80 Years of Shoreline Change in Northland, New Zealand

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Abstract

Understanding long-term shoreline change patterns is crucial for effective management of coastlines. Decadal-scale records of shoreline change are typically determined by mapping shorelines using series of historical aerial imagery. In New Zealand, such shoreline change records are limited and highly fragmented. A national assessment of coastal erosion has not been conducted since benchmark work completed in 1978. This paper reports on the first step in an ambitious project to map national-scale shoreline change in New Zealand over the past century. We present a dataset of shoreline change since the 1930s for unconsolidated beaches in Te Tai Tokerau (Northland). Over 3000 km of shoreline imagery was georeferenced and digitised for historical imagery in the national archive. Shoreline data were analysed for nearly 50,000 transects spaced at 10m intervals using the Digital Shoreline Analysis System. Coastal change hotspots are noted at several locations on both west and east coasts, particularly at the distil edges of sand spits, river mouths and harbours. The highest rate of shoreline accretion and erosion (90^{th} percentile rates ~ +10 and -8 m/y respectively) occur near North Head Kaipara Harbour. Localised areas of rapid coastal change occur along 90-Mile Beach and at Kokota Spit (Parengarenga) and Otiaia Point (Rangaunu Bay), and in these areas accretion is dominant, with 90^{th} percentile rates of ~+2.5 m/y and total shoreline accretion of 200-300m. The west coast shows overall accretion over the ~80-yr observation period at a median rate of ~+0.4 m/y whereas the east coast shows effectively no change: it has been remarkably stable despite interdecadal climatic fluctuations and observed sea-level rise over the past century. Sediment supply and vegetation appear to be key drivers of the observed coastal change patterns.

Keywords: coastal erosion, shoreline, coastal accretion, historical aerial imagery.

1. Introduction

Coastal erosion is a major hazard facing coastal communities throughout NZ and globally. Asset risk exposure is increasing with sea level rise (SLR), but we have an incomplete picture of shoreline change around NZ, which presents a challenge for reliable national scale erosion risk assessment [1]. Many sections of NZ's coast also exhibit complex behaviours that are hard to interpret (e.g. [2]). This reflects the fact that coastal systems have multiple potential drivers of shoreline change, such that it is extremely difficult to disentangle the role of SLR against myriad human and natural factors that also contribute to large-scale shoreline change. This is a well-known global science problem [3] that is partly responsible for the limited scientific basis that currently exists for projecting future shoreline positions [4].

A critical first step in understanding coastal behaviour is compilation of reliable historical change datasets. This need is reflected in multiple national-scale shoreline mapping programmes, including in the USA (e.g. USGS, National Assessment of Coastal Change Hazards [5]) and UK (Environment Agency, 2009, Shoreline management plans [6]). The aim of Pillar 1 of the Coastal Theme within the Resilience National Science Challenge is to collate, at national scale, the data necessary to understand historical trends of coastal change around NZ and provide the scientific datasets necessary for future-casting physical coastal change. Historical aerial photographs are available for much of NZ dating back to the late 1930s. These photographs, alongside other survey data, were last used in a nation-wide survey of erosion and accretion in the 1970's [7]. Since this time, coastal change work has been fragmented, often undertaken at local scale without a consistent approach to data collection and analysis. This sporadic approach has not provided a coordinated basis to understand and manage coastal change around the country.

In this paper we describe the first results of the Resilience Science Challenge coastal mapping project following the completion of shoreline change mapping in Te Tai Tokerau, Northland.

2. Methods

2.1 Imagery acquisition

Historical high-resolution aerial imagery were obtained for the entire Northland region in partnership with LINZ. The distribution of available imagery from the west and east coasts permits historical shoreline analyses dating back to 1938 with gradual increasing frequency of image capture that peaked in the late 1970s (Figure 1). Notable gaps in availability in the late 1980s and between 1988-2013. The large number of data points in

2014-2016 represents shorelines interpreted from an aerial photo survey undertaken during summer months in 2014, 2015 and 2016 which covered the entire Northland region. This provides the most recent, region-wide survey, and was downloaded from the LINZ data service and processed into a single mosaic file within ArcMap 10.8. The 2014-2016 mosaic has a spatial resolution of 40cm and a spatial accuracy of +/- 0.6m @ 67% confidence interval.

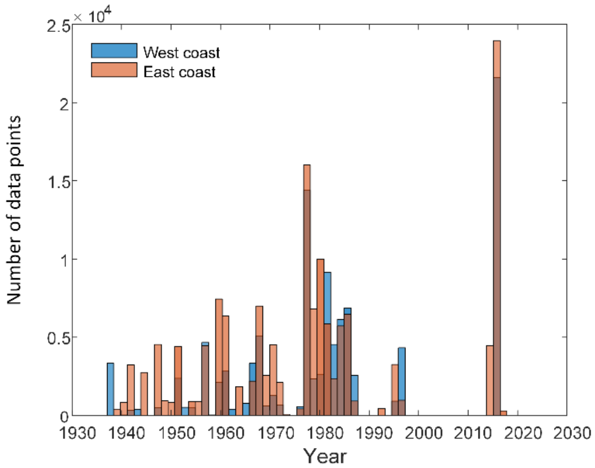

Figure 1. Number of shoreline change data points obtained from the historical photograph archive.

2.2 Georectification

We used the 2014-2016 mosaic as the source of ground control when georeferencing historic images. There are considerable challenges in georeferencing historic images within coastal settings due to a paucity of quality ground control points, particularly along sandy sections of the coast without either anthropogenic structures or stable geological features. The number of ground control points typically varied between 12 and 20 for each image, with a concentration of points along the coast to ensure that the photo was well-georeferenced near the coastline. Images were omitted were appropriate (e.g. lack of suitable ground control, cloud cover, poor quality).

2.3 Shoreline analysis

Considerable challenges exist in identifying a spatially consistent shoreline from imagery cover from diverse coastal settings. For this study we interpreted a shoreline as either the edge of vegetation or toe of dune or dune scarp, depending on the site, taking care for each location to use the same feature through time.

Shorelines were digitised as polyline shapefiles using the rectified historical imagery. Shorelines were drawn for all unconsolidated (sand or gravel) beaches that were >50 m in length. We excluded rocky coasts, ephemeral pocket beaches and estuarine and inner harbour shorelines.

The Digital Shoreline Analysis System (DSAS) [8] was used to analyse shoreline change. DSAS is a free extension for ArcMap which uses the point-transect intersect method for assessing planform shoreline change. Transects are generated perpendicular to a user-generated baseline, with the intersection between the transects and shorelines recorded as distances or rates of change calculated at each transect. DSAS calculates several shoreline change metrics including the net shoreline movement (NSM), which is the distance (m) between the oldest and most recent shoreline for each transect. Given the paucity of shorelines for many parts of Northland we could only uniformly calculate the end point rate (EPR), which is the rate (m/y) of accretion (+) or erosion (-) obtained by dividing the NSM by the time between the oldest and most recent shoreline.

3. Results

3.1 Regional spatial trends: west v east coast

Over 3000 km of shoreline was digitised for Northland. Shoreline change was analysed along a total of 49,138 transects, spaced at 10m intervals. 45% and 55% of transects were cast on the west and east coasts respectively.

Figure 2a provides a map of shoreline erosion and accretion around Northland over the past 80 years. A broad pattern of historical accretion occurs on the west coast, in comparison to muted shoreline change along much of the east coast. When areas of local rapid change (i.e. the distal portion of sand spits and river and harbour mouths) are omitted from calculations, the west coast shows overall accretion over the ~80-yr observation period at a median rate of +0.4 m/y whereas the east coast shows effectively no change in median shoreline position (the calculated rate of -0.01 m/yr is within the margin of mapping error).

Figure 2b shows that there are a broad number of coastal change outliers on both coasts, although in terms of NSM, these span a distance that is an order of magnitude larger on the west coast than east coast. A close inspection of the interquartile range (Figure 2b) shows that 50% of EPR observations on the west coast are between +0.05 and +1.4 m/yr, in contrast to rates of -0.1 to +0.1 m/yr on the east coast.

The east coast shows relatively little shoreline change overall, but when analyses are subdivided spatially, it is notable that in the north between Cape Reinga and Cape Karikari (Figures 2 and 3) there is a general accretionary trend (median EPR +0.2 m/y), between Cape Karikari and Bream Head there is negligible change (median EPR -0.01 m/y), and in the south between Bream Head and Pakiri the trend is slightly toward erosion (median EPR -0.07 m/y).

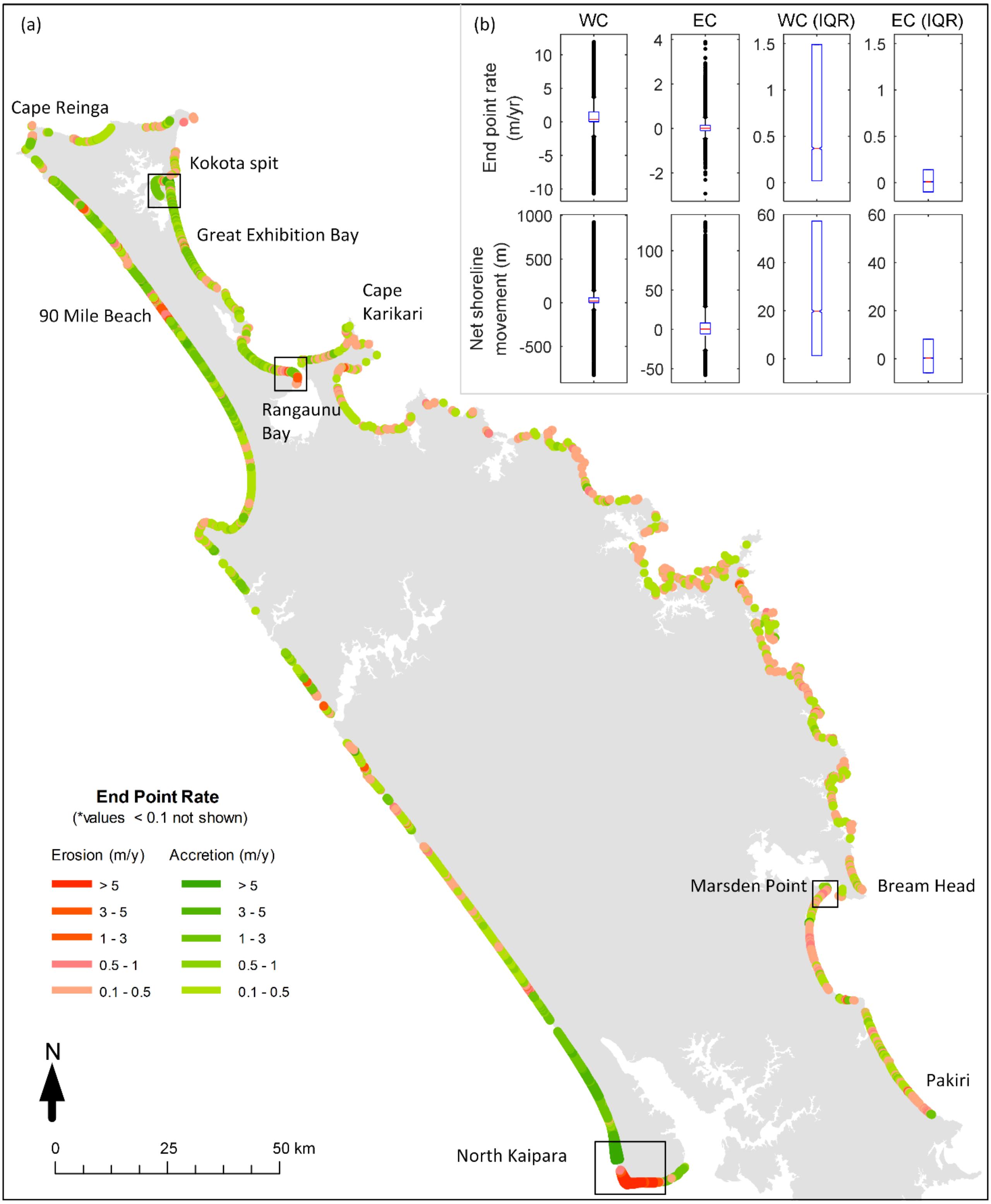

Figure 2a. End Point Rate (m/y) showing areas of erosion and accretion around Northland. Inset (2b) shows boxplots for the west coast (WC) and east coast (EC), outliers are shown as black dots and IQR = interquartile range.

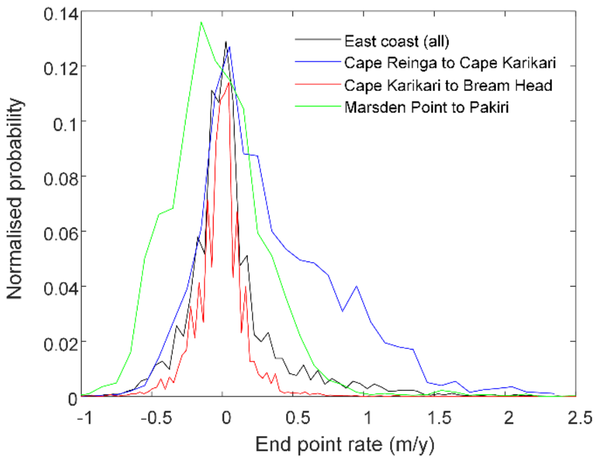

Figure 3. Normalised probability histograms showing spatial variability in coastal change rates on the east coast.

Coastal change hotspots can be observed at several locations on both west and east coasts, particularly around sand spits (e.g. Kokota spit in Parengarenga, Otiaia Point in Rangaunu Bay, Marsden Point in Bream Bay, North Kaipara, Figure 2a). Table 1 summarises statistics for selected coastal change hotspots. A notable feature is that each of the selected areas of rapid coastal change contain localised areas of both accretion and erosion. No single area is entirely dominated by shoreline change in a single direction.

	Max accretion (m)	Max erosion (m)	10th P EPR (m/yr)	90th P EPR (m/yr)
Kokota spit	315	89	-0.09	+2.50
Otiaia Point	202	146	-1.21	+2.52
Marsden Pt	96	58	-0.60	+0.71
Nth Kaipara	923	829	-8.14	+10.76
90 Mile	220	135	-0.36	+2.08

Table 1. Selected hotspots of rapid historical coastal change. Max and min values refer to total accretion and erosion within each area over several decades. 10th & 90th percentile statistics indicate erosion/accretion rates.

The highest rate of shoreline accretion in Northland over the 80-year observation period is a little over +10m/yr recorded on the open-coast 5-10km north of Kaipara Harbour. This area of accretion occurs immediately north of the area of highest shoreline erosion (~ -8 m/y) in Northland, which is on the south-facing distil portion of North Head Kaipara Harbour. On the west coast, localised high rates of shoreline change are also recorded along 90-Mile Beach, including areas of erosion and accretion, but accretion is predominant over erosion. A similar pattern occurs on the east coast at the distil spit of Kokota (Parengarenga) and Otiaia Point (Rangaunu Bay), where accretion is dominant over erosion, driving localised shoreline change at a rate of about +2.5 m/y and total shoreline accretion in the order of 200-300m. However, both locations also have areas of localised erosion, although this is notably less at Kokota. Of the selected hotspot areas, Marsden Point has the most significant infrastructure, and erosion rates in the order of -0.6 m/y indicate that more detailed local-scale analyses would be warranted at this site.

4. Discussion

Decoupling the drivers of coastal change is a notoriously difficult scientific problem [9] (Stive, 2004) and widespread coastal erosion of sandy beaches under SLR is yet to be detected [10]. The Northland coastal change dataset presented in this paper adds further evidence to the research literature that points to the complex nature of coastal change under SLR in the presence of myriad confounding factors (e.g. [11]).

Key drivers of historical shoreline change in Northland are likely to include longshore divergences in sediment flux and large-scale vegetation changes, but multi-decadal scale climatic drivers may also be important [12].

King et al. [13] and Blue and Kench [2] have drawn attention to large onshore fluxes of sediment on the west coast beaches of Auckland that result in complex and variable local patterns of historical erosion and accretion on beaches that are otherwise subject to similar wave climate and sea level trends. Ford and Dickson [14] noted the importance of sediment delivery from the massive ebb-tidal delta of the Manukau Harbour and speculated that cyclical rotation of the delta might release episodic pulses of sediment to up-drift beaches north of the delta. The Kaipara Harbour is one of the largest in the world with an ebb-tidal delta that contains massive quantities of sand [15]. It is plausible that period transfer of sediment between the delta and shoreline has contributed to the very high local rates of change observed at North Head, Kaipara.

In georeferencing large numbers of images for Northland we observed extensive revegetation of areas of open-sand during the historical period. This reflects the introduction of exotic sand binding species (e.g. marram) and also widespread exotic forestry plantation. We have yet to analyse the interaction between coastal sedimentation and vegetation, but it is possible that the combination between large sand fluxes on the west coast and introduction of vegetation has resulted in binding of large quantities of sand that would otherwise be mobile, leading to considerable shoreline accretion in some locations.

We are also yet to ascertain the reasons for large-scale shoreline stability on the east coast in the face of historical SLR, changes in vegetation, and interdecadal climatic fluctuations. However, it is notable that the areas of considerable shoreline change on the east coast are adjacent to harbours and inlets, where sediment exchange volumes are high. Much of the remaining east coast is highly indented with pocket beaches that probably have very little sediment exchange. It seems that the magnitude of SLR observed to date has not been sufficient to drive observable shoreline change in these environments.

5. Conclusion

Here we describe our first observations of a programme of historical shoreline mapping around New Zealand. Data from Te Tai Tokerau Northland show that much of the west coast has accreted over the last several decades whereas much of the east coast has exhibited very little net observable change.

Acknowledgements

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