Geographical Research

The Geography of the Anthropocene in New Zealand: Differential River Catchment Response to Human Impact

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Received 10 December 2014; Revised 8 May 2015; Accepted 21 May 2015

Abstract
New Zealand provides a useful environment to test the notion that the Anthropocene is a new geological epoch. There are two well-dated anthropogenic impact 'events': Polynesian settlement c. AD 1280, and European colonisation c. AD 1800. Little attention, however, has been given to regional catchment response to these, although it has been assumed that both Polynesian and European farming and land use management practices significantly increased erosion rates across most of New Zealand. This paper addresses the nature and timing of human impacts on river systems using meta-analysis of a recently compiled nationwide database of radiocarbon-dated fluvial deposits. This shows highly variable human impacts on erosion and sedimentation in river systems, which are often difficult to separate from naturally driven river activity. Catchment-scale data with high resolution dating control record clearer evidence of human disturbance. In Northland, anthropogenic alluviation is recorded from c. AD 1300 linked to early Polynesian settlement, enhanced further in the late 19th and 20th centuries by European land clearance, when sedimentation rates exceeded 25 mm year^{-1}. This study demonstrates significant geographical variability in the timing of human impact on river dynamics in New Zealand, despite two synchronous phases of human settlement, and highlights the difficulty of formally designating a simple and single 'Anthropocene Epoch/Age'.

KEY WORDS *Polynesian settlement; European colonisation; erosion; floodplain sedimentation; channel change*

Introduction

The onset of the Anthropocene as a geological epoch is currently debated, ranging from around AD 1800 (Steffen *et al*., 2007; Foley *et al*., 2013) to the mid-20th century (Waters *et al*., 2014). The key point in this debate is the need to identify a critical regime change at which time humans became the dominant factor in controlling environmental dynamics (Waters *et al*., 2014). The debate is not new: Marsh (1864) labelled 'Man as a disturbing agent in nature', and this is tracked in the alluvial record because floodplains archive landscape responses to human impacts (Lewin and Macklin, 2014).

Anthropogenically related changes in river discharge and sediment supply result in adjustment of channel morphologies and sediment storage (Knox, 1972; Macklin *et al.*, 2014). Brown *et al.* (2013) suggest that the nature, scale, and chronology of alluvial sedimentation have the potential to provide a clear marker for the Anthropocene. This is because land use changes, such as deforestation, agriculture, and mining, accelerate soil erosion that introduces sediment of distinctive volume and character into river systems, which Macklin *et al.* (2014) term 'anthropogenic alluvium'. Relating sedimentation to land-use change following European settlement is well established, particularly in North America and Australia, where the resulting deposits are referred to as post-settlement alluvium (Knox, 1972; Magilligan, 1985; Lecce, 1997; Wasson *et al.*, 1998; Olley and Wasson, 2003; Rustomji and Pietsch, 2007). More recently, some have referred to such material as 'legacy sediment' (James, 2013), which is a broader, catch-all term used to describe any 'anthropogenic sediment . . . produced episodically over a period of decades or centuries, regardless of position in the landscape, geomorphic process . . . or . . . characteristics' (James, 2013, 23). Anthropogenic alluvium, as defined by Macklin *et al.* (2014), can be considered as a category of legacy sediment. We avoid use of the term 'post-settlement' alluvium because its usage has generally implied a more narrowly defined activity strongly associated with European culture, and because Europeans were not the first to disturb New Zealand's landscape.

The timing and nature of Polynesian and European environmental impacts in New Zealand

Extensive deforestation of the New Zealand landscape was effected by small, transient, non-agricultural Polynesian populations arriving in New Zealand ca. 700–800 years BP who used fire to clear forests (McGlone, 1983; McGlone and Wilmshurst, 1999). This activity reduced forest cover by c. 50% (Masters *et al.*, 1957). The speed of this clearance was dramatic in drier areas, such as the eastern South Island, where it occurred in decades (McWethy *et al.*, 2010; 2014; Woodward *et al.*, 2014a; 2014b) and forest recovery following fires was rare (McGlone and Basher, 1995). Polynesian deforestation in less accessible (and generally wetter) parts of the North Island occurred later at around c. 400 years BP (Wilmshurst *et al.*, 2004), although in the drier eastern North Island, a human impact on the environment is recorded in the last 500 years of the Lake Tutira record (Page *et al.*, 2010). The extent of Māori forest clearance is depicted in Figure 1. Polynesian occupation was followed in the early 1800s by European settlement. This led to further deforestation, particularly in the North Island (Figure 1) in advance of agriculture in the late 19th and early 20th centuries. In addition to agricultural land clearance, gold mining developed in the late 19th century in Otago, Golden Bay, and the Coromandel Peninsula resulted in significant increases in sediment supply (Black *et al.*, 2004).

The purpose of this paper is to assess the extent to which New Zealand's river catchments may have been impacted by pre-European and European phases of human activity. First, we consider national and regional catchment responses to both Polynesian and European impacts using records of river activity derived from meta-analysis of the New Zealand fluvial radiocarbon database (Macklin *et al.*, 2012; Richardson *et al.*, 2013a). In this database, following Zielhofer and Faust (2007), periods of river activity have been inferred where dated organic material has been recovered from river channel and floodplain deposits, indicative of active sedimentation associated with flooding and channel change. Second, catchment-scale evidence is examined to evaluate the nature and timing of anthropogenic alluvium at selected sites in New Zealand. Because the impacts of Polynesian and European activity on New Zealand's river catchments represent a disturbance to the natural environment (deforestation), an enhancement of river activity and alluvial sedimentation relative to natural rates would be expected (cf., Macklin *et al.*, 2014). The Anthropocene is thus marked by the point at which human-effected erosion exceeded naturally occurring erosion in the landscape (cf., Brown *et al.*, 2013; Macklin *et al.*, 2014). As there was no human activity in New Zealand prior to the Polynesian migration of c. AD 1280 (McGlone and Wilmshurst, 1999), all earlier river activity and alluvial sedimentation must reflect natural processes, which provides a very clear context from which to assess the extent of human impact and the nature of the Anthropocene in New Zealand's river catchments: river activity and alluviation post c. AD

Figure 1 Vegetation cover in New Zealand (a) pre-Maori, (b) pre-European (ca. 1840), (c) post-European. Sources: (a and b): Malcolm McKinnon, ed., Bateman New Zealand historical atlas: ko papatuanuku e takoto nei. Auckland: David Bateman, 1997: (c): http://www.teara.govt.nz/en/map/15842/pastoral-land-use.

1280 are *potentially* attributable to human impact. The questions we address are whether river activity and alluvial sedimentation provide a clear marker to the onset of the New Zealand Anthropocene and, if so, is this ubiquitous and synchronous.

River activity: a national and regional database

River activity is recognised in the alluvial sedimentary archive by deposits recording active sedimentation associated with flooding and channel change (Richardson *et al*., 2013a). The New Zealand Holocene fluvial radiocarbon database developed by Macklin *et al*. (2012) and Richardson *et al*. (2013a) has been expanded to incorporate recently published and available radiocarbon dates (Nicol *et al*., 2000; Page *et al*., 2012; Richardson *et al*., 2013b) and now comprises 485 ^{14}C ages. Of these, 156 relate to the last 1000 years and are likely to coincide with human activity. Details of these dates are provided in the accompanying Supporting Information file online. The first human settlement in New Zealand is dated to ca. AD 1280 (McGlone and Wilmshurst, 1999); earlier arrival dates have been postulated, but remain controversial (Wilmshurst *et al*., 2008). Figure 2 plots the distribution of ^{14}C ages derived from the updated New Zealand fluvial radiocarbon database. Ages within the 2000–3500 cal. yr BP timespan are considered to represent natural river activity processes. Dated fluvial units within the 1000–2000 cal. yr BP time period also most probably record natural river dynamics in New Zealand. River activity between 1000 and 500 cal. yr BP coincides with Polynesian arrival and settlement, and finally 500 cal. yr BP to the present encompasses both Polynesian and European occupation.

Meta-analysis

Meta-analysis (see Jones *et al*., 2015 for an up-to-date guide to meta-analysis of ^{14}C-dated units in fluvial environments) was performed on river activity dates following the procedure described by Richardson *et al*. (2013a) and Macklin *et al*. (2014). All dates were calibrated using SHCAL04 (McCormac *et al*., 2004) and the individual probabilities summed using OxCal v4.2 (Bronk Ramsey, 2009) to generate cumulative probability function (CPF) plots, which in turn were normalised by dividing by the CPF of the entire database to produce relative CPF plots for North and South Islands (Figure 3) and each coherent precipitation region (Figure 4). These relative CPF plots are derived for (1) an extended period (0–3500 cal. yr BP) to provide a natural context of river activity in New Zealand and (2) for the last 1000 years to assess the impacts of human catchment disturbance on river activity (see Table S1 for details of the dates used in these analyses). Probability values exceeding one standard deviation above the mean relative probability were used to identify episodes of significant river activity. Our meta-analysis approach is not intended to identify individual flood events, as recently misconstrued by Chiverrell *et al*. (2011), but provides a probabilistic assessment of centennial-length and longer river activity episodes (Macklin *et al*., 2010; 2011).

North and South Island river activity

Statistical analysis performed on an alluvial radiocarbon database spanning the entirety of the Holocene (Richardson *et al*., 2013a) identified two periods in which river activity in the North and South Islands was significantly out-of-phase (12 000–5000 and 2000–0 cal. yr BP). It is therefore not surprising that results from the updated database presented here are in accord with this pattern (Figure 3), which Richardson *et al*. (2013a) attributed to climatic control related to phases of ENSO- and SAM-like conditions. Richardson *et al*. (2013a) suggested that river activity in the South Island was related to enhanced westerly flow across New Zealand, bringing storms across New Zealand from the Southern Ocean during El Nino-like conditions augmented by negative SAM-like conditions. In contrast, North Island river activity was more associated with La Nina-like circulation augmented by positive SAM-like conditions, which favoured southerly incursions of storms from the sub-tropical Pacific Ocean. There is nothing to suggest that river activity in the North Island is specifically responding to human disturbance: during the past 3500 years, the most significant periods of river activity occurred prior to human arrival. In the past 1000 years, there are some significant episodes of river activity, the first of which coincides with Polynesian arrival around 800 cal. yr BP. There are also significant episodes c. 450–350 cal. yr BP, coinciding with later forest clearance (Wilmshurst *et al*., 2004), and c. 150 and 80 cal. yr BP, coinciding with European arrival. However, these results show no dramatic change in river activity in direct response to human modification.

In the South Island, there is a significant episode of river activity at c. 650–550 cal. yr BP

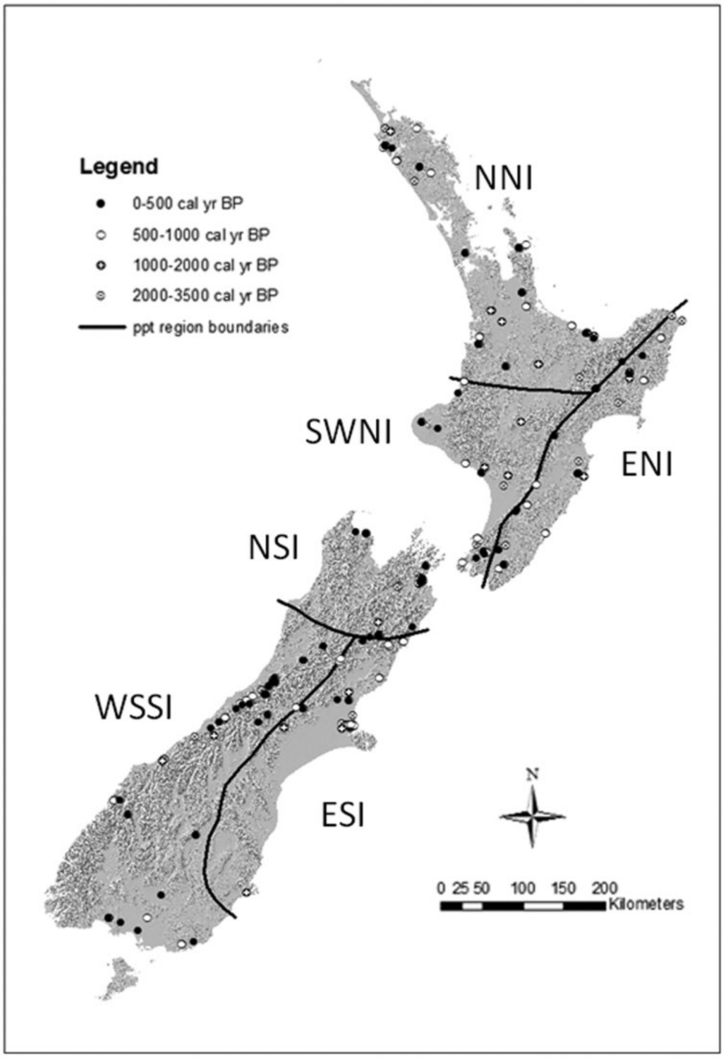

Figure 2 Distribution of ^{14}C ages from the NZ Holocene fluvial radiocarbon database grouped by age category and overlaid on the coherent precipitation regions proposed by Mullan (1998): NNI, Northern North Island; SWNI, Southwestern North Island; ENI, Eastern North Island; NSI, Northern South Island; WSSI, Western and Southern South Island; ESI, Eastern South Island.

(Figure 3), which follows large-scale deforestation identified by McWethy *et al.* (2010) and Woodward *et al.* (2014a; 2014b). However, this phase of accelerated river activity took place c. 200 years after a period of rapid and dramatic disturbance that was detected in other proxy records, in which vegetation change is suggested to have occurred within a matter of decades, rather than centuries (McWethy *et al.*, 2014). This highlights the sensitivity of small wetland systems to localised environmental change (Woodward *et al.*, 2014a), whereas in larger river catchments sediment supply and runoff responses to land cover and land use change may be delayed depending on the location and scale of land cover modification. Perhaps surprisingly, there does not appear to be any record of significant river activity associated with European catchment disturbance in the South Island. This might be explained by the following: (1) the impacts of European settlement were minimal (or resulted in no further disturbance) in comparison with the earlier Polynesian land clearance in the South Island (cf., Figure 1); and/or (2) natural tectonic and climatic factors, as well as past and present glacial activity, have a greater impact on sediment delivery than that arising from human-related catchment land-use and land

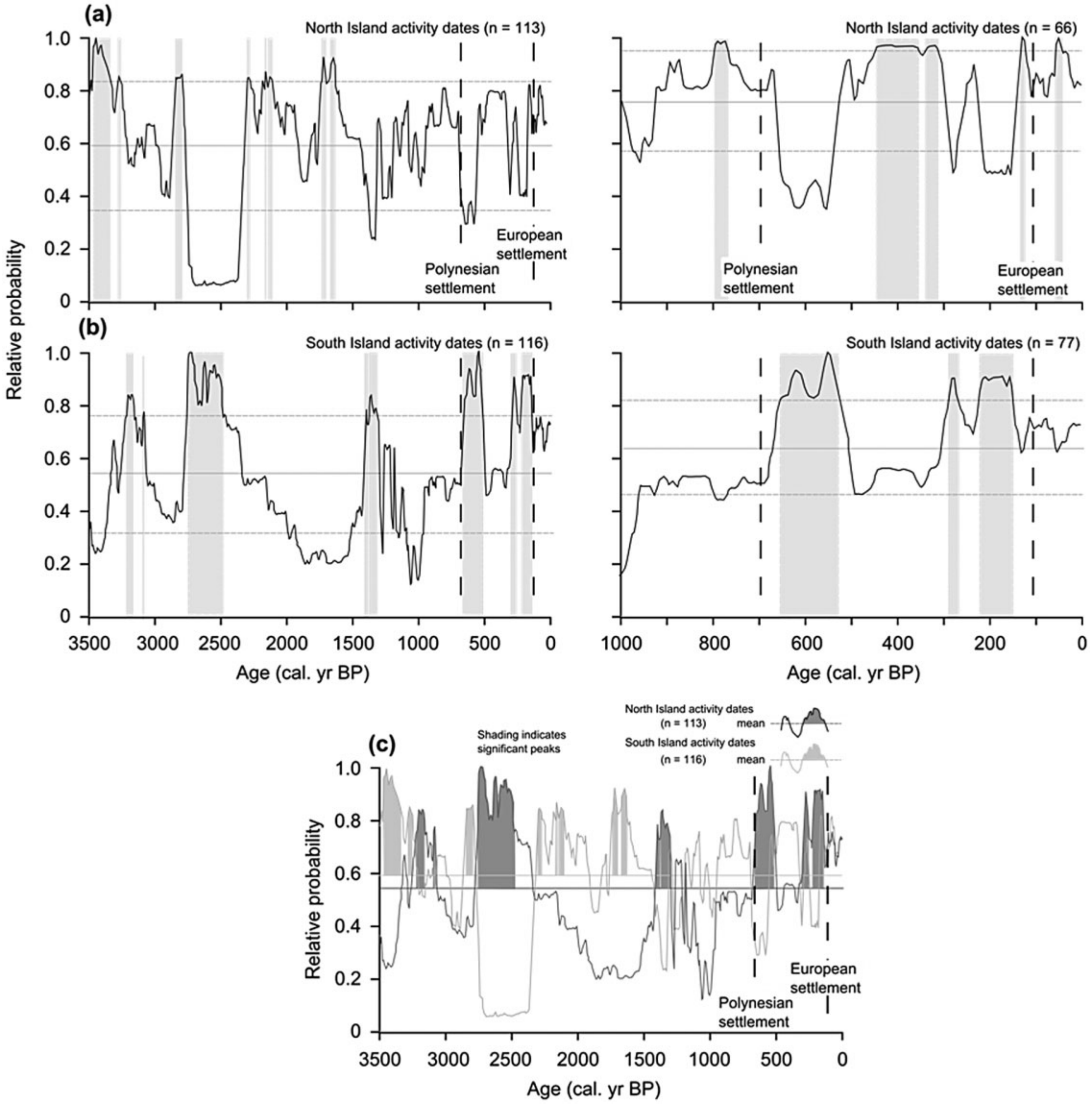

Figure 3 Relative CPF plots of river activity ^{14}C dates for (a) North Island and (b) South Island, 0–3500 cal. yr BP and 0–1000 cal. yr BP; and (c) North and South Island 0–3500 cal yr BP combined. Horizontal grey lines indicate the mean (solid line) and one standard deviation above and below the mean (dashed line). Vertical grey boxes highlight significant episodes of river activity. Black dashed line indicates timing of Polynesian and European settlement.

cover change (see, e.g. Davies and Korup, 2010); and/or (3) there are insufficient ^{14}C dates from the last ca. 150 years for a significant river activity period to be defined using this methodology.

Regional river activity

Aggregating river activity by coherent precipitation region (Figure 4, cf., Figure 2) permits a closer scrutiny of potential anthropogenic impacts on the fluvial sedimentary archive. Over the last 1000 years in northern North Island, some periods of river activity do coincide with Polynesian settlement (Figure 4a), which is a pattern repeated for the south and west North Island (Figure 4b). The eastern North Island and northern South Island register significant river activity coincident with European impacts (Figure 4c,d). It is notable that the most significant river activity in the eastern South Island in the past 1000 years at c. 700 cal. yrs BP is coincident with large-scale Polynesian clearance in this region (cf. McWethy *et al*., 2010).

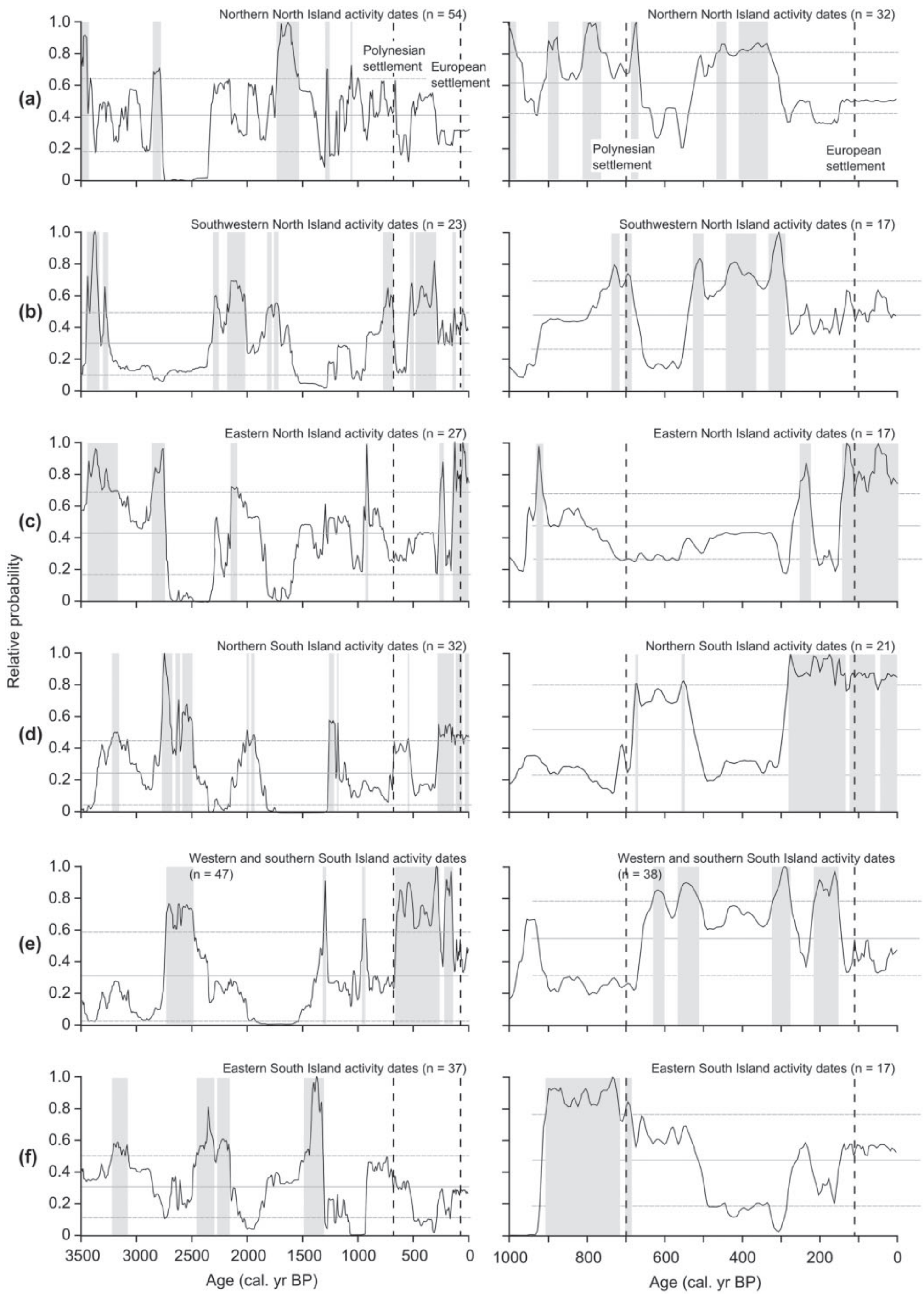

Figure 4 Relative CPF plots of river activity ^{14}C dates for each coherent precipitation region (cf., Figure 2): (a) NNI, (b) SWNI, (c) ENI, (d) NSI, (e) WSSI, (f) ESI, 0–3500 cal. yr BP and 0–1000 cal. yr BP. Horizontal grey lines indicate the mean (solid line) and one standard deviation above and below the mean (dashed line). Vertical grey boxes highlight significant episodes of river activity. Black dashed line indicates timing of Polynesian and European settlement. The number of dates in the 0–1000 cal yr BP period is inevitably small, which may limit to some degree the significance of river activity detected in this period using this exploratory approach. NNI, Northern North Island; SWNI, Southwestern North Island; ENI, Eastern North Island; NSI, Northern South Island; WSSI, Western and Southern South Island; ESI, Eastern South Island.

Significant river activity in the western and southern South Island does not show a clear relationship with Polynesian disturbance or European settlement.

Meta-analysis of the Holocene alluvial radiocarbon database provides a tool to explore the significance of river activity in relation to human disturbance associated with Polynesian and European settlement in New Zealand. These results suggest that while there is some coincidence of significant periods of river activity with these events, naturally driven river activity is probably more important in this record. There may, however, be an augmentation of natural river activity by human impact as deforestation, whether Polynesian or European, would have enhanced sediment supply and runoff. For example, Beatson and Whelan (1993) report anecdotal evidence of severe flooding and sedimentation soon after European settlement in the Motueka catchment (northern South Island) in the 1870s. Nevertheless, as a marker for the Anthropocene in New Zealand, river activity does not appear to provide a clear starting point, and it is certainly not synchronous.

Catchment responses

To elucidate the potential human impacts on erosion and sediment delivery, we have calculated long-term sedimentation rates for a variety of catchments in North and South Island (Figure 5). This much more clearly demonstrates the effects of human disturbance, as sedimentation rates have risen dramatically and significantly (Table 1) in the period since Polynesian arrival and especially since European settlement. However, it should be cautioned that because aggradation at a point is episodic and preservation bias favours younger deposits, higher sedimentation rates might be expected in the most recent period, but there is nevertheless a consistent, significant increase in sedimentation following Polynesian settlement. Richardson *et al.* (2014) have quantified this sedimentation in more detail in Northland floodplains. In this region, the natural mean sedimentation rate is c.0.3 to 0.7 mm year^{-1}. Following Polynesian settlement, sedimentation rates increased to between 3.3 and 10 mm year^{-1} (Richardson *et al.*, 2014). European arrival increased sedimentation rates to >13.5 mm year^{-1} (Richardson *et al.*, 2014). Recent ^{137}Cs analysis of samples at Kaeo (Figure 6) suggests that the 1964–1965 peak in ^{137}Cs occurs deeper than 2.0 m (Ditchcomb, pers. comm., 2014), which suggests a modern sedimentation rate of at least 25 mm year^{-1} at this site.

However, while these results do suggest a clear anthropogenic influence on floodplain sedimentation rates in Northland, these are similar to those recorded in some volcanically influenced catchments in the North Island, and glaciated catchments in the South Island (Figure 5). A preliminary appraisal of alluvial deposits found in the vicinity of selected lake sites showing greatest human disturbance in the northern Southern Alps (McWethy *et al.*, 2010) did not reveal any significant change in alluvial signature (Figure 7). This appraisal was based on an assessment of sediment architecture and type exposed in cut bank sequences. Further work will be required to seek age control at these sites and conduct a detailed stratigraphic investigation. Given the extent of disturbance evident (McWethy *et al.*, 2010), the absence of any immediately apparent change in alluvial signature might be surprising. However, these river systems are strongly influenced by a paraglacial inheritance, and will have a high natural erosion signature (Church and Ryder, 1972). Furthermore, wetland archives may be more sensitive to human impacts because background rates of sedimentation tend to be low and register a greater degree of disturbance upon human clearance (e.g. Woodward *et al.*, 2014a). This is in contrast with adjacent high-energy, high sediment-supply river systems: Woodward *et al.* (2014a) show a dramatic wetland ecosystem response to human arrival in the Canterbury alpine foothills, but also recognise the impact of an actively aggrading alluvial fan and avulsing river on this environment. It is unlikely that in this context, human impacts would generate a clear and discernable response in the alluvial record, especially because much of the catchment upstream would not have been naturally forested in the first place. Relatively small-scale, short-term (decadal) pulses of sediment detected in wetland records thus do not appear to be discernible in these (sub)alpine, paraglacial river systems.

Elsewhere in the North Island, East Coast Region rivers have been completely transformed by European land clearance for pastoral agriculture. Marden *et al.* (2014) suggest that the magnitude of erosion in this region since European occupation in the early 20th century has been greater than for any other part of New Zealand. Anecdotal evidence recorded the Waipaoa as clear-flowing, gravelly bottomed at c. 1900 prior

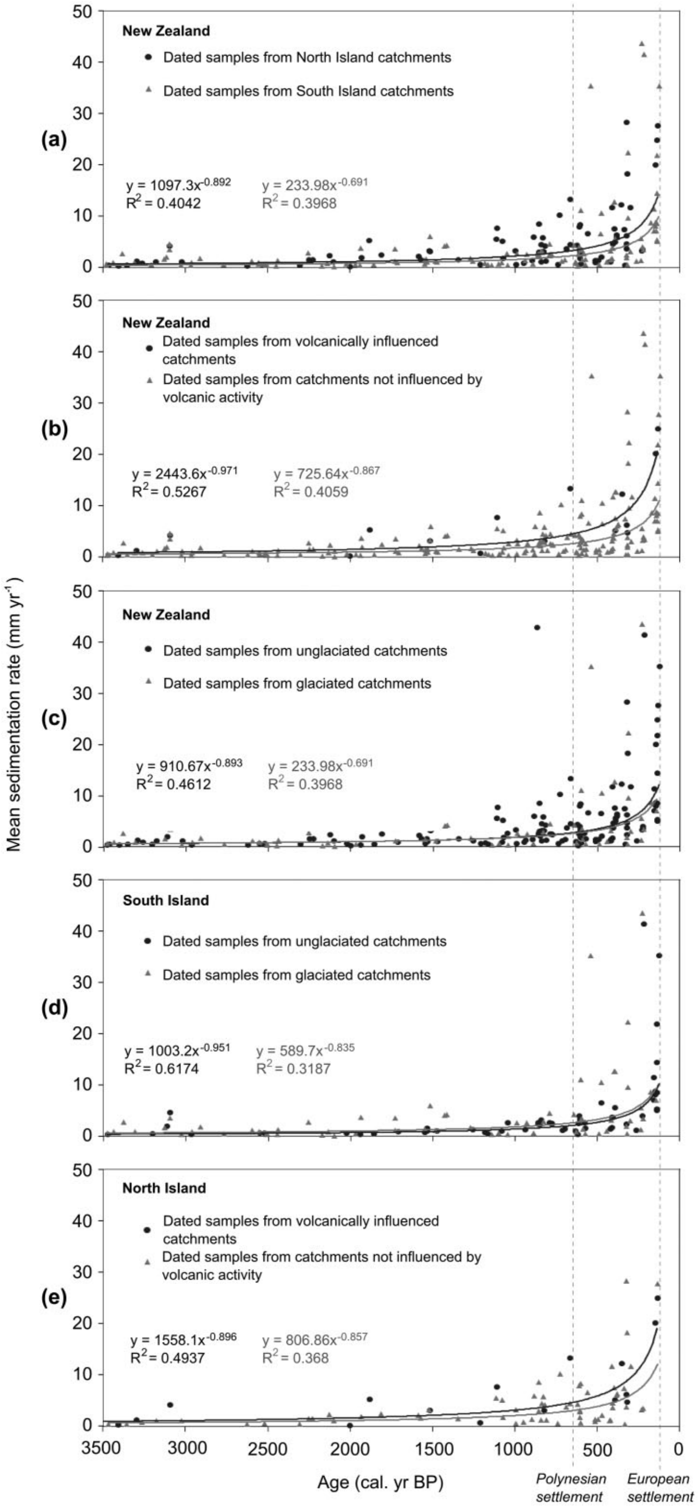

Figure 5 Floodplain sedimentation rates plotted for North and South Island Catchments (a); New Zealand catchments influenced and not influenced by volcanic activity (b); New Zealand glaciated and unglaciated catchments (c); North Island catchments influenced and not influenced by volcanic activity (d); and glaciated and unglaciated South Island catchments (e).

Table 1 Statistical analysis of sedimentation rates depicted in Figure 5, showing mean rates and standard deviation for the periods pre- and post-settlement, together with the P value for a one-tailed, two-sample equal variance t-test.

Catchments	Sedimentation rate (mm yr^{-1})				
	3500–700 cal. yr BP		Post-settlement		*t*-test
	$\bar{X}$	σ	$\bar{X}$	σ	P
North Island	2.59	2.38	8.66	10.18	0.0002
South Island	1.54	1.30	9.14	13.60	0.0000
NZ volcanically influenced	2.87	2.55	12.30	7.80	0.0041
NZ not volcanically influenced	1.88	1.79	8.66	12.53	0.0000
NZ unglaciated	2.12	2.04	8.21	9.97	0.0000
NZ glaciated	1.71	1.49	10.80	16.80	0.0020
South Island glaciated	1.66	1.47	10.80	16.79	0.0014
South Island unglaciated	1.39	1.05	7.60	9.85	0.0014
North Island volcanically influenced	2.87	2.56	12.30	7.80	0.0041
North Island not volcanically influenced	2.52	2.36	7.71	10.42	0.0056

All results show a significantly higher sediment rate post-settlement.

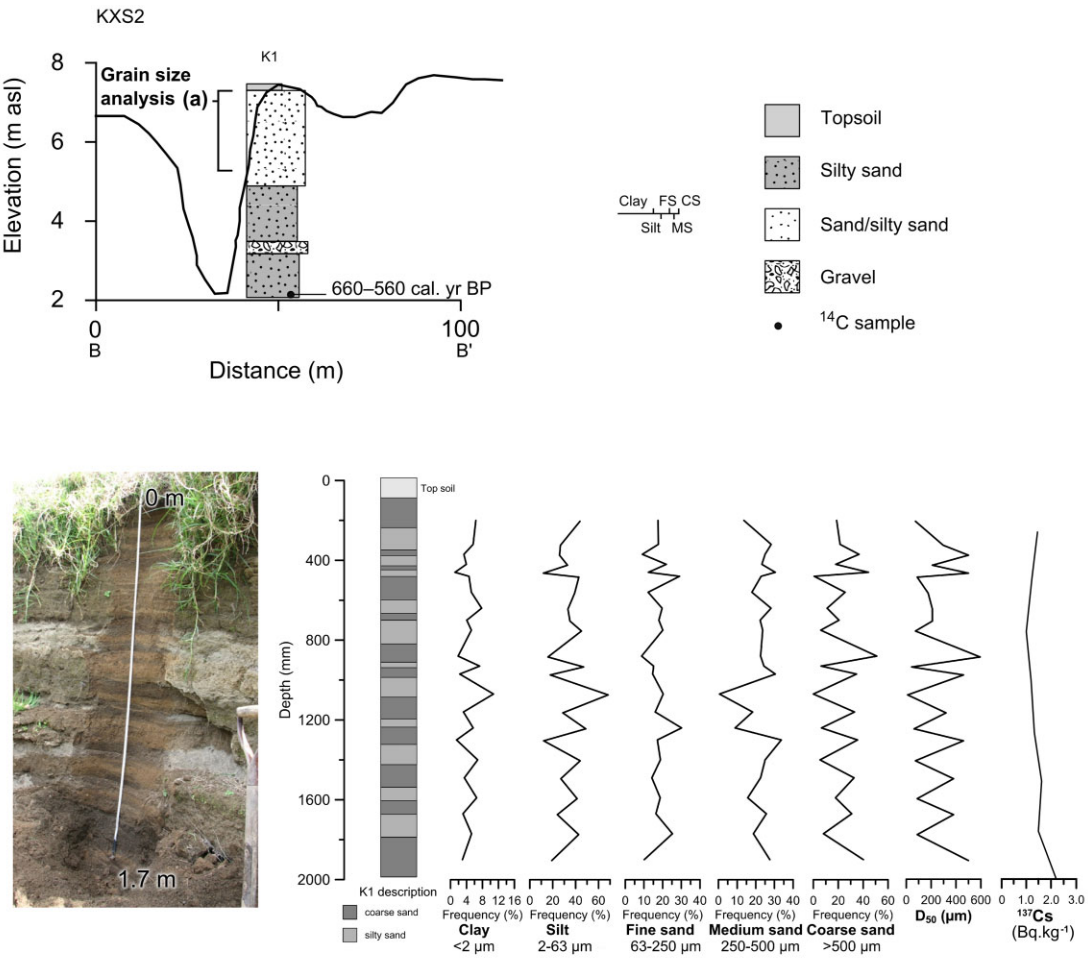

Figure 6 Anthropogenic alluvium at Kaeo (after Richardson *et al*., 2014).

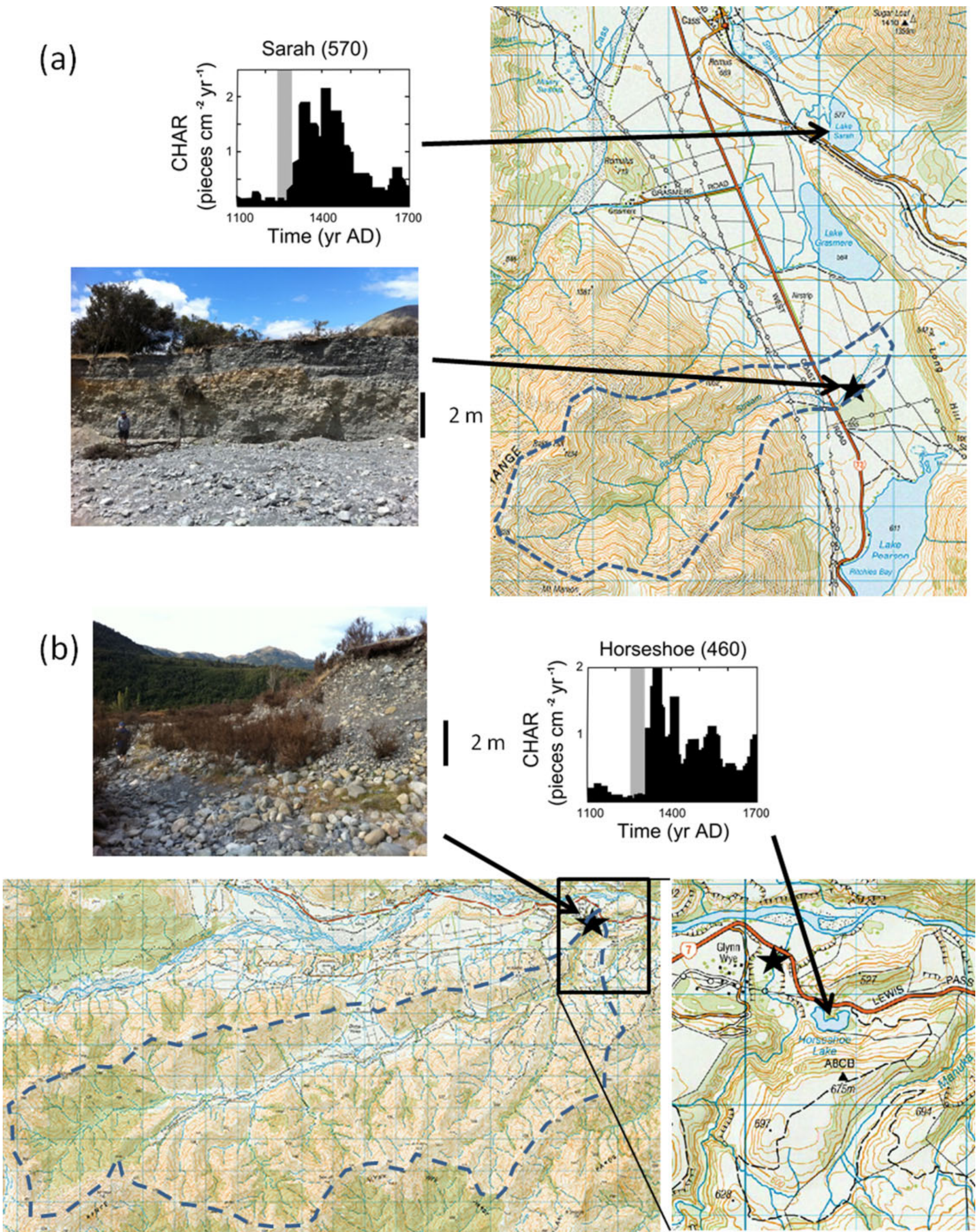

Figure 7 Alluvial architecture at sites with exposed alluvium within 5 km of Lakes (a) Sarah and (b) Horsehoe that demonstrate dramatic evidence of human disturbance (McWethy *et al*., 2010). No clear anthropogenic unit (typically marked by a change in sedimentation style) was evident. Gridlines on topographic map extracts are at 1 km; orientation is north. Catchments outlined in bold dashed lines; location of alluvial exposures indicated by star.

to clearance (Marden, pers. comm., 2014). The river now yields 15 Mt of suspended sediment to the ocean per annum (Hicks *et al*., 2000) and has aggraded its bed by over 20 m in some of the upper tributaries (Fuller and Marden, 2010). The adjacent (smaller) Waiapu catchment has a sediment yield of 35 Mt yr^{-1}, with >25% of the catchment area affected by gully erosion, generating 30 000 t km^{-2} $year^{-1}$ (Page *et al*., 2008), resulting in a rapidly aggrading, multi-thread river. These rivers have responded so dramatically to clearance of indigenous forest because catchment geology is highly susceptible to erosion, being weakly indurated, and storms have readily initiated and accelerated gully erosion in particular (Marden *et al*., 2014), although during the storms, landsliding is also prevalent (Hicks *et al*., 2000). The result is erosion rates that are an order of magnitude higher than the 1 mm $year^{-1}$ estimated for the period following the LGM in this region (Bilderback, 2012; Marden *et al*., 2014). Here, there is incontrovertible evidence that these catchments have been overwhelmed as a result of human activity and there is a clear starting point in the form of early 1900s deforestation: Gomez *et al*. (1999) record c. 8 m of floodplain aggradation since 1853 in the mid catchment of the Waipaoa.

Discussion and conclusions

Using the surrogate of river activity derived from meta-analysis of a large national database of ^{14}C dated Holocene fluvial units, which focuses on centennial-scale periods of activity derived from multiple catchments (cf., Figure 2), there is little evidence to suggest that Māori settlement and deforestation had a major impact on flooding and river dynamics in New Zealand. This is in contrast with wetland and lake records (cf., Page *et al*., 2010; Woodward *et al*., 2014a; 2014b), where a much clearer impact is discernible. River activity deduced from meta-analysis represents catchment behaviour at a large spatial scale (national/regional), as well as a longer temporal scale (centennial). Polynesian impacts discerned from lake records were over within a matter of decades (McWethy *et al*., 2010; Woodward *et al*., 2014a), and as such have not been resolved at the meta-analysis scale because the landscape changes did not constitute a sufficient disturbance to register above the natural background of centennial river activity in this analysis. Essentially, early human impacts in New Zealand were simply drowned out by a high natural rate of process at this scale.

In parts of the South Island, there appears to be relatively little modification of catchments with a strong paraglacial inheritance, even following European arrival, because catchments are dominated by a very high natural rate of erosion. In the North Island, catchments draining the central plateau are similarly dominated by a volcanic legacy (Grant, 1985; Manville *et al*., 2005). Grant (1985) attributed much of erosion and alluvial sedimentation he observed elsewhere in the North Island to periods of enhanced storminess, noting that the total amount of sediment deposited during successive periods of erosion appeared to be decreasing, in spite of increased human impacts in the last 1000 years. Furthermore, he suggested that burning of vegetation was not a primary cause of increased erosion and sedimentation because initiation and acceleration of erosion and sedimentation had taken place in forested wilderness undamaged by fire (Mosley, 1978; Robinson and McSaveney, 1980; Grant, 1983). The late 1800s, coincident with the onset of large-scale European deforestation (cf., Beatson and Whelan, 1993), was marked by a series of major floods in New Zealand (Cowie, 1957). The clearest evidence for human disturbance is found in the East Coast Region, where a regime change in system behaviour is evident and the natural processes here have been overwhelmed (*sensu* Steffen *et al*., 2007; Brown *et al*., 2013) as a consequence of human activity (deforestation) in these catchments (Marden *et al*., 2014).

The nature and timing of human impact in New Zealand's river catchments are highly variable between regions and catchments, and this makes any attempt at formally defining the Anthropocene problematic at best because there is no ubiquitous, synchronous marker in New Zealand river catchments that marks the start of the Anthropocene. In catchments draining the Southern Alps, natural processes are far more significant in determining erosion, sedimentation, and river activity (see Korup *et al*., 2004; Korup, 2005; Carrivick and Rushmer, 2009). The clearest evidence for Polynesian impact is found in Northland's catchments in the form of increased floodplain sedimentation. Here, the start of the Anthropocene could be considered to equate with Māori occupation c. 1280 AD, with further augmentation associated with European settlement in the 1800s and 1900s. Farther east, in the East Coast Region of the North Island, the start of the Anthropocene could be taken as c. 1920 when European clearance of indigenous vegetation in the Waipaoa and Waiapu catchments exposed a highly erodible terrain to a range of erosion processes (see Marden *et al.*, 2014), which resulted in erosion rates exceeding by an order of magnitude those estimated at the end of the Last Glacial Maximum. Each catchment and region must be recognised as unique in its response to human disturbance. New Zealand challenges the notion that the Anthropocene can be defined simply by a critical regime change in which human impact becomes the dominant controlling factor in the environment (Waters *et al.*, 2014), and overwhelms the forces of nature (Steffen *et al.*, 2007; Brown *et al.*, 2013). New Zealand's highly active tectonic and climatic regime largely mitigates against Mankind becoming the dominant factor controlling river activity and alluvial sedimentation in most of its naturally dynamic catchments. The exception is Northland and the East Coast Region, where a regime change has been identified by these systems having been overwhelmed by sediment generated as a result of human impact resulting in rapid valley-floor sedimentation. Arguably, the Anthropocene concept in New Zealand is most useful as a framework to help inform environmental management by highlighting the spatial and temporal variability of human influence at catchment and regional scales, as well as helping to document the recovery trajectories of anthropogenically impacted systems.

ACKNOWLEDGEMENTS

We thank the following researchers for their permission to use their unpublished ^{14}C ages in the meta-analysis presented here: AF Cooper, M Yetton, M Marden. We also thank Bob Ditchburn at GNS Science (Rafter Laboratory) for running ^{137}Cs analysis at Kaeo under contract. Fieldwork underpinning results presented in this paper were funded by Massey University Research Funding awarded to ICF and MGM.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1 New Zealand Holocene radiocarbon database subset of ages used in this paper.