International Forest Fire News (IFFN) No. 30 (January – June 2004, 84-93)

Prescribed Fire in a Scottish Pinewood: a Summary of Recent Research at Glen Tanar Estate, Aberdeenshire, Scotland

Summary

The role of natural disturbance in maintaining important ecological processes in natural Scots Pine woodland is becoming increasingly recognised. With increasing pressure to secure the future of pinewood species such as the Capercaillie (*Tetrao urugallis*), it has become necessary to develop innovative management techniques to manipulate habitat conditions in the absence of browsing pressure. The use of prescribed fire is one of the most promising such management techniques, and is widely used for resource management in similar ecosystems in North America and Australia. Preliminary research conducted at Glen Tanar Estate has demonstrated the potential benefits of prescribed burning, and has produced a number of useful insights to help shape the development of this technique in Scotland.

Introduction

The complex role of fire in the ecology of natural Scots' pine forest is well documented for many parts of its extensive distribution (Goldammer and Furyaev 1996), where fire is accepted as an important natural factor in the maintenance of a mosaic of forest types at the landscape scale. In Scotland, however, fire has generally been ignored as an ecological variable even though it has potentially positive attributes. This is presumably because the negative impacts of fire on native woodland have historically been very serious (Steven and Carlisle 1959) and there is an understandable fear of wildfire and its risks to person and property. Also the likelihood of fire occurring and its consequent ecological importance as a disturbance event is easily overlooked the oceanic climate of the United Kingdom.

Whilst caution is justified, the assumption that fire is not a significant natural force the UK climate is unfounded. It is likely that fire has been a significant *natural disturbance mechanism* within the native pinewoods of Scotland (Peterken 1996). Historical evidence (Aberdeen Journal 1826) indicates a significant risk of landscape scale fire started by dry lightning (*i.e.natural)* impacting upon remnant Scots' Pine woodland, particularly in the eastern highlands. This is an area that experiences a semi-continental climate where short-term droughts are common. At one site in the eastern highlands, Glen Tanar Estate, the natural fire return interval has been estimated to be in the region of 80-100 years, based upon the historical evidence of the past four centuries (Marren 1986, Miller and Ross 1990). By ignoring, rather than studying, the role of fire in forest ecology in Scotland, there is a danger of exposing areas to damaging wildfires and failing to recognise an important ecological process.

The distinctive wildlife of the pinewoods, such as the Capercaillie (*Tetrao urugallis*), is affected by the gradual changes to habitat structure that occur over time. In some long established native pinewoods such as Glen Tanar and Abernethy, where grazing has been restricted over a long period, Blueberry *(Vaccinium myrtillus)* areas are becoming dominated by long rank heather to the detriment of woodland grouse species (R. Moss, pers. comm.). Burning areas has been shown to help blueberry regenerate and compete with heather (Welch et al. 1994).

One of the key factors in improving the Capercaillie population is to undertake measures to improve chick survival. One way of achieving this is by providing Capercaillie broods with a varied habitat structure that allows movement and provides shelter and contains a relatively high proportion of Blueberry (Summers et al., in press), which is important for the diet of Capercaillie in a number of ways. Firstly, it supports caterpillars and other insects that are an important food source for chicks shortly after hatching (Cramp and Simmons 1980, Kastadalen and Wegge 1985, Picozzi et al. 1999). Secondly, the leaves are eaten (Storch 1993, 1994) especially in the summer, and the berries are eaten in the autumn (Borchtchevski 1994).

Figure 1. Rank heather in a prepared prescribed burn plot in the Glen Tanar Pinewood

In the UK the traditional muirburn techniques that are used to manage heather habitats for Red Grouse are the most common use of fire (Bruce 2002). Muirburn is also used extensively to manage and 'improve' grazing land for cattle, sheep and deer in upland areas (Hamilton 2000). However there are considerable differences between the traditional techniques used for burning in the UK and prescribed burning operations found in other countries.

The management team at Glen Tanar Estate recognised that there were significant gaps in their knowledge of fire and have therefore been actively involved in fire research and the development of improved fire suppression systems over the past five years (SGFFPG 1999, Bruce 2002, Murgatroid 2002, Lantra 2002). In the spring of 2002 the agency Scottish Natural Heritage commissioned Glen Tanar Estate to carry out applied research into prescribed burning in the form of a series of burning trials. Similar trials were also undertaken by the Royal Society for the Protection of Birds (RSPB) at Abernethy Forest Reserve in 2002.

Objectives For Prescribed Burning Trials at Glen Tanar

- To investigate the relationships between fire behaviour and fire effects in a pinewood context
- To increase the proportion of Blueberry in the shrub-layer of the pinewood, by burning a number of strips of heather without damaging other parts of pinewood ecosystem.
- To inform the development of *fire prescriptions* appropriate for the Scottish pinewood context.

Figure 2. Photo Prescribed Fire on the Strone in the Glen Tanar pinewood

Planning the trial burns

The lack of information on prescribed burning techniques appropriate to pinewoods in Scotland led the team towards adapting prescribed burning concepts and experience from other countries with similar ecosystems. One of the key concepts emerging from this review was that conifers similar to Scots Pine suffered from fire-induced mortality as a result of three main processes (Reinhardt and Ryan 1988):

a) crown scorch
b) damage to the cambium layer at the bole of the tree
c) damage to the roots.

A fire prescription was prepared with these factors in mind and with the knowledge of some key fire behaviour variables. First, that there is an established relationship between flame length, fireline intensity and height of lethal crown scorch for conifers. As a rule-of-thumb fire is lethal to foliage at a ratio of 1:6 to flame length (AFAC 1996) and mortality is likely when the scorch is greater than 30 – 50% of the live crown. (Alexander M, personal comment). Second, it has been established that damage to the cambium layer diminishes in proportion to the thickness of bark protecting the tree, and

furthermore that bark thickness generally increases with tree age and DBH (Wade 1986). Third, it is accepted that water creates an effective thermal barrier, therefore roots in saturated soil are reasonably well protected from the heat pulse generated by a passing fire front (Chandler et al. 1983).

As has been mentioned previously a key objective was to kill the heather and Blueberry bushes but not damage the Blueberry rhizomes. Work in Swedish pinewoods by Schimmel and Grandstrom (1996) indicated that by controlling ***fire severity*** (which is defined as fire effects upon soil and litter layers) that this would be possible. Again the method that can be used to achieve this is to use the protective qualities of a damp moss and litter layer.

The design of fire prescriptions therefore incorporated the need for tall enough trees to avoid excessive crown scorch; large enough trees to have sufficient protective bark, and soils that were sufficiently damp to avoid excessive root damage. Sites were chosen with these features and Prescribed Burn Unit Plans and Operational Plans were developed for each site.

Methods

The burn plots were encircled by a double-width swiped trail, a further control line was burned in stages against the wind up to the swiped line, to a safe depth of at least two and a half times the estimated maximum flame length. The control lines were patrolled by teams using beaters and fire-fogging units to prevent any escapes. Fires were then ignited across the whole width of the plots, usually 20-25 metres wide, using a modified knapsack sprayer and were burned as headfires (i.e. burned with the wind) in short strips of 15 to 35 metres in length.

Site, Environmental and Fuel Conditions

Table 1 below summarises information collected during experimental fires conducted at two carefully selected sites on 27 and 28 March 2002. The sites were chosen to be representative of areas where prescribed burning might be most usefully employed to improve field layer Capercaillie habitat. Two plots were burned at each site, a smaller plot for the initial test run and then a larger plot after conditions had been fully assessed.

Results

As the table below shows the speed and intensity of the fires in Site 1 clearly demonstrated the combined effects of a continuous and very high available fuel load, along with fairly low fine fuel moisture content (70–85 % dw) and a relatively strong and persistent wind. Flame lengths in the backing fire and flank fires were generally lower than those in the head fire, being in the range 0.5 to 1.5 m. The maximum rate-of-spread was estimated to be around 1200 m/hr (see Table 1), which is four times greater than any rate of spread of moorland fires in Scotland, previously recorded (Hobbs and Gimingham 1984).

At Site 2 considerable difficulty was encountered in trying to burn the first plot, due to the unreliability of the light winds at the time., However, by mid-afternoon burning conditions had improved dramatically: windspeed had increased to 11–16 km/h and there was a drop in relative humidity from 62 % to 48 %, and bright sunshine with air temperatures up to 17°C. Burning proceeded with caution, the need for which was emphasised when flames spotted forward onto the top of two adjacent 8M standing dead trees (snags) just outside the plot's control line. The burning snag had to be felled and removed to the blackened area to prevent the fire escaping. Flame lengths in the headfire were generally within the range of 1-3 metres, although flares up to 4-5 metres were noted in areas of open canopy where the heather fuel load was greatest. In the backing and flanking fires, and in areas of broken heather and *Vaccinium*, flame lengths were much shorter (0.5 to 1.5m), with patches of pure Blueberry burning in places with 30-40 cm flames.

Table 1. Summary: Site conditions, weather, fuel quantity, and fuel moisture

	Site 1: Counseltree Burn (forest edge site)	**Site 2: The Strone (within-forest site)**
Site description:		
Altitude	380 m	340 m
Aspect	S.W. facing	S. – S.W. facing
Slope	5 – 10%	10%
Soil	Shallow, well-drained podsol on granite substrate	Moist peaty soil over granite, impeded drainage in places
Area	Plot 1: 25 x 60m (0.15 ha) Plot 2: 27 x 100m (0.27ha)	Plot 1: 23 x 44m (0.10 ha) Plot 2: 30 x 50m (0.15 ha)
Field Layer Vegetation	NVC H12b: *Calluna* - *Vaccinium* dry heath with scattered mature pine trees and limited pine regeneration	NVC W18b: Dry pine woodland with *Calluna* and *Vaccinium* dominated understorey, with occasional *Sphagnum* spp. and *Empetrum nigrum*.
Overstorey	None	Mature well-spaced Scots pine with an average dbh of 50.5 cm, average heights of 14-18m, average canopy base 6-10m and a density of around 160 trees per hectare.
Fuel Load	High: estimated 20.5 t/ha of 'available' fuel (<5mm diameter)	Moderate: estimated 11.8 t/ha of available fuel
Weather conditions:		
Average windspeeds	15 – 30 km/h	3 – 13 km/h
Max windspeeds	40 – 48 km/h occasionally	14 – 15 km/h
Relative humidity	65 – 70% throughout the day	62% (at 11 am) 48% (at 1 pm)
Fuel moisture content:		
Fine fuel %MC (dw)	70 –85%	83 – 94%
Moss/Litter % MC (dw)	287 % (at 10 am) 197 % (at 4 pm)	205% (at 10 am) 100% (at 4 pm)

Table 2. Summary of fire behaviour characteristics

	Site 1: Counseltree Burn (forest edge plots)	**Site 2: The Strone (understory – forest plots)**
Typical headfire flame lengths	3-4m, with flares up to 6-7m	0.5 – 3m, with flares up to 5m
Typical flank/backfire flame lengths	0.5 – 1.5m	0.5 – 1m
Forward rate of spread	500 – 1260 m/hr	150 – 385 m/hr
Fireline intensity*	6800 – 15400 kWm^{-3}	1150 – 3050 kWm^{-3}

* N.B. Fireline intensities were much higher than any previously recorded in Scotland and are at the upper limit for surface fires recorded in other countries (Chandler, 1983). In the Australian Fire Danger Rating system (AFAC, 1996) these fires would carry "very high" and "extreme" fire danger ratings.

Fire effects

Despite the relatively high fire intensity the fires at both sites largely succeeded in improving the condition of the field layer for woodland grouse. The majority of the rank heather was killed by the fire and is being succeeded by vigorous regeneration of *Vaccinium* spp., particularly in the woodland site where Blueberry has rapidly become the dominant component of the field layer. The majority of the dense moss layer was also killed off by the burning, and in some places was visibly consumed by the

fire. This is also likely to create slightly more favourable micro-sites for tree seedling establishment. However the main humus layer that hinders regeneration (Edwards 1980), remains.

Two weeks after the understorey burns at the Strone, a detailed examination was made of the fire effects within the plots. Individual trees within burned plots were mapped and examined closely for crown scorch, bole charring, and any other fire-related effects. A total of 12 and 28 trees were located and assessed within the plots, and a summary of the results can be seen in Figure 3 and Tables 3.

Over three-quarters of the trees examined suffered crown damage, in the form of needle-scorch, to varying extents. The crown scorch is seen to have affected foliage up to 16 m above the ground in places, with an average upper limit of 7-8 m above ground level. The average proportion of the entire crown that has been scorched is around 20-25%, but around 18% of the trees studied (7/40) have suffered crown scorch of 50% or more.

The amount of crown scorch seemed to relate closely to the flame length of the fires as they passed under the trees. This in turn was related to whether this was part of the headfire, flank fire or backfire and also depended upon the variability of fuel loading across the site.

The ultimate impact of this level of crown scorch on mature Scots Pine trees is not yet clear. The damage may accelerate mortality due to poorer nutrition through loss of foliage and increased susceptibility to insect and pathogen attack. However, studies upon red and white pine in North America have indicated that individual trees have a 50% chance of surviving a 75% loss of foliage (Methven, cited in Van Wagner, 1973). All trees, even those with more than 75% crown scorch, in the understorey burn plots on the Strone were still alive when inspected in August 2004.

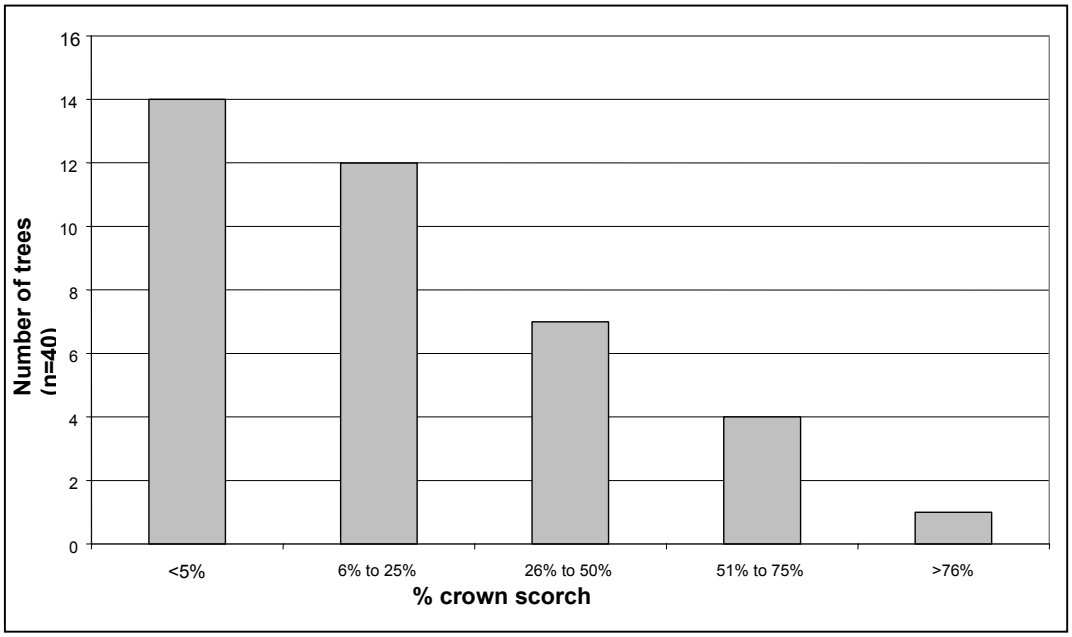

Figure 3. Number of trees within each crown scorch band

Almost all of the trees within the plots were affected by bole charring(see Table 3) however no specific data on cambial damage has been collected, and the contribution of this factor to tree mortality is difficult to determine. It is reasoned that cambial damage was minimised by selection of a stand of mature large diameter trees, with proportionally thick bark to provide thermal protection.

Table 3. Summary of bole charring and crown scorch resulting from experimental understorey burning trials within Scots Pine woodland (Site 1) at Glen Tanar Estate.

		Height of Bole Charring (m)		**Crown Scorch**	
		Lee side	**Windward side**	**Upper limit of crown scorch (m)**	**% of total crown affected**
Plot 1 (n=12)	Range	0 – 2.5m	0 – 1m	0 – 14m	0 – 60%
	Mean	1.1m	0.38m	8.17m	19.6%
Plot 2 (n=28)	Range	0 – 5m	0 – 1m	0 – 16m	0 – 81%
	Mean	2.2m	0.38m	7.0m	24.6%

The impact of the fire upon below ground processes is much more difficult to assess. However, it is envisaged that root damage was minimised by ensuring that burning took place at a time when the moss/litter layer was wet, thus providing a high degree of thermal insulation to the soil. The vigorous recovery of Blueberry from underground roots and stems (Figure 4) indicates that this strategy was successful.

Figure 4. Blueberry regeneration in understorey three months after fire

Figure 5. Vigorous Blueberry regeneration

Conclusions

- The project has shown that it is possible both in operational and ecological terms to use prescribed burning, even with high fire intensities, to successfully modify the shrub layer structure and composition to improve Capercaillie habitat within pinewood areas. The fires have achieved the primary objective of improving the environment for Blueberry, by removing competition from heather without damaging Blueberry rhizomes.

- The fire intensities were on average within prescription. Some damage has nonetheless been inflicted on the trees, largely caused by headfires. To minimise damage to the overstorey it will be necessary to restrict flame lengths. This could be achieved by:

    - Changing the ignition pattern to include more backfires, flank fires and narrow spot line ignition.
    - Burning when fuel moisture contents are higher.
    - Burning downhill.
    - Alternatively, burning could simply be concentrated at the forest edge and in canopy gaps.

- The very high fire intensities produced by these fires have highlighted the potential dangers of a wildfire occurring in rank heather, where flame lengths and fireline intensities can reach the top end of the spectrum for surface fires There is a need to give careful consideration to the hazards and risks created by such fires and the need to put in place effective control measures. These may include fire planning, training, sourcing of appropriate equipment, and the use of prescribed burning to reduce fuel loads and to create firebreaks.

- The successful use of prescribed fire to simulate natural disturbance events should stimulate a process of re-evaluating the range of potential benefits of prescribed fire in Scottish pinewoods, and should call into question fire policies that completely exclude the use of fire.

IFFN contribution by:

Michael Bruce
Glen Tanar Estate
Aboyne
Aberdeenshire
AB34 5EU
Scotland

e-mail: michael@glentanar.co.uk

and

Gary Servant
Lochaber Native Woodlands
1 Sycamore Cottages
Inchree
Fort William, PH33 6SG
Scotland

e-mail: gary@lochabernativewoodlands.co.uk

References

Aberdeen Journal. 5 July 1826.

Australian Fire Authorities Council (AFAC). 1996. Learning Manual 3.17 Prescribed Burning 1. Addison, Wesley and Longman.

Australian Fire Authorities Council (AFAC). 1996. Learning Manual 2.29 Wildfire Suppression 2. Addison, Wesley and Longman

Bruce, M. 2002. Country Report for the United Kingdom, International Forest Fire News No. 27, 68-76.

Borchtchevski, V.G. 1994. Diet of juvenile and adult capercaillie (*Tetrao urogallus*) in the western part of the Russia taiga. Gibier Faune Sauvage 11, 21-38.

Chandler, C., P. Cheney, P. Thomas, L. Trabaud, and D. Williams. 1983. Fire in Forestry. Volume 1: Fire Behaviour and Effects. John Wiley & Sons.

Cramp S., and K.E.L. Simmons. 1980. The birds of the Western Palearctic Vol. 2. Oxford Univ. Press, Oxford.

Edwards, I.D. 1980. The conservation of the Glen Tanar Native Pinewood, near Aboyne, Aberdeenshire. Aberdeen University (PhD thesis).

Goldammer, J.G., V.V. Furyaev. 1996. Fire in ecosystems of boreal Eurasia: Ecological impacts and links to the global system. In: Fire in Ecosystems of Boreal Eurasia (J.G. Goldammer and V.V. Furyaev, eds.), 1-20. Kluwer Academic Publishers, Netherlands.

Hamilton, A. 2000. The characteristics and effects of management fire on blanket-bog vegetation in north-west Scotland, University of Edinburgh (PhD Thesis).

Hobbs, R.J., and C.H. Gimingham. 1984. Studies on fire in Scottish heathland communities. J. Ecology 72, 223-240.

Kastdalen, L., and P. Wegge. 1985. Animal food in capercaillie and black grouse chicks in south east Norway - a preliminary report. International Grouse Symposium 3, 499-513.

Lantra, 2002. Forest and Moorland Fire Fighting Level 2 and 3: National Occupational Standards, Lantra Sector Skills Council.

Lantra. 2002. Heather Burning Level 2 and 3: National Occupational Standards, Lantra Sector Skills Council

Marren, P. (ed.). 1986. Glen Tanar: Its human and natural history. Nature Conservancy Council.

Miller H., and I. Ross I. 1990. Management and silviculture of the forests of Deeside, Conf. Proc. Ed. Gordon P.,Silvicultural Systems, Institute of Chartered Foresters.

Murgatroid, I. 2002. Forest and Moorland Fire Suppression, Technical Note 3, Forestry Commission

Peterken, G.F. 1996. Natural woodland. Cambridge University Press.

Picozzi, N., R. Moss, and K. Kortland. 1999. Diet and survival of capercaillie *Tetrao urogallus* chicks in Scotland. Wildlife Biology 5, 11-23.

Reinhardt, E.D., and K.C. Ryan. 1988. How to estimate tree mortality resulting from underburning, Fire Management Notes, USDA.

Schimmel, J., and A. Granstrom. 1996. Fire severity and vegetation response in the boreal forest. J. Ecology 77, 1436-1450.

South Grampian Forest Fire Protection Group (SGFFPG). 1999. Standard Operating Procedures (unpub.)

Spidsø, T.K., and O.H. Stuen. 1988. Food selection by capercaillie chicks in southern Norway. Can. J. Zool. 66, 279-283

Steven, H.M., and A. Carlisle. 1959. The native pinewoods of Scotland. Oliver and Boyd, Edinburgh.

Storch, I. 1993. Habitat selection by capercaillie in summer and autumn: is bilberry important? Oecologia 95, 257-265.

Storch, I. 1994. Habitat and survival of capercaillie *Tetrao urogallus* nests and broods in the Bavarian Alps. Biol. Conserv. 70, 237-243.

Summers, R.W., R. Proctor, R.A. Mavor, and G. Avey. 2004. Habitat selection and diet of capercaillie *Tetrao urogallus* in Abernethy Forest, Strathspey, Scotland (in prep.).

Van Wagner, C.E. 1973. Height of crown scorch in forest fires. Canadian J. Forest Res. 3, 373-378.

Wade, D. 1986. Linking fire behaviour to its effects on living plant tissue. Conference Paper, Society of American Foresters.

Welch, D., D. Scott, R. Moss, and N. Bayfield. 1994. Ecology of blaeberry (blueberry) and its management in British moorlands.