A foraminiferal sea-level reconstruction from Pauatahanui Inlet, southern North Island, New Zealand

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Abstract

Vertical land movement associated with interseismic subsidence and slow-slip events pose a major complicating factor when understanding how sea-level rise is likely to affect New Zealand's capital city of Wellington. To understand how these factors have affected sea level in the long-term, and thereby gain geological context for these movements, the nearest undisturbed salt marsh (Pauatahanui Inlet) was surface sampled and cored. These samples were used to assess the relationship between species of foraminifera (a group of testate protists) and elevation, then apply these relationships down-core to calculate past sea level. The nearest continuous GPS station (Paekakariki Hill) displays 1.7±0.35 mm/yr subsidence since its installation in the year 2000 (Tenzer and Fadil, 2016). However, according to a variety of transfer functions (statistical techniques which relate foraminiferal assemblage to elevation), our sediment core data indicate that, since the 1855 earthquake (which leaves a very distinct signature in the record), relative sea level has risen at Pauatahanui by ~1.4 to 1.6 mm/yr. This is less than what would be expected from subsidence alone, yet also must incorporate a significant signal from anthropogenic sea-level rise. We therefore interpret that the slow subsidence in the cGPS record likely indicates a short-term signal which, over the course of the past century, has been counteracted by the combined influence of events such as slow-slip associated with the Kapiti Coast source region, post– and co-seismic uplift, and possibly variations in subsidence rate. This, combined with the lower than expected rates of sea-level rise at the Wellington tide gauge from nearby cGPS stations, suggests that it is unwise to base local sea level projections on the observed recent net subsidence alone without factoring in the long-term effect of slow-slip and co-seismic uplift.

Context

- GPS stations in the city of Wellington are currently undergoing subsidence on the order of~2.6-2.8 mm/yr, while Wellington tide gauge indicates 2.18 ± 0.17 mm.yr sea-level rise since 1891 (Denys et al. 2020)
- The proximity of the city to the subsidence-uplift hinge line means that minor changes in coupling distributions can change the sense and direction of vertical land movement (VLM) (Denys et al., 2020).
- The nearest salt marsh to Wellington (Pauatahanui Inlet) is analysed to attempt to determine long-term land-movement trend by generating a sea-level reconstruction using foraminifera.
- Pauatahanui is one of 3 regions where this methodology is being applied to provide geological (centennial baseline) context for the MBIE Endeavour-funded NZSeaRise

Methodology

2 transects & 7 sediment cores taken across marsh to characterise foraminiferal relationship with elevation (Figure 1a-b)), and assess stratigraphy

2 master cores taken for use in sea level reconstruction

Samples taken every 2 cm decrease in elevation and washed between 500-63 µm for picking of foraminifera, which are then counted

Development of transfer functions (statistical techniques which relate species assemblage to elevation) using surface transect data and application of them to sediment cores

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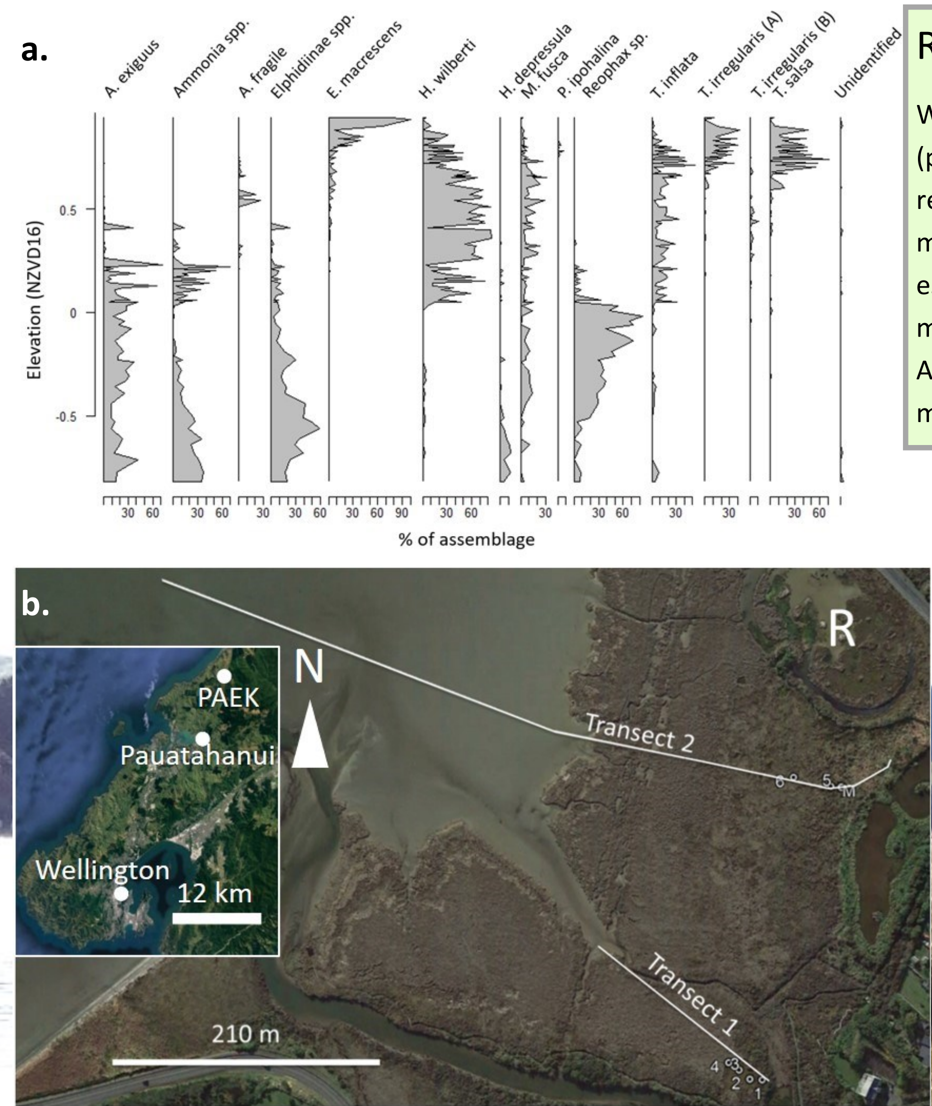

Fig. 1 a) Foraminiferal assemblage across Pauatahanui salt marsh, plotted against elevation (satellite imagery: Google Earth) b) location and orientations of transects (lines) and core sites (numbered/lettered dots) within the marsh, as well as position of the site relative to Wellington City and Paekakariki Hill (PAEK) (inset). R is the position of the former motorcycle racetrack

Stratigraphy

Cores from across the marsh all contain an abrupt transition from underlying coarse sands (analogous to the adjacent tidal flat) to salt-marsh peat or peaty clay at depth of 19-21 cm depth, indicating consistent sedimentation rate across the marsh since its inception

This abrupt change is interpreted, based on the historical record (see Reilly, 2012) to represent uplift in the 1855 earthquake.

Results

When applied down-core, all of the best-performing transfer functions (presented are unfiltered draft results) indicate ~1.4 to ~1.6 mm/yr mean relative sea-level rise since 1855 (Fig. 2). These data also indicate 1 ±~0.16 m uplift in the 1855 earthquake, significantly exceeding prior 30–60 cm estimates for the site (Grapes and Downes, 2010; McFadgen, 2010), which may be due to the models performing best in the high marsh environment. All model results have root-mean-squared-errors between ±0.14 and ±0.16 m (model and sample-dependent), and R^2 values 0.84 to 0.88

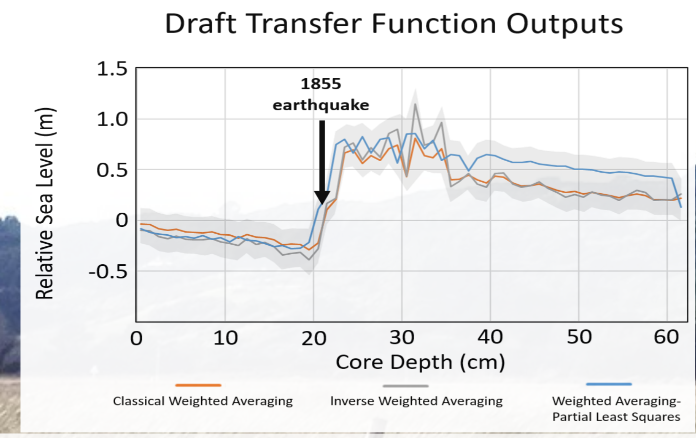

Fig. 2. Outputs from the three best performing transfer functions.

Conclusions

Though further development of models and chronology are necessary, these highly preliminary data suggest lower or equivalent rates of relative sea-level rise at Pauatahanui when compared with the rate of subsidence observed in the nearest cGPS station for the past two decades (1.7±0.35 mm/yr (Tenzer and Fadil, 2016)).

As this also includes sea-level rise induced by climate change, the short-term GPS-measured subsidence rate must have been overcome by uplift (e.g. during slow-slip events, see Wallace (2020)) or have fluctuated significantly with time.

Next Steps

- Complete transfer function development
- Derive a high-resolution chronology for the site, incorporating pollen, X-ray fluorescence, bomb-spike radiocarbon (if sufficient dateable material is present), and lead-210 isotope work
- Apply the techniques learned at this site to other sites adjacent to Dunedin (Aramoana salt marsh), and Auckland (an unnamed salt marsh on Rangitoto Island).

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