Integrating space- and time-scales of sediment transport for Poverty Bay, New Zealand, and the nearfield continental shelf

Aaron Bever* and Courtney Harris. Virginia Institute of Marine Science. abever@vims.edu

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INTRODUCTION / LOCATION

Poverty Bay, a small embayment on the eastern shore of the north island of New Zealand (Fig. 1), receives freshwater and sediment from the Waipaoa River, a small, mountainous river that discharges sediment during short episodic pulses (see Fig. 2). The Waipaoa River freshwater discharge averages only 32 m^3s^{-1}, yet it carries nearly 15 million metric tons of sediment each year. Funded by NSF Margins Source-to-Sink, we are analyzing the modification of sediment supply as it transits Poverty Bay, and the sediment transport pathways it takes as it is exported to the shelf.

The Poverty Bay shoreline has been actively prograding for the last 7 ky, but showed a marked decrease in progradation rate about 3500 years ago. A definitive description of the processes responsible for this slowdown has not yet been presented.

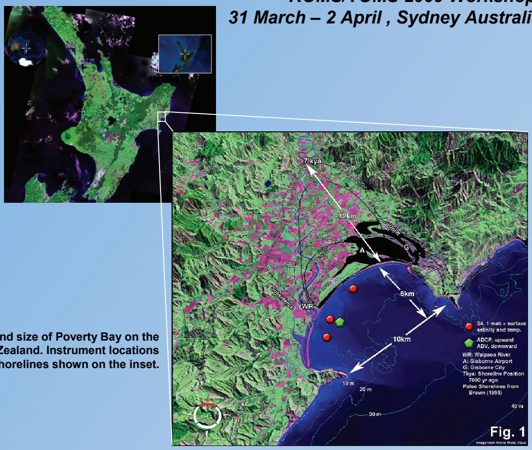


Fig. 1. Location and size of Poverty Bay on the North Island, New Zealand. Instrument locations and paleo shorelines shown on the inset.

METHODS

Numerical models for hydrodynamics (ROMS), sediment transport (ROMS), and waves (SWAN) were used to represent sediment dispersal within Poverty Bay for 1 January, 2006 through 28 August, 2006. The model was configured as follows:

- Model grid: recent multibeam from within Poverty Bay, and shelf bathymetry provided by S. Stephens (NIWA). Paleo- bathymetry (7kya) was from Wolinsky et al. (in review).
- Open boundaries: gradient conditions (tracers, 3D momentum), Chapman (free surface), and Flather (2D momentum).
- Advection and turbulence: MPDATA and GLS turbulence closure.
- Tides: based on the OSU global tidal model.
- Discharge: hourly observations of freshwater (Gisborne District Council), sediment discharge based on a rating curve (Hicks et al. 2000) (Fig. 2AB).
- Atmospheric: observations of hourly winds from the Gisborne airport (Fig. 2C), with other variables monthly means.
- Sediment properties: two fluvial sediment classes (table 1).
- Time-varying waves (SWAN): modern and paleo geometries, using winds from the Gisborne airport and open boundaries from WW3.

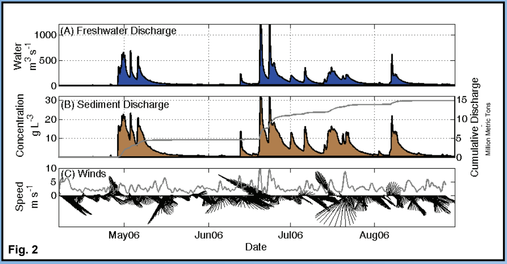


Fig. 2. Input used for ROMS. Wind vectors point in the direction the winds are blowing towards. Note the largest discharge events coincide with onshore winds. Both the ROMS and SWAN results highlight the storm in May. Little discharge occurs before 28 April.

River Sediment Class	Fraction	w_s (mm s^{-1})	τ_{cr} (Pa)	Erosion Rate (kg m^{-2} s^{-1})
1	99%	0.1	0.03	$5x10^{-5}$
2	1%	1.0	0.08	$5x10^{-5}$

Table 1. Sediment classes discharged from the Waipaoa River.

OBJECTIVES

1. Determine how sediment from the Waipaoa River is modulated before being exported to the continental shelf.
2. Determine the sediment transport pathways through Poverty Bay to the continental shelf.
3. Examine the 7 kya Poverty Bay from a short-term process based standpoint; and contrast this to modern day processes.

SWAN WAVES

MAIN POINTS:

1. The SWAN model with WW3 boundary conditions accurately reproduced wave sheltering and the timing and magnitude of wave events in the modern bay (Fig. 3).
2. Local storms produced energetic waves within Poverty Bay (Fig. 4C, D), with wave sheltering evident (Fig 4).
3. Wave sheltering reduced wave heights throughout much of the 7 kya Poverty Bay (Fig. 4 B, D).
4. The change in progradation rate of the Poverty Bay shoreline through time may be explained by the increase in wave energy as the shoreline advanced toward the open ocean (Fig. 5).

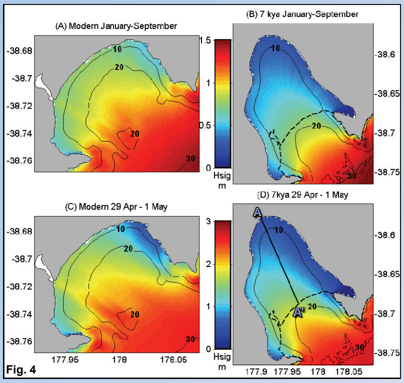
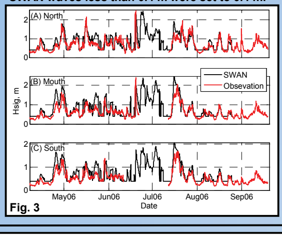


Fig. 4. Seasonal (A,B) and moderate storm (C,D) time-averages of SWAN estimated wave height within Poverty Bay.

Fig. 3. SWAN estimated waves compared to data collected at S4s within Poverty Bay (see Fig. 1). SWAN waves less than 0.4 m were set to 0.4 m.



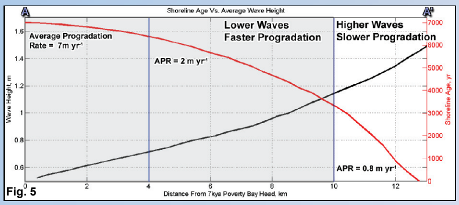


Fig. 5. (Black line) Wave height during a moderate storm estimated along the A – A' transect (Fig. 4D) for the 7kya Poverty Bay. (Red line) Age of the shoreline as it advanced along the A – A' transect from the paleo-bay head to its modern position. In the x-axis, A – A' is represented by 0 - ~13 km. Shoreline age from Wolinsky et al. (in review).

ROMS RESULTS

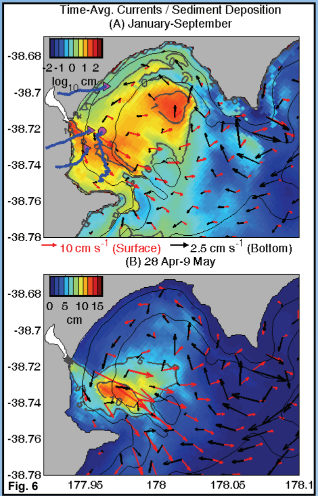


Fig. 6. Time-averaged surface and bottom currents (arrows) and sediment deposition (colors) for the specified times in 2006. (A) S4 (triangle) and ADCP (circle) observed counterclockwise and onshore velocities within the nearshore of Poverty Bay are shown; blue lines are nearbed progressive vectors from two ~2.5 month deployments. (B) 28 April – 9 May represents deposition during moderately stormy, elevated discharge conditions (see Fig. 2).

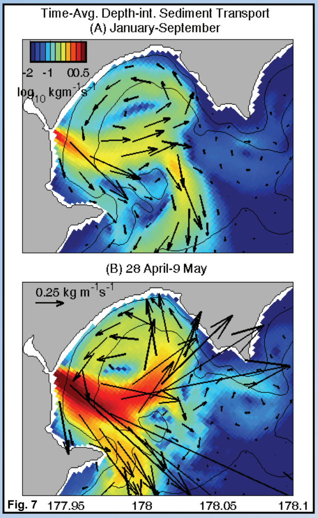


Fig. 7. Depth-integrated, time-averaged sediment transport vectors, showing the estimated direction and magnitude of sediment transport from the Waipaoa River mouth during 2006. Panel A represents average conditions that included summer, fall, and winter; while B shows moderate storm driven transport.

MAIN FEATURES OF MODEL ESTIMATES

1. Surface outflow with a bottom return flow, highlighting the baroclinic pressure gradient and offshore wind induced upwelling flows (Fig. 6).
2. Ephemeral deposition within Poverty Bay (Fig. 6).
3. Three different sediment transport pathways were identified: sediment transported to the shelf towards the (1) northeast and (2) southwest during storms, and (3) out of the middle of the bay and deflected southward during fair-weather (Fig. 7).
4. Modeled deposition patterns matched well with Poverty Bay bathymetry, observed sediment grain size distributions, and ^{7}Be distribution patterns (not shown).
5. Qualitatively the model reproduced the observed counterclockwise circulation, some of the onshore flow (Fig. 6A), and storm driven hydrodynamics (not shown).

Conclusions

1. The Waipaoa River differs from the paradigm of "small mountainous rivers" because much sediment is deposited in the nearfield during the initial flood, even though the flood coincides with an oceanic storm.
2. Temporarily deposited sediment is later resuspended by energetic waves and follows a transport path different than sediment exported during the flood.
3. Wave sheltering helps to explain the decrease in progradation rates in Poverty Bay over the past 7ky.
4. Short-term process studies can give useful insight into understanding long-term shoreline progradation.

Future Work

- Couple ROMS and SWAN to better capture nearshore dynamics.
- Continue to evaluate the models compared to observational data.
- Generate the input files to model hydrodynamics and sediment transport for the 7 kya bay.

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