Integrating geomorphology and ecology for resilient river management in an era of global change

Intégrer la géomorphologie et l'écologie pour une gestion résiliente des rivières à l'heure du changement global

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RÉSUMÉ

Cet article fait état d'une approche qui intègre la géomorphologie et l'écologie pour favoriser une gestion plus résiliente des rivières face aux défaillances catastrophiques et offrant une grande diversité d'habitats pour la vie aquatique. Nous atteignons cet objectif à plusieurs niveaux. En utilisant des documents d'archives pour l'évaluation des canaux pré-élaborés, nous identifions les formes de rivières ayant un équilibre naturel. Cet état de la rivière est ensuite comparé à l'état actuel du cours d'eau, et un indice de qualité de l'habitat fluvial (IQH) quantifié pour identifier l'ampleur du changement de l'assemblage de canaux avant et après l'ingénierie. L'IQH peut ensuite être utilisé pour recommander des changements pour le génie fluvial futur afin d'améliorer la résilience et la qualité de l'habitat à la lumière des évolutions environnementales prévues. L'évaluation préalable et postérieure à l'ingénierie peut être exécutée pour établir la nature et l'ampleur des changements effectués par l'intervention d'ingénierie. Nous illustrons l'intégration de la géomorphologie et de l'écologie pour obtenir un indice de qualité de l'habitat à différentes échelles temporelles et spatiales à l'aide d'études de cas réalisées en Nouvelle-Zélande et, dans cet article, nous nous intéressons à l'exemple de la rivière Motueka.

ABSTRACT

This paper reports on an approach that integrates geomorphology and ecology to encourage river management that is more resilient to catastrophic failure, and provides a diversity of habitat for aquatic life. We achieve this objective at a number of levels. By using archive material to assess pre-engineered channels, we identify natural equilibrium river forms. This state of the river is then compared with the current river condition, and a river habitat quality index (HQI) quantified to identify the scale of change from pre- to post-engineered channel assemblage. The HQI can then be used to recommend changes for future river engineering to improve resilience and habitat quality in light of predicted environmental change. Pre-and post-engineering assessment can poterntially be executed to establish the nature and extent of changes effected by engineering intervention. We illustrate the integration of geomorphology and ecology to derive a habitat quality index at different temporal and spatial scales using case studies from New Zealand, and in this abstract focus on one example from the Motueka River.

KEYWORDS

Ecology, environmental change, geomorphology, river habitat, river resilience

1. INTRODUCTION

A range of river types can be considered as being resilient, where disturbance is absorbed, and river form retained or recovered in a dynamic equilibrium. Wohl (2016) has argued that healthy rivers are those that manifest diversity and complexity of expected form. These ‘messy rivers’ have a natural capacity to adjust in response to disturbance (e.g. floods), which makes them resilient to change. In its unaltered condition a river will respond with resilience to even the largest floods, because its natural form and character will adjust and recover over time. The problem for river management is that many rivers are now no longer in a natural catchment setting. Flood protection schemes typically involve channel straightening and a reduction in geomorphic complexity. Engineered rivers are also usually fixed in place to reduce channel migration. These over-managed rivers are expensive to maintain. Disconnection with adjacent floodplains limits replenishment of bedload calibre sediment leading to bed degradation, which undermines costly hard-rock bank protection. These rivers are managed to resist change, but are in fact highly vulnerable to catastrophic failure when floods occur that exceed their design limits, and as such are not resilient. Furthermore, in a narrowed, deepened, simplified form, these rivers lack the diversity of habitat to sustain healthy river ecosystems, compromising river health. A tool is needed to inform river managers concerning the extent of river modification in order to improve river resilience, especially in the context of accelerating global change and forecast increase in flood frequency and magnitude. The paper focuses on results from New Zealand rivers to highlight the issue, and this abstract reports the method and results from the Motueka River as an example.

2. METHOD

GIS layers of the river corridor were generated using the earliest and most recently available rectified aerial photo imagery for the river. These map the key features of the river corridor, identifying the mosaic of features in both 1946 (pre-management) and 2012 (Figure 1). The change in character and habitat quality is assessed using a Habitat Quality Index (HQI), which provides a ratio of change in habitat features between the two dates. This index provides a broad overview of change attributable largely to river management. HQI is derived by dividing the area or length of a feature at time 2 by its area or length at time 1. No change yields a ratio of one, an increase in the unit results in a ratio above one, while a reduction yields a value below one, with the smaller the number, the greater the change. HQI values are provided in Table 1 for each of the key habitat components measured in the Motueka.

3. RESULTS & DISCUSSION

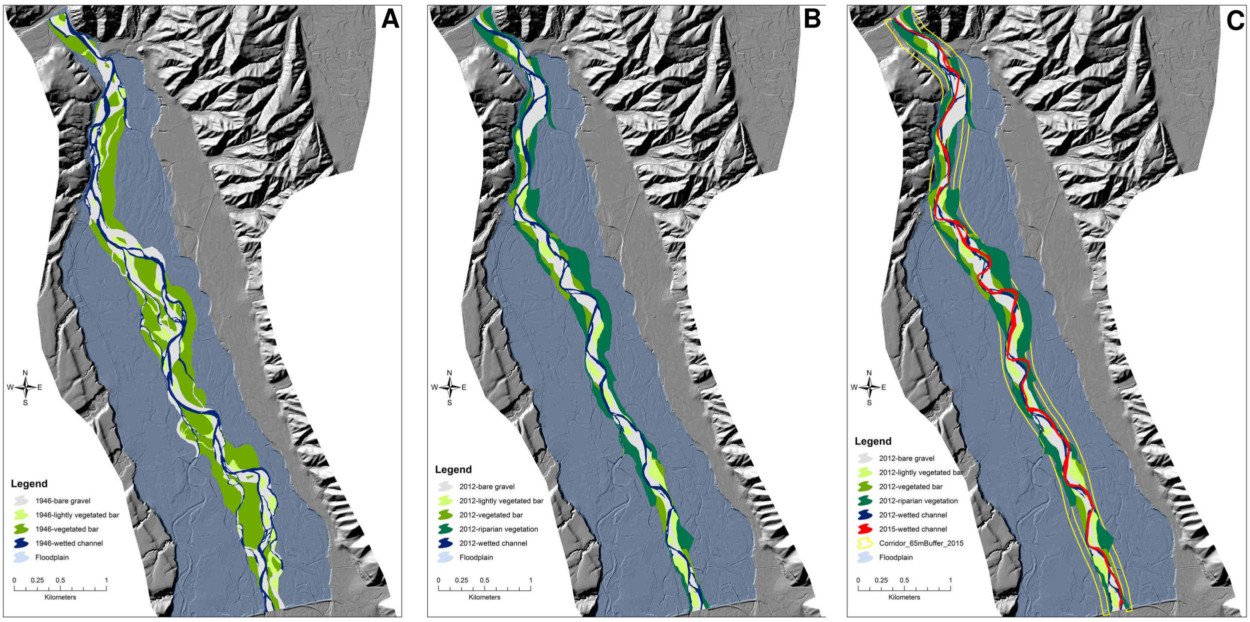

Figure 1. Change in river corridor characteristics, upper Motueka River and vulnerability to change: A, 1946, B, 2012, C, 2015 channel and management buffer overlaid, demonstrating propensity to break-out of this over-narrowed corridor.

Table 1 Habitat Quality Index assessment, Motueka River

Feature	**Area 1946 (m^2)**	**Area 2012 (m^2)**	**HQI**
Active channel	2496630	1814895	0.73
Wetted channel	405502	242831	0.60
Backwater area	49435	16147	0.33
Bare gravel	700023	465127	0.66
Lightly vegetated bar	195196	208482	1.07
Vegetated bar	1195909	197732	0.17
Riparian vegetation	n/a	700721	-
Veg bar + Riparian veg	1195909	898454	0.75
	Length 1946 (m)	**Length 2012 (m)**	
Active channel width	358.81	256.15	0.71
Thalweg length	14973	9661	0.65
Channel bank vegetation	2017	4280	2.12

With the exception of lightly vegetated bar areas, all habitats show a reduction in area in response to active channel contraction between 1946 and 2012. There is a slight increase in lightly-vegetated bar during this period. In terms of aquatic habitat, the most significant change occurs in the backwater areas, which are reduced by two thirds. These are particularly important as day-time habitat and refugia to many species of native fish and are often the habitats reduced by flood management. This is a consequence of channel rationalisation and reduction in the active channel area, with narrowing of the active channel width by 29%. Thalweg length is also reduced by 35%. Channel rationalisation and narrowing of the active channel has also reduced the area of active bars, represented by bare gravel in the river corridor. All these activities serve to channelize flows that reduces habitat diversity, flow refugia and flow microhabitats that are critical limiting factors for many river biota.

Riparian planting represents a significant additional habitat improvement to the channel mosaic, and this is combined with vegetated bar in 2012 to assess changes to the most stable areas within the active channel. Given the reduction in river corridor width in this period, the total area is reduced compared with the area of vegetated bar in 1946 (by 25%). The total length of streambank vegetation in 2012 has, however, increased dramatically compared with 1946 by over 100%. While this bankside vegetation provides important areas of shade for aquatic fauna, the overall habitat mosaic has nevertheless been homogenised.

The vulnerability of the upper Motueka in its modified form is demonstrated in Figure 1C. The current river is eroding the buffer zone, and likely to break out in the event of a large flood. The river in this form is not resilient to change, it is not in equilibrium with catchment boundary conditions, and a disturbance event is likely to result in catastrophic change. Furthermore, it appears that the upper Motueka displays a classic ‘hourglass’ morphology, with wider, instability zones represented by multiple channels, separated by relatively stable zones characterised by a single channel. The greatest channel movement between 2012 and 2015 occurs with and immediately downstream from the downstream instability zone : these areas are most vulnerable to change.

4. CONCLUSIONS

Management to a narrowed river corridor has over-constrained the upper Motueka, which resulted in loss of habitat, especially backwaters and a variety of wetted channel habitats. Multiple channel threads have been replaced by a larger, single, relatively more uniform channel. The existing river corridor is simply too narrow to effectively permit movement of the river channel without requiring significant remedial works. River habitat diversity and thus river health has been compromised. There is a need to accommodate reach diversity in river management, which also entails providing room for the channel to move, especially in areas prone to instability. Room to move should also allow for avulsions, where characteristic of this channel type, which enhances habitat diversity. The HQI provides a tool for river managers to assess the extent of deviation from natural river form in river reaches and target more resilient river management.

LIST OF REFERENCES

Wohl E. 2016. Messy rivers are healthy rivers: The role of physical complexity in sustaining ecosystem processes. In: Constantinescu, G., Garcia, M. & Hanes, D. (Eds.) *River Flow 2016*, Taylor & Francis, London, pp 24-29.