A Management Oriented Study of the Birch-Rowan-Hazel woodland at Murlough Bay, Co. Antrim, Northern Ireland

PIERRE BINGGELI and BRIAN S. RUSHTON

Department of Biology, New University of Ulster, Coleraine, Co. Londonderry.

SUMMARY

A management oriented study of the Birch-Rowan-Hazel woodland at Murlough Bay, Co. Antrim, Northern Ireland was conducted in order to establish the balance of tree species composition, population age structure and regeneration of the tree species, grazing pressure and the status of Sycamore (*Acer pseudoplatanus* L.) and Ash (*Fraxinus excelsior* L.) which are invading the woodland. The woodland forms part of the National Trust Nature Reserve.

Results indicated that:

1. the most common trees were Birch (*Betula pubescens* Ehrh.) 1016 trees/ha, Rowan (*Sorbus aucuparia* L.) 244 trees/ha and Hazel (*Corylus avellana* L.) 236 trees/ha whilst Sycamore and Ash accounted for 21.4 and 14.8 trees/ha respectively;

2. the main tree species were, by and large, segregated within the woodland with Hazel just below the cliff, Birch in the lower, damper areas and Rowan between;

3. plots of Log. Tree Number against Log. Tree Age indicated that populations of all the above five tree species were declining;

4. regeneration appeared to be sparse despite the very large numbers of seedlings produced whilst there was extensive evidence of grazing pressures from goats and sheep;

5. assuming no regeneration or mortality of the Sycamore, its canopy cover is likely to increase from 4.0% to 11.4% of the total in the next 50 years; that of Ash will increase from 2.0% to 6.7% over the same period.

A management plan, directed towards restricting grazing and Sycamore eradication by tree-barking is suggested.

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INTRODUCTION

After the extensive and systematic clearance of the forests by Scottish and English settlers very few natural or semi-natural woodlands have survived in Ulster and, today, plantations of exotic conifers constitute almost exclusively the Ulster forested landscape. Tomlinson (1982) in his review of woodlands in the north of Ireland described oakwoods, ashwoods, and mixed woods dominated by oak and ash but did not mention the existence of birch woodland. In the Scottish Highlands, birchwoods are the commonest semi-natural woodland (McVean 1964) but they are usually small and isolated and, like so many natural and semi-natural woodlands, they are under threat. Chard (1953), for example, estimated that since 1900 some 50,000 ha of birchwoods have disappeared from the Scottish Highlands due to suppression of regeneration. Throughout Britain, numerous woodlands are also being invaded by the non-native species, Sycamore (*Acer pseudoplatanus* L.) and, because of the mild climate of Ireland, Irish woods are particularly susceptible to such invasion. Dierschke (1982) has indicated that in Ireland, Sycamore is capable of rapid spread. Sycamore is the most likely tree species to regenerate under shaded conditions and it will most probably replace mature native species like Birch and as a result alter the character of the woods it invades (Linhart & Whelan 1980).

Birchwoods in Northern Ireland are not particularly common. One example is at Murlough Bay (Co. Antrim, D188428) where a Birchwood, which includes substantial numbers of other tree species including Rowan (*Sorbus aucuparia* L.) and Hazel (*Corylus avellana* L.), nestles under the Fair Head cliff face. Whilst the woodland is part of the National Trusts' designated nature reserve, little information is available concerning the balance of tree species composition, age structure, grazing pressure and the status of Sycamore and Ash (*Fraxinus excelsior* L.). This paper reports the findings of a quantitative study aimed at investigating some of these aspects and proposes a tentative management policy for the wood.

STUDY AREA

The wood has an east/north-east aspect and is situated on a steep slope between 90 and 190m above sea level. The terrain is littered with large boulders shattered from the cliff above and there are also some scree slopes. Study was confined to the northern parts of the wood (about 5 ha in extent) where the wood is at its most homogeneous and widest (Fig 1). The wood at this point consists of a series of plateau areas separated from each other by steep and hazardous cliffs. This presented several practical sampling problems.

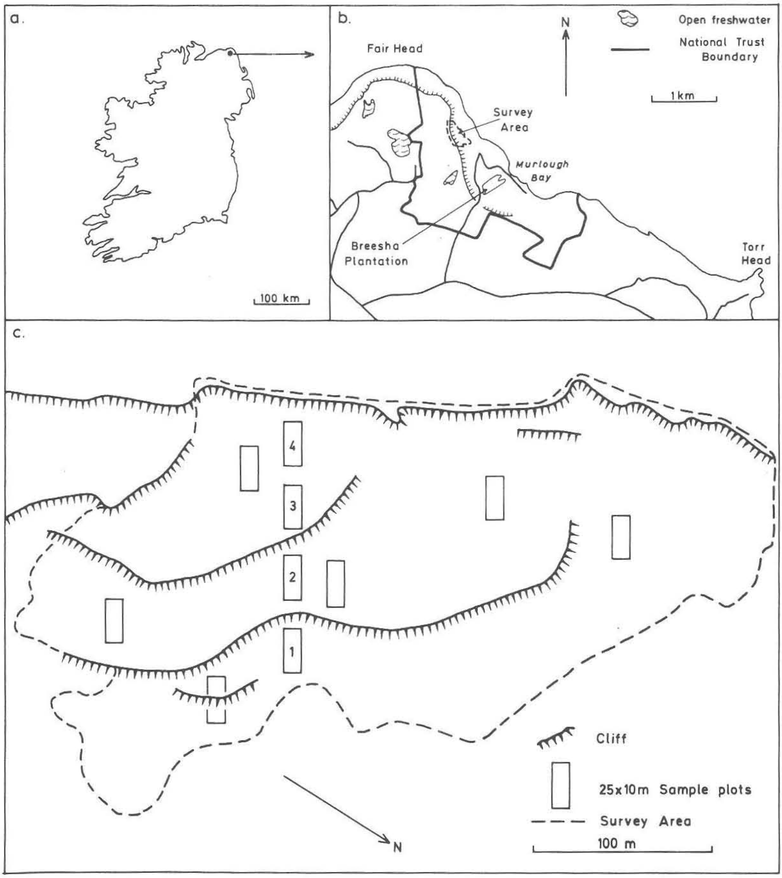

Fig 1. The woodland at Murlough Bay, Co. Antrim.
a) General position
b) Survey area in relationship to the National Trust area
c) Position of the 10 25m x 10m sample plots. Those plots labelled 1 to 4 formed the transect down the slope.

The soil consists of 86-88% sand and 12-14% silt and clay and may therefore be described as a sandy-loam. The pH ranges from 5.1 to 6.1 (Siddal 1977).

The woodland is dominated by *Betula pubescens* Ehrh. (Birch), *Sorbus aucuparia* L. (Rowan), and *Corylus avellana* L. (Hazel). Other tree species include *Acer pseudoplatanus* L. (Sycamore), *Fraxinus excelsior* L. (Ash), *Quercus* L. spp. (Oaks), *Populus tremula* L. (Aspen), *Crataegus monogyna* Jacq. (Hawthorn), *Fagus sylvatica* L. (Beech), *Salix* L. spp. (Willows), and the occasional *Ilex aquifolium* L. (Holly). The ground flora is predominantly composed of mosses (36.0%), herbs (25.7%), grasses (14.4%) and the Woodrush, *Luzula sylvatica* (Huds.) Gaud. (10.6%). Ferns, mainly *Pteridium aquilinum* (L.) Kuhn, *Dryopteris* Adans. spp. (5.4%), and *Vaccinium myrtilus* L. (1.3%) account for a much smaller proportion of the ground vegetation. Bare soil accounts for 2.7% of the ground surface (Binggeli 1980). The uncommon fern *Hymenophyllum wilsonii* Hook. is also present.

The woodland has not been free from human interference. During the 19th century, coal mining took place in the lower parts of the wood where numerous tracks can still be seen. Other signs of human activity can also be observed. For example, at the top of the wood there is a row of mature Beeches and an overgrown hedge adjacent to a collapsed stone wall. Wood extraction was carried out up to 25 or 35 years ago and it is locally known that fishermen from Rathlin Island used to cut Hazel to make lobster cages. However no Hazel stumps have been observed during fieldwork but cutting may have taken place in parts of the wood not studied.

METHODS

The following aspects of the woodland were investigated:

1. Tree species composition
2. Variation in tree species composition and the height related to position on the slope
3. Tree age distribution
4. Regeneration
5. An assessment of grazing intensity
6. The status of both Sycamore and Ash within the wood.

Since little basic information other than species lists exist for the woodland, an initial survey was designed to examine and characterise the main tree species in the area. Ten plots, each

25m x 10m were used (Fig 1). Six were randomly located, the remaining four were part of a transect (see below). In each plot, the number of each of the major tree species were recorded. Trees with a girth less than 50mm at a height of 1.3m were not included.

In order to examine variation with altitude, four 25m x 10m plots were arranged in a straight line down the slope of the woodland from the base of the cliff to the grassland below. The plots were 10m apart and therefore the total length of the transect line was approximately 130m. In each plot, the number of trees of each species was recorded together with their heights. Tree height was also recorded for trees growing between the plots — thus tree height was recorded from a belt transect 130m long and 10m wide. The ground surface was also categorised in each plot as:

1. Scree 2. Large boulders (>1.5m diameter)
3. Small boulders (<1.5m diameter) 4. Sandy-loam.

Tree age distribution was investigated in order to obtain some insight into whether the tree species in the wood were declining, actively spreading or whether the wood was in a stable state.

The methodology and analysis used here follows that of Leak (1975). Essentially the technique relies on graphical plots of Log. Tree No. x Log. Age Class. Leak (1975) has argued that three distinct relationships may be shown by such graphs:

a) Linear relationships, indicative of stable populations.

b) A tendency towards a concave slope to the graph indicative of increasing populations.

c) A tendency towards a convex slope (in its extreme form a bell-shaped curve) indicative of declining populations with a low birth rate.

In the ten 25m x 10m sample plots described above, the girth of all trees of Birch, Rowan and Hazel were measured at a standard height of 1.3m. For Hazel, the girth of the largest pole was recorded, for Ash and Sycamore, every single tree in the study area was measured. Any tree with a girth measurement below 50mm was excluded from the analysis, leaving 538 trees. Age was determined on a sub-sample of 132 trees using cores taken just above the root collar. Although the Birch cores were processed using the method of Tucker (1979), counting the rings proved very difficult and therefore there is likely to be a greater degree of error with this species than with the others. Cores were taken on 34 trees of Birch, 24 trees of Hazel, 19 trees of Rowan, 21 trees of Ash, and 34 trees of

Sycamore. These data were analysed by a Model II Regression (Sokal and Rohlf 1969). For each tree species there was a significant regression at $p<0.01$ and it was concluded that the age of each tree could be estimated from girth measurements. Using these regressions, the ages of all the trees was estimated.

To determine the extent of regeneration, 189 one m^2 quadrats were randomly positioned throughout the wood by means of a random walk. Due to the difficult terrain, the wood was subdivided into six sample plots and the number of quadrats placed in each plot was in proportion to the plot area. In each quadrat, the number of tree seedlings and saplings was recorded. Seedlings were defined as being less than one year old; saplings were two years old or more and less than 1.5m tall.

Grazing pressures were assessed by comparing the age and growth of Sycamore saplings in the wood with a fenced area (free from grazing) in an adjacent mixed hardwood plantation (Breesha Plantation). Age, current year growth increment and height were measured for a small sample of saplings from each area.

An attempt was made to investigate in more detail the status of Sycamore and Ash within the woodland. All trees of both species within the study area were located and mapped. A small, square quadrat was then repeatedly, randomly placed over each map and the number of trees of Sycamore and Ash in each quadrat recorded. These data were then analysed using a chi-square to determine if the species were randomly distributed. Canopy diameter was estimated on a sample of trees of both species. For each tree, canopy diameter was measured twice at right angles and averaged. Girth was also measured on the same trees so that a relationship between girth and canopy crown diameter could be established through regression. For both species this regression proved significant ($p<0.01$). Using this relationship, cover of the two species was estimated from girth measurements and, from the relationship previously established between age and girth, predictions could be made about changes in the canopy cover of Ash and Sycamore.

RESULTS

Tree species composition

The estimated tree density in the study area was 1,532.2 trees/ha. The commonest species was Birch (1,016 trees/ha, 66.3%), followed by Rowan (244 trees/ha, 15.9%). Sycamore and Ash accounted for 21.4 trees/ha (1.4%) and 14.8 trees/ha (1.0%) respectively. Willows, although not accounted for in the sampling were numerous along the edge of the wood.

Variation in species composition and tree height related to position on the slope

Table 1: Variations in % species composition of five tree species, canopy height, and general terrain features in four plots in the natural woodland, Murlough Bay. Plot 1 was the lowest; Plot 4 was arranged just under the main cliff (see Fig 1).

Percentage Occurrence	Plot				
Species	1	2	3	4	
Betula pubescens	89	70	60	17	
Salix spp.	3	0	0	0	
Acer pseudoplatanus	0	3	3	0	
Sorbus aucuparia	0	18	34	12	
Corylus avellana	8	9	3	71	
				Bottom	Top
Av. Canopy Height (m)	5.0	7.5	5.4	4.9	2.9
Max. Canopy Height (m)	7.5	10.0	7.0	6.5	3.5
Min. Canopy Height (m)	4.0	5.0	3.5	2.5	2.5
General Terrain Features	Sandy Loam	Small Boulders	Large Boulders	Scree	

Table 1 shows the variation in species composition up the slope; this is shown diagrammatically in Fig 2. The relative proportion of each species changed greatly along the altitudinal profile. At the bottom of the wood, where the ground was composed of a sandy-loam and conditions were damp, Birch constituted an almost pure stand with a few Willows and Hazel. However, its dominance diminished in the upper parts of the wood and it was absent from the scree slope below the top cliff. Above the first cliff, where small boulders covered a large proportion of the ground, Rowan occurred and this species increased to 34% of the total tree number above the second cliff. Here, the terrain was mainly large boulders with deep crevices between. Although Rowan was present in the topmost plot, it was absent just below the top cliff. In the wood, many of the Rowan trees had rooted onto the large boulders and, because this is a precarious position, many of the older trees had fallen. In these

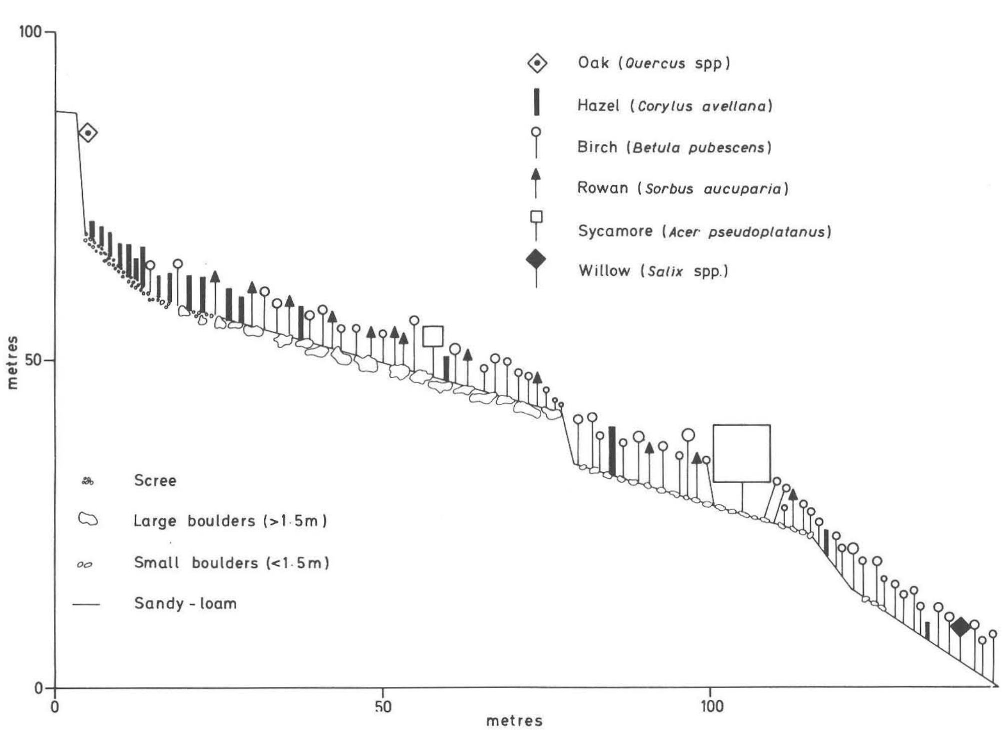

Fig 2. A diagrammatic representative profile showing the variation of tree species composition along the slope of the woodland.

cases, growth was continuing through the vertical growth of side branches. On the scree at the base of the top cliff, Hazel was found in pure stand although below, in the lower parts of plot 4, it was mixed with smaller proportions of Rowan and Birch. Throughout the rest of the wood however Hazel represented less than 10% of the trees. Sycamore was sparsely distributed through the wood whilst Ash, although not actually recorded in the sample plots, seemed to be restricted to the damper lower areas.

Oaks, although not present in the main plots, were found on the main cliff above the scree area. Thirteen Oaks or groups of Oaks were observed in this position, but only one mature Oak was found in the wood itself. The Oaks on the cliff were very stunted and mainly inaccessible. A small number were sampled and these proved to be *Quercus robur* L. although a small number of characters on some leaves might have indicated a degree of hybridity. The leaves of some individuals were rather distorted, making accurate assessment difficult.

The general pattern of species distribution was repeated in other parts of the wood from the lower slopes up to the base of the topmost cliff.

Variation in the height of the tree canopy is shown in Table 1. The average canopy height decreased from 5.9m at the bottom of the wood to 2.9m just below the top cliff. The high mean value obtained for plot 2 (7.5m) was probably due to the shelter that three tall Sycamores provided. Generally the Sycamores were much taller than the other species and stood well above the rest of the trees reaching an estimated height of 13m.

Tree age distribution

The results are presented in Fig 3 where Log. Tree No. has been plotted against Log. Tree Age for 20 year age classes for each of the five species investigated. All five species exhibited a tendency to produce a convex plot which was particularly noticeable below the 35-55 year age class. Such a result may be interpreted (Leak 1975) as indicating that the populations are declining. The two main species in the wood, Birch and Rowan, appear to be declining to a much greater degree than the others and Rowan, in particular, exhibits a tendency towards the bell-shaped curve characteristic of populations undergoing substantial decline. With the exception of Birch and Rowan, all species beyond the 75-95 year age class showed a slightly concave distribution indicating that up until the early parts of this century, the populations may have been slowly expanding. However, it would appear that the decline of both Birch and Rowan began about 50 years ago and that of Hazel, Ash and Sycamore more recently.

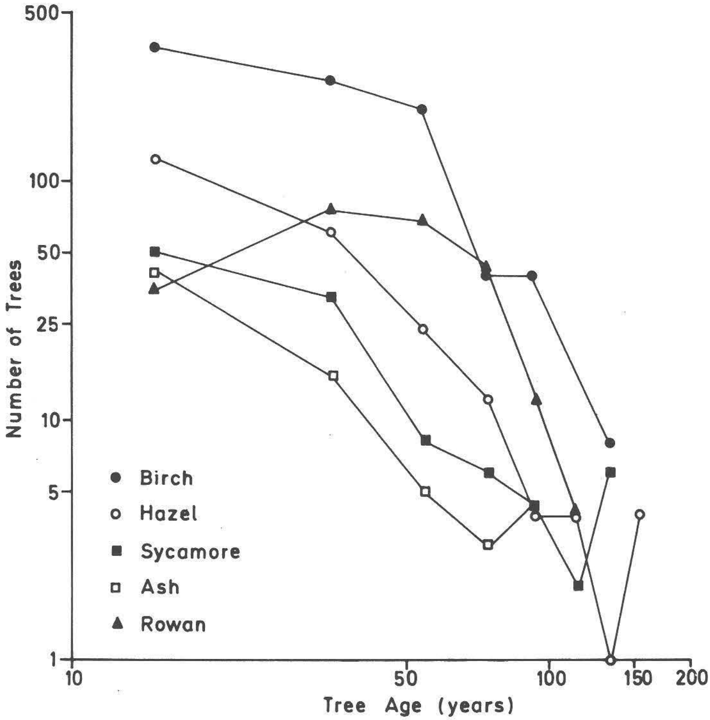

Fig 3. Log. Tree No. plotted against Log. Tree Age for 20 year age classes for five tree species.

Only Birch occurred in sufficient numbers throughout the altitudinal transect to allow any investigation of age with slope position. The age distribution was similar for all the four transect plots with a tendency for the lower plot to have a higher proportion of younger trees ($<$20 years old) and a lower proportion of older trees ($>$60 years old) than the upper parts of the slope.

Regeneration

Seedlings of only three species were recorded in the quadrats. The mean seedling density of Birch was 3.7/m^2 ($\pm$ 2.73) and that of Rowan 0.08/m^2 ($\pm$ 0.29). A very small number of Hazel seedlings were also recorded. Only 10 saplings of Rowan were recorded and although saplings of both Birch and Sycamore were noticed in the wood none occurred in the quadrats. The absence of Birch saplings and the substantial number of seedlings would indicate that seedling mortality is high.

Grazing Pressure

The results are shown in Table 2. In the natural woodland, the Sycamore saplings were significantly older but also shorter and with a smaller 1979 growth increment than those in the adjacent planted stand. Several saplings in the wood had a "seedling-like" appearance — one of these was only 21cm tall but 15 years old. Throughout the wood there was ample evidence of grazing, e.g. wool, droppings and damage. In the vicinity there is also a herd of (elusive) feral goats which are known to frequent the wood.

Table 2: A comparison of Sycamore saplings from the Birch-Rowan-Hazel wood and an adjacent mixed hardwood plantation.

	Birch-Rowan-Hazel wood	Breesha Plantation
Number of saplings sampled	9	15
Sapling height (m)	1.87 ± 0.28	2.76 ± 0.50
Sapling age (years)	17.0 ± 4.8	8.0 ± 0.0
1979 Growth increment (cm)	12.5 ± 9.8	90.0 ± 17.0
Number of saplings with grazed leaders	3	0

Distribution and canopy cover of Sycamore and Ash

Within the five ha studied, 107 individuals (trees, saplings, and seedlings) of Sycamore and 74 individuals of Ash were recorded. Since it was found more difficult to discern the Ash seedlings and saplings under the forest canopy, this latter figure is likely to be an underestimate. Fig 4 shows the distribution of the two species in the wood; both species were found to be non-randomly distributed and showed a clumped distribution. All the mature Ash trees were restricted to the damp lower areas with younger trees further up the slope, whereas the Sycamores were well dispersed throughout the area. Estimation of the changes in canopy cover of Ash and Sycamore over the next 50 years are given in Table 3. These data assume no further regeneration and no mortality of the existing individuals. The estimated cover of both Ash and Sycamore in 1979 was 5.9%; by 2004 this is likely to increase to 11.0% and by 2029 to 18%. It should be noted that these are likely to be over-estimates since the present positioning of small saplings and trees in clumps (Fig 4) would indicate that eventually their canopies will begin to overlap.

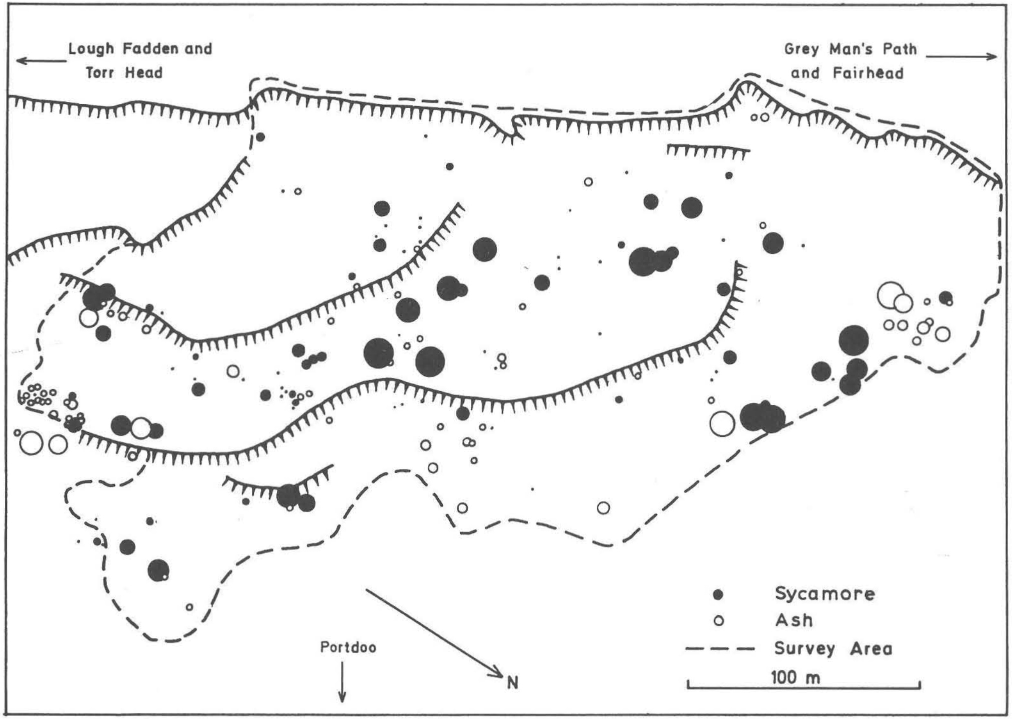

Fig 4. Distribution and canopy cover of Sycamore (*Acer pseudoplatanus* L.) and Ash (*Fraxinus excelsior* L.) in the study area.

Due to its dense canopy, Sycamore produces comparatively dense shade conditions which affects other tree species and ground vegetation alike. It was observed, for example, that underneath four large Sycamores there were decaying trunks and stumps of Birch and the live Birches at the periphery of the Sycamore crowns were all bending out towards the light with their inner branches leafless. The ground vegetation under the Sycamore was limited to moss and ferns whereas the surrounding ground flora was much more diverse and luxuriant.

Table 3: Predicted changes in the canopy cover of Sycamore *(Acer pseudoplatanus* L.) and Ash (*Fraxinus excelsior* L.) over the next 50 years.

	Percentage Canopy Cover		
Species	1979	2004	2029
Ash	2.0	3.9	6.7
Sycamore	4.0	7.1	11.4
Combined	5.9	11.0	18.0

Regression equations used:

Ash	Girth = –4.45 + (1.50 × Age) Canopy diameter = 1.8 + (0.060 × Girth)
Sycamore	Girth = –6.30 + (1.28 × Age) Canopy diameter = 1.6 + (0.058 × Girth)

with Girth in cm, Age in years, and Canopy diameter in m.

DISCUSSION

The natural woodland at Murlough Bay is predominantly composed of three tree species, Birch, Rowan and Hazel. The distribution of these within the woodland is broadly differentiated — Hazel at the top of the slope, Rowan below and Birch though common throughout the wood is more frequent on the lower slopes. Similar examples of the occurrence of Hazel scrub at the base of cliffs has been reported by Steele (1968). He argued that such a distribution may be the result of local soil nutrient enrichment due to seepage. The instability of the scree at the base of the main cliff at Murlough Bay might also favour the growth of Hazel rather than Birch or Rowan. The limited distribution of Rowan appears to be correlated also with terrain features, namely large boulders. Rowan is particularly susceptible to grazing pressures (McVean 1964) and may be taken preferentially by herbivores. Also, Rowan regeneration appears to be extensive in the absence of grazing (McVean 1964). The area where Rowan is found is the most inaccessible to grazing animals and it is likely that it survives here but fails to spread into the adjacent areas where grazing pressure is greater. The distribution of the very small number of Oaks is probably similarly restricted; no Oak seedlings were found at all in the wood. The distribution of Ash (mainly in groups in the damper areas, Fig 4) is similar to that observed by Wardle (1961) and Okali (1966a, b) and that of Sycamore (much more widely dispersed and comparatively more isolated) is also similar to that observed by Okali (1966a, b).

McVean (1964) and Kinnaird (1968) have described the commonest Birchwood structure in Scotland as being composed of even-aged stands of Birch with young seedlings one or two years old, but with very few individuals in any of the intermediate age classes. A rarer type has trees of two generations, old trees surrounded by groups of younger individuals. The age structure of the Birch in Murlough Bay does not conform to either of these descriptions and the woodland is represented by a wide range of age classes. In the case of Birch, there were very few saplings, but a large number of seedlings indicative of heavy grazing pressure. Emberlin and Baillie (1980) have argued that the main factor controlling the regeneration of Birch is grazing although several other factors are known to influence the process and are potentially important at Murlough Bay. Birch seedlings need suitable moist conditions for successful development such as those provided by a cushion of *Sphagnum* — rare in the wood — or sheltered bare soil — often created by animals' hooves (Kinnaird 1974, Miles 1974, Emberlin and Baillie 1980). Futhermore, prolific growth occurs in ericaceous associations rather than in communities dominated by grasses such as those found in most of the wood. Saplings may also be affected by canopy cover — increasing shade limits the growth and if this is compounded by grazing the saplings are unlikely to survive (Miles 1971, Miles and Kinnaird 1979a).

The grazing pressure is evidenced by the age distribution curves which indicate that all the species investigated are declining in numbers. This is particularly true of Rowan but is also true of Birch itself. Kinnaird (1968) has argued that Birch may regenerate successfully under grazing pressure provided that there is an adequate number of seedlings which are vigorous enough to compete against the grazing pressures. In Murlough Bay, seedling number does not appear to be a problem; the difficulty seems to lie with the ability of the seedlings to overcome grazing. Kinnaird

(1968) believes that "vigour" is a function of soil fertility and on poorer sites may also be related to the development of mycorrhizal associations. The poor soil development at Murlough Bay, coupled with the effects of grazing probably accounts for the lack of regeneration and the apparent decline in the Birch population.

The main threat to adult, mature trees in the wood appears to derive from the invasion of Sycamore and Ash. Sycamore and Ash already have a strong foothold in the wood and it is predicted that their canopy cover will increase three fold in the next 50 years. Field observations have indicated that Birch cannot compete effectively with the more vigorous growth of Sycamore. Linhart & Whelan (1980) have shown that Sycamore is itself susceptible to grazing. Dense shade may also limit the growth of Sycamore (Jones 1945) but this is unlikely to be an important factor at Murlough Bay because of the openness of the Birch and Rowan canopy. Under the conditions pertaining at Murlough Bay, the Sycamore seedlings and saplings appear to be more tolerant of grazing than Birch or Rowan. It is clear that even if grazing is maintained at the present levels, Sycamore will increase its hold in the wood and become co-dominant with Ash replacing the present dominant overstorey species. From a landscaping point of view, the dark foliage of Sycamore does not blend into the lighter coloured foliage of Birch, Rowan and Hazel. Ash, on the other hand is less offensive in this respect and blends more naturally into the landscape.

One of the uncommon ferns of Northern Ireland, *Hymenophyllum wilsonii* Hook. is found in the Birch-Rowan-Hazel wood at Murlough Bay. Here it grows predominantly on large boulders. The effect of the Sycamore invasion on *H. wilsonii* is complex. Richards & Evans (1972) note that in parts of Killarney, where humidity is very high, *H. wilsonii* is found in the higher parts of the Oak canopy where the trees are tall and ground level light intensity is low. Conversely, if the canopy is lower and/or more open, then it is more likely to be found on the lower parts of the trunks or on rock surfaces. They also point out however that it is intolerant of deep shade and grows better in moderate shade conditions. Both humidity and light seem to be important factors in determining its distribution. At Murlough Bay, the effect of increased canopy cover and therefore deeper shade conditions from Sycamore invasion would probably be to the detriment of *H. wilsonii*. *H. wilsonii* has not been recorded as an epiphyte on Sycamore (Richards & Evans 1972) and therefore it may not respond to increased shade by a more elevated position.

A suggested management policy

The objectives of nature conservation in British woods have been outlined by Peterken (1982). The following points may be considered of importance with respect to the management of the Murlough Bay Birch-Rowan-Hazel woodland:

1. Maintenence of an element of wooded wilderness in the Murlough Bay area;
2. Maintenence of an example of a Birch-Rowan-Hazel woodland;
3. To allow self perpetuation of the native flora and fauna.

To achieve these ends it would be necessary to provide a low intensity ecosystem management which should include the eradication of Sycamore, the preservation of *H. wilsonii* and the encouragement of the regeneration of the present native tree species. Ash is seen to be less of a problem because it occurs in fewer numbers, is less vigorous on the site, and blends more naturally into the landscape.

Successful regeneration will only occur when grazing is decreased or suppressed. However, if an area is fenced, Birch is unlikely to regenerate if seedlings are not already established. One paradox is that trampling may provide suitable niches for seedling establishment and this may be particularly important in years when viable seed production is poor.

Before the regeneration of native species is encouraged by a decrease or suppression of grazing, Sycamore should be eradicated. In this instance, tree barking would seem preferable to felling as this would do less damage to surrounding trees. Because of its high basal sprouting rate the Sycamore should be checked during the following years and the young shoots removed.

In this way it may be possible to maintain the character of this woodland.

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REFERENCES

BINGGELI, P. 1980. The Birch-Rowan-Hazel Woodland at Murlough Bay: A Study. B.Sc. Thesis, The New University of Ulster.

CHARD, J. S. R. 1953. Highland Birch. Scott. For. 7:125-128.

DIERSCHKE, H. 1982. The significance of some introduced European broad-leaved trees for the present potential natural vegetation of Ireland. J. Life Sci. R. Dubl. Soc. 3:199-207.

EMBERLIN, J. C. and I. C. BAILLIE. 1980. Aspects of birch regeneration in two woods in Intervolly National Nature Reserve, Western Ross. Scott. For. 34:13-34.

KINNAIRD, J. W. 1968. Ecology of birch woods. Proc. Bot. Soc. Brit. Isl. 7:181-182.

KINNAIRD, J. W. 1974. Effect of site conditions on the regeneration of Birch (*Betula pendula* Roth and *B. pubescens* Ehrh.) J. Ecol. 62:467-472.

LEAK, W. B. 1975. Age distribution in virgin spruce and northern hardwoods. Ecology 56:1451-1454.

LINHART, Y. B. and R. J. WHELAN, 1980. Woodland regeneration in relation to grazing and fencing in Coed Gorswen, North Wales. J. Appl. Ecol. 17:827-840.

McVEAN, D. N. 1964. Woodland and scrub. in Burnett, J. H. Ed. The Vegetation of Scotland. Oliver and Boyd, Edinburgh and London.

MILES, J. 1974. Effects of experimental interferences with stand structure on establishment of seedlings in Callunetum. J. Ecol. 62:675-687.

MILES, J. and J. W. KINNAIRD, 1979a. The establishment and regeneration of birch, juniper and Scots pine in the Scottish Highlands. Scott. For. 33:102-119.

MILES, J. and J. W. KINNAIRD, 1979b. Grazing: with particular reference to birch, juniper and Scots pine in the Scottish Highlands. Scott. For. 33:280-289.

OKALI, D. U. U. 1966a. A comparative study of the ecologically related tree species, *Acer pseudoplatanus* and *Fraxinus excelsior* I. The analysis of seedling distribution. J. Ecol. 54:129-141.

OKALI, D. U. U. 1966b. A comparative study of the ecologically related tree species. *Acer pseudoplatanus* and *Fraxinus excelsior* II. The analysis of adult tree distribution. J. Ecol. 54:419-425.

PETERKEN, G. F. 1982. Woodland Conservation and Management. Chapman and Hall, London.

RICHARDS, P. W. and G. B. EVANS, 1972. Biological flora of the British Isles. *Hymenophyllum tunbrigense* (L.) Sm. and *H. wilsonii* Hooker. J. Ecol. 60:245-268.

SIDDAL, K. 1977. Management Plan for Open Country — MurloughBay/Fairhead, County Antrim. B.Sc. Thesis, The New University of Ulster.

SOKAL, R. R. and F. J. ROHLF, 1969. Biometry. Freeman, San Francisco.

STEELE, R. C. 1968. The ecology of some western oakwoods. Proc. Bot. Soc. Br. Isl. 7:185-187.

TOMLINSON, R. W. 1982. Vegetation. In CRUICKSHANK. J. G. and WILCOCK, D. N. Eds. Northern Ireland: Environment and Natural Resources. Queen's University, Belfast and The New University of Ulster, Coleraine.

TUCKER, J. J. 1979. Estimation of tree age using the increment borer. Arboricultural J. 3:527-531.

WARDLE, P. 1961. Biological flora of the British Isles. *Fraxinus excelsior* L. J. Ecol. 49:739-75.