Rehabilitating Anthropocene riverscapes using geomorphic river stories: East Coast Aotearoa New Zealand

Réhabilitation des paysages fluviaux de l'Anthropocène à l'aide d'histoires géomorphiques fluviales : Côte Est d'Aotearoa en Nouvelle-Zélande

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RÉSUMÉ

Des roches récemment soulevées et hautement érodables et des tempêtes récurrentes de haute intensité génèrent des taux d'érosion et de sédimentation extrêmement élevés dans la région de la côte Est (Tairāwhiti) d'Aotearoa en Nouvelle-Zélande. Les perturbations humaines ont profondément modifié les trajectoires évolutives des systèmes fluviaux de la région. Nous documentons ici la variabilité de la signature anthropique bassin par bassin versant sous forme d'histoires géomorphiques de rivières pour cinq bassins versants (Waiapu, Hikuwai, Waimatā, Waipaoa, Mōtū). Nous montrons comment des programmes de réhabilitation ciblés et adaptés, basés sur des processus et gérant à la source et à grande échelle, sont nécessaires pour faciliter la récupération des rivières dans chacun de ces bassins versants. Nous soutenons que les récits géomorphologiques des rivières fournissent une plate-forme cohérente pour les stratégies de réhabilitation de l'Anthropocène qui fonctionnent avec le caractère, le comportement et les trajectoires évolutives des systèmes fluviaux.

ABSTRACT

Recently uplifted, highly erodible rocks, and recurrent high intensity storms, generate exceedingly high erosion and sedimentation rates in the East Coast Region (Tairāwhiti) of Aotearoa New Zealand. Human disturbance has profoundly altered evolutionary trajectories of river systems across the region. Here we document catchment-by-catchment variability in anthropogenic signature as geomorphic river stories for five catchments (Waiapu, Hikuwai, Waimatā, Waipaoa, Mōtū). We show how targeted, fit-for-purpose process-based rehabilitation programmes that manage at source and at scale are required to facilitate river recovery in each of these catchments. We contend that geomorphic river stories provide a coherent platform for Anthropocene rehabilitation strategies that work with the character, behaviour and evolutionary trajectories of river systems.

KEYWORDS

Catchment transformation and connectivity, river geomorphology, river futures, river recovery
Transformation et connectivité des bassins versants, géomorphologie des rivières, avenir des rivières, récupération des rivières

1 INTRODUCTION

Concepts of 'Anthropocene rivers' recognise the profound extent and scale to which rivers have been transformed by human activity. Regime shift and state-change engender persistent modification as anthropogenic landscape forcing overwhelms natural process regimes. In many parts of the world this shift of regime and state reflects direct (planned, purposeful) anthropogenic modification of river systems. In the East Coast Region (Tairāwhiti) of Aotearoa New Zealand it reflects landscape response to deforestation.

We define a river "story" as a succinct account of catchment-specific evolutionary trajectory, based on observed changes over time (decades, at least). We contend that geomorphic river stories provide an insightful lens to unravel and communicate profound variability in river responses to systematic, rapid deforestation in an area that was already subject to exceedingly high rates of erosion and sedimentation prior to anthropogenic disturbance around 650 years ago. Initial impacts of Polynesian settlement on river systems in Tairāwhiti did not result in regime shift. When Europeans arrived, streams were clear-flowing and cobbly. Deforestation following European colonisation from the late 1800s to early 1900s exposed highly erodible terrains to a range of erosion processes, increasing erosion rates by an order of magnitude relative to estimated rates at the end of the Last Glacial Maximum. We focus on historic trajectories of five major rivers in this region where the anthropogenic signature is especially pronounced.

1.1 Catchments

The Raukumara Ranges are the backbone of Tairāwhiti (East Coast Region of Aotearoa New Zealand). Although the five study catchments (Figure 1) Waiapu (1758 km^2), Hikuwai (560 km^2), Waimatā (370 km^2), Waipaoa (2208 km^2), Mōtū (1373 km^2) have been subject to similar land use impacts associated with rapid deforestation, marked variability in recovery and rehabilitation prospects reflect significant differences in geomorphic responses to anthropogenic disturbance. These are outlined in terms of the dominant process regime, evolutionary trajectory, management actions, and geomorphic river story in Section 2 for each river.

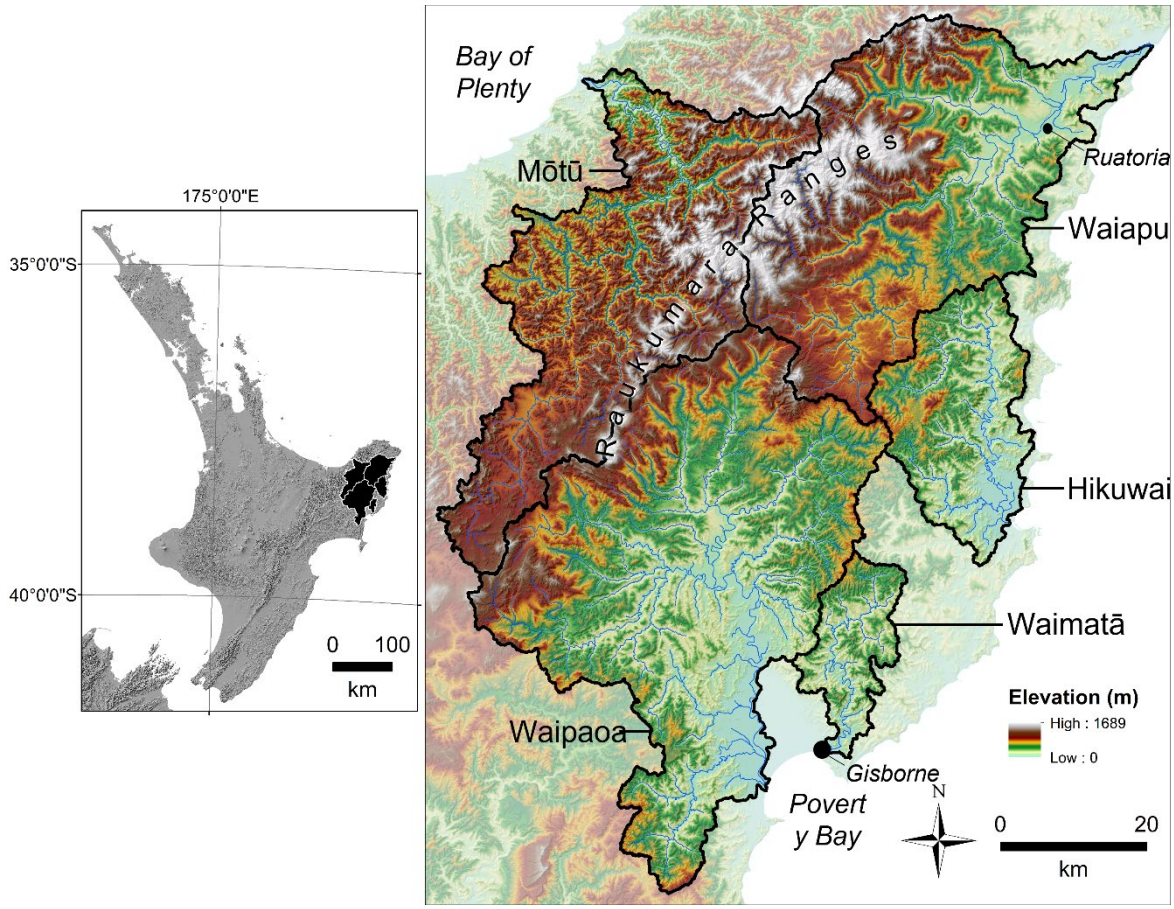

Figure 1. Catchment locations in New Zealand

2 GEOMORPHIC RIVER STORIES

2.1 Waiapu

Process Regime	Evolutionary trajectory	Management actions	Geomorphic river story
Sensitive, rapidly-aggrading (overloaded) rivers with high hillslope-valley floor, tributary-trunk stream and upstream-downstream connectivity	Indication that bed levels are stabilising or slightly degrading in upstream reaches, but aggradation will continue for centuries in downstream reaches. Gully mass movement complexes are dominant sediment source. Poor condition rivers with limited recovery prospects over next 50-100 years.	Revegetation of areas prone to gully-mass movement activity. Catchment-wide reafforestation Protect high value sites (e.g., key infrastructure), but otherwise leave channel alone to use its own energy as far as practicable.	Wild river prone to rapid sediment input from gully mass movement complexes. A globally significant example of a river subject to significant sediment flux and dramatic geomorphic adjustment (aggradation).

2.2 Hikuwai

Process Regime	Evolutionary trajectory	Management actions	Geomorphic river story
Highly connected from the Mountains to the Sea. High hillslope-valley floor connectivity in headwaters, but significant buffering by terraces and broad floodplain downstream. Slot-like channels in lower reaches have limited channel-floodplain connectivity and are not prone to lateral adjustment, but large volumes of fine-grained sediment are stored and reworked along channel banks.	Dynamic river with significant sediment flux but limited indication of notable change in geomorphic structure and function in recent decades. Active hillslope failures feed the river, with significant re-storage and reworking of fine-grained sediments along banks in mid-lower course reaches. Poor condition rivers with limited recovery prospects over next 50-100 years.	Reafforestation in headwaters and prioritised revegetation of riparian margins. Retire areas of production forest on highly connected slopes to allow reversion of indigenous vegetation to mitigate slash mobilisation.	Excessive fine-grained sediment flux (and forestry logs) readily conveyed within a slot-like channel from the Mountains to the Sea

2.3 Waimata

Process Regime	Evolutionary trajectory	Management actions	Geomorphic river story
Terrace-constrained flume-like channel with high longitudinal connectivity but limited channel-floodplain connectivity. Large volumes of fine-grained sediment are stored and reworked along channel banks.	High sediment flux (fine-grained sediments, logs), but limited and localised changes to geomorphic structure and function in recent decades (transfer reaches). Shallow landslides, incremental inputs from earthflows and occasional mud volcanoes are primary sediment inputs, but large volumes of fine-grained sediments are temporarily trapped and recurrently reworked along channel banks. Poor condition rivers with moderate recovery prospects over next 50-100 years (sediment inputs and forms/rates of geomorphic adjustment are less pronounced than other rivers in the region).	Reafforestation in headwaters and prioritised revegetation of riparian margins. Native reversion where production forestry marginal or risk of slash.	Terrace-constrained flume-like chute that readily conveys fine-grained sediments (and forestry logs) from the Mountains to the Sea

2.4 Waipaoa

Process Regime	Evolutionary trajectory	Management actions	Geomorphic river story
Sensitive, dynamically-adjusting rivers. Pronounced hillslope-valley floor connectivity creates overloaded, aggrading rivers in headwaters. High longitudinal connectivity promotes rapid floodplain aggradation in lower reaches, where stopbanks now limit capacity for lateral adjustment.	Dynamically adjusting rivers are subject to rapid rates and high volumes of sediment input (sometimes extreme). Significant, recurrent reworking of fans and bed materials. Decadal aggradation rates may have diminished, but sediment flux remains exceedingly high. Gully mass movement complexes and pervasive landslips generate extreme sediment loads. Poor condition rivers with limited recovery potential over next 50-100 years.	Revegetation of areas prone to gullying and surface erosion (earthflows and landslides). Continued use of targeted reafforestation and native regeneration of erosion-prone land. Protect high value sites (e.g., key infrastructure), but otherwise leave channel alone to use its own energy as far as practicable.	Globally significant example of an overloaded channel with exceedingly high sediment flux that is prone to profound, rapid and recurrent geomorphic adjustment, reflected in marked transition from rapidly aggrading bedload to aggrading suspended load dominated river along its length. Gully mass movement complexes and landslips induce rapid fan and valley floor aggradation. Sediment stores are readily reworked. High connectivity from the Mountains to the Sea

2.5 Motu

Process Regime	Evolutionary trajectory	Management actions	Geomorphic river story
Upper catchment is a moderately sensitive river subject to incision and lateral channel expansion (high channel-floodplain connectivity). Terraces buffer sediment input. High longitudinal connectivity, with limited accommodation space downstream of the gorge.	Incision and lateral channel expansion have increased sediment inputs and flux in meandering reaches in recent decades. Moderate to poor condition rivers with moderate recovery potential over next 50-100 years.	Bed control structures, increased wood loading and riparian vegetation management is the key priority to increase channel roughness and dissipate stream powers, reducing potential for bed degradation and channel expansion. Although warranted, reafforestation will reduce flow inputs but have limited impacts on the sediment regime.	High accommodation space has created opportunity to store large volumes of sediment on valley floors in the upper catchment, separated from the coast by a gorge. Terraces buffer hillslope sediment inputs to the channel in the upper catchment. Reworking of valley floor sediments by incision (headcut erosion) and channel expansion of the laterally migrating river is the dominant sediment source.

3 CONCLUSION

These five geomorphic river stories highlight profound variability in river diversity, process regimes (sediment sources, connectivity relations) and evolutionary trajectories (Section 2). They present significant management challenges as they respond to massive sediment inputs from rapidly eroding slopes. The physical manifestation of anthropogenic disturbance, and associated prospects for geo-ecological recovery through appropriately targeted rehabilitation practices, vary markedly from catchment to catchment. Geomorphic river stories synthesize process-based insights into catchment-specific evolutionary trajectories to understand what is realistically achievable in management of a river system. This develops fit-for-purpose rehabilitation strategies that work at source and at scale, targeting primary contemporary sediment sources. Managing at source, at scale and in a timely manner are key to the success of proactive and precautionary management plans that promote geomorphic river recovery (Fuller et al., 2023).

LIST OF REFERENCES

Fuller, I.C., Brierley, G.J., Tunnicliffe, J., Marden, M., McCord, J., Rosser, B., Hikuroa, D., Harvey, K., Stevens, E., Thomas, M. (2023). Managing at source and at scale: The use of geomorphic river stories to support rehabilitation of Anthropocene riverscapes in the East Coast of Aotearoa New Zealand, *Frontiers in Environmental Science*, 11:1162099.