IS THE DEFINITION OF SCALE KEY TO OUR UNDERSTANDING AND DELIVERY OF THE RESTORATION OF ECOSYSTEMS?

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Reclamation Across Industries
Topic & Purpose

Re-establishment of semi-natural ecosystems and ecosystem services on mined land in the UK

Practical measurable and workable criteria for better design & evaluation to meet the restoration challenges posed by pending implementation of legislation and policies arising from the implementation of the Convention Biological Diversity
Context – surface coal mine
Context – aggregate quarry
Context – sand quarry
Ecosystems

- Comprising **biotic** (living individuals & populations) & **abiotic** (non-living environmental) components
- Sheer complexity makes it seemingly impossible to grasp and apply in mine reclamation
- Defining the **scale** of complexity the key?
- Tansley (1930s) used plant vegetation communities as the **scale** to form a rational system describing ecosystem development and succession
Restoration of Ecosystems

Likened to the repair of a damaged watch, the repairer needs –

“... a kit of parts and the knowledge of how to fit together ... and ... if done properly the watch will acquire the emergent property of the whole ...”

J L Harper (1987)
Thompson (2010) commenting on the achievements of ecological restoration considered that for the **abiotic** environment had largely been perfected in contrast to the **biotic**

What are the **essential biotic elements** in

- 1) design & implementation of mine reclamation schemes?
- 2) assessment of restoration achievement?
Biotic Elements

Three Temperate Ecosystems Considered:

- Woodland
- Dwarf Shrub (Heathland)
- Grassland
Sessile Oak woodland
Birch woodland
Calluna dry heath (dwarf shrub)
Bent–Fescue acid upland grassland
Monitoring & Assessment Standards already exist!!

Common Standards Monitoring (CSM) -

UK Government’s JNCC criteria for assessing the functioning of nationally important and ‘pristine’ ecosystems.

SIX – structural elements * –

Canopy-Age-Regeneration-Genetic-Indicator-Exotic

*based on Tansley’s ecosystem approach
C–A–R–G–I–E for Woodland

1. Canopy Cover – tree layer 30–90% + 20% understory + 10% open space
2. Age Class – at least 3 age–classes (all in first cycle) + min 3no. fallen & 4no. standing dead trees
3. Regeneration Potential – production of seed and maturation of recruits to at least sapling stage
4. Genetic Pool – min 95% native species & provenance
5. Indicators of Local Distributions – can be distinctive species or habitats
6. Exotic / Alien & Weed Species – eradication
C–A–R–G–I–E for Dwarf Shrub (Heath)

1. **Canopy Cover** – *tree layer 25–90% + 25–30% groundcover + 10% bare ground space*

2. **Age Class** – Pioneer 10–40% + Building/Mature 20–80% + Degenerate <30% + Dead <10%

3. **Regeneration Potential** – *production of seed*

4. **Genetic Pool** – *min 95% native species & provenance*

5. **Indicators of Local Distributions** – *can be distinctive species or habitats*

6. **Exotic / Alien & Weed Species** – <1% alien/weedy species + <5% Bracken + <10% trees/scrub
C–A–R–G–I–E for Upland Grassland

1. **Canopy Cover** – 70–80% groundcover + tree/Bracken layer <10% + <10% bare ground space

2. **Age Class** – > 25% mature flowering + >5cm height & >25% mature non-flowering + <5cm height + Dead <10%

3. **Regeneration Potential** – *production of seed*

4. **Genetic Pool** – *min 95% native species & provenance*

5. **Indicators of Local Distributions** – *can be distinctive species or habitats*

6. **Exotic / Alien & Weed Species** – <1% *alien species* + <25% *weedy species* + <5% Bracken + <10% soft rush <10% trees/scrub
CARGIE – Implications

Coincidence of mandatory structural C–A–R elements to meet functioning ecosystem criteria

- **Target** of seed/seedlings/nursery stock + saplings + mature/seed bearing trees + decaying/over mature trees + dead/fallen trees
- Reclamation schemes represent in early years sequential and **incomplete** series starting with planted stock (1 element) > saplings (1) > mature/seed bearing + seed/seedlings (2) > mature/decay + saplings (2) > dead + mature/seed bearing + seed/seedlings (3) etc
## Time Implications for Woodland

<table>
<thead>
<tr>
<th>Tree Layer Life Cycle</th>
<th>Birch Woodland</th>
<th>Oak Woodland</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5</td>
<td>Planted stock/seedling</td>
<td>Planted stock/seedling</td>
</tr>
<tr>
<td>5–15</td>
<td>Sapling</td>
<td>Pre-sapling</td>
</tr>
<tr>
<td>15–20</td>
<td>Mature</td>
<td>Sapling</td>
</tr>
<tr>
<td>20–30</td>
<td>Seed bearing + seedling</td>
<td>Sapling</td>
</tr>
<tr>
<td>30–50</td>
<td>Seed bearing + seedling</td>
<td>Mature</td>
</tr>
<tr>
<td>50–70</td>
<td>Decaying + sapling</td>
<td>Seed bearing + seedling + sapling</td>
</tr>
<tr>
<td>70–80</td>
<td>Dead + decaying + mature</td>
<td>Seed bearing + seedling + sapling</td>
</tr>
<tr>
<td>80–100</td>
<td>Dead + seed bearing + seedlings</td>
<td>Seed bearing + seedling + sapling</td>
</tr>
<tr>
<td>100–120</td>
<td>Seed bearing + seedling + sapling</td>
<td>Seed bearing + seedling + sapling + mature</td>
</tr>
<tr>
<td>120–150</td>
<td>Decaying + mature + sapling</td>
<td>Mature + sapling + seed bearing + seedling</td>
</tr>
<tr>
<td>150–200 = Birch Woodland</td>
<td>Dead + decaying + mature + seed bearing + seedlings</td>
<td>Decaying + sapling + mature + seed bearing + seedling</td>
</tr>
<tr>
<td>200–250</td>
<td>Dead + decaying + mature + seed bearing + seedlings</td>
<td>Decaying + sapling + mature + seed bearing + seedling</td>
</tr>
<tr>
<td>250–350 = Oak Woodland</td>
<td>Dead + decaying + mature + seed bearing + seedlings</td>
<td>Dead + decaying + mature + seed bearing + seedlings</td>
</tr>
</tbody>
</table>
Implications for Woodland Ecosystem Reclamation

Reliance on planting nursery stock:
- Birch >> 150–200 years**#
- Oak   >> 250–350 years**#

Planting plus Intervention – providing seed/additional planting + dead wood:
- Birch >> 15–20 years (reduced by factor x10)#
- Oak   >> 30–50 years (reduced by a factor x 8)#

** Expect reliance on natural colonisation to be longer
#  Does not account for slow colonising floras & faunas
Dead-wood structural component

![Dead-wood structural component](image-url)
Felled woodland a source of dead-wood in reclamation schemes
Dead-wood recovered for use in woodland reclamation scheme
Standing dead-wood placed in woodland reclamation scheme
## Time Implications for Dwarf Shrub & Grassland Communities

<table>
<thead>
<tr>
<th>Life Cycle</th>
<th>Dwarf Shrub</th>
<th>Upland Grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5 Years</td>
<td>Seedling/pioneer</td>
<td>Seedling + tillering + mature + seed bearing</td>
</tr>
<tr>
<td>5–10</td>
<td>Building/seed bearing + seedling</td>
<td>Seedling + tillering + mature + seed bearing + decaying</td>
</tr>
<tr>
<td>10–15 = Grassland</td>
<td>Building/seed bearing + seedling</td>
<td>Seedling + tillering + mature + seed bearing + decaying + dead</td>
</tr>
<tr>
<td>15–20</td>
<td>Mature + building/seed bearing + seedling</td>
<td></td>
</tr>
<tr>
<td>20–30</td>
<td>Decaying + mature + building/seed bearing + seedling</td>
<td></td>
</tr>
<tr>
<td>30–50 = Dwarf Shrub</td>
<td>Dead + decaying + mature + building/seed bearing + seedling</td>
<td></td>
</tr>
</tbody>
</table>
Implications for Dwarf Shrub & Grassland Ecosystem Reclamation

Reliance on seeding:
- Dwarf Shrub >> 30–50 years**#
- Upland Grassland >> 10–15 years**#

Seeding + Intervention (provision of dead material):
- Dwarf Shrub >> 15–20 years (reduced by factor x2)#
- Upland Grassland >> 5–10 years (reduced by a factor x 0.3)#

** Expect reliance on natural colonisation to be longer
# Does not account for slow colonising floras & faunas
Conclusions
Prospect of applying Biotic component of ecosystem concept to mine reclamation might be bewildering in its complexity … however …

- Tansley’s plant community provides a structural scale – recognisable, pragmatic and encompasses ecosystem structure & functions as represented by CARGIE Model
- **Time** (as life-cycle dynamics) is the key dimensional scale and ultimate determinant of reclamation success
Paper introduces and examines a measurable and workable concept of **scale** for natural ecosystem reclamation on mine sites.

**CARGIE** Model helps understand what is needed – contributes to better design indicates where biotic component of ecosystem reclamation can be more certain, enhanced and speeded up.

Provision of **dead/decaying** biotic element is **principle limiting biotic factor** in woodland/dwarf shrub temperate ecosystem reclamation.
Relative Effects of Introducing Dead Wood on Rate of Ecosystem Development

Age Class (X axis) vs Years (Y axis)

Oak WOODLAND: 1 = seed/transplant  2 = sapling  3 = mature
4 = seed baring  5 = dead wood
Dwarf Shrub: 1 = seed  2 = pioneer  3 = seed baring  4 = mature
5 = dead wood
Concluding Words (2)

- **Abiotic** component determining the capability of undisturbed and restored sites not considered, but acknowledged
- **Biotic** below ground and slow coloniser components ignored
- **Biotic** approach proffered seemingly simplistic but UK JNCC use **CARGIE biotic** criteria in their CBD assessments
- **CARGIE** based on standard criteria familiar and accepted by authorities & regulators (compliant with CBD expectations for natural habitats in the UK – no need to invent bespoke reclamation criteria)
Acknowledgement

To Jim Burger for raising the topic of ecosystem restoration on mined lands at the 2012 Tupelo ASMR Meeting

The opinions expressed are solely the author’s