The influence of the geometry of Poverty Bay on sediment dispersal within the Waipaoa Sedimentary System: numerical model investigations comparing Holocene configurations

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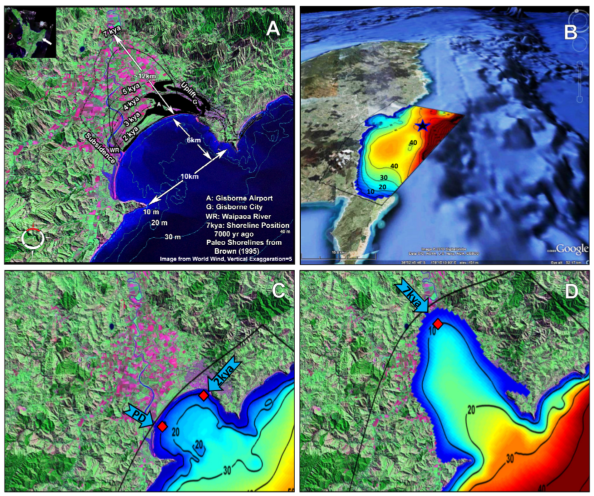
1. Introduction/Methods: Poverty Bay is a significant part of the Waipaoa River sedimentary dispersal system. It has acted as a sediment sink over the past 7,000 years, and processes within the bay significantly modify the fluvial sedimentary signal before transfer to the continental shelf. We represented hydrodynamics, waves, and sediment-transport within Poverty Bay (Fig. 1A), using the Regional Ocean Modeling System (ROMS) coupled to the Simulated WAves Nearshore (SWAN) model. Model grids were generated to represent Poverty Bay at the present-day, 2 kya (Fig. 1B,C), and that at maximum transgression, ~7 kya (Fig. 1D). We used realistic time-series of winds, river discharge, and waves to generate model inputs, based on the winter of 2006 and a flood in October, 2005 (Fig. 2). Sediment discharge was estimated based on Hicks et al. (2000) and adjusted to pre-anthropogenic conditions by dividing by 6.6 (Kettner et al., 2007). Model input was held constant, except for changes to bathymetry, shoreline position, and sediment load. No attempt was made to account for changes to climate or to sediment grain-size distributions. Instead, the modeling exercise focused on changes to the geometry of Poverty Bay.

Objectives were to determine:

1) If marine dispersal, basin shape, and marine energy levels influence the transfer of sediment to the shelf and can help explain shoreline progradation rate changes within Poverty Bay (See Fig. 1A)?
2) How sediment sorting and the segregation of coarse and fine sediment have changed since the maximum marine transgression, due to routing through Poverty Bay?
3) Whether changes to sediment dispersal and wave energy within Poverty Bay since maximum transgression can explain varying mean grain sizes observed in sediment cores on the adjacent shelf (See Fig. 3)?



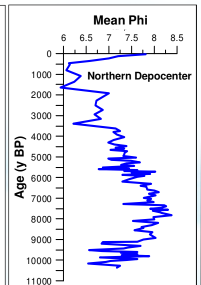


Figure 3: Observed grain size on the shelf through time. Figure courtesy of Lila Rose. (Kuehl et al. In Prep)

Figure 1: (A,B) Location of Poverty Bay, (B) the spatial extent of the numerical model grids, (C) the modern bay, and (D) the 7 kya bay. Bathymetry shown in meters. (A) shows the shoreline position through time. (C,D) Arrows show the (PD) present–day, 2 kya, and 7 kya Waipaoa River mouth locations. (D) 7 kya bathymetry from Wolinsky et al. (2010). ★ in 1B is the location of shelf core MD972122. ◆ for Fig. 6.

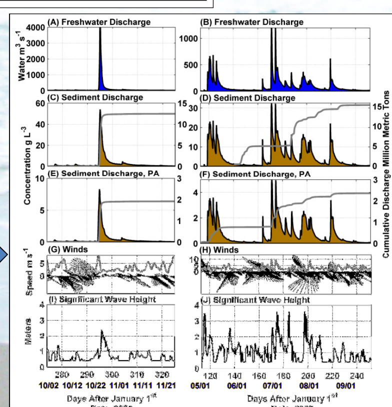


Figure 2: (A,B) Waipaoa River freshwater, (C,D) present day sediment (Hicks et al. 2000), and (E,F) pre-anthropogenic sediment discharges (Kettner et al. 2007). (G,H) Wind forcing from Gisborne Airport. (I,J) Wave time-series from inside the modern Poverty Bay. The event in October, 2005 represents a roughly 40 yr recurrence interval flood.

Table 1: Sediment characteristics used in these model runs.

Class	Diameter (μm)	W_s (mm s^{-1})	τ_{cr} (N m^{-2})	Erosion Rate Parameter (kg m^{-2} s^{-1})	Fraction of Discharge
1	7.8	0.038	0.02	5×10^{-4}	40
2	15	0.15	0.03		30
3	31	0.62	0.06		30
4	125	10	0.14		1

2. Results: Wave sheltering reduced the wave height and orbital velocity in the 7 kya Poverty Bay, compared to the more modern configurations (Fig. 4). A transect down the 7 kya configuration (A"-A') showed shoreline progradation decreased and wave energy increased as the shoreline approached the open coastline (Fig. 5). Current speeds were increased in the modern bay geometries over that of 7 kya (Fig. 6), helping to increase the amount of sediment transferred to the shelf. The cumulative sediment transferred to the shelf responded strongly to periods of increased river discharge and to swell events (Fig. 7). The grain size transferred to the continental shelf was the finest 7 kya, and coarsened toward the 2 kya and modern configurations, for both the winter and flood scenarios (Fig. 8). Sediment sorting within Poverty Bay was much more pronounced in the longer time-frame winter simulation than the extreme flood, due to repeated wave remobilization (Fig. 8). Overall, the most sediment was retained within the 7 kya bay (Table 2, Figs. 7,9).

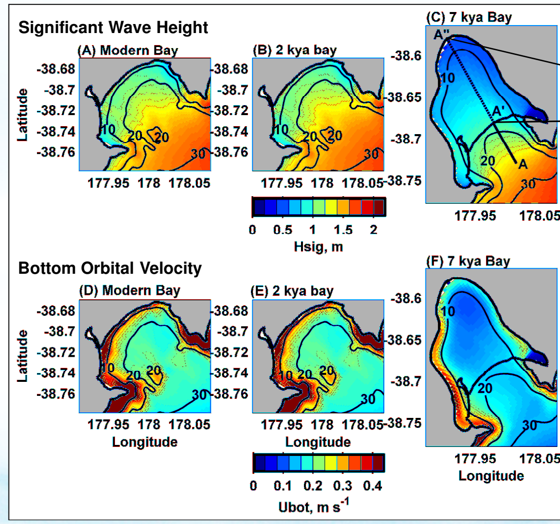


Figure 4: Time-averaged significant wave height and bottom orbital velocity over the winter simulation. Flood and swell averages produce patterns consistent with these.

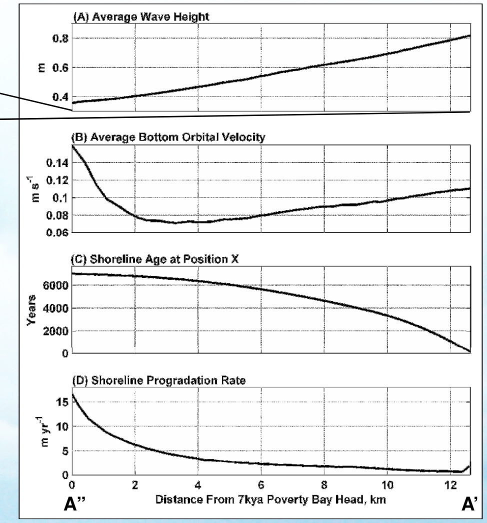


Figure 5: Time-averaged (A) significant wave height and (B) bottom orbital velocity over the winter simulation. (C) Shoreline position through time and (D) shoreline progradation rate. Shoreline position from Wolinsky et al. (2010)

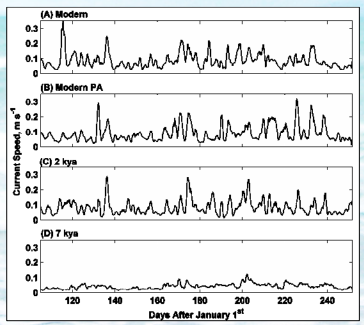


Figure 6: One meter above the bed current speeds in 10 m water depth seaward of the river mouth during the winter scenario. Locations shown as diamonds in Fig. 1C and D.

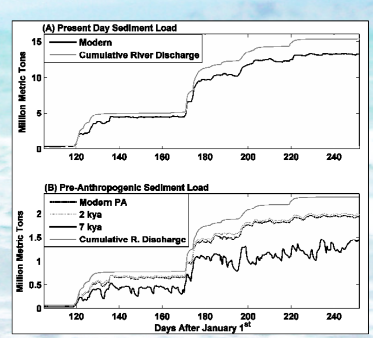


Figure 7: Cumulative sediment export from Poverty Bay during the winter scenario. The Modern PA and 2 kya curves fall nearly over top of each other. Significant wave resuspension events occurred near days 156, 181, and 229 (see Fig. 3J).

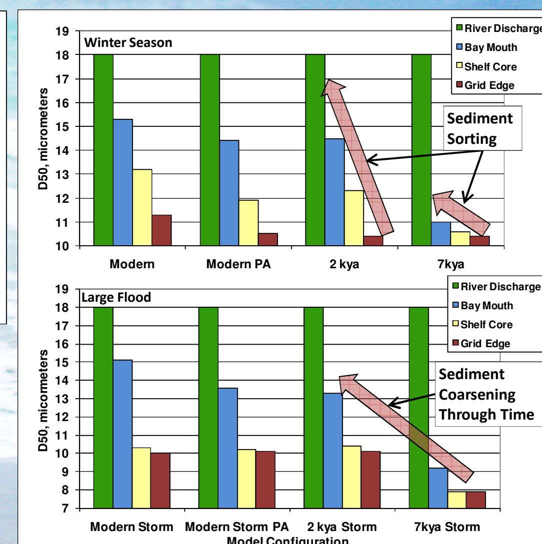


Figure 8: Average grain size discharged from the Waipaoa River and transferred to three distances from the Waipaoa River mouth. The distances correspond to the mouth of Poverty Bay, the shelf core MD972122, and the edge of the model domain. Note: without the 1% sand fraction the river discharges a grain size of 16.9 μm.

Table 2: The percent of the Waipaoa River discharge deposited on the seabed within three distances from the river mouth.

Meteorology	Model grid	Poverty Bay Mouth	Shelf Core MD972122	Edge of Model Grid
Winter Season	Modern	13	27	42
	Modern PA	18	34	46
	2 kya	18	33	48
	7 kya	41	44	48
Large Flood	Modern	14	53	59
	Modern PA	33	49	54
	2 kya	25	50	53
	7 kya	75	86	90

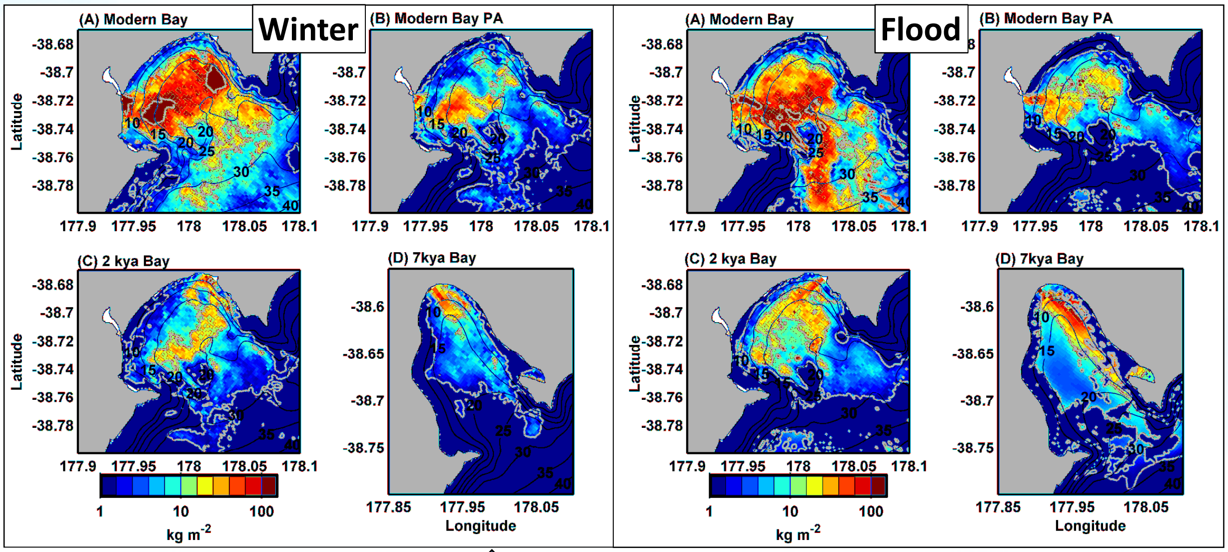


Figure 9: Sediment deposition at the end of the winter and flood scenarios. Color-scale axis labels are contoured for clarity. Bathymetry is contoured in meters. kg m^{-2} translates to mm of thickness assuming a porosity of ~65%.

Ask to see model visualizations of sediment dispersal, deposition, and transfer to the continental shelf.

3. Conclusions:

- **Model results show that shoreline progradation enhanced sediment export to the shelf, by increasing Poverty Bay's exposure to waves and currents and by reducing the distance from the river mouth to the open shelf.**
- **Poverty Bay geometry and the impact on physical processes lead to a coarsening of sediment transferred to the continental shelf through the Holocene, consistent with long cores on the shelf (Gomez et al., 2004; Kuehl et al,. In Prep).**
- **Analysis of model results support assertions that anthropogenic changes to the Waipaoa River sediment grain size explains the fining upward trend in modern cores by Wilmshurst et al. (1999), Gomez et al. (2004) and Kuehl et al. (In Prep).**
- **Model estimates using realistic basin geometries and time-series meteorological forcing showed that marine dispersal is important when examining Holocene time-scale trends in the Waipaoa Sedimentary System.**
- **Transport processes within even relatively small bays can significantly modulate the sediment transferred to the continental shelf.**

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