Reference State Selection in Scottish Restoration: A Case Study of Ardtornish Estate.

"If you wanted to know whether a restoration project is succeeding, what would you compare it to?"

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Project
Background

This research evaluated reference-state approaches for ecological restoration planning, using Ardtornish Estate as the case study.

- ✓ **Restoration is a national priority in Scotland, but there's no established guidance on how to select the benchmarks that define success.**
- ✓ **The objective is to determine how different reference-state approaches can guide restoration targets, monitoring design, and long-term management decisions across a multi-habitat Highland estate**

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About

FPP & Ardtornish

The Forest and Peatland Programme (FPP) is a University of Edinburgh initiative that expands forests and restores peatlands across Scotland, aiming to capture carbon while benefiting nature (University of Edinburgh, 2023).

- ✓ **FPP has carried out restoration at several university and partnership sites; Ardtornish is one, and this project sits within that wider programme.**
- ✓ **Ardtornish is a ~14,250-hectare Highland estate on the Morvern Peninsula, Lochaber, with 1,440 hectares under its Long-Term Forest Plan and three contrasting habitats: woodland, peatland, and freshwater.**

Defining Reference States

A ‘Reference State’ provides the ecological benchmark to measure recovery, comparing where we are to where we could be. Every approach also distinguishes an ‘ideal’ state (the full ecological aspiration) from a ‘target’ (what's actually funded and measurable).

Within-System Change

FPP's current approach

Compares the site to its own pre-restoration baseline.

Method: monitoring data, site surveys.

Limitation: no external reference point.

Historical

Reconstructs the site's pre-degradation condition.

Method: palaeoecology, historical accounts.

Limitation: often unmeasurable or contested.

Contemporary

Compares the site with similar extant sites.

Method: field surveys, classification.

Limitation: comparable sites are hard to find; 'healthy' status is inherited, not independently verified.

Future

Models projected ecological change.

Method: climate models, successional data.
Limitation: non-linear change is hard to predict.

Why Reference

States Matter

Restoration outcomes are often partial; global studies show ecosystems rarely fully recover (Jones et al., 2018; Benayas et al., 2009), raising a fundamental question: what should a restored site be compared against, and who decides?

- ✓ **In Scotland, the Biodiversity Strategy to 2045, Forestry Strategy 2019–2029, and National Peatland Plan set ambitious woodland, peatland, and freshwater targets, but how success is measured remains underexplored.**
- ✓ **Reference states are the field's answer to that question, but the concept itself is contested, and no single approach fits every context.**

The Shackelford Framework: Nine Combinations

Reference states aren't one thing. Shackelford et al. (2024) framework provides the systematic process for selecting these benchmarks. Shackelford et al. (2024) organise them along two axes, how far back in time you look, and how far outward in space, giving nine possible combinations.

	Historical (pre-degradation)	Contemporary (current)	Future (projected)
Local (within site)	**Historical – Local**	**Contemporary – Local**	Future – Local
Ecosystem (comparable habitat nearby)	Historical – Ecosystem	Contemporary – Ecosystem	Future – Ecosystem
Regional (across a spectrum of ecosystems)	Historical – Regional	**Contemporary – Regional**	Future – Regional

- Combinations with usable data at Ardtornish, covered on the next slides.

Shackelford, N. et al. (2024) 'Measuring at all scales: sourcing data for more flexible restoration references', Restoration Ecology, 32(8), e13541.

The Approach

What works, not just what's ecologically ideal.

1

Framework: Shackelford et al. (2024)

Nine reference approaches, mapped across two axes: when (historical, contemporary, future) and where (local, ecosystem, regional). Applied separately to woodland, peatland and freshwater.

2

Extension: My contribution

Shackelford's framework organises what data exists, but not whether using it is workable. I developed fourteen evaluation criteria, including cost, expertise, and policy fit, to guide my interviews and build a feasibility matrix per habitat. Cost and expertise drove most decisions; things like community fit barely varied.

3

Grounding: Site visit and Interviews

A site visit and two in-depth interviews, one with Ardtornish, one with the FPP, tested the desk-based analysis against what practitioners experience on the ground.

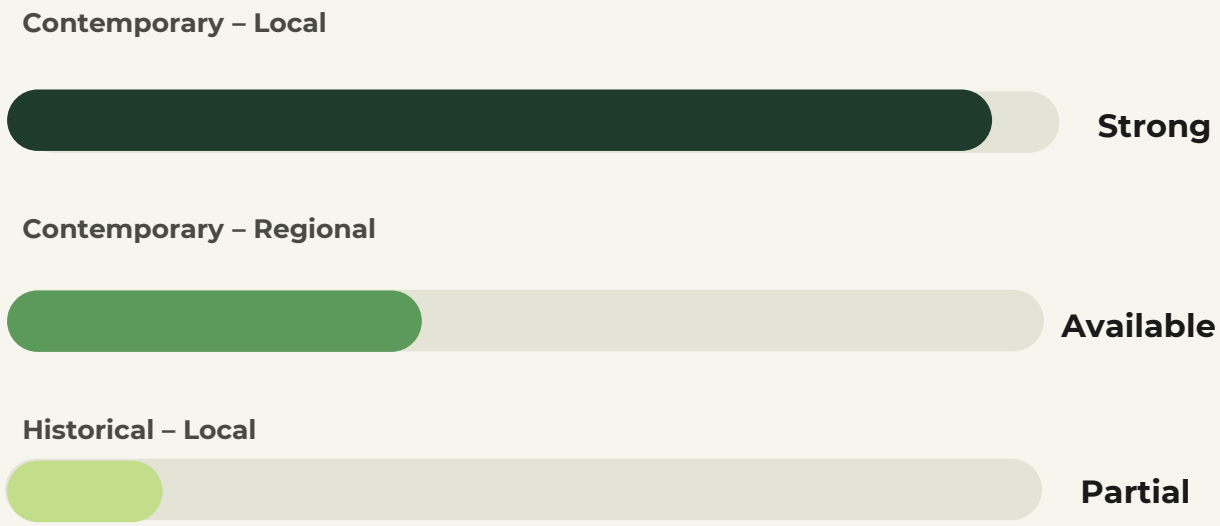
Documentary sources, spatial data, and original GIS analysis (QGIS) underpin the findings.

Findings: Data Availability

Contemporary-local data dominates restoration monitoring across all three habitats.

92% of studies rely solely on contemporary-local data

Shackelford et al. (2024) — Ardtornish figures below are this research's own findings.



This pattern tracks carbon accountability, not ecological importance, peatland (strict carbon reporting) is best-monitored; freshwater, with no carbon mechanism, is the most overlooked.

Data-Richness Comparison

Contemporary-local sources (site-specific surveys, drone imagery, fixed monitoring plots) provide the richest baseline for Ardtornish.

Contemporary-regional data (NatureScot habitat maps, national peatland inventories) supplements but rarely replaces local measurement.

Historical-local records (estate forestry plans, old OS maps) are sparse and often qualitative, limiting their use as formal reference states.

Findings: Peat Condition

81% of the deepest peat points were also recorded as degraded.

Spatial Focus

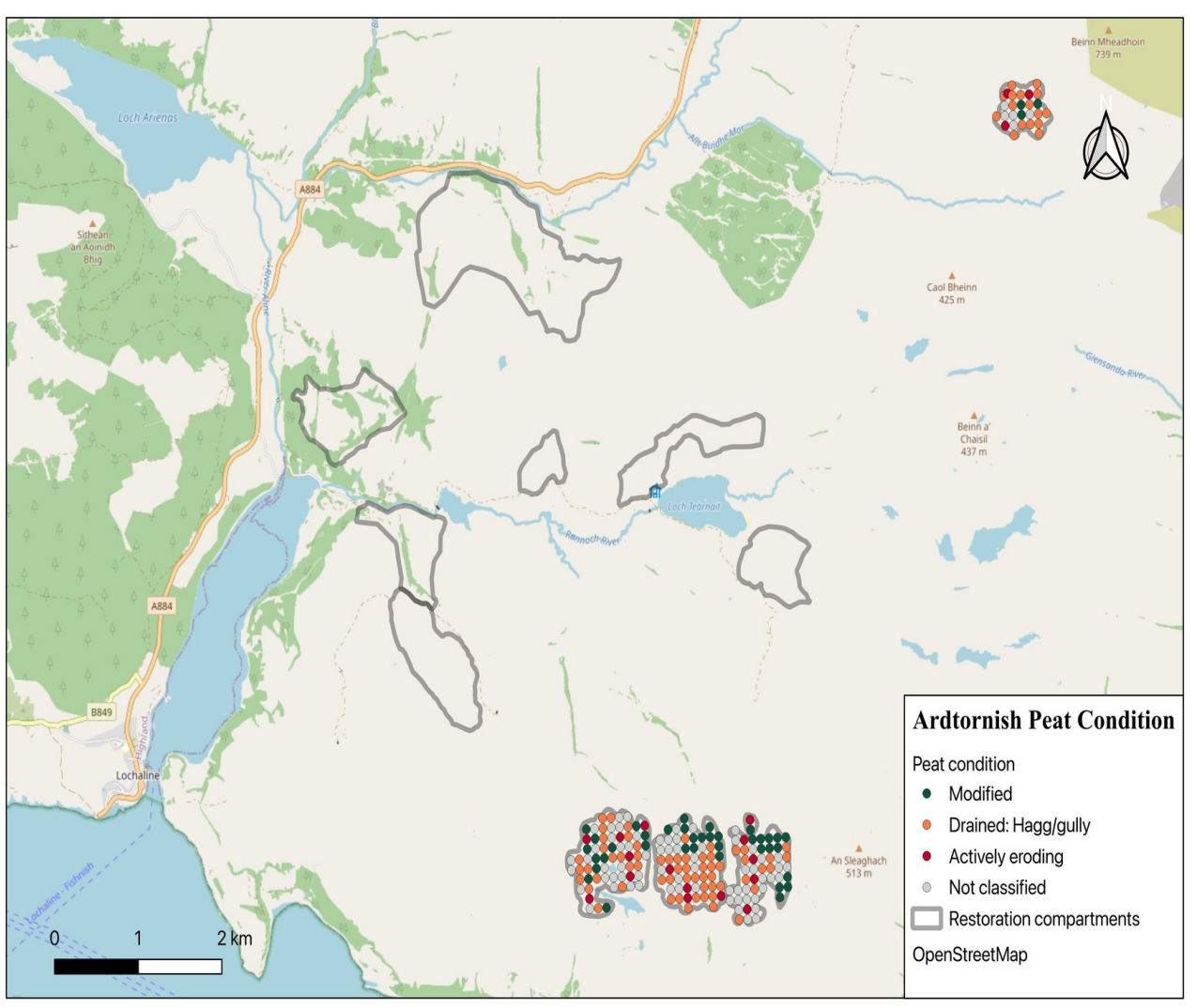
Deep peat concentrated in the southern and northern survey clusters, with degradation most severe where drainage and historical burning overlap.

Carbon Potential

The deepest deposits represent the highest carbon density per hectare, making their condition a priority for national accounting.

Restoration Priority

Overlap between depth and degradation creates a clear spatial hierarchy for intervention, restore the deepest, most damaged areas first.



Note: this finding concerns carbon risk specifically, not an overall claim about hydrological or ecological importance.

Findings: Management Zones

Ardtornish operates across three distinct zones, each requiring a tailored yardstick.

Protect & Restore

Focused on active habitat recovery through targeted interventions such as peatland rewetting, native woodland expansion, and invasive species control.

Self-Willed

The largest zone. Areas left to natural processes with minimal human intervention, monitored for direction of ecological change rather than fixed targets.

Regenerative Farming

Productive agricultural land where food production is the primary objective and ecological improvement a secondary outcome.

The Feasibility Verdict

Each combination's overall fit for each habitat, once data availability and the 14 criteria are weighed together. Darker green = stronger fit; orange/red = weaker fit.

Combination	Woodland	Peatland	Freshwater
Historical – Local			
Historical – Ecosystem			
Historical – Regional			
Contemporary – Local			
Contemporary – Ecosystem			
Contemporary – Regional			
Future – Local			
Future – Ecosystem			
Future – Regional			

High Moderate-High Moderate Low-Moderate Low

Findings: The Ideal vs. Target Gap

FPP policy distinguishes between ‘ideal’ and ‘target’ states, but funding structures ultimately decide the target before anyone chooses.

The 'Ideal' State

The ecological aspiration: the habitat that could be if all constraints were removed. This represents the theoretical endpoint of full restoration, unconstrained by funding timelines, land-use pressures, or political priorities.

The 'Target' Reality

The funded objective: what is measurable and accountable within project timelines. Targets are shaped by grant conditions, reporting cycles, and the metrics that funders recognise as evidence of progress.

Synthesis and Implications

So, what should you compare a restoration project to?

There is no one fixed answer. It depends on the habitat, the zone, and the funding structure.

Habitat Context

Management Zone

Funding Reality

Context-dependent benchmarking is the first step toward better restoration.

Ardtornish and FPP can lead the way here, starting with a freshwater baseline and auditing data richness before locking in benchmarks.

For Other Land Managers

Ardtornish is one estate, but the pattern behind these findings generalises.

1

Audit your data before you pick a benchmark.

Don't assume rich data across every habitat you're restoring — richness at Ardtornish ranges from strong to partial depending on the combination.

2

Monitoring follows funding, not ecology.

Expect carbon-funded habitats to be data-rich and non-carbon habitats (like freshwater) to lag, that gap needs deliberate investment, not just discovery.

3

Match the benchmark to the zone, not the whole site.

A single fixed target rarely fits protected, self-willed, and productive land equally, tailor reference states per management zone.

4

Name the ideal-vs-target gap out loud.

Funders and stakeholders should know when a ‘target’ is a funding-shaped compromise, not the ecological ideal, don't let that gap go unspoken.

Thank You

Questions and discussion welcome.

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Appendix

Backup detail for questions

Beyond Ecology: The Evaluation Criteria

Data availability alone doesn't make a reference state usable. Each of the nine combinations was also scored against 14 operational and social criteria, these feed directly into the feasibility verdicts shown later.

A. Operational Criteria (11)

1. Relevance to restoration goals
2. Financial requirements
3. Time requirements
4. Technical expertise & data
5. Frequency of measurement
6. Habitat applicability
7. Scale of application
8. Speed of ecological change
9. Quantification of change
10. Policy alignment
11. Replicability / transferability

B. Social Criteria (3)

12. **Alignment with stakeholder objectives**
13. **Fit with land use history & local context**
14. **Community & socio-economic considerations**

Applied to each combination during the site visit and formal interviews with estate and FPP representatives.

Findings: The Carbon Influence

Monitoring investment follows carbon accountability, not necessarily ecological importance.

- **Peatland (Strongest)**

High data richness due to strict carbon accounting requirements under peatland restoration funding.

- **Woodland (Mediated)**

Intermediate data richness linked to the Woodland Carbon Code and its verification requirements.

- **Freshwater (Weakest)**

Lack of carbon obligations leads to data gaps and lower monitoring priority despite ecological value.

Monitoring
Recommendations

Management Zone	Primary Goal	Reference Benchmarking
Protect & Restore	Habitat Recovery	Contemporary-Local (High Precision)
Self-Willed	Natural Process	Direction of Change Tracking
Regenerative Farming	Food & Nature	Contemporary-Ecosystem Comparators

The Path Ahead

Ardtornish and FPP can lead the way as the Ecosystem Restoration Code develops.

- **Integrated Monitoring:** Moving beyond carbon to full ecological health.
- **Freshwater Priority:** Urgent need to establish baselines for non-carbon habitats.
- **Policy Opportunity:** Being ahead of the curve in restoration standards.