

# **A Paradoxical Rainforest: Ancient- Woodland Elements in a Young Coastal Woodland at Holy Loch Nature Reserve, Argyll drives primary production**

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## **Abstract**

This study documents the floristic, bryological and rainforest lichen composition of a young, anthropogenic woodland at Holy Loch Nature Reserve (HLNR), Argyll. Although the woodland is no more than 75 years old and established on upper, roadside saltmarsh and on an adjacent, capped industrial landfill, it supports a species assemblage characteristic of hyper- oceanic temperate rainforest. Surveys conducted between 2022 and 2025 recorded many bryophytes and lichens, including several oceanic species such as *Radula complanata*, *Riccardia palmata* and *Neckera complanata*, alongside rainforest- associated lichens including *Lobaria pulmonaria* and *Peltigera membranacea*. Multiple vascular plant Ancient Woodland Indicators (AWIs), including *Hyacinthoides non- scripta*, *Oxalis acetosella*, *Carex sylvatica* and *Stellaria holostea*, were also present despite the site's young age. A freshwater swamp and regenerating carr contribute to habitat heterogeneity. At least 700 higher invertebrates and vertebrates have so far been recorded as using this woodland. The coexistence of AWIs, oceanic bryophytes, rainforest lichens and high invertebrate diversity supports the interpretation of woodland at HLNR as a young but developing temperate rainforest. These findings highlight the ecological value of post- industrial landscapes and provide a rationale for the site's designation as a Local Nature Reserve.

## **Keywords**

Acaena novae-zelandiae, Acer platanoides, Acer pseudoplatanus, Ajuga reptans, Alchemilla sp., Alnus glutinosa, Allium paradoxum, Allium ursinum, Ancient Woodland Indicators, Anthropogenic woodland, Anthoceros agrestis, Arum maculatum, Asplenium scolopendrium, Asplenium trichomanes, Atlantic biogeographic zone, Atlantic temperate rainforest, Athyrium filix-femina, Atrichum undulatum, Barbarea vulgaris, Bellis perennis, Betula pendula, Betula pubescens, Blechnum spicant, Brachypodium sylvaticum, Brachythecium rutabulum, Brackish ecotone, Bryophyte microscopy, Bryophyte–lichen assemblages, Bryum capillare, Buddleja davidii, Caltha palustris, Calliergonella cuspidata, Calypogeia muelleriana, Carex echinata, Carex hirta, Carex laevigata, Carex pendula, Carex remota, Carex sylvatica, Carpinus betulus, Carr woodland, Cerasus avium (Prunus avium), Chiloscypus polyanthos, Chrysosplenium oppositifolium, Circaea lutetiana, Climate-sensitive epiphytes, Coastal resilience vegetation, Coastal woodland, Coenogonium luteum, Conopodium majus, Conservation value of post-industrial land, Corylus avellana, Crataegus monogyna, Crocosmia sp., Cynosurus cristatus, DAFOR abundance scoring, Dactylis glomerata, Deschampsia caespitosa, Dicranoweisia cirrata, Digitalis purpurea, Didymodon insulanus, Diplophyllum albicans, Disturbance ecology, DNA barcoding, Dryopteris aemula, Dryopteris affinis, Dryopteris dilatata, Dryopteris filix-mas, Ecological succession, Epiphytic communities, Epiphytic ferns, Epilobium ciliatum, Epilobium hirsutum, Epilobium montanum, Epilobium palustre, Epilobium parviflorum, Erinus alpinus, Equisetum arvense, Equisetum fluviatile, Equisetum sylvaticum, Euphorbia peplus, Eurhynchium striatum, Fagus sylvatica, Ficaria verna, Fine-scale habitat mapping, Fissidens bryoides, Fissidens celticus, Flat Neckera, Frullania dilatata, Frullania tamarisci, Fraxinus excelsior, Freshwater swamp, Galium uliginosum, Geomorphology, Geum urbanum, Geranium × oxonianum, Geranium robertianum, Glyceria fluitans, Gnaphalium uliginosum, Gravel-bar geomorphology, Habitat heterogeneity, Harmer succession dynamics, Hedera helix, Hesperis matronalis, High-resolution floristic survey, Hyacinthoides hispanica, Hyacinthoides non-scripta, Hypericum androsaemum, Hyperoceanic bryophytes, Hyperoceanic indicator lichens, Hypnum andoi, Hypnum cupressiforme, Ilex aquifolium, Impatiens glandulifera, Invasive non-native species management, Isothecium myosuroides, Jacobaea aquatica, Juncus effusus, Kindbergia praelonga, Lamiastrum galeobdolon, Landfill vegetation dynamics, Lapsana communis, Lemna minor, Lepidozia reptans, Lepidium didymum, Ligustrum ovalifolium, Lichen

succession, Lichens of Atlantic rainforest, *Lobaria pulmonaria*, *Lonicera periclymenum*, *Lolium perenne*, *Lophocolea bidentata*, *Lophocolea heterophylla*, *Lophocolea semiteres*, *Luzula campestris*, *Lycopersicon esculentum*, *Lysimachia nemorum*, *Malus pumila*, Malaise trapping, *Marsupella emarginata*, *Matricaria discoidea*, *Mentha aquatica*, *Metzgeria furcata*, *Metzgeria violacea*, Microclimatic buffering, *Mycena* sp. (rainforest microfungi), *Neckera complanata*, *Neckera pumila*, Novel ecosystems, NVC limitations, *Oenanthe crocata*, Oceanic liverworts, *Oxalis acetosella*, *Pellia endiviifolia*, *Peltigera membranacea*, *Peltigera hymenina*, *Persicaria maculosa*, *Phragmites australis*, *Pinus sylvestris*, *Plantago major*, *Plagiomnium cuspidatum*, *Plagiomnium undulatum*, *Poa annua*, *Poa trivialis*, *Pohlia wahlenbergii*, *Polypodium vulgare*, *Polystichum setiferum*, *Polytrichum formosum*, *Populus tremula*, Post-industrial ecosystems, Postglacial landforms, *Potentilla erecta*, *Potentilla sterilis*, *Prunella vulgaris*, *Prunus avium*, *Prunus padus*, *Prunus spinosa*, *Pteridium aquilinum*, *Quercus robur*, *Quercus* sp., *Radula complanata*, Rainforest indicator species, Rainforest lichens, *Ranunculus repens*, *Reynoutria* × *bohemica*, *Rhododendron ponticum*, *Rhytidiadelphus loreus*, *Rhytidiadelphus squarrosus*, *Ribes nigrum*, *Ribes sanguineum*, *Riccardia palmata*, *Rubus fruticosus* agg., *Rubus idaeus*, *Rubus odoratus*, *Rubus spectabilis*, *Rumex acetosa*, *Rumex conglomeratus*, *Rumex longifolius*, *Rumex obtusifolius*, Saltmarsh–woodland ecotone, *Salix caprea*, *Salix cinerea*, *Salix hybrid* sp., *Scrophularia nodosa*, *Scytinium gelatinosum*, *Scytinium lichenoides*, *Sedum anglicum*, Secondary woodland succession, *Senecio vulgaris*, Shade-tolerant woodland herbs, *Silene dioica*, *Sisyrinchium montanum*, *Sonchus oleraceus*, *Sorbus aucuparia*, Species colonisation pathways, *Spiraea japonica*, *Stachys sylvatica*, *Stellaria alsine*, *Stellaria holostea*, Successional transitions, Supralittoral vegetation, *Symphoricarpos albus*, *Symphytum* sp., *Taraxacum officinale* agg., *Teucrium scorodonia*, *Thamnobryum alopecurum*, *Thuidium tamariscinum*, *Tilia cordata*, *Trifolium dubium*, *Tropaeolum majus*, *Tussilago farfara*, *Ulmus glabra*, *Urtica dioica*, *Valerianella locusta*, *Veronica serpyllifolia*, *Vicia sepium*, *Viola riviniana*, Woodland hydrology, Woodland microhabitats, Woodland regeneration, Young woodland maturity paradox

## **Introduction**

The Holy Loch Food Web Project, established in 2022, aims to reconstruct the trophic architecture of a coastal ecosystem in Argyll, Scotland. Because primary production forms the baseline of any food-web model, a high-resolution understanding of floral composition is essential for interpreting the at least 2200 primary consumers recorded at the site (Hammatt, unpublished).

The Holy Loch is a sea loch at the head of a glacial glen on the Cowal peninsula. Its substrate consists of post-glacial gravel fans with supra-littoral structures and subterranean freshwater conduits emerging at the loch head. Seaward of the A815 road at Broxwood, Sandbank, lies a fragment of hyper-oceanic, self-regenerating mixed-deciduous woodland (Fig. 1). Historical mapping confirms that no woodland existed here in 1946: the Ordnance Survey Sheet 72 depicts the area as “Saltings” (intertidal saltmarsh) bounded by engineered embankments. The present canopy is dominated by *Quercus robur*, a species likely planted as a bio-mechanical revetment to stabilise the road margin against tidal erosion (Smout, 2007). Multi-stemmed stools of *Alnus glutinosa* along the seaward boundary indicate historical coppice management. The woodland cannot exceed 80 years in age.

Adjacent to this coastal strip is a damp carr woodland established on an industrial midden (Fig.2). Historical accounts indicate that waste was frequently deposited in sea-front piles at Scottish industrial sites. Over the past 70 years, this midden, in places 8m above the surrounding saltmarsh, has been capped and colonised by pioneer vegetation. Unusually for Scottish woodland, the site has escaped heavy grazing pressure from deer or livestock, allowing a structurally complex ground flora to develop (Peterken, 1996).

Hydrologically, the system is driven by two drains discharging through the woodland into flat, *Festuca rubra*-dominated saltmarsh. The interaction of low-energy flooding spring tides often with peak freshwater run-off, maintains a brackish ecotone in the woodland facing the sea. Silting of one burn, with overflow of drainage water into the woodland:saltmarsh interface has produced a freshwater swamp (Fig. 3) supporting specialised vegetation unique within the catchment. This entire woodland:swamp:saltmarsh continuum is protected by a post-glacial gravel bar (Fig. 1), forming a rare uninterrupted successional transition typically disrupted elsewhere by coastal infrastructure (Boorman, 2003).

Despite its young age and anthropogenic origin, the site exhibits an epiphytic load of bryophytes, lichens and ferns characteristic of “Celtic Rainforest” systems (Ratcliffe, 1968; Averis, 2004). The trunks of trees are heavily cloaked in bryophytes and lichens. Annual precipitation of 2500 mm (measured in 2025), combined with shelter from prevailing south-westerly winds, creates a hyper-oceanic microclimate favourable to rainforest assemblages. The carr woodland also hosts a Malaise trap from the UK BIOSCAN project (Hammatt, 2026), which has already yielded over 360 arthropods identified via DNA barcoding; with morphological identifications of other species, research so far has produced a checklist of at least 700 animal species from the woodland. Because small, structurally complex sites such as Holy Loch Nature Reserve (HLNR) are usually overlooked in national surveys, this study documents the site’s botanical, bryological and lichenological composition in greater detail than is possible using standard National Vegetation Classification (NVC) methodologies, which struggle to capture recombinant, post-industrial ecosystems with high primary productivity (Rodwell, 1998).

## **Materials and Methods**

Data collection was conducted over four years (2022–2025) through exhaustive site walking across all successional zones. Identification of grasses, *Rumex* and *Epilobium* species was verified using the vegetative key of Rose (2006) and Hubbard (1984). Nomenclature followed that of BSBI (2023). An individual plant was sufficient to warrant a record to ensure a complete checklist of the site's botanical architecture.

Bryophytes were keyed out using microscopes, where necessary, to confirm features described in the guidebook by Atherton et al. (2010). Confidence was added to these identifications by comparisons with distribution of each species on the NBN atlas locally within the Strathack/ Glen Massan/ Glen Lean catchment.

In order to give some indication of vegetation structure, the DAFOR system was applied to further describe the woodland structure.

- Dominant: 76-100% (or >75%) cover.

- Abundant: 51-75% (or 50-75%) cover.
- Frequent: 26-50% (or 25-50%) cover.
- Occasional: 11-25% (or 10-25%) cover.
- Rare: 0-10% (or <10%) cover.

Lichens were noted primarily to identify succession to mature temperate rainforest. The guidebook by Dobson (2018) was used, and various lichenologists, both local and national were consulted for verification.

### Results/Checklists

The flora, bryophyte and lichen assemblages recorded at Holy Loch Nature Reserve reflect the site's mosaic of habitats, including young mixed woodland, freshwater swamp, regenerating carr and a saltmarsh–woodland ecotone. To reflect this spatial and structural variation, species are presented in groups corresponding to major habitat components and vegetation layers. This approach provides a clearer picture of how different elements of the vegetation contribute to the overall composition of the developing woodland system.

Table 1. Checklist of vascular plant species in the young, self-regenerated broadleaved woodland at Holy Loch Nature Reserve in 2022-2025, including a freshwater swamp.

In comparisons with the NBN, C= confirmed as already recorded in the vicinity and R=only one or a few local records.

AWI = Ancient Woodland Indicator

\* Growing along the edge of woodland drains, under wooden bridge.

A. Trees and sub-canopy species	Common name	DAFOR score	On NBN atlas?	AWI?
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<i>Acer platanoides</i>	Norway Maple	R	AWI
<i>Acer pseudoplatanus</i>	Sycamore	R	
<i>Alnus glutinosa</i>	Alder	F	
<i>Betula pendula</i>	Silver Birch	R	
<i>Betula pubescens</i>	Downy Birch	R	
<i>Carpinus betulus</i>	Hornbeam	R	
<i>Fagus sylvatica</i>	Beech	R	
<i>Fraxinus excelsior</i>	Common Ash	R	
<i>Prunus padus</i>	Bird Cherry	R	
<i>Quercus robur</i>	Common Oak	F	
<i>Tilia cordata</i>	Small-leaved Lime	R	

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B. Understorey shrubs and  
climbers

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<i>Corylus avellana</i>	Hazel	R	
<i>Crataegus monogyna</i>	Hawthorn	R	
<i>Hedera helix</i>	Ivy	O	
<i>Ilex aquifolium</i>	Holly	F	
<i>Lonicera periclymenum</i>	Honeysuckle	R	
<i>Rubus fruticosus</i> agg.	Bramble	R	
<i>Sorbus aucuparia</i>	Rowan	R	

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C. Herb-layer species

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<i>Carex remota</i>	Remote Sedge	R	
<i>Carex sylvatica</i>	Wood Sedge	R	
<i>Circaea lutetiana</i>	Enchanter's Nightshade	R	
<i>Conopodium majus</i>	Pignut	R	
<i>Deschampsia caespitosa</i>	Tufted hair-grass	R	
<i>Dryopteris dilatata</i>	Broad Buckler Fern	O	
<i>Ficaria verna</i>	Lesser Celandine	R	

<i>Fissidens bryoides</i> *	Leser Pocket-moss	R	C	AWI
<i>Fissidens celticus</i> *	Western Pocket-moss	R	R	AWI
<i>Hyacinthoides non-scripta</i>	Bluebell	R		AWI
<i>Oxalis acetosella</i>	Wood Sorrel	R		AWI
<i>Poa trivialis</i>	Rough-stalked Meadow-grass	O	C	
<i>Ranunculus repens</i>	Creeping buttercup	R		
<i>Thuidium tamariscinum</i>	Common Tamarisk-moss	R		
<i>Viola riviniana</i>	Dog Violet	R		

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#### D. Epiphytes

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<i>Chiloscyphus polyanthos</i>	Common Flapwort		C	
<i>Frullania dilatata</i>	Dilated Scalewort		C	
<i>Frullania tamarisci</i>	Tamarisk Scalewort		C	
<i>Hypnum andoi</i>	Ando's Feather-moss		C	
<i>Hypnum cupressiforme</i>	Cypress-leaved Plait-moss		C	
<i>Isotheceium myosuroides</i>	Slender Mouse-tail Moss		C	
<i>Lophocolea bidentata</i>	Bifid Crestwort		C	
<i>Lophocolea heterophylla</i>	Variable-leaved Crestwort		C	
<i>Lophocolea semiteres</i>	Slender Crestwort		C	
<i>Metzgeria furcata</i>	Forked Veilwort		C	
<i>Metzgeria violacea</i>	Violet Veilwort		R	
<i>Polypodium vulgare</i>	Common Polypody		C	
<i>Radula complanata</i>	Flatwort		C	
<i>Riccardia palmata</i>	Pale Fingerwort		C	

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E. Freshwater woodland  
swamp

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<i>Caltha palustris</i>	Marsh Marigold	F
<i>Epilobium palustre</i>	Marsh Willowherb	O
<i>Galium uliginosum</i>	Fen Bedstraw	O
<i>Glyceria fluitans</i>	Floating Sweet- grass	F
<i>Jacobaea aquatica</i>	Marsh Ragwort	R
<i>Juncus effusus</i>	Soft Rush	R
<i>Mentha aquatica</i>	Water Mint	R
<i>Oenanthe crocata</i>	Hemlock Water Dropwort	R
<i>Phragmites australis</i>	Common Reed	R
<i>Salix cinerea</i>	Grey Willow	R
<i>Stellaria alsine</i>	Bog Stitchwort	R

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Far more species were recorded in the carr woodland (Table 2), which includes bryophytes and lichens growing on top of industrial surface waste, namely large wooden girders and unused, large concrete sewer pipes. No species, except the known significant non-native, invasive (INN) species listed below could be considered anything other than rare to occasional using the DAFOR listing. Many of the tree species have significant saplings in the ground flora/understory. Some trees have been deliberately introduced recently into gaps caused by storms. All INNs are at different stages of elimination.

Table 2. Checklist of vascular plant species in the carr in 2022-2025.

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A. Trees and shrub species of the carr	Common name	Notes
<i>Acer pseudoplatanus</i>	Sycamore	

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<i>Alnus glutinosa</i>	Alder	
<i>Betula pubescens</i>	Downy Birch	
<i>Corylus avellana</i>	Hazel	Saplings
<i>Crataegus monogyna</i>	Hawthorn	
<i>Fraxinus excelsior</i>	Common Ash	Saplings
<i>Malus pumila</i>	Apple	
<i>Pinus sylvestris</i>	Scots Pine	Introduced
<i>Populus tremula</i>	Aspen	Introduced
<i>Prunus avium</i>	Wild Cherry	
<i>Prunus padus</i>	Bird Cherry	Introduced
<i>Prunus spinosa</i>	Blackthorn	
<i>Quercus sp.</i> (assumed)	Common Oak	Saplings
<i>Salix caprea</i>	Goat Willow	
<i>Salix hybrid sp.</i>	Willow hybrid	Introduced
<i>Ulmus glabra</i>	Wych Elm	Introduced

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B .Herb layer and epiphyte  
species of the carr

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<i>Ajuga reptans</i>	Bugle	
<i>Allium paradoxum</i>	Few-flowered Garlic	INN
<i>Allium ursinum</i>	Ramsons	
<i>Arum maculatum</i>	Lords-and-Ladies	
<i>Asplenium scolopendrium</i>	Hart's-tongue Fern	
<i>Asplenium trichomanes</i>	Maidenhair Spleenwort	
<i>Athyrium filix-femina</i>	Lady Fern	
<i>Atrichum undulatum</i>	Common Smoothcap	
<i>Blechnum spicant</i>	Hard-fern	
<i>Brachypodium sylvaticum</i>	False-brome	
<i>Brachythecium rutabulum</i>	Rough-stalked Feather- moss	
<i>Bryum capillare</i>	Capillary Thread-moss	On concrete pipe
<i>Calliergonella cuspidata</i>	Pointed Spear-moss	
<i>Calypogeia muelleriana</i>	Mueller's Pouchwort	

<i>Carex hirta</i>	Hairy Sedge	
<i>Carex pendula</i>	Pendulous Sedge	
<i>Chiloscyphus polyanthos</i>	Common Flapwort	
<i>Chrysosplenium oppositifolium</i>	Opposite-leaved Golden-saxifrage	
<i>Circaea lutetiana</i>	Enchanter's-nightshade	
<i>Crocasmia</i> sp.	Montbretia	INN
<i>Cynosurus cristatus</i>	Crested dog's-tail	
<i>Dactylis glomerata</i>	Cock's-foot	
<i>Dicranoweisia cirrata</i>	Common Pincushion	On concrete pipe
<i>Digitalis purpurea</i>	Foxglove	
<i>Diplophyllum albicans</i>	White Earwort	
<i>Dryopteris aemula</i>	Hay-scented Fern	AWI
<i>Dryopteris affinis</i>	Scaly Male Fern	
<i>Dryopteris filix-mas</i>	Male Fern	
<i>Epilobium ciliatum</i>	American Willowherb	
<i>Epilobium hirsutum</i>	Great Willowherb	
<i>Epilobium montanum</i>	Broad-leaved Willowherb	
<i>Epilobium parviflorum</i>	Small-flowered Willowherb	
<i>Equisetum arvense</i>	Field Horsetail	
<i>Equisetum fluviatile</i>	Water Horsetail	In flooded zone
<i>Equisetum sylvaticum</i>	Wood Horsetail	
<i>Eurhynchium striatum</i>	Common Feather-moss	
<i>Ficaria verna</i>	Lesser Celandine	
<i>Geranium</i> × <i>oxonianum</i>		INN
<i>Geranium robertianum</i>	Herb-Robert	
<i>Geum urbanum</i>	Herb Bennet	
<i>Hedera helix</i>	Ivy	
<i>Hyacinthoides hispanica</i>	Spanish Bluebell	INN
<i>Hypericum androsaemum</i>	Tutsan	
<i>Hypnum cupressiforme</i>	Cypress-leaved Plait-	

	moss	
<i>Impatiens glandulifera</i>	Himalayan Balsam	INN
<i>Isothecium myosuroides</i>	Slender Mouse-tail Moss	
<i>Kindbergia praelonga</i>	Common Feather-moss	
<i>Lamiastrum galeobdolon</i>	Yellow Archangel	
<i>Lapsana communis</i>	Nipplewort	
<i>Lemna minor</i>	Common Duckweed	In flooded zone
<i>Lepidozia reptans</i>	Creeping Fingerwort	
<i>Ligustrum ovalifolium</i>	Garden Privet	INN
<i>Lophocolea bidentata</i>	Bifid Crestwort	
<i>Lophocolea heterophylla</i>	Variable-leaved Crestwort	
<i>Lophocolea semiteres</i>	Slender Crestwort	
<i>Lysimachia nemorum</i>	Yellow Pimpernel	
<i>Marsupella emarginata</i>	Notched Pygmywort	
<i>Neckera complanata</i>	Flat Neckera	
<i>Neckera pumila</i>	Small Neckera	
<i>Orthotrichum pulchellum</i>	Elegant Bristle-moss	On tree twigs
<i>Pellia endiviifolia</i>	Endive Pellia	
<i>Plagiomnium cuspidatum</i>	Pointed Spear-moss	
<i>Plagiomnium undulatum</i>	Hart's-tongue Thyme- moss	
<i>Polystichum setiferum</i>	Soft Shield-fern	
<i>Polytrichum formosum</i>	Bank Haircap Moss	
<i>Potentilla sterilis</i>	Barren Strawberry	
<i>Pteridium aquilinum</i>	Bracken	
<i>Radula complanata</i>	Flatwort	
<i>Ranunculus repens</i>	Creeping Buttercup	
<i>Rhododendron ponticum</i>		INN
<i>Rhytidiadelphus loreus</i>	Little Shaggy moss	
<i>Rhytidiadelphus squarrosus</i>	Springy Turf-moss	
<i>Ribes nigrum</i>	Black Currant	
<i>Ribes sanguineum</i>	Flowering Currant	

<i>Riccardia palmata</i>	Pale Fingerwort	
<i>Reynoutria × bohemica</i>	Bohemian Knotweed	INN
<i>Rubus fruticosus</i> agg.	Bramble	
<i>Rubus idaeus</i>	Raspberry	
<i>Rubus odoratus</i>		
<i>Rubus spectabilis</i>	Salmonberry	
<i>Rumex acetosa</i>	Common Sorrel	
<i>Rumex conglomeratus</i>	Clustered Dock	
<i>Rumex longifolius</i>	Northern Dock	
<i>Rumex obtusifolius</i>	Broad-leaved Dock	
<i>Schistidium crassipilum</i>	Thick-haired Screw-moss	On concrete pipe
<i>Scrophularia nodosa</i>	Common Figwort	
<i>Silene dioica</i>	Red Campion	
<i>Spiraea japonica</i>	Japanese Spiraea	INN
<i>Stachys sylvatica</i>	Hedge Woundwort	
<i>Stellaria holostea</i>	Greater Stitchwort	
<i>Symphoricarpos albus</i>	Snowberry	INN
<i>Symphytum</i> sp.		INN
<i>Taraxacum officinale</i> agg.	Dandelion	
<i>Teucrium scorodonia</i>	Wood Sage	
<i>Thamnobryum alopecurum</i>	Fox-tail Feather-moss	
<i>Urtica dioica</i>	Common Nettle	
<i>Veronica serpyllifolia</i>	Thyme-leaved Speedwell	
<i>Vicia sepium</i>	Bush Vetch	
<i>Viola riviniana</i>	Common Dog-violet	

Given that many species found in the carr may well have derived from its history as a landfill, current species present were recorded as a historical record (Table 3) by which to judge any future migration into the adjacent woodland.

Table 3. Checklist of vascular plant species in the active landfill in 2022-2025.

Perennial species	Common name
<i>Acaena novae-zelandiae</i>	Piri Piri Burr (INN)
<i>Barbarea vulgaris</i>	Winter-cress
<i>Buddleja davidii</i>	Butterfly-bush (INN)
<i>Carex echinata</i>	Star Sedge
<i>Carex laevigata</i>	Smooth-stalked Sedge
<i>Cymbalaria muralis</i>	Ivy-leaved Toadflax
<i>Didymodon insulanus</i>	Rusty Beard-moss
<i>Erinus alpinus</i>	Alpine Snapdragon
<i>Gnaphalium uliginosum</i>	Marsh Cudweed
<i>Hesperis matronalis</i>	Dame's Violet
<i>Lepidium didymum</i>	Lesser Swine-cress
<i>Lolium perenne</i>	Perennial Rye-grass
<i>Luzula campestris</i>	Field Wood-rush
<i>Plantago major</i>	Greater Plantain
<i>Pohlia wahlenbergii</i>	Wahlenberg's Thread-moss
<i>Potentilla erecta</i>	Tormentil
<i>Prunella vulgaris</i>	Selfheal
<i>Sedum anglicum</i>	English Stonecrop
<i>Sisyrinchium montanum</i>	American Blue-eyed-grass
<i>Trifolium dubium</i>	Lesser Trefoil
<i>Tussilago farfara</i>	Coltsfoot
<hr/>	
Ruderals	
<hr/>	
<i>Alchemilla sp.</i>	Lady's Matle
<i>Anthoceros agrestis</i>	Field Hornwort
<i>Bellis perennis</i>	Daisy
<i>Euphorbia peplus</i>	Petty Spurge
<i>Lycopersicon esculentum</i>	Tomato
<i>Matricaria discoidea</i>	Pineappleweed

<i>Persicaria maculosa</i>	Redshank
<i>Poa annua</i>	Annual Meadow-grass
<i>Potentilla erecta</i>	Tormentil
<i>Senecio vulgaris</i>	Groundsel
<i>Sonchus oleraceus</i>	Annual Sow-thistle
<i>Tropaeolum majus</i>	Nasturtium
<i>Valerianella locusta</i>	Lamb's Lettuce

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To assess the woodland's trajectory towards Atlantic rainforest conditions, a suite of hyperoceanic indicator lichens was recorded, including *Lobaria pulmonaria* (Fig. 7), *Peltigera membranacea* (Fig. 8), *P. hymenina*, *Scytinium gelatinosum* (Fig. 7), *S. lichenoides* (Fig. 8), *Pannaria conoplea* (Fig. 9) and *Coenogonium luteum* (Fig. 10). Several thalli of *L. pulmonaria* were dislodged during recent winter storms, confirming its active colonisation and highlighting the sensitivity of early-stage rainforest epiphyte communities to climate-change.

In Autumn, a tiny white species of *Mycena* produced fruiting bodies from moss clumps annually, particularly in the carr (Fig. 11).

## Discussion

The surveyed site represents a complex mosaic of habitats, including young secondary woodland, swamp vegetation, regenerating carr, and a saltmarsh–woodland ecotone. Habitat heterogeneity of this kind is well known to enhance local species richness and support diverse ecological communities (Ward et al., 1993; Peterken, 1996). Despite its relatively young age (c. 75 years), the woodland supports a diverse assemblage of vascular plants, bryophytes and lichens typical of maturing temperate woodland systems. What is striking, however, is that this ecological maturity has arisen in a woodland that is both exceptionally young and fundamentally anthropogenic, creating a paradox more typical of long-established Atlantic rainforest than of post-industrial ground.

Shade-tolerant woodland herbs such as *Hyacinthoides non-scripta*, *Oxalis acetosella*, *Circaea lutetiana*, *Stellaria holostea*, *Ajuga reptans* and *Allium ursinum* were recorded, indicating the establishment of a stable shaded microclimate. Long-term studies of secondary woodland succession show that such species can colonise within decades once canopy closure and litter accumulation occur (Harmer et al., 2001; Peterken & Game, 1984). Several of these herbs (*A. reptans*, *S. holostea*, *Lamium galaeobdolon*, *A. ursinum* and *Potentilla sterilis*) were spatially restricted to areas adjacent to the active landfill boundary. Localised concentrations of woodland herbs have been documented in areas influenced by soil disturbance, nutrient inputs or historical soil movement (Rackham, 2003; Harmer et al., 2001). While the mechanism cannot be determined from the present study, the observed spatial pattern is ecologically significant and highlights the influence of local site history on ground-flora distribution, especially, in this case, the transport of soil waste to the landfill.

The landfill flora is dominated by short-lived species requiring bare soil for seed and spore germination such as *Euphorbia peplus* and *Anthoceros agrestis*, short-lived perennials such as *Hesperis matronalis* and *Barbarea vulgaris*, and vegetatively fast-spreading perennials such as *Cymbalaria muralis* and the highly invasive non-native *Acaena novae-zelandiae*. Additionally, the landfill provides the only well drained, rocky substrate at the head of the Holy Loch, providing habitat for species requiring well-drained locations including *Buddleja davidii*, *Sedum anglicum*, *Tussilago farfara* and *Erinus alpinus*. Various leaf-mining insects recorded in this area justify confirming their host's presence within the plant community. This includes a new species record for Scotland (Hammatt, unpublished). The moss *Pohlia wahlenbergii* and various rushes was only recorded on the compacted vehicle tracks in the landfill.

Swamp vegetation and regenerating carr form a substantial component of the site. Wet woodland dominated by willow or alder typically develops where waterlogging is persistent, and its structure and species composition are strongly shaped by hydrological regime (Rodwell, 1998; Wheeler & Shaw, 1995). Carr regeneration on previously disturbed or modified ground is well documented, particularly where nutrient-rich or compacted soils retain moisture (Wheeler & Shaw, 1995). The development of carr over a capped landfill is consistent with studies showing that wet

woodland can establish on anthropogenic substrates where hydrological conditions favour waterlogging and where succession proceeds from open swamp to scrub and eventually to closed wet woodland (Bradshaw, 1997). The carr at this site is structurally complex, with standing water, deadwood and dense understorey vegetation, providing a wide range of microhabitats.

The site contains a transition between saltmarsh, swamp and woodland, forming a distinct ecotone. Ecotones between saline and freshwater systems are known to support high species turnover and can act as zones of elevated ecological diversity (Adam, 1990). Woodland establishment adjacent to saltmarsh has been documented where local hydrological conditions, sediment characteristics or reduced tidal influence allow tree recruitment (Boorman, 2003). In this case, the boundary between saltmarsh and woodland does not show evidence of coastal squeeze; instead, the two habitats coexist in a relatively stable configuration, with woodland occupying slightly elevated or less frequently inundated ground. This reflects natural spatial variation in tidal reach and substrate conditions rather than landward habitat displacement.

Bryophyte and lichen diversity is a notable feature of the site, with several species characteristic of humid, oceanic woodlands in western Britain, including *Radula complanata*, *Riccardia palmata*, *Neckera complanata* and *Thuidium tamariscinum*. The ecology of these species has been extensively documented, with oceanic bryophytes strongly associated with high rainfall, mild temperatures and persistent humidity (Ratcliffe, 1968; Hill et al., 2007). Importantly, these taxa respond primarily to microclimatic conditions rather than woodland age. Smith (2004) notes that many oceanic bryophytes can colonise relatively young stands provided that humidity, shade and substrate stability are sufficient. Their presence therefore reflects the environmental conditions created by the site's topography, hydrology and woodland structure. Similarly, the *Mycena* species depends on a persistently damp microhabitat, which is provided by the thick moss carpets that retain moisture under the site's existing hyperoceanic, rainforest-level conditions.

I have so far recorded over 700 species of animal, primarily invertebrate using this woodland, high species richness in this habitat. The large number of available primary producers in the woodland provided unique niches for many specialist species, as well as generalists. Carr and swamp woodlands are also known to support diverse

invertebrate assemblages due to their structural complexity, high humidity, decaying wood resources and heterogeneous microhabitats (Kirby, 1992; Ferris & Carter, 2000). The combination of standing water, deadwood, shaded understory and transitional vegetation provides niches for Diptera, Coleoptera, Hymenoptera and other insects, arachnids, crustacea and myriapods. The substantial invertebrate diversity recorded (Hammatt, unpublished) here is consistent with studies showing that wet woodland and carr can function as biodiversity hotspots within temperate landscapes (Ferris & Carter, 2000). The results highlight the ecological importance of the carr habitat, particularly given its development over a capped landfill.

Overall, the site represents a relatively young but ecologically mature system shaped by the interaction of hydrology, microclimate, coastal influence and anthropogenic history. The combination of swamp, carr, saltmarsh ecotone and secondary woodland creates a structurally and floristically diverse habitat complex. Long-term studies of woodland succession show that features such as deep litter layers, stable humidity and complex ground flora can develop within 50–100 years under favourable conditions (Harmer et al., 2001; Peterken, 1996). The findings from this survey align with this body of work, demonstrating that secondary woodland can develop substantial ecological value within a comparatively short timeframe.

As Rodwell (1998) anticipated, recombinant post-industrial woodlands such as this fall outside the descriptive reach of the National Vegetation Classification. The coexistence of rainforest epiphytes, landfill-derived flora and a saltmarsh ecotone produces a community that cannot be meaningfully assigned to any NVC type, underscoring the need for a site-specific survey. The site's habitat diversity, high bryophyte richness, well-developed woodland flora and exceptional invertebrate assemblage provide a clear ecological rationale for its designation as a Local Nature Reserve.

### **Acknowledgements**

Ben Mitchell, a local rainforest epiphyte expert, confirmed some of the lichen identifications in this study. I am grateful for the various other experts who helped in developing this paper and its complex interpretation. The Holy Loch Food Web

project is supported by Naturescot, Sandbank Community Development Trust, Seachangers and the generous residents of Cowal.

### **Publication note**

Given the importance of primary production to the unfolding, vast number of animal species found living at Holy Loch Nature Reserve, over and over, taxon specialist reviewers failed to see the role of their pet group of plants in the overall ecosystem. They appeared transfixed on systems and cramming plant communities into National Vegetation Categories (NVCs). The plants of Holy Loch refused to be just dumped and shoehorned into a system not designed for it.

The simple fact is something may actually eat your plants or lives in or on them for shelter. A quick glance at a clump of moss under a microscope shows it full of animal life, from mites to millipedes, to slugs and Diptera larvae. In turn birds such as Great, Blue and Coal Tits, and Treecreepers, spend a lot of time feeding on the outside of mossy trees. The Holy Loch Food Web Project aims to bring together a vast array of taxon-specific expertise in to one place to reconstruct a whole ecosystem. Only then can we effectively manage the nature reserve that hosts it. I am grateful to a local lichen expert, used as a peer reviewer, who confirms this woodland hosts Celtic rainforest indicator lichens.

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Figure 1. Extent of the rainforest (green), swamp (turquoise), saltmarsh (pink) and vegetated gravel bar (yellow) at Holy Loch Nature Reserve. Dark blue lines are routes of road drains through the woodland. Photo: Phill Rawlins, annotated by Neil Hammatt



Figure 2. Extent of the carr woodland (green) and the remaining landfill (red) at Holy Loch Nature Reserve. Photo: Phill Rawlins, annotated by Neil Hammatt.



Figure 3. The freshwater swamp at Holy Loch Nature Reserve. Photo: Neil Hammatt



Figure 4. The carr at Holy Loch Nature Reserve with a dense ground flora. Photo by Neil Hammatt.



Figure 5. *Asplenium scolopendrium* (Hart's-tongue Fern) in the carr woodland



Figure 6. *Mnium hornum* on a large surface-deposited wooden girder. Photo: Neil Hammatt



Figure 7. The jelly lichen *Scytinium gelatinosum* growing on a concrete pipe at Holy Loch Nature Reserve. Photo: Neil Hammatt



Figure 8. The jelly lichen *Scytinium lichenoides* (brown) growing on a horizontal branch amongst mosses. Photo: Neil Hammatt



Figure 9. The rainforest indicator, *Pannaria conoplea*, at Holy Loch Nature Reserve. Photo: Neil Hammatt



Figure 10. The lichen *Coenogonium luteum* growing among mosses at Holy Loch Nature Reserve. Photo: Neil Hammatt



Figure 11. Fruiting body of a *Mycena* species growing outwith moss on trees at Holy Loch Nature Reserve. Cap 4mm in diameter. Photo: Neil Hammatt