I.S. Rivers
INTEGRATIVE SCIENCES
RECHERCHES ET ACTIONS

Benchmarking fluvial geomorphic processes for river restoration and monitoring

Analyse comparative des processus géomorphologiques fluviaux pour la restauration et la surveillance des rivières

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ABSTRACT

River restoration generally implies efforts to return the integrity and resilience of river forms, processes and connectivity in the hope of a significant and sustained uplift in biodiversity. While there are various means of characterising changes in river forms and river connectivity, there have been few methods for benchmarking fluvial geomorphic processes as a channel evolves. We showcase a rapid assessment protocol developed to quantify the mode and intensity of river channel adjustments and to assess whether the channel is functionally stable. Of note, we separate field observations from their interpretative conversion into 'adjustment indices' to reduce inter-surveyor bias and allow for post-survey interpretative improvement. The approach was tested in relatively undisturbed high elevation meadow channels in California and highly modified lowland channels of Ireland. The method estimates 14 indices representing modes of channel adjustment, categorised into 4 levels of apparent intensity, and with integrative outcomes summarising the channel's sensitivity to change, lateral activity and relative instability. As a rapid assessment, the approach is well-suited to pre- and post-project monitoring to judge the evolutionary trajectory of channel adjustment processes and relative stability as part of benchmarking fluvial geomorphic processes for river management and restoration.

Introduction

- River restoration usually aims to restore the ecological (i.e., physical and biological) integrity of river systems.
- Evaluating the success of restoration activities ideally requires monitoring the evolution of forms, processes and connectivity and over a sufficient time period to determine that the restoration actions have created a resilient and self-sustaining river environment.
- Lack of effort/resources for establishing pre-project baseline conditions has seen the gradual development of self-referencing (i.e., benchmarked) methods scoring from low to high, whereby the good score implies conditions that are near-natural or fully-functional. Examples: habitat inventory: Gurnell et al., 2020; river connectivity van de Bund et al., 2024.
- For river processes, multiple modes of river adjustment, operating at different intensities, prevent a singular score from low-to-high. In response, we have developed an approach to codify and combine field observations to identify different modes of channel adjustment, the relative intensity of such processes, and summary outcomes reflecting whether a channel appears functionally stable or instead displays signs of instability (Booth and Downs, 2025; Downs et al., in prep.).
- Results demonstrate the conversion of field observations into 14 modes of channel adjustment, 4 levels of apparent adjustment intensity, and summary judgments about channel's relative stability.

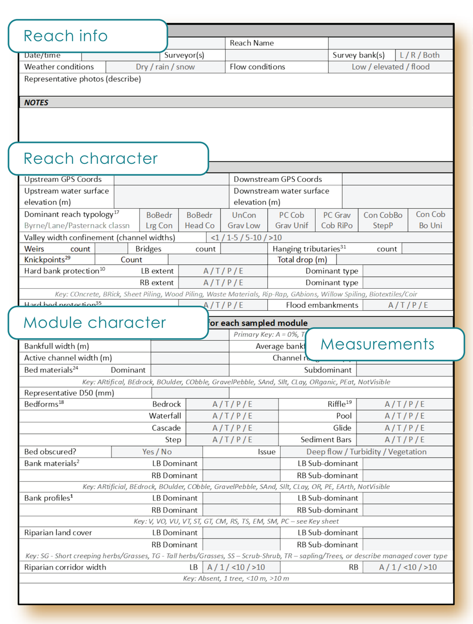
Method

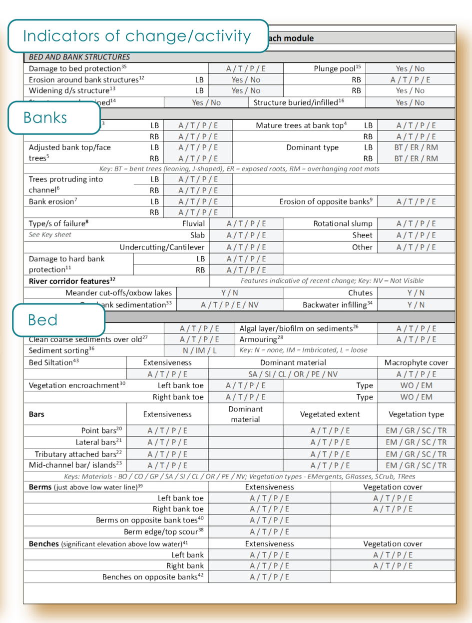
Steps:

1. Assemble indicator set (≈40) diagnostic of potential channel adjustment,
2. Make structured observations ('read the river') over a representative river reach (width-scaled), using non-linear extensiveness values (DAFOR variation, per Gurnell et al., 2020)
3. Assemble individual observations (i.e., indicators of change) into suites of observations (equations) indicative of one particular mode of channel adjustment. 14 modes identified, with equations utilizing 1-9 indicators
4. Convert Indicators to Values to Scores, taking care that Values in each equation are comparable and do not create an inherent weighting towards certain indicators. Values are banded into Scores to allow comparability between equations. Scores ranges from 0-3 according to negligible (0), some (1), moderate (2) or considerable (3) evidence for change. Can revisit without jeopardizing field surveys.
5. Group equations according to whether they could be interpreted as reflecting the channel's inherent sensitivity to change, evidence for lateral activity (e.g., as part of natural meander migration processes) or whether the adjustments seemed indicative of prevailing channel instability.

Diagnostic indictator set → Structured data collection → Estimate 14 modes of adjustment → Convert observations to values ↓ Combine values as comparable scores → Apply interpretative framework

2. Structured Data Collection





3. Estimates of Adjustment

Mode of Adjustment Equation					
1	Channel responsiveness	6	Bank erosion certainty	10	Bank failure severity
2	Bank erodibility	7	Sediment transport activity	11	Channel widening
3	Bank suscept: morphology	8	Barform activity	12	Channel narrowing
4	Bank suscept: vegetation	9	Planform activity	13	River bed erosion
5	Channel suscept: structural			14	River bed aggradation
Sensitivity to Change		Lateral Activity		Channel Instability	

4. Convert Observations to Values to Scores

EQ 14. CERTAINTY OF BED AGGRADATION			
Rationale	Active bed aggradation is indicated from multiple lines of morphological, vegetational and structural evidence.		
INDICATOR VALUES			
Observation	Response	Indicator values	Range
Structures buried	Presence	Y = 2, N = 0	0-2
Backwater infilling	Presence	Y = 2, N = 0	0-2
Bed siltation	Extensiveness	E = 3; P = 2	0-9 (Product of bed siltation × vegetation extent)
Vegetation with bed siltation	Extensiveness	A = 3; T = 2, P = 2, E = 1	
Dominant material with bed siltation	Count, per reach	Silt = 2, sand = 1, other = 0	0-2
Opposite bank depositional berms	Count, per reach	E = 3; P = 1	0-3
Form of equation	∑indicator values and vegetated bed siltation product		
INDICATOR SCORES			
Value total (0-18)	Description		Indicator Score
0-1	Little/no evidence of bed aggradation		0
2-5	Limited evidence of bed aggradation		1
6-9	Moderate evidence of bed aggradation		2
10-18	Extensive, clear evidence of bed aggradation		3

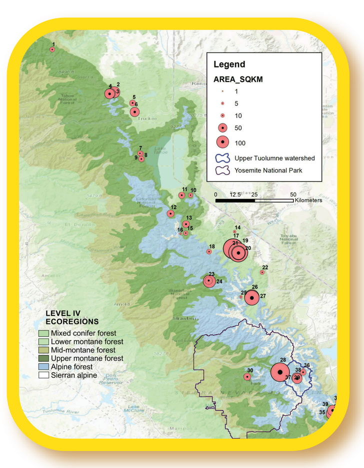
5. Stability Interpretation

Field Tests and Results

Pilot field tests were undertaken in the summers of 2023 and 2024, high elevation meadows of the Sierra Neveda of California, and channelised lowlands of Ireland. Banded scores from the 14 'mode of adjustment' equations are provided under each photograph ranging from red where there is negligible evidence for change to green where there is considerable evidence. The grouped scores for channel sensitivity to change, lateral activity and channel instability are shown as percentages inset on each photograph.

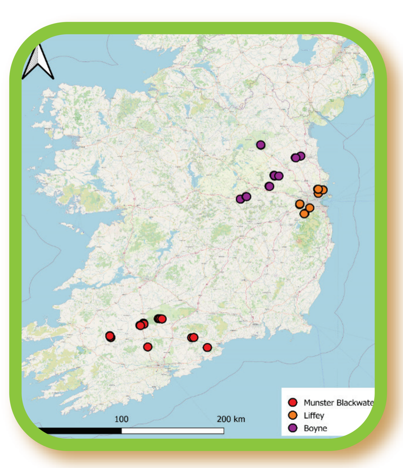
California (2003-24)

> Re-occupy upland biological ref sites (Ode 2016)
> Expectation: dynamic stability, (historical alteration?)
> 1-module approach, 54 sites



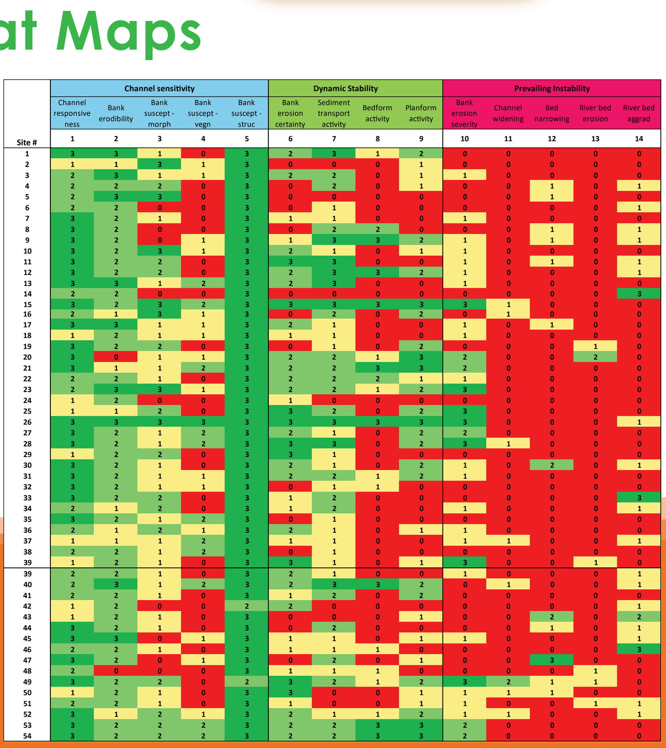
Ireland (2023)

> Validation of a restoration planning tool (RiverREST)
> Lowland sites
> Expectation: fine sediment led recovery or stasis through maintenance
> 5-module approach, 46 sites

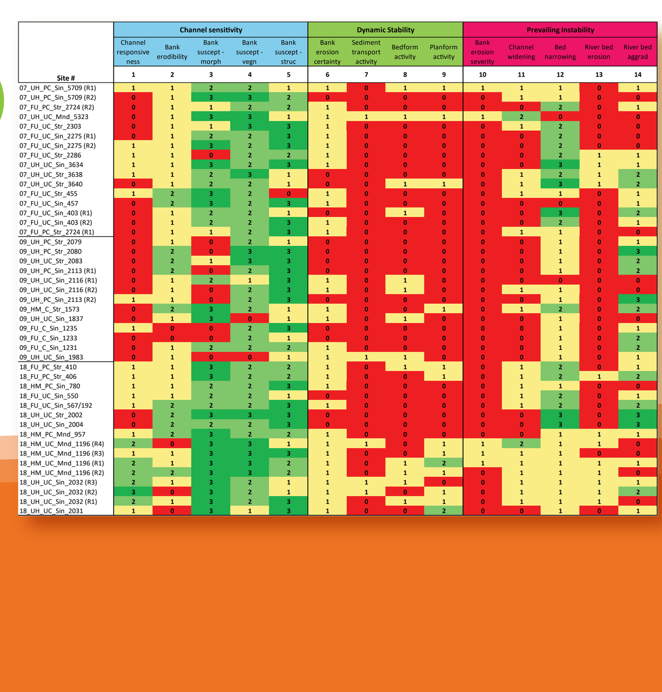


Heat Maps

CA



IE



The **Reach Summaries** illustrate generally expected adjustment type outcomes from the two environments

The sampled rivers in California are generally sensitive to change (composed of erodible materials and with little constraining infrastructure), run a broad spectrum of lateral activity types from channels that are highly active (top left) to those with far lower apparent rates of change, and generally show low levels of channel instability (top right). Such results appear logical with their setting as meadows at high elevation in a National Park.

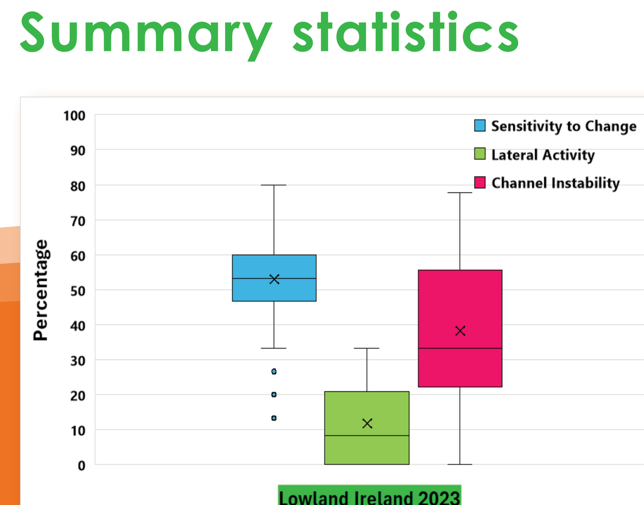
The sample set from Ireland are also generally quite sensitive to change largely because they are free to adjust, but as frequently oversized, straightened channels, they show few signs of lateral activity but instead are far more unstable than the California sites. Instability is generally in the form of channel recovery through fine sediment-led processes of channel narrowing and aggradation **(see Heat Map)**.

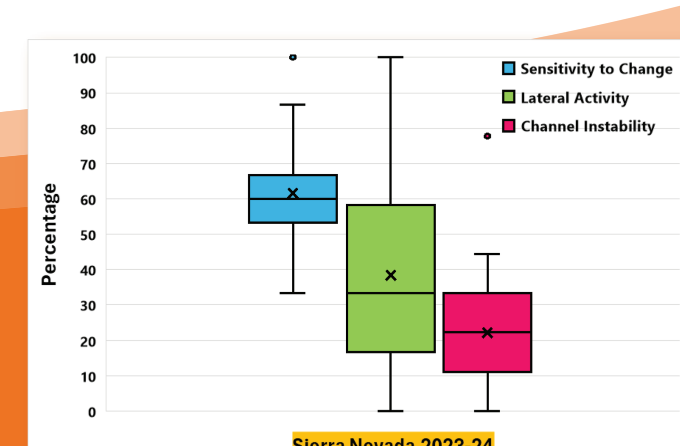
These results are borne out more generally in the **Summary Statistics** illustrating the greater degree of lateral activity in the near-reference California sites and the greater instability of the heavily management Ireland sites.

Reach summaries

Channel sensitivity					Dynamic Stability				Prevailing Instability				
Resp	B erodi	Sus-m	Sus-v	Sus-s	B eros	Sed tran	Bar act	Plan act	Mass f	Wide	Narrow	Incise	Aggrad
0	1	2	2	1	0	0	1	1	0	1	3	1	2

Summary statistics





Conclusions and Next Steps

Pilot test results were consistent with our expectations, providing evidence that the approach has potential in judging channel adjustment processes and relative stability. The assessment technique takes only 1-2 hours per reach (5 modules), making the approach highly suitable to repeat monitoring, even when monitoring is poorly funded.

Inter-surveyor bias is minimized by restricting the surveyor to field observation; interpretations are provided via expert judgments embedded into the equations. Results from earlier surveys can readily be recalculated if the equations are adjusted. The scoring system is benchmarked according to apparent intensity of dynamics (0–3) and percentage likelihood in relation to the channel's sensitivity to change, lateral activity and relative instability. percentage related to equations grouped score.

The approach allows comparative assessment of channel adjustment processes which has not been possible before.

The accuracy of the outcomes and the calibration of the banded value ranges for each equation will benefit from further testing. Assessment precision will be assisted by the development of formalised training procedures, supporting documentation and using a 5-module form of the assessment. The efficiency of the approach will be aided by developing a system of tablet computer-based data collection and automated data processing.

For restoration, approach reduces the emphasis on pre-project monitoring - a nearby unrestored reach of river could probably provide a sufficient baseline for judging restoration success in sustainably restoring river processes. The approach can be combined with inventories of riverine habitat diversity and connectivity to provide overall evaluation of river restoration success.

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