation show that the 43 plans generally failed to provide a strong, solid factual basis for tsunami management. Two-thirds of the jurisdictions identify tsunami hazard and most of them put tsunami impact as a low probability in their jurisdictions. A majority (68%) of the counties only identify their area's general geologic structure and seismic activity. Only 59% of the plans list their tsunami histories, only 50% delineated tsunami risk areas, and only 30% included tsunami inundation maps. Only 39% of the plans identify infrastructure and facilities that are vulnerable to tsunamis and only 20% of them identify vulnerable population segments.

In the goals and objectives component, 73% of the plans set goals to reduce property damage from tsunami hazards, 68% set goals to protect population safety, and 61% set goals to preserve the natural and built environment. However, only 39% address socioeconomic impacts.

In the policies, tools, and strategies component, there are large variations among the indicators. Less than half of the counties planned to use traditional planning tools including land use permits (39%), seismic or coastal zoning (30%), hazard review (30%), building code control (41%), or buffer zones (39%). Although Hawaii, Oregon, and Washington have reported some tsunami legislation available or in development (Jonientz-Trisler 2005), only 18% of these counties plan to pass hazard legislation. Many researchers have emphasized the importance of monitoring and warning systems as a tool for tsunami hazard management (Darienzo et al. 2005; Kintisch 2005; McCreery 2005; Titov et al. 2005), but only 36% of the plans mention such systems. Additionally, only 23% of the counties describe organizational procedures for rapid tsunami confirmation and response and only 27% plan to undertake critical facilities preparedness. Only one county specifies volunteer or community groups for tsunami events and only 5% of them address tsunami insurance programs. There are 41% of the counties that have started hazard education programs and 27% have devised hazard information exchange networks. However, few of them describe specific measures for increasing the hazard awareness of tourists and visitors (7%), posting signs in high hazard areas (9%), or making hazard information more accessible (11%).

In the interorganizational coordination component, 52% of coastal counties mention necessary coordination procedures for hazard monitoring, warning, and response. However, only 34% of the plans address coordination with neighboring county, state, or federal agencies and fewer still define procedures for coordinating with multiple agencies (e.g., USGS and NOAA's Tsunami Warning Centers) and current tsunami programs. Only 14% of the jurisdictions address the linkage of science, technologies, and policies.

In the implementation component, only 27% of the plans designate specific responsibility for hazard management plan implementation, and 25% identify the sources needed for necessary technical assistance. Moreover, less than 10% of counties provide clear timetables and identify financial support for plan implementation. Only 7% of the plans discuss incorporating tsunami hazard management into an all-hazard management plan.

Discussion

The results of this study address all five of the research questions. Regarding the first question ("To what extent do NTHMP program goals correspond to the plan evaluation components identified by planning scholars?"), the results indicate a reasonable correspondence between program goals and plan evaluation components. Regarding the second question ("To what extent do local hazard management plans effectively address tsunami risks?"), the results indicate that Pacific coastal counties have relatively low quality hazard management plans. Regarding the third question ("What are the plan components and indicators that receive the greatest attention?"), the results indicate that these counties' plans were strongest in stating goals and objectives; somewhat weaker in presenting a factual basis; weaker still in addressing coordination mechanisms; very weak in describing tools, policies, and strategies; and weakest in addressing implementation issues. Regarding the fourth question ("Do the contextual characteristics of these jurisdictions affect the quality of local tsunami hazard management plans?"), the results indicate that none of the contextual conditions were significantly related to plan quality. Regarding the fifth question ("Does the type of plan used for tsunami hazard management affect its quality?"), the results indicate that none of the four type of plans used for tsunami hazard management had an impact on plan quality.

The results of this study are partially consistent with previous studies on hazard plan quality (Berke et al. 1996; Berke et al. 1997; Nelson and French 2002). In these studies, California and Washington hazard mitigation plan quality was generally low in the 1990s (Berke et al. 1996; Brody 2003a; Nelson and French 2002). Weaknesses were also found in the hazard plan components of factual basis, goals/objectives, and policies/strategies/tools. The plan component indicators were slightly different in the previous studies, so it is not possible to determine if scores on total plan quality or on each plan component are systematically better or worse in this study than in previous plan evaluation studies. However, the rank order to the plan components is the same. This study found the five plan components were ranked from highest to lowest in terms of quality as goals/objectives, factual basis, policies/tools/strategies, coordination, and plan implementation. This is the same rank order (goals, factual basis, policies) as found in Washington and California by Berke et al. (1996) and Brody (2003a).

The findings of this study are somewhat inconsistent with those of previous studies that found plan quality and other planning outcomes are related to the community context and the quality of the planning process. This might be due, in part, to previous studies finding that community conditions have small (and marginally statistically significant) correlations with planning outcomes (Lindell and Brandt 2000; Lindell et al. 1996a, b). Thus, the small sample size in this study might have limited the ability to find statistically significant correlations between community context and plan quality. Second, the studies reporting the strongest correlations of planning outcomes with other variables examined the performance of local emergency planning committees (LEPCs) that were specifically established by federal mandate to prepare for toxic chemical releases [see Lindell and Perry (2001) for a summary]. Some LEPCs had very low scores, as was generally the case for coastal counties in this study. However, other LEPCs had performed quite well, so those studies had much more variance in the dependent variable that could be related to community characteristics. This suggests that the failure to find any significant correlations with community characteristics in this study might also have been due to a difference between tsunami hazard planning (for which there is no state or federal mandate) and toxic chemical emergency planning (for which there is a mandate). Accordingly, the results seem to be consistent with previous findings on the importance of mandates (Burby 2005; Nelson and French 2002). Finally, the studies of LEPCs found plan quality and planning outcomes were most strongly correlated with variables measuring the planning process, none of which were measured in this study.

This study makes small but significant contributions to theories of hazard planning by taking the broad theoretical principles of rationalism, communication, and collaboration and converting them into a model of how to actually achieve planning objectives. First, this study adds to the theory of rational planning by integrating tsunami hazard management, which is rarely covered in current planning activities, into local comprehensive plans, coastal management plans, emergency operations plans, and stand-alone mitigation plans. This study also provides a comprehensive model, augmented by specific indicators, to guide local jurisdictions' development of tsunami hazard management plans. Application of this model empirically documents the gaps in current tsunami hazard management plans and provides insights on how these plans can be improved. By understanding the areas in which their plans are deficient, policy makers can be more effective in their efforts to promote safety in their jurisdictions. Specifically, tsunami hazard management plans should address the indicators of the five plan components listed in Table 3—fact basis; goals and objectives; policies, tools, and strategies; coordination; and plan implementation.

Specifically, these jurisdictions must first improve the factual basis of their hazard management plans. Local planners must accurately identify tsunami risk areas, so state and federal programs must provide comprehensive information about tsunami hazards to local planners (Bernard 2005; Darienzo et al. 2005; Dengler 2005; Johnston et al. 2005; Jonientz-Trisler et al. 2005; McCreery 2005; Oppenheimer et al. 2005; Ramirez and Perez 2004; Titov et al. 2005). In fact, much of this information is available on the internet and some is GIS based, so it is readily available. For example, the NTHMP has produced 22 tsunami inundation maps covering 113 coastal communities with a population at risk of over 3 million people (Bernard 2005). The failure of local jurisdictions to use this information adequately is disappointing but not surprising. Recent studies have documented significant impediments to local emergency managers' utilization of hazard analysis information (Hwang et al. 2001; Lindell et al. 2002). Future research should identify and test methods of overcoming obstacles to the dissemination of such information.

Second, coastal jurisdictions should commit themselves to comprehensive goals and specific objectives in their hazard management plans. This can be difficult because tsunami risk has a low priority in many jurisdictions. However, tsunami hazard management requires many of the same activities as other coastal hazards such as coastal storms, inland flooding, wildfires, and earthquakes. For example, many activities for tsunami hazard/vulnerability analysis, hazard mitigation (e.g., land use practices and building construction practices), and disaster preparedness (e.g., warning and evacuation) apply to these other hazards as well. Thus, a coordinated set of hazard management goals can address vulnerability to many hazards simultaneously.

Third, local jurisdictions should expand the policies, tools, and strategies they consider for tsunami hazard mitigation, disaster preparedness, and risk communication. One particularly relevant recent finding is the importance of incentive strategies in improving local jurisdictions' planning capacity (Brody 2003b,c). This suggests that Pacific coastal jurisdictions should also adopt incentives (e.g., tax abatement, density bonus, low interest loans or tsunami insurance) to mitigate tsunami hazard (Lindell et al. 1997).

With respect to disaster preparedness strategies, many recent studies have advocated the development of warning and evacuation systems for tsunamis (Cyranoski 2005; Kintisch 2005; Bhattacharjee 2005; Kerr 2005; Danielsen 2005; Krishna 2005; Levy and Gopalakrishnan 2005; Lorch 2005; Marris 2005). However, it is also advisable to develop preimpact plans and procedures for disaster recovery (Lindell et al. 2006; Schwab et al. 1998). These include procedures for damage assessment, infrastructure restoration, housing reconstruction, and economic recovery.

With respect to risk communication, it is important to recognize that the public generally fails to participate in hazard mitigation planning despite obvious evidence of perils to life and property from frequent natural hazards (Godschalk et al. 2003; Lindell and Perry 2000; Lindell and Prater 2000). Local jurisdictions must develop multiple approaches to risk communication (Connor 2005; Lindell and Perry 2004). Moreover, a tsunami information exchange network should be developed to coordinate tsunami information, signs, and related products across counties and states. This will reduce the amount of wasted effort as planners in one jurisdiction develop hazard awareness materials that have already been developed by others. In addition, it will avoid inconsistencies between jurisdictions, which would be confusing to tourists and others who move from one jurisdiction to another.

Fourth, local jurisdictions need to develop interdisciplinary, interorganizational coordination mechanisms for tsunami hazard management. Integrating different disciplines into local tsunami planning is crucial to developing a more practical, useful plan. Interdisciplinary and inter-organizational coordination requires linking federal agencies' tsunami monitoring and warning technology with state and local tsunami hazard management—a problem that has been observed during previous tsunami warnings (Oregon Emergency Management 2005). Such coordination is likely to become increasingly challenging as a result of the expansion of the National Tsunami Hazard Mitigation Program to include Atlantic and Gulf states, as well as Puerto Rico and the Pacific territories.

Fifth, local jurisdictions should specify plan implementation mechanisms and incorporate tsunami elements into all-hazard plans. Since the plan evaluation results have identified implementation as the weakest plan component, local jurisdictions should identify specific tasks, designate agency responsibilities, allocate adequate staffing levels and financial resources, and set clear timelines for task completion. Given the infrequency of tsunamis, local jurisdictions should systematically integrate tsunami hazard management with other hazard management plans. Since this study found that only three (7%) of the jurisdictions explicitly attempted to integrate tsunami hazard management into other hazard management plans, it seems logical that the other counties can more fully use their existing hazard management resources to create a more effective platform for tsunami hazard management.

As is the case with all research, there are some limitations in this study. First, it is subject to hazard management plan availability and approximately 41% of the counties in these states were omitted because of lack of data. In particular, this study missed 71% of the coastal counties in Oregon and 65% in Alaska. If these county plans were missing at random, there would be no effect on the results, but random unavailability seems unlikely. Instead, it seems most likely that the unavailable plans are either of poorer quality or are nonexistent. The education level of the missing counties ($M=17.37\%$) is significantly lower than the available counties ($M=22.33\%$) at $p<0.05$; however, population and income do not show statistical differences between the missing counties and the available counties. This finding suggests the results are more likely to have overestimated the quality of local plans than to have underestimated them. A second study limitation is that 81% of coastal counties in these five states addressed tsunami hazard management within their comprehensive plans. This approach has the practical advantage of integrating hazard management policies, tools, and strategies into the local community's long-term development strategies—including many aspects of social, economic, and environmental planning. However, only two coastal counties addressed tsunami hazard management in coastal management plans, another two addressed it in their emergency operations plans, and four addressed it in stand-alone mitigation plans. This means the statistical tests of the correlations between plan type with plan score had a low statistical power and, thus, had a very limited ability to detect a true effect. Thus, the question of whether certain plan types yield higher scores must be considered as unanswered in this study.

Future research should seek to identify the variables that influence tsunami plan quality. None of the contextual variables showed any significant correlations with plan quality, but this might be because the variables have such a remote influence. In particular, Lindell and his colleagues have found that the effects of external contextual variables on planning outcomes are mediated by internal contextual variables associated with the planning process (Lindell and Brandt 2000; Lindell and Whitney 1995; Lindell et al. 1996a, b). Modeling the specific linkages among external and internal variables might be required to identify the ways in which these plans can be improved. Future studies should examine the influence of external factors (e.g., hazard vulnerability and community support) and internal factors (e.g., staffing and structure, automated technology, and emergency planning resources) on the quality of hazard management plans. In addition, future research should examine local planners' and emergency managers' perceptions of different hazard management practices (e.g., posting tsunami warning signs, considering tsunami vulnerability in capital improvement plans). Such research could assess perceptions of important aspects such as political support or opposition, impacts on economic development, and requirements for specialized knowledge or training. Identifying perceived barriers to implementation of different planning and policies would be an important step toward overcoming them.

Acknowledgments

This paper was supported by the National Science Foundation under Grant No. CMS 0527699 to the fourth writer and Grant No. SES 0527699 to the second and third writers. None of the conclusions in this paper necessarily reflect views other than those of the writers.

References

Alexander, E. R., and Faludi, A. (1989). "Planning and plan implementation—Notes on evaluation criteria." *Environ. Plan. B: Plan. Des.*, 16(2), 127–140.

Arlikatti, S., Lindell, M. K., Prater, C. S., and Zhang, Y. (2006). "Risk area accuracy and hurricane evacuation expectations of coastal residents." *Environ. Behav.*, 38(2), 226–247.

Berke, P. R., and Beatley, T. (1992). *Planning for earthquakes: Risk, policy and politics*, Johns Hopkins University Press, Baltimore.

Berke, P. R., Beatley, T., and Wilhite, S. (1989). "Influences on local adoption of planning measures for earthquake hazard mitigation." *Int. J. Mass Emerg. Disasters*, 7(1), 33–56.

Berke, P., Dixon, J., and Ericksen, N. (1997). "Coercive and cooperative intergovernmental mandates: A comparative analysis of Florida and New Zealand environmental plans." *Environ. Plan. B: Plan. Des.*, 24(3), 451–468.

Berke, P., and French, S. (1994). "The influence of state planning mandates on local plan quality." *J. Plan. Educ. Res.*, 13(4), 237–250.

Berke, P., Roenigk, D., Kaiser, E., and Burby, R. (1996). "Enhancing of plan quality: Evaluation of the role of the state planning mandates for natural hazard mitigation." *J. Environ. Plann. Manage.*, 39(1), 79–96.

Bernard, E. N. (2005). "The US national tsunami hazard mitigation program: A successful state-federal partnership." *Natural Hazards*, 35(1), 5–24.

Bhattacharjee, Y. (2005). "Indian Ocean tsunami—In wake of disaster, scientists seek out clues to prevention." *Science*, 307(5706), 22–23.

Boyce, D. E. (1970). "Toward a framework for defining and applying urban indicators in plan-making." *Urban Affair Q.*, 6(2), 145–171.

Brody, S. D. (2003a). "Are we learning to make better plans? A longitudinal analysis of plan quality associated with natural hazards." *J. Plan. Educ. Res.*, 23(2), 191–201.

Brody, S. D. (2003b). "Examining the role of resource-based industries in ecosystem approaches to management: An evaluation of comprehensive plans in Florida." *Soc. Nat. Resour.*, 16(7), 625–641.

Brody, S. D. (2003c). "Implementing the principles of ecosystem management through local land use planning." *Popul. Environ.*, 24(6), 511–540.

Brody, S. D., Godschalk, D. R., and Burby, R. J. (2003). "Mandating citizen participation in plan making—Six strategic planning choices." *J. Am. Plan. Assn.*, 69(3), 245–264.

Brody, S. D., Highfield, W., and Carrasco, V. (2004). "Measuring the collective capabilities of local jurisdictions to manage ecological systems in southern Florida." *Landsc. Urban Plann.*, 69(1), 33–50.

Burby, R. J. (2005). "Have state comprehensive planning mandates reduced insured losses from natural disasters?" *Hydrol. Sci. J.*, 6(2), 67–81.

Burby, R. J., and Dalton, L. (1994). "Plans can matter! The role of land use plans and state planning mandates in limiting the development of hazardous areas." *Public Admin. Rev.*, 54(3), 229–237.

Burby, R. J., Deyle, R. E., Godschalk, D. R., and Olshansky, R. B. (2000). "Creating hazard resilient communities through land-use planning." *Hydrol. Sci. J.*, 1(2), 99–106.

Burby, R. J., French, S. P., Cigler, B., Kaiser, E. J., Moreau, D., and Stiftel, B. (1985). *Flood plain land use management: A national assessment*, Westview Press, Boulder, Colo.

Burby, R. J., French, S. P., and Nelson, A. C. (1998). "Plans, code enforcement, and damage reduction: Evidence from the Northridge earthquake." *Earthquake Spectra*, 14(1), 59–74.

Burby, R. J., and May, P. (1998). "Intergovernmental environmental planning: Addressing the commitment conundrum." *J. Environ. Plann. Manage.*, 41(1), 95–110.

Connor, D. (2005). "Outreach assessment: How to implement an effective tsunami preparedness outreach program." *State of Oregon Dept. of Geology and Mineral Industries Open File Rep. No. OFR 0-05-10*, Nature of the Northwest Information Center, Portland, Ore.

Cyranoski, D. (2005). "Solo efforts hamper tsunami warning system." *Nature*, 433(7024), 343.

Dalton, L. C., and Burby, R. J. (1994). "Mandates, plans, and planners—Building local commitment to development management." *J. Am. Plan. Assn.*, 60(4), 444–461.

Danielsen, F. et al. (2005). "The Asian tsunami: A protective role for coastal vegetation." *Science*, 310(5748), 643.

Darienzo, M. et al. (2005). "Local tsunami warning in the Pacific coastal United States." *Natural Hazards*, 35(1), 111–119.

Dengler, L. (1998). "Strategic implementation plan for tsunami mitigation projects, approved by the mitigation subcommittee of the National Tsunami Hazard Mitigation Program, April 14, 1998." *Technical Rep. NOAA Technical Memo. ERL PMEL-113 (PB99-115552)*, NOAA/Pacific Marine Environmental Laboratory, Seattle, Wash, ⟨http://www.pmel.noaa.gov/pubs/PDF/deng2030/deng2030.pdf⟩ (September 12, 2006).

Dengler, L. (2005). "The role of education in the National Tsunami Hazard Mitigation Program." *Natural Hazards*, 35(1), 141–153.

Deyle, R. E., French, S. P., Olshansky, R. B., and Paterson, R. C. (1998). "Hazard assessment: The factual basis for planning and mitigation." *Cooperating with nature: Confronting natural hazards with land-use planning for sustainable communities*, R. J. Burby, ed., Joseph Henry Press, Washington, D.C. 119–166.

Deyle, R. E., and Smith, R. A. (1998). "Local government compliance with state planning mandates: The effects of state implementation in Florida." *J. Am. Plan. Assn.*, 64(4), 457–469.

Geist, E. L., and Parsons, T. (2006). "Probabilistic analysis of tsunami hazards." *Natural Hazards*, 37(3), 277–314.

Godschalk, D. R., Beatley, T., Berke, P., Brower, D. J., and Kaiser, E. J. (1999). *Natural hazard mitigation*, Island Press, Washington, D.C.

Godschalk, D. R., Brody, S. D., and Burry, R. (2003). "Public participation in natural hazard mitigation policy formation: Challenges for comprehensive planning." *J. Environ. Plann. Manage.*, 46(5), 733–754.

Gonzalez, F. I. et al. (2005). "Progress in NTHMP hazard assessment." *Natural Hazards*, 35(1), 89–110.

Greenhough, B., Jazeel, T., and Massey, D. (2005). "Introduction: Geographical encounters with the Indian Ocean tsunami." *Geographical J.*, 171(4), 369–371.

Guagano, G. A., and Markee, N. (1995). "Regional differences in the sociodemographic determinants of environmental concern." *Popul. Environ.*, 17(2), 135–149.

Hill, M. (1968). "A goals-achievement matrix for evaluating alternative plans." *J. Am. Inst. of Planners*, 34(1), 19–29.

Hwang, S. N., Sanderson, W. G., and Lindell, M. K. (2001). "Analysis of state emergency management agencies' hazard analysis information on the Internet." *Int. J. Mass Emerg. Disasters*, 19(1), 85–106.

Johnston, D., Paton, D., Crawford, G. L., Ronan, K., Houghton, B., and Burgelt, P. (2005). "Measuring tsunami preparedness in coastal Washington, United States." *Natural Hazards*, 35(1), 173–184.

Jonientz-Trisler, C. et al. (2005). "Planning for tsunami-resilient communities." *Natural Hazards*, 35(1), 121–139.

Kaiser, E. J., and Godschalk, D. R. (1995). "20th-century land-use planning—A stalwart family tree." *J. Am. Plan. Assn.*, 61(3), 365–385.

Kartez, J. D., and Lindell, M. K. (1987). "Planning for uncertainty: The case of local disaster planning." *J. Am. Plan. Assn.*, 53(4), 487–489.

Kartez, J. D., and Lindell, M. K. (1990). "Adaptive planning for community disaster response." *Cities and disaster: North American studies in emergency management*, R. T. Silves and W. L. Waugh, Jr., eds., Charles C. Thomas Pub., Springfield, Ill, 5–33.

Kent, T. J. and Jones, H. R. (1990). *The urban general plan*, American Planning Association, Chicago.

Kerr, R. A. (2005). "South Asia tsunami—Failure to gauge the quake crippled the warning effort." *Science*, 307(5707), 201.

Kintisch, E. (2005). "Disaster preparedness—Global tsunami warning system takes shape." *Science*, 307(5708), 331.

Krishna, K. S. (2005). "Science plan for coastal hazard preparedness." *Curr. Sci.*, 89(8), 1339–1347.

Levy, J. K., and Gopalakrishnan, C. (2005). "Promoting disaster-resilient communities: The great Sumatra-Andaman earthquake of 26 December 2004 and the resulting Indian Ocean tsunami." *Int. J. Water Resour. Dev.*, 21(4), 543–559.

Lindell, M. K., and Brandt, C. J. (2000). "Climate quality and climate consensus as mediators of the relationship between organizational antecedents and outcomes." *J. Appl. Psychol.*, 85(3), 331–348.

Lindell, M. K. et al. (1997). "Adoption and implementation of hazard adjustments." *Int. J. Mass Emerg. Disasters*, 15(3), 327–453.

Lindell, M. K., and Meier, M. J. (1994). "Effectiveness of community planning for toxic chemical emergencies." *J. Am. Plan. Assn.*, 60(2), 222–234.

Lindell, M. K., and Perry, R. W. (2000). "Household adjustment to earthquake hazard: A review of research." *Environ. Behav.*, 32(4), 590–630.

Lindell, M. K., and Perry, R. W. (2001). "Community innovation in hazardous materials management: Progress in implementing SARA Title III in the United States." *J. Hazard. Mater.*, 88(2–3), 169–194.

Lindell, M. K., and Perry, R. W. (2004). *Communication environmental risk in multiethnic communities*, Sage, Thousand Oaks, Calif.

Lindell, M. K., and Prater, C. S. (2000). "Household adoption of seismic hazard adjustments: A comparison of residents in two states." *Int. J. Mass Emerg. Disasters*, 18(2), 317–338.

Lindell, M. K., Prater, C. S., and Perry, R. W. (2006). *Introduction to emergency management*, Wiley, Hoboken, N.J.

Lindell, M. K., Sanderson, W. G., and Hwang, S. N. (2002). "Local government agencies' use of hazard analysis information." *Int. J. Mass Emerg. Disasters*, 20(1), 29–39.

Lindell, M. K., and Whitney, D. J. (1995). "Effects of organizational environment, internal structure, and team climate on the effectiveness of local emergency planning committees." *Risk Anal.*, 15(4), 439–447.

Lindell, M. K., Whitney, D. J., Futch, C. J., and Clause, C. S. (1996a). "The local emergency planning committee: A better way to coordinate disaster planning." *Disaster management in the U.S. and Canada: The politics, policymaking, administration and analysis of emergency management*, R. T. Silves and W. L. Waugh, Jr., eds., Charles C. Thomas Pub., Springfield, Ill, 234–249.

Lindell, M. K., Whitney, D. J., Futch, C. J., and Clause, C. S. (1996b). "Multi-method assessment of organizational effectiveness in a local emergency planning committee." *Int. J. Mass Emerg. Disasters*, 14(2), 195–220.

Lorch, R. (2005). "What lessons must be learned from the tsunami?" *Build. Res. Inf.*, 33(3), 209–211.

Marris, E. (2005). "Inadequate warning system left Asia at the mercy of tsunami." *Nature*, 433(7021), 3–5.

Masser, I. (1983). *Evaluating urban planning efforts: Approaches to policy analysis*, Gower Pub. Co., Aldershot, Hampshire, U.K.

McCreery, C. S. (2005). "Impact of the National Tsunami Hazard Mitigation Program on operations of the Richard H. Hagemeyer Pacific Tsunami Warning Center." *Natural Hazards*, 35(1), 73–88.

Nelson, A. C., and French, S. P. (2002). "Plan quality and mitigating damage from natural disasters: A case study of the Northridge earthquake with planning policy considerations." *J. Am. Plan. Assn.*, 68(2), 194–207.

Olshansky, R. B. (2001). "Land use planning for seismic safety: The Los Angeles County experience, 1971–1994." *J. Am. Plan. Assn.*, 67(2), 173–185.

Olshansky, R. B., and Kartez, J. D. (1998). "Managing land use to build resilience." *Cooperating with nature: Confronting natural hazards with land-use planning for sustainable communities*, R. J. Burby ed., Joseph Henry Press, Washington, D.C., 167–202.

Oppenheimer, D. H. et al. (2005). "The seismic project of the National Tsunami Hazard Mitigation Program." *Natural Hazards*, 35(1), 59–72.

Oregon Emergency Management. (2005). *After Action Report: West Coast Tsunami Warning June 14, 2005*, Salem Ore.

Ramirez, F. J., and Perez, P. C., (2004). "The local tsunami alert system ["SLAT"]: A computational tool for the integral management of a tsunami emergency." *Natural Hazards*, 31(1), 129–142.

Schwab, J., Topping, K. C., Easie, C. C., Deyle, R. E., and Smith, R. A. (1998). *Planning for pstdisaster recovery and reconstruction*, PAS Report 483/484, American Planning Association, Chicago.

Titov, V. V. et al. (2005). "Real-time tsunami forecasting: Challenges and solutions." *Natural Hazards*, 35(1), 41–58.

Tsunami Hazard Mitigation Federal/State Working Group. (1996). "Tsunami hazard mitigation implementation plan—A report to the Senate Appropriations Committee." 〈http://www.ppi.noaa.gov/weather_water/PDF/Hazard3.pdf〉 (September 12, 2006).