Shelterbelt trials in the Outer Hebrides after fifty years: a study in competition, survival and succession

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Abstract

Shelterbelt trials were established in North Uist and Lewis in the Outer Hebrides in 1963 as part of a programme to evaluate the suitability of a wide range of species to grow in extremely exposed conditions. They were supplemented by further planting in the first few years, and evaluated in 1972, 1975 and 1990. The sites were revisited in 2016-8 and the survival and condition of species was evaluated. The planting plans are partly reconstructed from the surviving specimens. All plots were very densely planted, suffered from windthrow and did not provide a timber crop, but some species had reasonable survival rates, providing shelter, and have acted as nurse areas for a range of self-seeded species.

Key words: exposure; forestry; windthrow

Introduction

The Outer Hebrides have been largely treeless in modern times, with native trees largely restricted to cliffs, islands and loch margins, where they are protected from muirburn and grazing (SNH & Comhairle nan Eilean Siar 2008). A growing interest in forestry led to the establishment of experimental plantations after the Second World War, and several more extensive plantations from the late 1960s, although much of the available land was marginal for economic returns from forestry (Sharpe & Jacyna 1993, Harrison *et al*. 2007). There was also interest in whether woodland could be established primarily to provide shelter, rather than for wood production. Shelterbelts have a range of economic benefits in different conditions (Caborn 1957, chapter 3), and experiments were needed to test whether woodland could be established to generate similar benefits in very exposed conditions.

Therefore, the Scottish Agricultural College set up shelterbelt trials in the Outer Hebrides, on North Uist and Lewis, in the 1960s. The trials have not been well documented or reported on, and the published information on them is scattered. The aim of this article is to bring together the existing information and summarise the long term results. The original planting plans are now lost, so in addition to a new follow-up evaluation in 2016-18, an important objective was to reconstruct them as far as possible from the surviving specimens.

Description of the shelterbelt trials

The North Uist plot was established on machair (sandy soil) at Clachan Farm, centred around grid reference NF883763, exposed to the west, and was planted in 1963 (Sutherland 1973, Quine & Sharpe 1997). The Lewis trial plot was established at Laxay on peaty ground, on land to the W of Loch Ulapuil, centred around grid reference NB324224, which had formerly been used as a plot for testing reseeded pasture grassland. The shelterbelt trial was planted in 1963, after the application of shell sand (10 tons per acre) (Sutherland 1973). In 1964, a second plot was planted on higher ground with thinner peat, behind the manse at Laxay, centred around grid reference NB321222 (Fig. 1). There were further plantings in 1966 and 1967, when some additional species were added.

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Fig. 1: The experimental plots at Laxay, October 2017. The upper plot is left of centre in the photo, and the lower plot by the loch on the right, both outlined.

A wide range of species was planted in the trials (See Tables 1-3), including both conifers and broadleaved trees. Several different provenances of *Pinus contorta* (lodgepole pine) were included. Groups of six of each species/provenance were planted, each group in a row, and there was some replication within plots. The multiple provenances meant that more *P. contorta* were planted than other species. A range of shrubs was also included, both as shelter for the developing trees and to see how well they performed in providing shelter themselves.

The plantings were at high density (spacing was approx 185 × 125cm at Clachan (Jacyna 1990)), and some species either did not establish or were quickly outcompeted. Additional efforts were made at Clachan to control the growth of herbaceous plants ("weeds") in the establishment phase, and different treatments were used – hand-cutting, paraquat weedkiller and black polythene mulch. Only the latter had any effect, with improved growth of some conifers, but poorer establishment of deciduous trees because of the ringbarking activity of voles which lived under the polythene. There are said to be no voles in Lewis (Arnold 1993, p14), and in any case this mulching treatment was not applied at Laxay.

Although the further plantings in 1966-67 replaced some of the establishment losses, surveys in 1972 and 1975 (Sutherland 1973, 1976) failed to find some of the species. The trial plots were revisited in 1990, and the trees and shrubs measured and assessed for survival (Jacyna 1990). There was no management or maintenance of the plots after the initial establishment phase (Sharpe & Jacyna 1994), and they therefore became very dense.

The trials were slightly unusual in that a range of shrub species was planted with the trees to provide shelter during the establishment phase and longer-term shelter near ground level, with no expectation that they would produce a commercial product.

The Clachan plot is the most exposed, open to the north-west and on a slight slope. The Laxay plots are more protected by surrounding low hills. The upper plot is on a low rise and therefore more exposed, while the lower plot by the margin of Loch Ulapuil is more sheltered, particularly because it has further forestry plots to the north which additionally act as windbreaks (though these were not present when the trials were started).

A plantation of *Picea sitchensis* and *Pinus contorta* adjacent to the Clachan experimental plot was used in a tatter flag study of exposure (Quine & Sharpe 1997). The study showed that the shelter at Clachan did not extend very far beyond the *Pinus*/*Picea* belt with 80% of the wind effect reinstated after five tree heights.

General conditions of the experimental plots 2016-8

The Clachan site is well fenced, and the fencing has been renewed on the southern and western sides. The interior is extremely dense, and has suffered from windthrow in some areas, making it a significant challenge to move around inside the plot. The northern end of the woodland was being thinned in 2016, which was therefore much more open, and this may mean that some species which were surviving had been cut.

The lower Laxay plot has an old and deteriorating wire fence on three sides, with a newer fence to the west. Additional plots around the site (particularly to the north) have been planted with commercial species, mainly *Picea sitchensis*, probably not long after the trial was set up, as the trees are well-grown. These have provided additional shelter. The western end of the plot, and the area to the south have been recently planted, with the plantings still in protective tubes.

The Upper Laxay site is well fenced, with the fencing all round relatively recent. The specimens at the margins have the best long-term survival, in common with the Clachan plot and consistent with the expectations of Gardiner et al. (2006), as such specimens are smaller and therefore more resistant to the wind. There is a large area in the main part of the plot where the trees are windthrown (Figs. 4-5), creating an almost impenetrable tangle of fallen trees; no attempt was made to measure or identify the largely dead specimens in this area.

Reconstruction of the arrangement of the species planted

Unfortunately the planting plans are lost, so it is only from the surviving specimens that they can be partially reconstructed (see Figs. 2-4). A very wide range of species was used in the original plantings, but the absence of planting plans makes it quite challenging to assess which have survived. The process is additionally complicated because it is suspected that not all the species which were originally planted corresponded to those specified for the study (Jacyna 1990), some specimens have apparently been recorded as different species during the various follow up evaluations (including the latest one reported here), and the species lists in the various reports are not consistent. In particular Sutherland (1973) gives *Aesculus matsumurae* and *Aesculus rubra*, whereas Sutherland (1976) gives *Alnus matsumurae* and *Alnus rubra*, both valid species pairs in their respective genera. Neither has apparently survived, but on balance the growth rates (compared with *Aesculus hippocastanum*) and the likelihood of use for experiments in forestry suggest that *Alnus* is correct, and this is therefore adopted below (in contrast to Jacyna (1990) who did not cite Sutherland (1976) and continued with *Aesculus*).

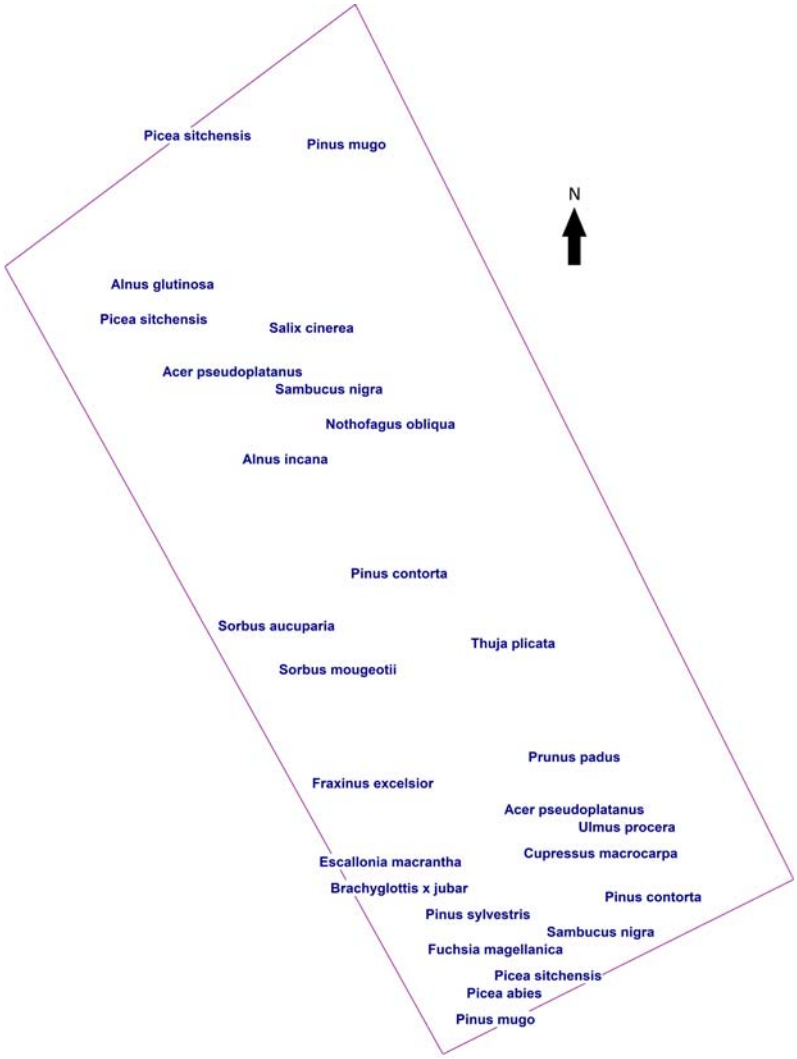

Fig. 2: Approximation to the planting plan for the plot at Clachan, N Uist, based on surviving species August 2018.

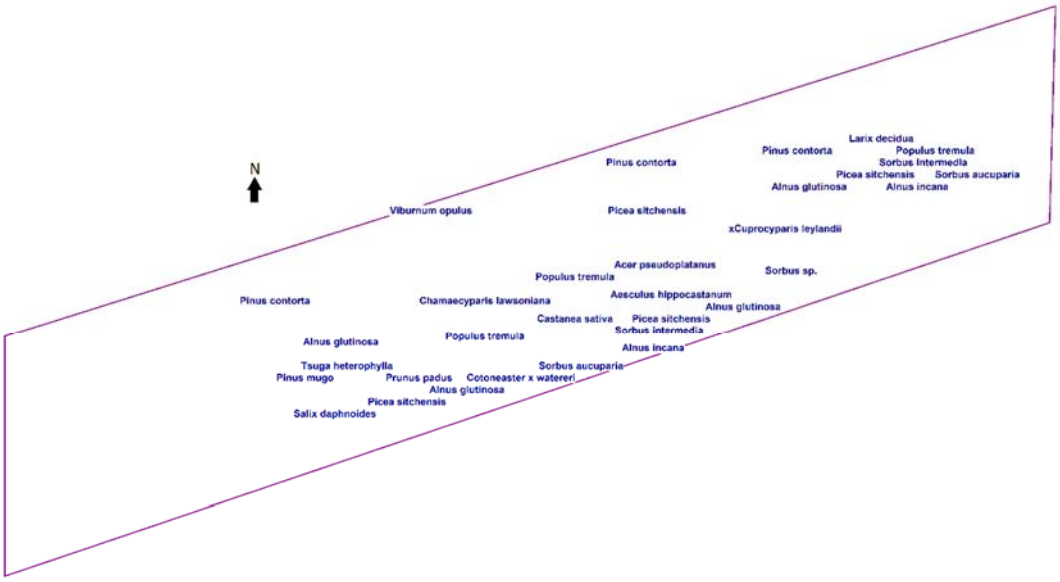

Fig. 3: Approximation to the planting plan for the original (lower) plot at Laxay, Lewis, based on surviving species August 2017.

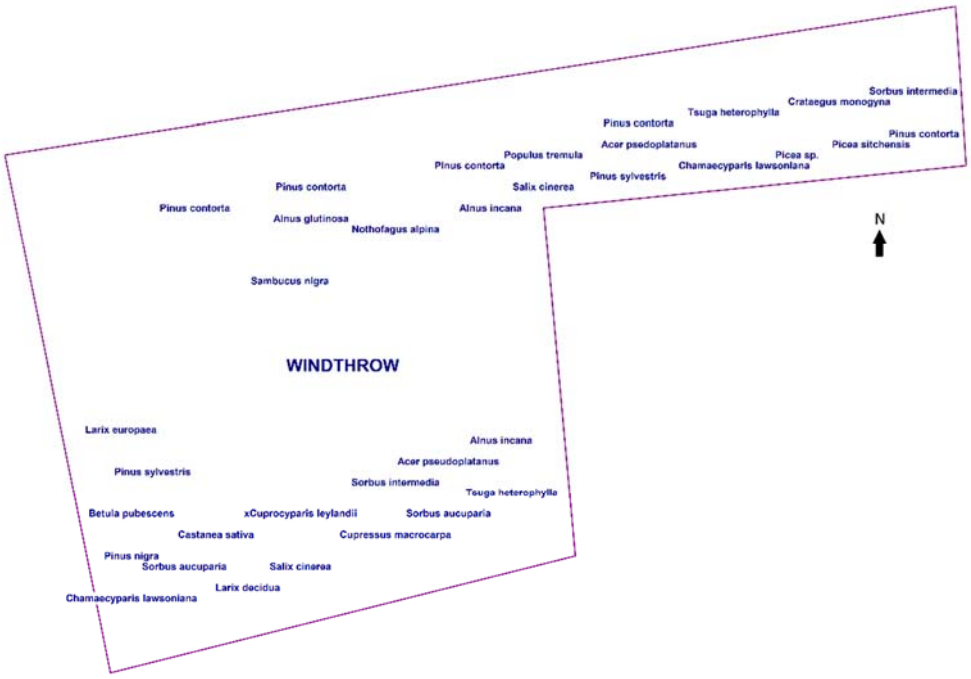

Fig. 4: Approximation to the planting plan for the second (upper) plot at Laxay, Lewis, based on surviving species August 2017.

Assessment

The assessments of the trials have not used consistent measures. Sutherland (1973) used 11-point (0 to 10) subjective scales for ease of establishment, susceptibility to dieback, and shelter afforded, and these were assessed across all three trial sites together (distinguishing between the peat of Laxay and sand of Clachan for three species, probably those where there were the most obvious differences). These values were repeated in Sutherland (1976). The height of the tallest tree in each plot was also recorded, and heights recorded in 1972 and 1975 are given.

Jacyna (1990) also recorded the height of the tallest specimen of each species in each plot, although survey conditions meant that not all species were assessed at lower Laxay. At Clachan the percentage survival and diameter at breast height (dbh) were also recorded.

A further assessment was undertaken on all three plots during visits in 2016-18. A survey of Clachan in May 2016 recorded the estimated height of the tallest tree per plot, and diameters were measured for some species; a second visit in August 2018 completed measurements of diameters. At Laxay the sites were surveyed in August 2017, and the number of trees of each species and the largest diameters of the surviving trees were measured systematically, but no heights were estimated. Tree growth in the Outer Hebrides is generally affected by the exposed conditions and soils, and many of the broadleaved trees and shrubs branch low down, so in all plots diameters were measured at the base (d@b), and at breast height (dbh) where that was possible.

The results of all the assessments are summarised in tables 1-3; two to three measurements are given in some cases where there were two to three relatively large specimens

Table 1: Summary of planted and extant species and assessments at Clachan, N Uist.

Tree species	**1972**	**1975**		**1990**		**2016-8**	
	Ht (m)	Ht (m)	surv%	Ht (m)	Dbh (cm)	est ht† (m)	dbh/ d@b (cm)
Abies grandis/nordmanniana			85	6.0	22	7.0	
Acer platanoides	0.91	1.80	65	7.0	12		
Acer pseudoplatanus	1.67	2.40	85	8.0	15	10.0	28/55* -/40 26/30
Aesculus hippocastanum	0.30	0.30					
Alnus glutinosa	1.52	2.70	50	6.5	14	8.0	-/41
Alnus incana	1.67	2.40	30	7.5	15	10.0	-/54 28/42
Alnus matsumurae	0.91	1.80	ns				
Alnus rubra	1.22	2.40					
Betula pubescens (as *B. alba*)	ns	ns	ns				
Castanea sativa	1.13	1.60	35	5.0	9		
Chamaecyparis lawsoniana	1.22	1.80	15[s]	7.5	na		
Crataegus oxycantha	1.12	1.20	15	4.5	na		
×*Cuprocyparis leylandii*	1.37	2.10	50	7.5	14		
Cupressus macrocarpa	0.91	1.20				4.0	-/39
Fagus sylvatica							-/13
Fraxinus excelsior							-/20
Larix decidua	0.91	2.70					
Larix griffithii	0.30	0.30	ns				
Larix kaempferi (*leptolepis*)	1.29	2.10					
Larix ×*marschlinsii* (*eurolepis*)	1.44	2.80	na	6.75	13		
Nothofagus alpina (*procera*)	1.37	2.40		6.25	20	7.0	-/59
Picea sitchensis	2.74	3.60	na	8	21	8.0	
Pinus contorta	1.83	3.00	na	na	na		-/28 -/81
Pinus mugo	1.37		na	4.7	na		-/29
Pinus nigra	1.52	2.10	ns				
Pinus nigra ssp *maritima*	1.83	3.00	30	7.2	22		
Pinus sylvestris	0.91	2.10					-/20
Populus alba	1.37	1.20	na	4.0	15		
Populus robusta	1.44	1.80	ns				
Populus serotina	1.52	1.80	15	6.0	19		
Populus tremula	ns	ns	ns				
Populus trichocarpa	1.22	3.00	ns				
Prunus padus	0.76	1.20	50[s]				15/24* -/22
Quercus ilex	0.76	1.50	15[s]				
Quercus rubra	0.61	0.90	45	4.0	4		
Salix alba	1.06	ns	ns				
Salix caprea	2.13	2.40	na	na	6		-/11

Salix cinerea						5.0	-/19
Salix daphnoides	2.89	3.00					
Salix ×calodendron (=*dascyclados* auct.)	1.22	ns	ns				
Salix pentandra	1.22	1.80					
Salix purpurea							
Salix viminalis 'gigantea'	0.91	ns	ns				
Sambucus nigra						6.0	19/59*
Sorbus aucuparia	1.83	3.00	30	6.5	na	8.0	-/16
Sorbus mougeotii (originally as *S. intermedia*)	1.37	1.50	30	6.5	8	3.5	-/13
Thuja plicata	0.76	1.50	ns				-/19 36/53*
Tsuga heterophylla	0.91	1.00					
Ulmus glabra	0.91	1.50	65	7.0	15		
Ulmus procera						10	28/22 25/39
Ulmus stricta	0.91	0.90	ns				

ns = not surviving, na = not assessed, ^{s} = surviving but very suppressed. † heights estimated, not measured with a clinometer; * = stool diameters in multi-stemmed specimens.

Table 2: Summary of planted species and assessments at Laxay lower plot, Lewis.

Tree species	**1972**	**1975**	**1990**	**2017**	
	Ht (m)	Ht (m)	Ht (m)	#trees (no. after / is estimated no. planted)	dbh/ d@b (cm)
Acer platanoides	1.37	2.40	3.5		
Acer pseudoplatanus	0.37	1.65	8.0		
Aesculus hippocastanum	0.30	0.60	4.0	4/6	14/17
Alnus glutinosa	1.52	2.70		4/6 5/6	-/39
Alnus incana	2.44	3.00			43/40
Alnus matsumurae	0.61	2.10			
Alnus rubra	0.91	2.20			
Betula pubescens (as *B. alba*)	ns	ns	7.5		
Castanea sativa	0.45	0.90	7.5	1/6	24/30
Chamaecyparis lawsoniana	1.52	1.80		3[a]/6	40/47
Crataegus oxyacantha = monogyna	0.91	1.05			
×Cuprocyparis leylandii	2.13	2.55	9.0	4/6	-/53
Cupressus macrocarpa	1.22	ns			
Larix decidua	0.91	1.65		3/6	21/24
Larix griffithii	0.30	ns			
Larix kaempferi (*leptolepis*)	1.83	3.45			
Larix ×marschlinsii (*eurolepis*)	1.22	3.15			
Nothofagus alpina (*procera*)	0.61	ns			
Picea sitchensis	2.59	3.60		9/?12	38/47

Pinus contorta	2.74	3.20		2/6	29/35
Pinus mugo	1.74	2.70		2/6	42/48
Pinus nigra	1.67	1.90			
Pinus nigra ssp *maritima*	1.98	2.70			
Pinus sylvestris	1.13	1.95			
Populus alba	2.13	2.70	3.0[s]		
Populus robusta	0.91	1.80			
Populus serotine	1.52	2.25	4.0		
Populus tremula	1.83	3.00	9.0	3[b]/6 1/6	29/31 28/31
Populus trichocarpa	0.61	1.80			
Prunus padus	0.30	0.35		several[c]/6	-/14
Quercus ilex	0.30	0.30			
Quercus rubra	0.30	0.30			
Salix alba	0.91	dead			
Salix caprea	3.05	3.60			
Salix daphnoides	3.66	3.95	4.0[d]	✓	
Salix ×calodendron (=*dascyclados* auct.)	0.61	1.20			
Salix pentandra	1.06	1.50			
Salix viminalis 'gigantea'	0.61	dead			
Sambucus nigra					
Sorbus aucuparia	1.22	1.80			15/15
Sorbus intermedia	1.52	2.00		12/? 12/?	8/10 20/28
Thuja plicata	1.06	1.80			
Tsuga heterophylla	1.22	1.70		5/6	29/45
Ulmus glabra	0.45	0.80			
Ulmus stricta	0.00	0.00			

ns = not surviving, na = not assessed, [s] = surviving but very suppressed.
[a] of which 2 windthrown and prostrate
[b] with many suckers
[c] access very difficult
[d] Jacyna (1990) gives this for "Purple Willow" whereas *S. daphnoides* is usually Violet Willow, but the continuity of measurements suggests that they refer to the same taxon, and *S. daphnoides* is the only long-leaved willow still present.

Table 3: Summary of planted species and assessments at Laxay upper plot, Lewis.

Tree species	**1972**	**1975**	**1990**	**2017**	
	Ht (m)	Ht (m)	Ht (m)	#trees (no. after / is estimated no. planted)	dbh/ d@b (cm)
Acer platanoides	0.45	dead			
Acer pseudoplatanus	1.22	2.70	8.0	4/6 3/6	18/24 29/48

Aesculus hippocastanum	0.30	0.30	2.0		
Alnus glutinosa	1.83	2.70	5.2	1[a]/?	
Alnus incana	1.83	2.50	5.9	4/6	31/51 38/41
Alnus matsumurae	0.61	0.70			
Alnus rubra	0.91	2.70			
Betula pubescens (as *B. alba*)	ns	ns	6.0	3/6	-/21
Castanea sativa	0.61	0.60	5.7	2[b]/6	24/29
Chamaecyparis lawsoniana	1.22	1.65	4.1	3/6 1/6	26/46 14/25
Crataegus oxyacantha	0.76	0.80	3.0	1/6	-/11
×*Cuprocyparis leylandii*	1.67	3.00	8.2	4/6	
Cupressus macrocarpa	1.22	0.90	7.7	2/6	-/58
Fagus sylvatica			7.5[c]		
Larix decidua	0.76	1.95	5.0	6/6 2/6	25/29 18/21
Larix griffithii					
Larix kaempferi (*leptolepis*)	1.13	1.95	6.75		
Larix ×*marschlinsii* (*eurolepis*)	1.52	2.10	6.75		
Nothofagus alpina (=*procera*)	0.61	0.90		2[d]/6	-/34
Picea sitchensis	2.44	2.70	8.7	4/6	53/67
Pinus contorta	1.83	3.30	5.7	2/6 3/4[e] 2/6	44/57
Pinus mugo	0.61	2.10			
Pinus nigra	1.52	1.80		3/6	40/45
Pinus nigra ssp *maritima*	1.52	2.70	6.5		
Pinus sylvestris	1.13	2.10	7.0	2/6 1/6	38/47 22/25[f]
Populus alba	1.37	2.00			
Populus robusta	0.91	1.20			
Populus serotine	0.00	0.00	0.5		
Populus tremula	0.45	dead	3.0	1[g]/6	14/17
Populus trichocarpa	0.45	0.90			
Prunus padus	0.30	0.60			
Quercus ilex	0.30	0.30			
Quercus rubra	0.30	0.30			
Salix alba	0.00	-			
Salix caprea	2.44	3.00	5.2		
Salix cinerea				6 (or 7)/6 3/6	22/34[h] -/40
Salix daphnoides	2.74	3.00			
Salix ×*calodendron* (=*dascyclados* auct.)	0.61	1.20			
Salix pentandra	0.91	0.90	3.1		
Salix purpurea					
Salix viminalis 'gigantea'	0.61	dead			
Sambucus nigra				2	-/14
Sorbus aucuparia	1.52	2.10	7.5	4/6 1/6	 -/35

Sorbus intermedia	1.22	1.50	4.7	5/6 2/6	-/20 15/17
Thuja plicata	0.61	1.90			
Tsuga heterophylla	1.22	1.85	5.5	1/6 1/6	10/17 20/25
Ulmus glabra	0.61	0.50			
Ulmus stricta	0.61	0.50			

ns = not surviving, na = not assessed, * = surviving but very suppressed.
[a] possibly self sown
[b] one windthrown but surviving
[c] perhaps *Nothofagus*?
[d] both windthrown but surviving
[e] 2 felled
[f] the largest specimen was a dead one
[g] with one sucker shoot
[h] all trees multistemmed, these are dimensions of largest bole; stool 94cm d@b

Survival
Assessing survival over the whole period is quite challenging for some species, where the sequence of measurements does not seem consistent (and in some cases because the number of individuals planted was not clear).

Some species have grown well in the plots, and it is unsurprising that these are the ones commonly used for wood production, such as *Pinus contorta*, *Pinus nigra* and *Picea sitchensis*. Even though six trees of each species/ provenance were planted together, the high density and resulting competition means that generally only one or two have grown well, even if more have survived. The plot size for each species is extremely small, and neighbour effects (where the one species overtops and outcompetes its neighbour) have been very important in these trials, and might have resulted in total death of some species that could potentially survive the conditions if they had not been shaded by a more vigorous neighbour. Species such as *Aesculus hippocastanum* have survived, but been so outcompeted by the neighbouring vegetation that they form spindly specimens reminiscent of saplings, despite their 50 year age. Their ability to persist under these conditions is impressive.

A number of species have been susceptible to windthrow, apparently particularly *Pinus contorta* of various provenances, although this has also affected *Nothofagus obliqua* at upper Laxay and Clachan. Other species such as *Cupressus macrocarpa* have succumbed to breakage rather than windthrow. Gardiner *et al*. (2006) point out that windthrow is usually in the centre of plots because of increased wind shear, and this is certainly consistent with the patterns in all the experimental plots (eg Fig. 5).


Fig. 5: Area of windthrown, and largely dead, trees in the centre of the main area of the upper Laxay plot.

Some observations on selected species are presented below.

Abies grandis
This species was recorded in 1990 but is not on planting lists from Sutherland (1973); there is a single, tall specimen which appears to be this at the southern end of the Clachan plot.

Acer pseudoplatanus
This species normally grows well even in relatively exposed conditions in the Outer Hebrides, but at upper Laxay not all survived, and the survivors were being out-competed by the neighbouring conifers. Seedlings were frequent at Clachan in 2018, but the frequency of saplings is low, so high mortality is assumed.

Betula pubescens
B. pubescens is native to the Outer Hebrides, often persisting as multi-stemmed shrubby specimens on cliffs where they are protected from browsing, although there are larger trees in places. It is therefore a surprise that this species largely failed in the experimental plantings; it was reported as "not surviving" in all sites in the 1970s evaluations, but was found in both Laxay sites in 1990, and persisted in the upper Laxay plot in 2017; it is not clear whether this is regeneration or an original specimen.

Crataegus monogyna
Sutherland (1973) gives *C. oxyacantha* (now = *C. laevigata*), but the sole surviving specimen at upper Laxay is *C. monogyna*.

Fagus sylvatica
Beech seems not to have been among the initial plantings, but there is a single tree at Clachan (13cm d@b), which is presumably a recent addition. Jacyna (1990) reports a *Fagus* measuring 7.5m tall at Upper Laxay, one of the tallest trees present, but there is no sign of such a specimen now; this may have been a misidentification of *Nothofagus alpina*.

Fraxinus excelsior
This species is not mentioned in any of the follow-up evaluations, but there is a single tree at Clachan, which may represent secondary planting.

Populus tremula
Also native to the Outer Hebrides, forming suckering groups on cliffs, to which it is largely restricted by browsing mammals. At lower Laxay, plants have formed suckers, some of which are forming larger 'saplings', but at upper Laxay only one small sucker shoot was seen. It is perhaps surprising that this species has not performed better, and this is possibly due to the competition in the dense plantings.

Sambucus nigra
There are many self-seeded plants of *Sambucus nigra*, particularly at Clachan, where they give the impression that the woodland would eventually become *Sambucus* scrub if left long enough.

Ulmus procera
Surviving only at Clachan, where there are small sapling-like stems present, though it is not clear whether these are seedlings or suckers. The original plantings purportedly included *U. glabra* and *U. stricta*, but only *U. procera* is present.

Shrubs

A range of shrub species was planted with the trees to provide shelter during the establishment phase and they have continued to provide shelter near ground level. Table 4 shows the planted species, and the (rather selective) evaluations of them. Some observations on selected species are given below.

Table 4: Summary of planted shrub species and assessments in the plots at Clachan and Laxay.

Shrub species	Clachan		Laxay lower	Laxay upper
	height (m)	d@b (cm)	dbh/d@b (cm)	d@b (cm)
Brachyglottis × *jubar*	3	24		
Cotoneaster × *watereri*			-/50	
Escallonia cv	4	29		
Euonymus europaeus var *intermedius*			✓	
Ligustrum ovalifolium	✓			
Lonicera involucrata (=*ledebourii*)	2	15	-/16	
Olearia macrodonta		43		
Olearia solandri[a]	2			
Phormium tenax	2½			
Ribes alpinum		✓		
Ribes nigrum				✓
Viburnum opulus			3/4 4/14[b]	

✓ = present

[a] possibly a subsequent introduction

[b] diameter @ base is a stool, dbh is the largest stem

Cotoneaster × *watereri*

There is a single large specimen of this species, a small open tree around 3m high, on the margin of the lower Laxay plot. It is not listed in any of the assessments, but from its size it seems likely to have been established soon after the trials started. *C.* × *watereri* is not currently known as an escaped or wild-planted species in the Outer Hebrides, so a long distance dispersal event would have been needed; the lack of current spread (ripe fruits were present in 2017) provides circumstantial evidence that establishment of this species is not straightforward. Therefore the most plausible suggestion is that it was a contaminant in the original plantings.

Euonymus europaeus var *intermedia*

Euonymus is not native in the Outer Hebrides, which lacks suitable calcicolous habitats. It has been planted earlier at Stornoway (Heslop Harrison 1948), and here is present only at lower Laxay, next to *Cotoneaster* × *watereri*.

Lonicera involucrata (= *L. ledebourii*)

This shrub was assessed as of no value as cover by Sutherland (1973), but persists and forms a dense screen in one area at Clachan. It is much more scattered at lower Laxay, but not surviving at upper Laxay.

Viburnum opulus

Viburnum is a calcicole where it occurs as a native in the north of the Scottish mainland, and would therefore have been expected to do better at Clachan where the sands are non-acidic, but the only surviving plants were at the lower Laxay plot.

Plot conditions and regeneration

The high density of planting led to some reasonable density of growth on the plots. It is however clear from Fig. 6 that at least part of the Clachan plot had no understorey; only a herb layer was present beneath the trees in 1990. This situation persists, with some parts having only a layer of bryophytes beneath the trees (Fig. 7), and some herbs in the northern part of the plot (which has been opened up). Elsewhere within the plot *Rubus fruticosus* (bramble) has seeded in, probably through the action of birds taking advantage of the shelter, and the old canes form a dense thicket (Fig. 8) where light reaches the shrub layer. Similar thickets are present at Laxay, sufficient to make access to parts of the plot quite challenging.

It is interesting to compare the photographs in Fig. 9, showing the edge of the plot at Clachan in 1990 and 2016. The trees and shrubs have clearly spread sideways, but there appears to be little change in the maximum height of the vegetation, which is affected by both exposure and windthrow.

A range of species has apparently seeded into the plots. It is difficult to infer which have arrived from local sources, and which were introduced in the original plantings but not recorded in the species list in Sutherland (1973). Trees apparently in rows are likely to have been originally planted, but single trees could result from poor survival of plantings as well as from more recent arrivals, and the generally low stature of many species in the plots means that height is not a good indicator of age. *Salix cinerea* ssp *oleifolia*, a common species locally, is likely to have seeded in at Clachan.

More naturally colonising species are in the shrub layer. *Rubus fruticosus* agg is found in all three plots, *R. dasyphyllus* and *R. mucronulatus* at Laxay, and a third *Rubus* species at Clachan. The assessments mention only *Ribes alpinum*, which is still present at Clachan, but *Ribes nigrum* occurs at upper Laxay, and may possibly have colonised naturally.

Incoming and spreading species either have light seeds (such as the sallows) or berries so that they are bird-sown (such as *Sambucus nigra*, *Sorbus aucuparia*); bird-sown species seem to predominate in the plots. Some of the originally planted species have spread within the plots. This is particularly marked for *Alnus glutinosa* which is more widespread and with apparently younger specimens than would be expected from the original experiment. Seedlings of *Acer pseudoplatanus*, *Sorbus aucuparia* and *Ribes alpinum* were noted at Clachan.

The trial plots have also modified the habitats considerably, and a range of other organisms has colonised. The wood-rotting fungi *Auricularia auricula-judae* and *Schizophyllum commune* are present at Clachan, and *Stereum rugosum* at upper Laxay. Clachan and lower Laxay both have infections of *Ganoderma* sp., on *Olearia macrodonta* and a long-dead unidentified fallen bole respectively. Fungi are well known to be able to disperse over long distances; the nearest records of *Ganoderma* are from Stornoway Castle grounds, 15km from Laxay and 79km from Clachan, although this is not necessarily the origin of the spores. There are also likely to be other fungi present in the plots which were not fruiting at the time of the visits reported here.

Fig. 6: interior of the plot at Clachan, 1990 © Simon Jacyna.

Fig. 7: A more open part of the interior of the Clachan plot in 2016 with a bryophyte ground flora.

Fig. 8: Part of the interior of the plot at Clachan in 2016 showing dense old *Rubus fruticosus* agg (bramble) stems.

Fig. 9: Eastern side of the plot at Clachan looking north, in 1990 (above, © Simon Jacyna) and 2016 (below) showing the spread of trees over the fenceline, but little change in height.

Berneray trial plot

A further shelterbelt trial was established on machair on Berneray, an island in the Sound of Harris north of North Uist, (grid reference NF910820) in April 1990 by Forest Research. It used a range of species, many in common with the earlier trials plots, and including both tree and shrub species. The experiment also tested two different shelter treatments (paraweb and shrub shelters) as the site was very exposed. The experiment was weeded, beaten up and fertilised for the first three years, however, survival after 2 years was extremely low due to the high exposure at the site, and most of the surviving trees had suffered severe browning, die-back and socketing. A final assessment was carried out at six years, after which the experiment was closed and the site reverted to grazing land. The site was

revisited in 2018, and now only a few *Ulex europeaus* bushes remain, with stem diameter up to 4 cm, presumably because their spines deter grazing mammals.

Discussion and conclusions

The experiments at Clachan and Laxay were designed to assess the possibilities for establishing woodlands primarily for shelter. They were not designed to assess wood production, although a range of commercial species (and provenances) was used. As any type of commercial forestry these plots have not been successful. However, with the exception of the Berneray plot, as experiments in establishing woodland they have been a considerable success. They have persisted as recognisable woodland blocks, with a subset of the original species, but also with transitions to a more natural type of woodland from self-seeding of both the original species and colonising species. The natural regeneration now occurring in the woodland conditions will be better adapted to the site conditions, and hence more suitable for persistent woodland.

The plots have had significant additional benefits in terms of diversification of habitat and providing refugia for native species otherwise restricted to sheltered or ungrazed sites. There are also signs that these habitats are used by a range of bird species, although these were not systematically surveyed.

The dense plantings have additionally acted as an interesting experiment in competition between woody species. Most of the species which have done well under these conditions are, perhaps predictably, the fast growing coniferous species which are used commercially such as *Picea sitchensis*, *Pinus contorta* and *Pinus nigra*. But *Nothofagus procera* has also produced substantial boles, though is susceptible to windthrow. An interesting outcome is the ability of certain species, such as *Aesculus hippocastanum* and *Viburnum opulus*, to survive in suboptimal soils when overtopped by other trees.

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