UMEÅ UNIVERSITET

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Drivers of channel morphology in semi-alluvial boulder-bed streams & implications for river restoration

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1. Summary

2. Introduction: Very little is known about the drivers of river morphology in semi-alluvial rivers such as those with legacy sediment from glaciation (e.g. boulder moraines). This knowledge is required to manage and restore these rivers and predict how they will respond to climate change.

Research question: What is the relative importance of fluvial versus glacial legacy controls on **(1) channel morphology** and **(2) boulder distribution** in boulder-bed rivers in northern Sweden?

3. Methods: Field and GIS surveys of 20 rivers across northern Sweden

4. Results:

- Cross-section geometry associated with catchment size and discharge = fluvial control.
- Channel slope, sinuosity, width and sediment size showed no self-organisation = legacy glacial controls.
- Boulder size and density independent of fluvial controls = legacy glacial controls.

5. Conclusions & implications for restoration:

- Glacial legacy control on boulder density and size and channel width whilst fluvial control on cross-section area of channel.
- Boulder distribution therefore cannot be predicted from reach or catchment characteristics but can be predicted from terrstrial boulder density.
- Boulder restoration can be used to reduce or stimulate geomorphic processes; need to be used with consideration.

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What drives channel morphology in previously glaciated catchments?

- Alluvial rivers can adjust their width, sinuosity, bed elevation and bedform roughness to changes in landscape scale drivers such as the discharge and sediment regimes.

- In areas with previous continental glaciation, legacy sediment (e.g. moraines) complicate this self-organisation of alluvial rivers. We know very little about what controls channel form in these areas.

- These rivers typically contain a high density of boulders which also influence channel form, modifying sediment transport and hydraulic processes. Furthermore, bulders are important ecologically, for example, boulders provide flow refugia for fish and emergence and ovipositioning (egg laying) sites for insects.

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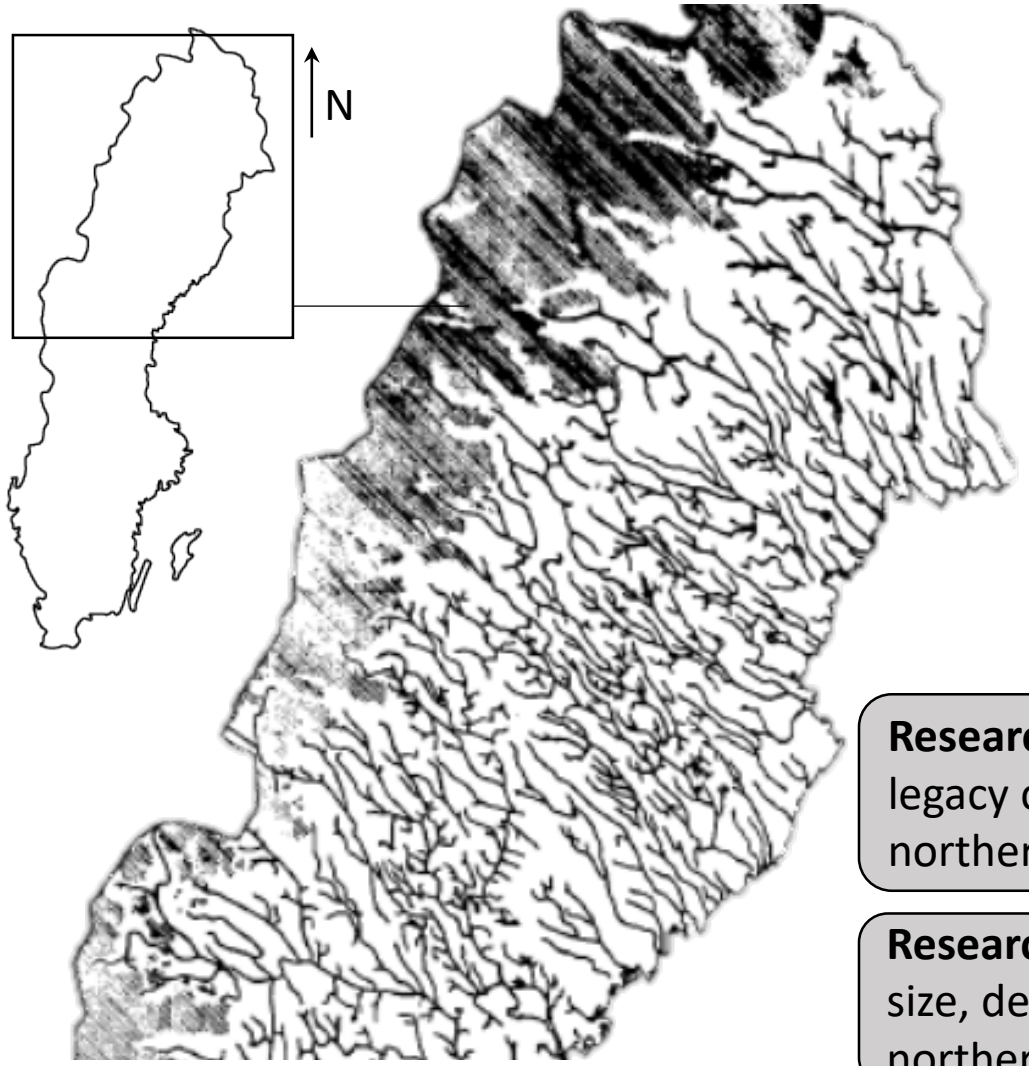
Restoration of boulder-bed rivers requires knowledge of drivers of both channel morphology and boulder distribution



Map of timber floated rivers, 1907
(Adapted from Andersson, 1907, IN: Törnlund & Östlund, 2006. Mobility without wheels. *The Journal of Transport History* 27, 48-70.)

- Swedish rivers have been extensively modified for floating timber. A network of float pathways from the inland forests to the coast was created (see map). To facilitate timber floating these rivers were straightened, side channels blocked and boulders removed.

- Therefore its important to know both the drivers of channel morphology and boulder distribution to enable restoration to successfully restore geomorphic, hydrological and biological processes.

Research question 1: What is the relative importance of fluvial versus glacial legacy controls on reach scale channel morphology of boulder-bed rivers in northern Sweden?

Research question 2: What glacial or fluvial factors are associated with the size, density and distribution of boulders within boulder-bed rivers in northern Sweden?

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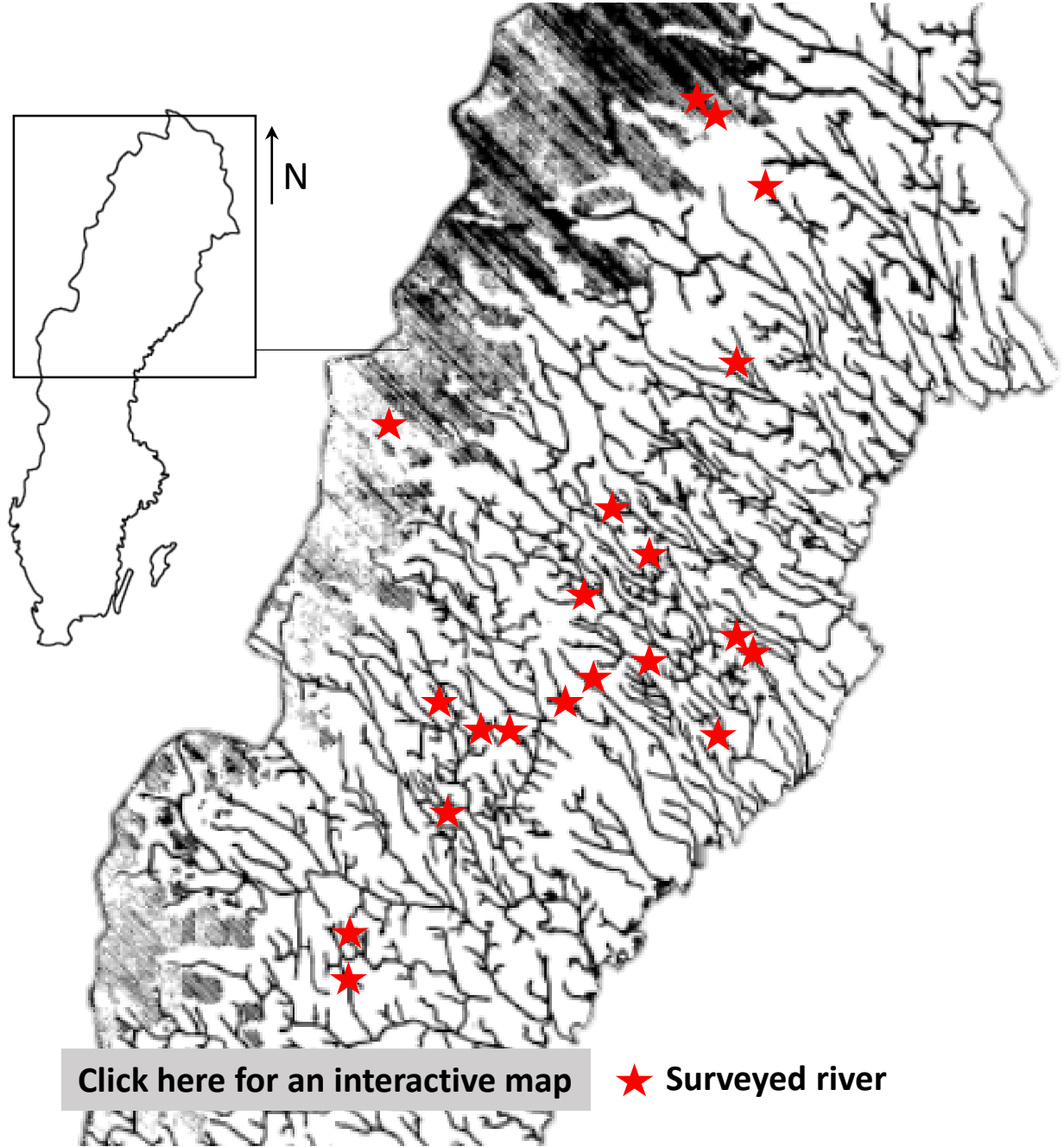
Surveys of un-impacted boulder bed rivers



Click here for an interactive map

★ Surveyed river

We conducted surveys of 20 reaches of minimally human disturbed boulder-bed rivers in northern Sweden to measure reach scale morphology and landscape scale hydrological and geological controls.

- Detailed morphological surveys at the reach scale.
- GIS analysis to determine catchment characteristics.

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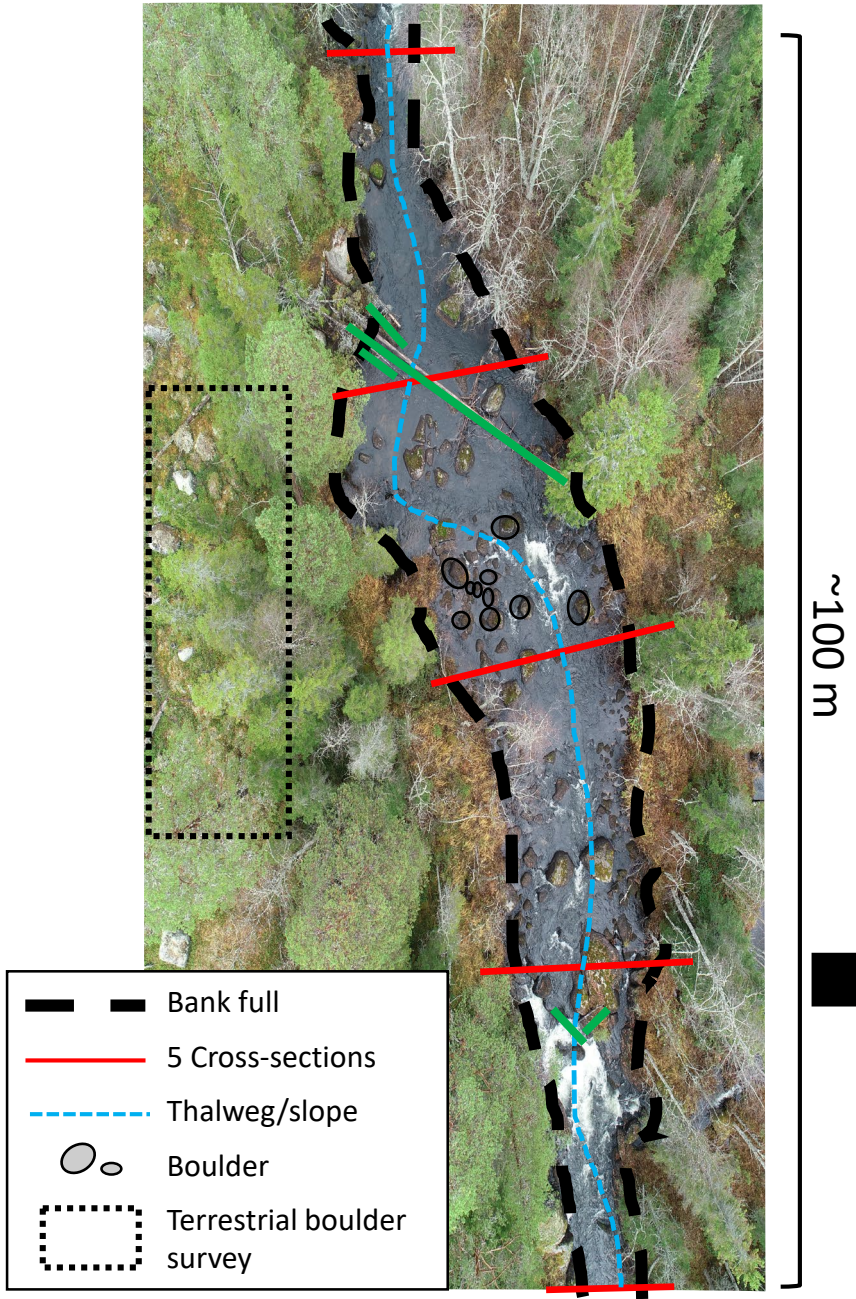
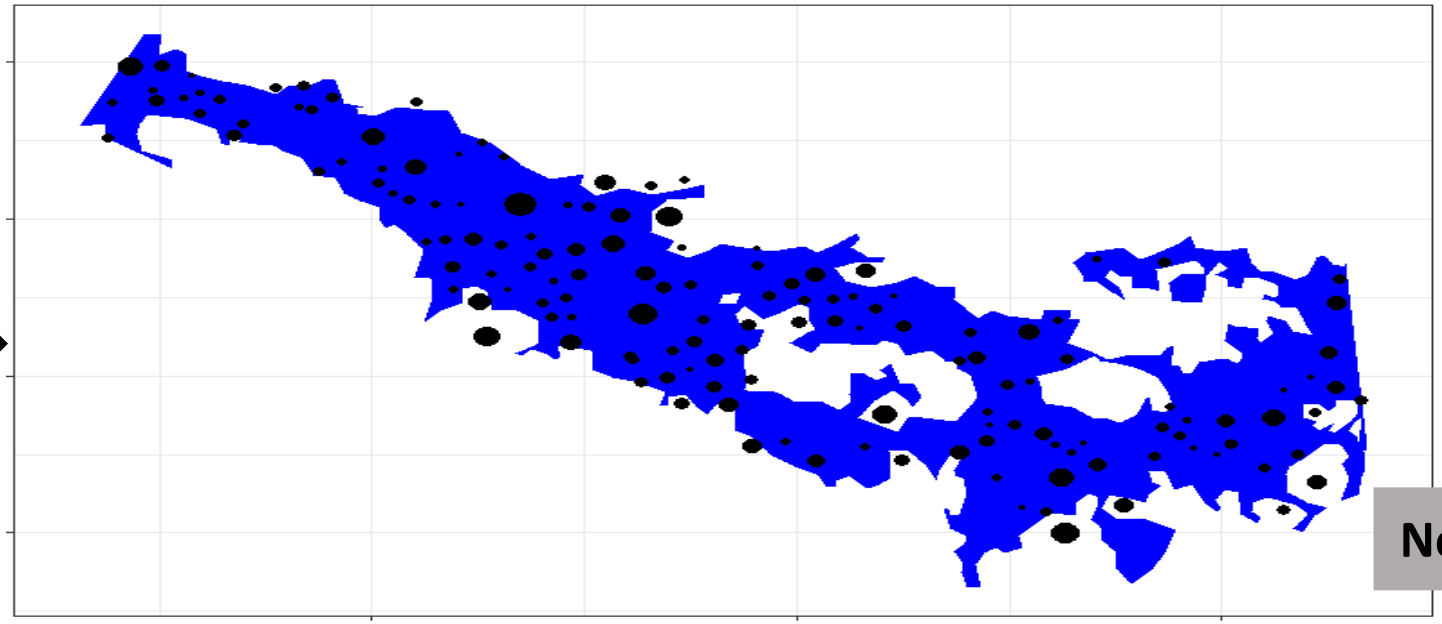
Reach surveys



- Measurement of detailed channel morphology.
- Measurement of size, location and protrusion of every boulder (b axis > 1 m) within the ~100 m reach.
- Analysis in R to determine reach characteristics including boulder density.



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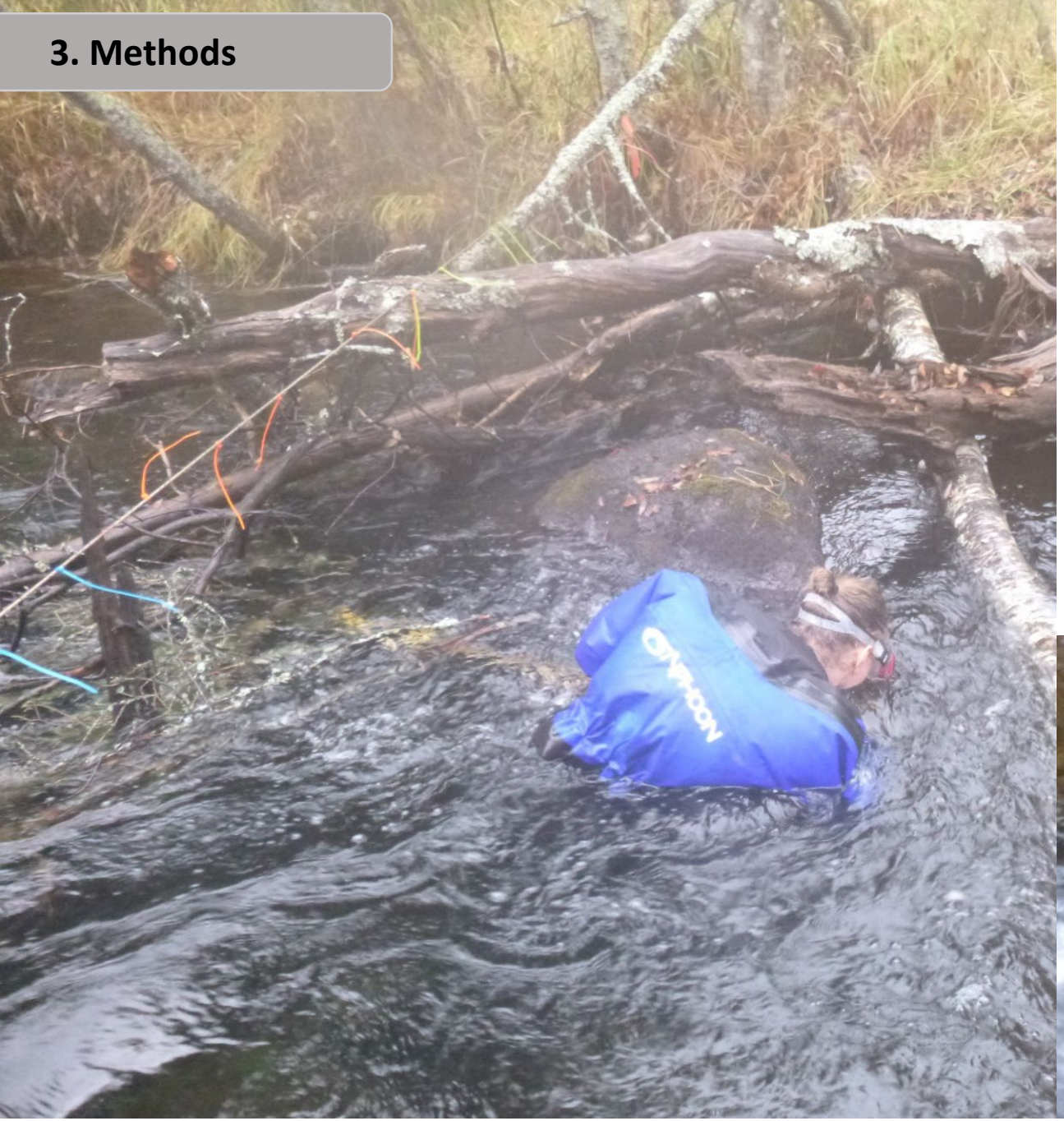

Yes, we measured every boulder!

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Thanks Jens Andersson for commitment to boulder measurements!

Rivers varied considerably in morphology and the size and density of boulders

Catchment area: 13.5 – 114.3 km^2

Slope: 1 - 8 % (low – medium slope)

Cross-section area: 2.1 - 10.3 m^2

D_{50}: 0.1 - 1.2 m (large)

D_{84}: 0.3 - 2.1 m (very large!)

Boulder density: 0.01 - 0.43 m^{-2}

Click here for an interactive map

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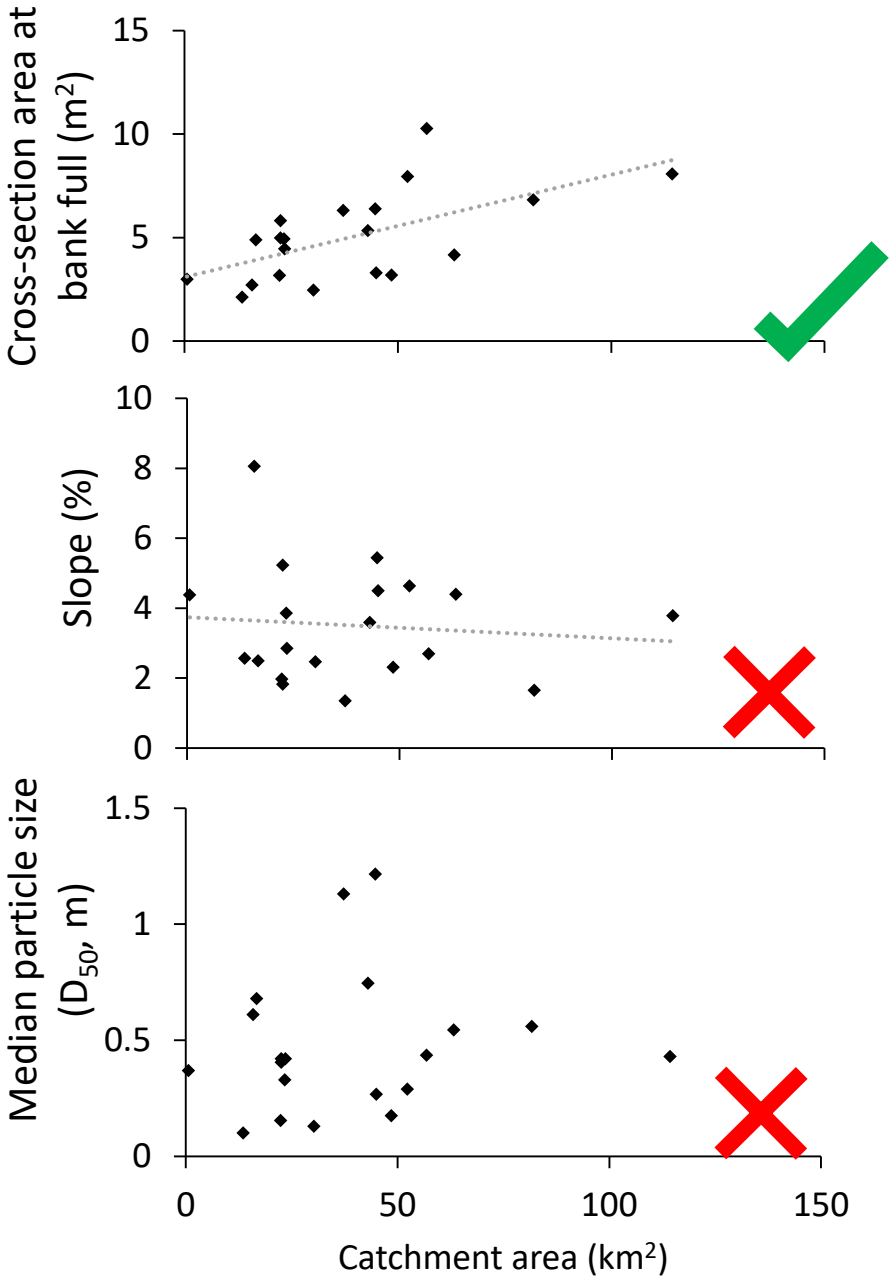
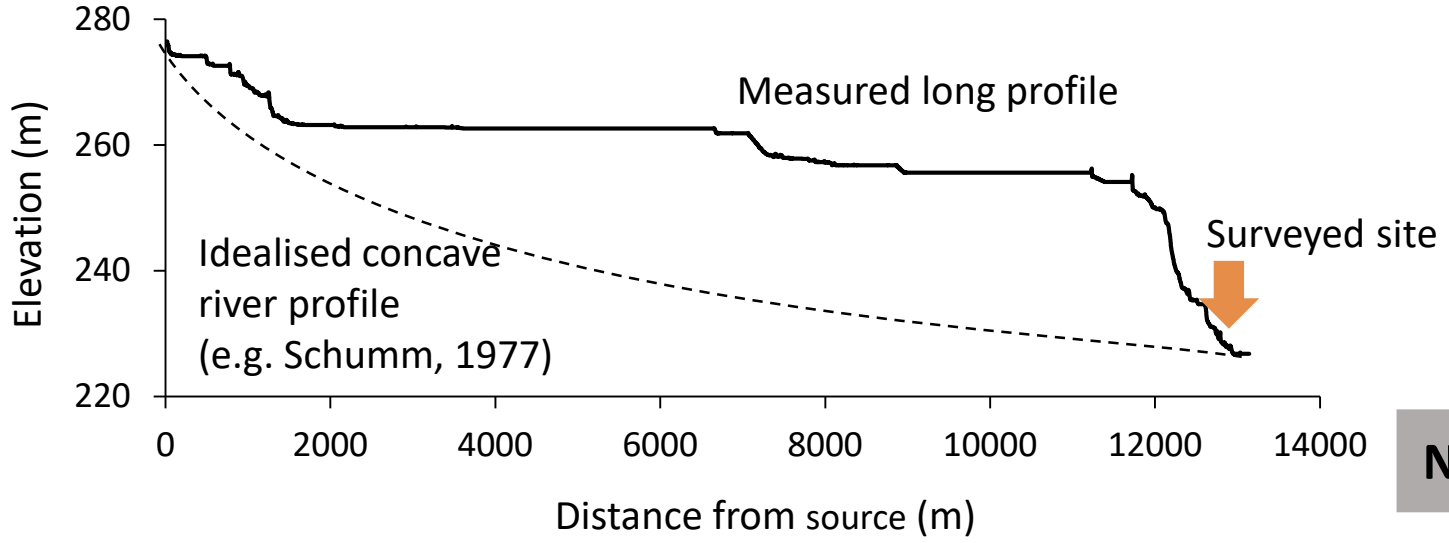
Only cross-section area was associated with catchment area/discharge



- The size of the channel (cross-section area of river at bank full) increases with catchment area and discharge.
- Slope and sediment size do not correspond to patterns typical of alluvial rivers (downstream decreases in slope and sediment size).

Example long profile: Skraveltjärnbäcken



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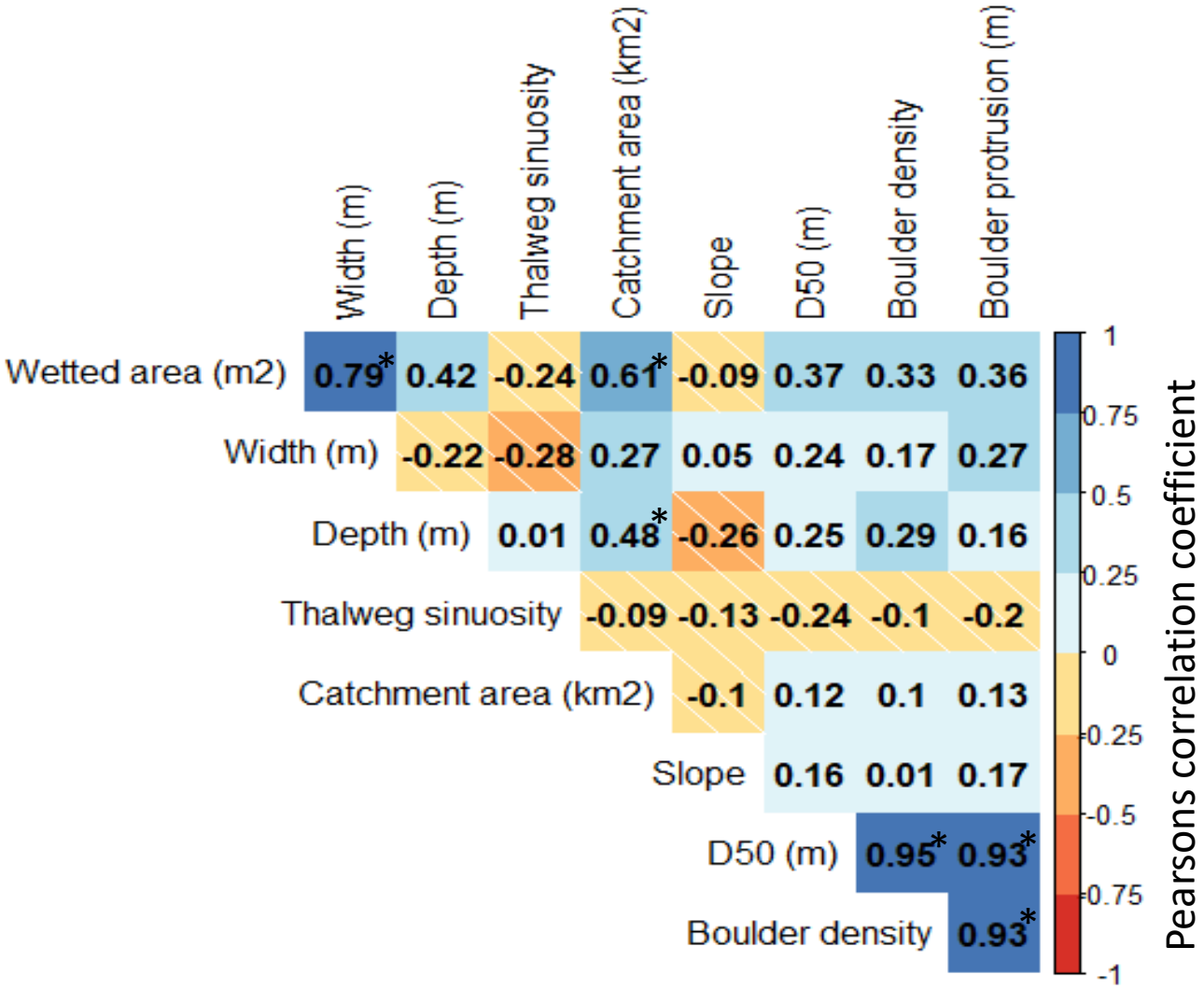
Boulder distribution and size is independent of fluvial controls



Correlation plot of catchment and reach scale hydromorphological variables.
Significance indicated by *, where $p < 0.05$.

- Density and size of boulders independent of catchment area, discharge and slope.
- Boulder protrusion and D_{50} are positively correlated with boulder density.

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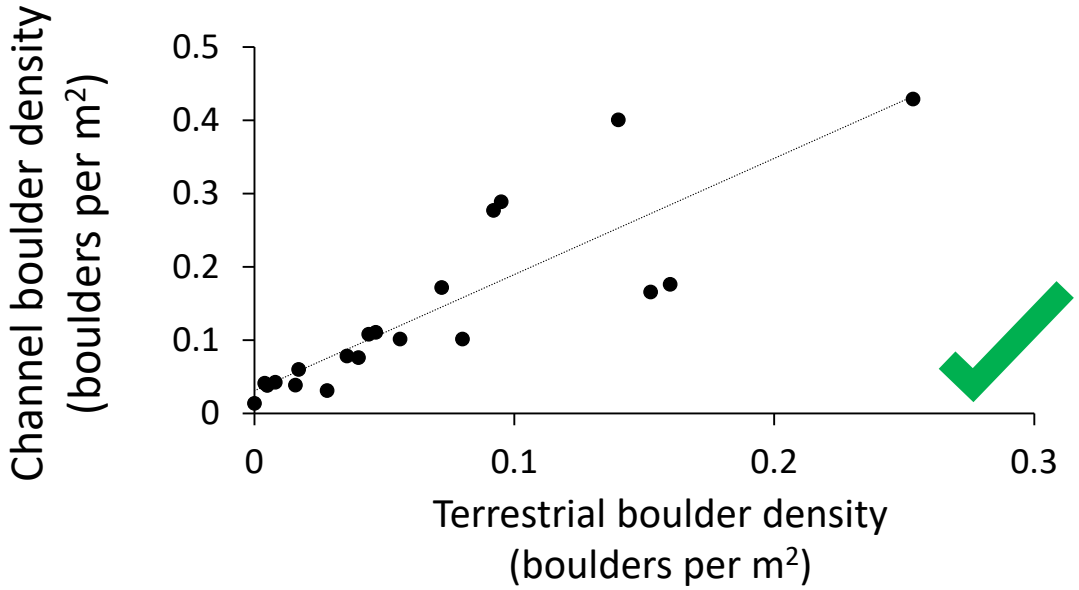
5. Conclusions

Implications for restoration

- Restoration of boulders in rivers is often based on expert judgement and aesthetics rather than a quantified estimate of density, size and distribution of boulders in a reference river.

- This can mean that restoration fails to achieve objectives. Boulders can promote natural processes and habitat complexity, but may also reduce these processes (e.g. bank armouring).



- In northern Sweden, the number of boulders to be restored can be determined from surveys of terrestrial boulders but isnt a 1:1 association.

Recently completed boulder restoration, N Sweden

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5. Conclusions

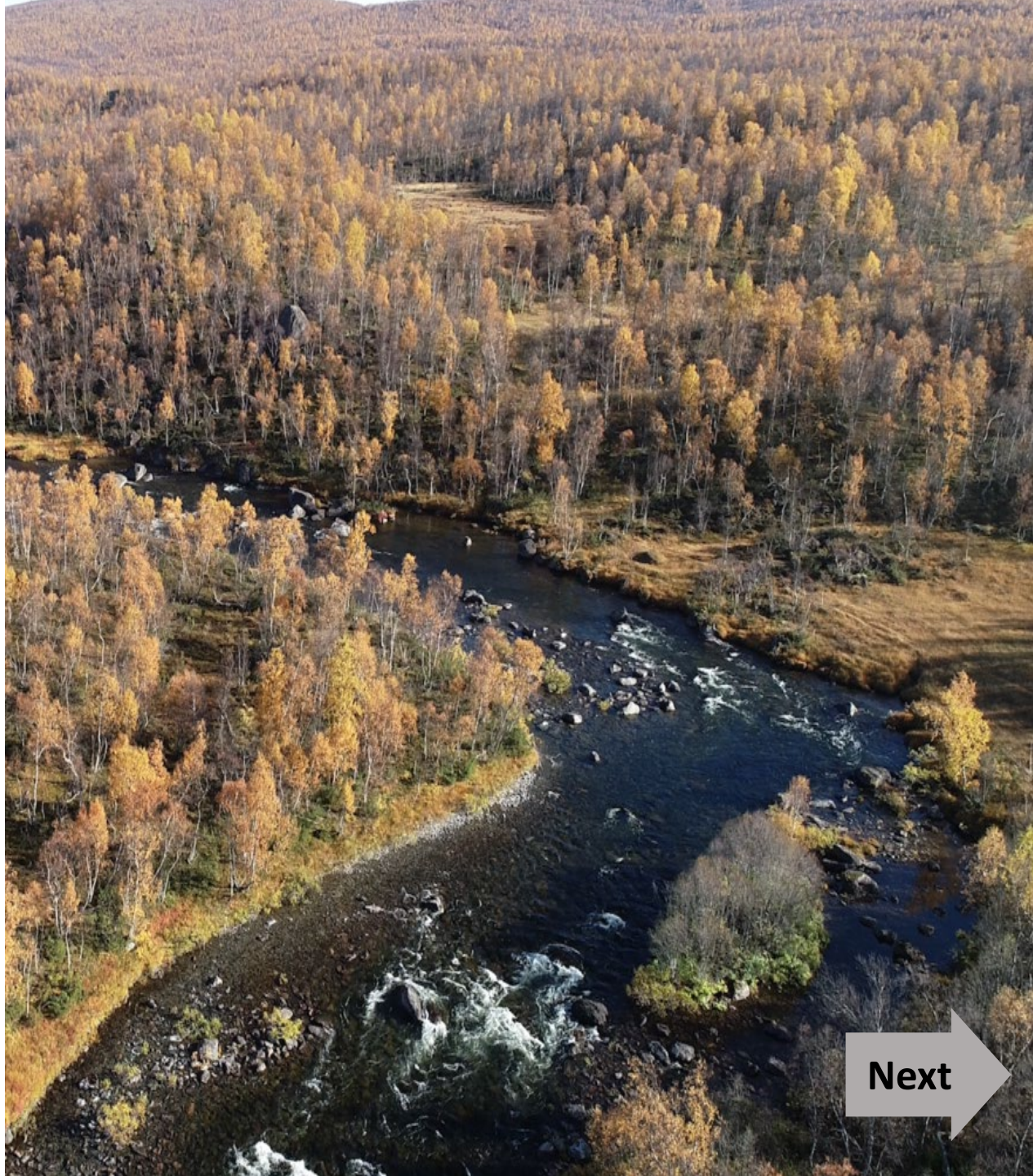
- Results indicate a combination of fluvial and legacy glacial controls on channel morphology and boulder distribution.

- The slope and sinuosity of channels appears to be constrained by glacial legacy sediment (including many boulders).

- Cross-section channel area responded to fluvial controls more than width or depth independently. This suggests that rivers form a channel with sufficient capacity within and between the constraints of boulders.

Future work:

- We observed few boulder jams creating step-pool sequences. However, we will test for boulder clustering along the river to see if boulders may have been reorganised by fluvial activity.



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Thank you!

Chat with me Fri 30 Apr or send a message at any time

Thank you to Jens Andersson and Mariana Busarello for field help and Pija Lapajne for assistance with GIS analysis.

Thank you also to the many people who recommended boulder-bed river sites relatively unimpacted by timber floating.

Link to session
Fluvial systems: Dynamics and interactions across scales

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