Comparison of Strong Currents and Impacts on the California (USA) Maritime Communities from the 2010 Chile and 2011 Japan Teletsunamis

by Rick Wilson[1], Kevin Miller[2], Clif Davenport[3], Troy Nicolini[4], Lori Dengler[5], Amanda Admire[5], Costas Synolakis[6], Aggeliki Barberopoulou[6], Jose Borrero[6], Patrick Lynett[6], Bruce Jaffe[7], and Ed Curtis[8]

1 California Geological Survey - Sacramento (*correspondence: rick.wilson@conservation.ca.gov; PG 5878, CEG 1881)
2 California Emergency Management Agency – San Francisco Bay Area
3 California Geological Survey – Santa Rosa
4 NOAA National Weather Service, Weather Forecast Office – Eureka
5 Humboldt State University
6 University of Southern California – Tsunami Research Center
7 U.S. Geological Survey – Santa Cruz
8 Federal Emergency Management Agency – Region 9

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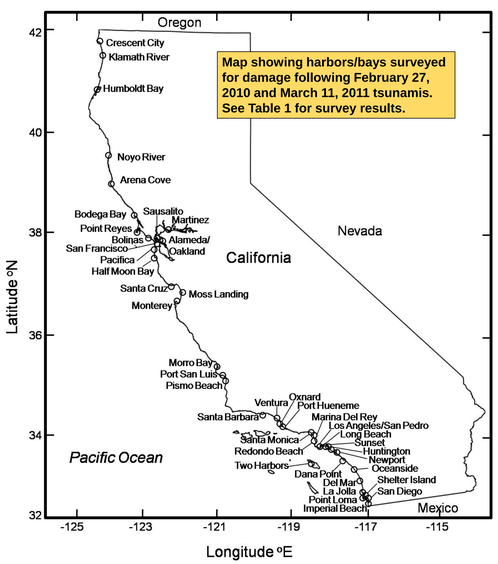
Abstract

The February 27, 2010 Chile and March 11, 2011 Japan tsunamis caused dramatic loss of life and damage in the near-source region, and notable impacts in distant coastal regions like California. Comprehensive post-tsunami surveys and the availability of hundreds of videos within harbors and marinas allow for detailed documentation of these two events by the State of California Tsunami Program (Wilson and others, 2011). Although neither event caused significant inundation of dry land in California because peak arrival occurred during low tide, damage to docks, harbor infrastructure, and boats was noteworthy. The 2010 Chile tsunami caused approximately $3-million in damage to a dozen harbors, primarily in central and southern California locations like Santa Cruz Harbor, Ventura Harbor and San Diego Bay. The 2011 Japan tsunami caused over $50-million in damage to more than two dozen harbors along the entire coast of California, most extensively to harbors/marinas in Crescent City, Noyo River, and Santa Cruz. During both events, strong tsunami currents, with some observed estimates greater than 15 knots, were generated at harbor entrances and along inside bends and narrows within harbors. Preliminary evaluations of harbor infrastructure and the interaction of boats indicate that drag along the base of large ships exacerbated the damage to docks to which the ships were tied. Evaluation of tsunami currents and damage will help in the validation/calibration of numerical tsunami model currents with the ultimate goal of developing tsunami current hazard maps for harbors statewide. These hazard maps will improve emergency response and infrastructure planning within harbors.



Strong Currents

Even relatively minor tidal fluctuations (~1 meter peak-to-trough) caused strong tsunami currents that made navigation difficult and caused damage to boats, docks, and infrastructure. Visual estimates by some harbor masters indicated extreme currents could have reached 15 to 20 knots in some harbors. Analysis of video indicates maximum velocities at the mouth of the Crescent City small-boat basin likely only reached 8 knots (Amanda Admire, personal communication). Other types of tsunami current hazards such as bores and eddies also caused damage at Santa Cruz and Noyo River, respectively. Additional video analysis is needed to verify the current velocities and better understand the unique types of hazard which can strike harbors and ports.

Table 1: Forecasted, recorded, and observed arrival times, maximum amplitudes, and damage estimates in California from the February 27, 2010 and March 11, 2011 tsunamis. Blank cells indicate that data was not collected for those locations; they do not represent zero values. Red boxes associated with photos to the right. Data gathered by the California Tsunami Clearinghouse.

Harbors, Ports, Bays, and Docks Surveyed (from north to south)	First Arrival Times				Maximum Tsunami Amplitudes (meters)				Reported Damage or Other Effects from Tsunami (NDR = no damage reported; damage estimates in parentheses)	
	Feb. 27, 2010		March 11, 2011		Feb. 27, 2010		March 11, 2011		Feb. 27, 2010	March 11, 2011
	Forecasted (PDT)	Observed Tide Gauges or Estimated by Others* (PDT)	Forecasted (PST)	Observed Tide Gauge or Estimated by Others* (PST)	Forecasted	Observed Tide Gauge or Estimated by Others*	Forecasted	Observed Tide Gauge or Estimated by Others*		
Crescent City	1340	1346	0723	0734	0.61	0.64	2.50	2.47	NDR	Near complete destruction of small boat harbor ($20M)
Klamath River							2.36		NDR	One fatality (drowning)
Humboldt Bay	1336	1333	0722	0734	0.2	0.23	1.33	0.97	NDR	NDR
Noyo River								0.8-1.0*	NDR	Major damage to docks/boats ($4M)
Arena Cove	1248	1304	0726	0729	0.49	0.39	1.30	1.74	NDR	NDR
Bodega Bay							0.97	0.5-0.7*	NDR	NDR
Point Reyes	1259	1259	0739	0746	0.46		0.63	1.35	NDR	NDR
Bolinas								0.7-0.9*	NDR	NDR
Sausalito							0.37	1.2-1.5*	NDR	Houseboat damage; broken sewer line
Martinez				0950*				0.06	NDR	NDR
Alameda/ Oakland	1344	1345		0836	0.18	0.12	0.29	0.51	NDR	Minor damage at nearby Berkeley Marina
San Francisco	1320	1326	0808	0812	0.22	0.32	0.73	0.62	NDR	Two piles broken
Pacifica							0.85	0.8-1.0*	NDR	NDR
Half Moon Bay					0.96	0.6*	0.92	0.7*	NDR	NDR
Santa Cruz					0.51	0.9*	1.01	1.6-1.9*	Minor damage to boats and harbor infrastructure	Multiple docks destroyed, 14 boats sunk ($28M)
Moss Landing						0.3*		2.0*	NDR	200 piles damaged ($1.75M)
Monterey	1231	1243	0744	0748	0.45	0.36	0.52	0.70	NDR	NDR
Morro Bay				0800	0.82	0.5*	1.18	1.6	NDR	Damage to several docks and boats ($500k)
Port San Luis			0803	0810	0.84	0.8*	2.14	2.02	NDR	NDR
Pismo Beach					1.43	0.9-1.2*	0.73	0.7-1.0*	NDR	NDR
Santa Barbara	1230	1231		0829	0.75	0.91	0.48	1.02	Minor damage to dredging equipment	Damage to barges and boats ($70k)
Ventura						0.6-0.9*	0.88	1.3*	Over 20 docks damaged; buoys moved ($300-500k)	Damage to dock and number of boats ($150k)
Oxnard				0830*		1.0*		0.9-1.2*	Dock damage from large boat wake	Minor damage to docks
Port Hueneme						0.5-0.7*		1.2-1.4*	NDR	NDR
Santa Monica	1225	1225	0840		1.18	0.64	0.84	0.85	NDR	NDR
Marina Del Rey				0830*		0.1*		0.9-1.0*	Minor damage to dock	Minor damage to docks; dingies sunk
Redondo Beach							0.65	0.6-0.7*	NDR	Dock destroyed; five boats damaged
Two Harbors/ Catalina						0.6-0.9*			Minor damage to several docks	Damage to several docks and 10 boats
Los Angeles/ San Pedro	1215	1215	0832	0840	0.77	0.42	0.39	0.49	Minor damage to docks and marine infrastructure	Minor damage to docks and boats
Long Beach									NDR	Minor damage to docks and boats
Sunset						0.3-0.5*			NDR	NDR
Huntington							0.71		NDR	Boat pulled off mooring
Newport				0846*		0.5*		0.3*	NDR	NDR
Dana Point				0830*		0.5-0.7*		0.6*	Bait barge severed	Pylon damaged when hit by boat
Oceanside						0.6*		0.5*	Minor dock damage; several buoys carried to sea; boat trailer swamped	NDR
Del Mar							0.58	0.9*	NDR	NDR
La Jolla	1202	1202	0841	0847	0.84	0.60	0.70	0.9*	NDR	NDR
Mission Bay									Small sailboat swamped trying to leave harbor; buoys moved	Dock destroyed, 13 boats damaged ($136k)
Point Loma							0.69	0.5	NDR	NDR
Shelter Island, San Diego Bay						0.9-1.2*		0.8*	North Island: Moderate damage to docks, concrete piers, and boats	South Island: a boat sunk and there was damage to dock
San Diego Bay/ Interior	1204	1208			0.27	0.40	0.35	0.63	NDR	NDR
Imperial Beach				0930*			0.78	0.5*	NDR	NDR

February 27, 2010 M8.8 Chile

Strong currents near entrance to Crescent City Small Boat Harbor make navigation difficult.

Boats brake loose in upper portion of Santa Cruz Harbor.

Large tidal fluctuations cause severe damage to 20 docks in The Keys section of Ventura Harbor.

Strong currents result in damage to dock in north Shelter Island, San Diego Bay.

March 11, 2011 M9.0 Japan

Extreme currents within Crescent City Small Boat Harbor destroyed docks and sunk boats.

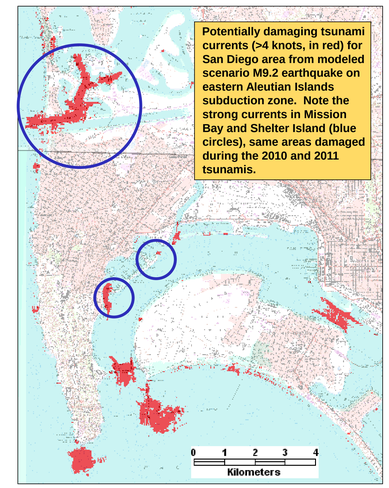
One meter bores in upper Santa Cruz Harbor causes damage to docks and boats.

Strong surges overtop docks in Ventura Harbor. Dock damage occurs 15 hours after first arrival.

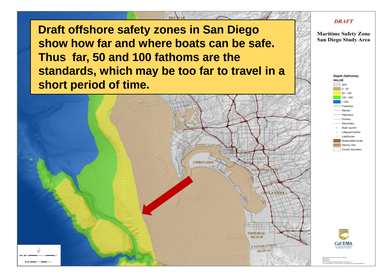
Boat sinks and damages dock due to strong drag in south Shelter Island, San Diego Bay.

Maritime Work

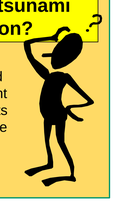
Data from the March 11, 2011 event is still being evaluated, including harbor currents and sediment movement. One of the more interesting situations to be studied is the successful evacuation of most of the commercial fishing fleet out of Crescent City Harbor prior to the arrival of the tsunami. Evaluation of the experiences of these and other boaters will help understand their decision making process, how far they had to go offshore to be safe, and how others can learn from their experience.



The California tsunami program in cooperation with FEMA has begun implementing a plan to increase awareness of tsunami generated hazards to the maritime community (both ships and harbor infrastructure) through the development of in-harbor hazard maps (above), offshore safety zones for boater evacuation (below), and associated guidance for harbors and marinas so boaters will know if, when, and where to go offshore (Miller and others, 2011). An initial step in the program will be to calibrate current velocity modeling results against measured flow velocities associated with both the 2010 and 2011 tsunamis. The hope is that the maritime guidance and associated education and outreach program will help save lives and reduce exposure of damage to boats and harbor infrastructure. Promoting faster recovery will also be a focus.



Should visual estimates of tsunami current velocities be relied on?



We received dozens of current velocity estimates from harbor masters, but based on comparison to video particle-movement analysis in Crescent City, the visual results either overestimate the velocity or they are only representative of micro-harbor conditions, not a good representative sampling for a harbor overall.

Issues for Maritime Community

The two events caused a number of problems for the maritime/boating community:

- **Harbor masters had to make quick, critical decisions about evacuations within the harbor.** Although life-safety was the primary concern, the uncertainty about recommending evacuation of boats out to sea is an important consideration.
- **Boaters, especially recreational boaters, had to make under-informed decisions about whether or not to take their boats offshore prior to the arrival of the tsunami.** Most did not plan ahead for this contingency so they had to leave their boats in harbor. In most cases, leaving their boats docked was the right thing to do for these particular tsunamis.
- **Most recreational boaters don't understand that strong tsunami activity can last a long time, more than 8 hours during the February 27, 2010 tsunami and 24 hours in during the March 11, 2011 event.** For boaters that did go offshore, many did not have supplies or the experience to stay offshore until the dangerous tsunami activity was over. Boaters that tried to return to the harbors during the tsunami had difficulty doing so and caused damage to other boats and docks, and injury to harbor personnel when trying to dock.
- **Maritime communities like Crescent City and Santa Cruz are still trying to recover nine months after the March 11 tsunami.** Permitting and funding delays have put a strain on reconstruction efforts, reducing the income for these harbors to help with recovery.

Acknowledgements and References

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Other tsunami information for California: www.tsunami.ca.gov