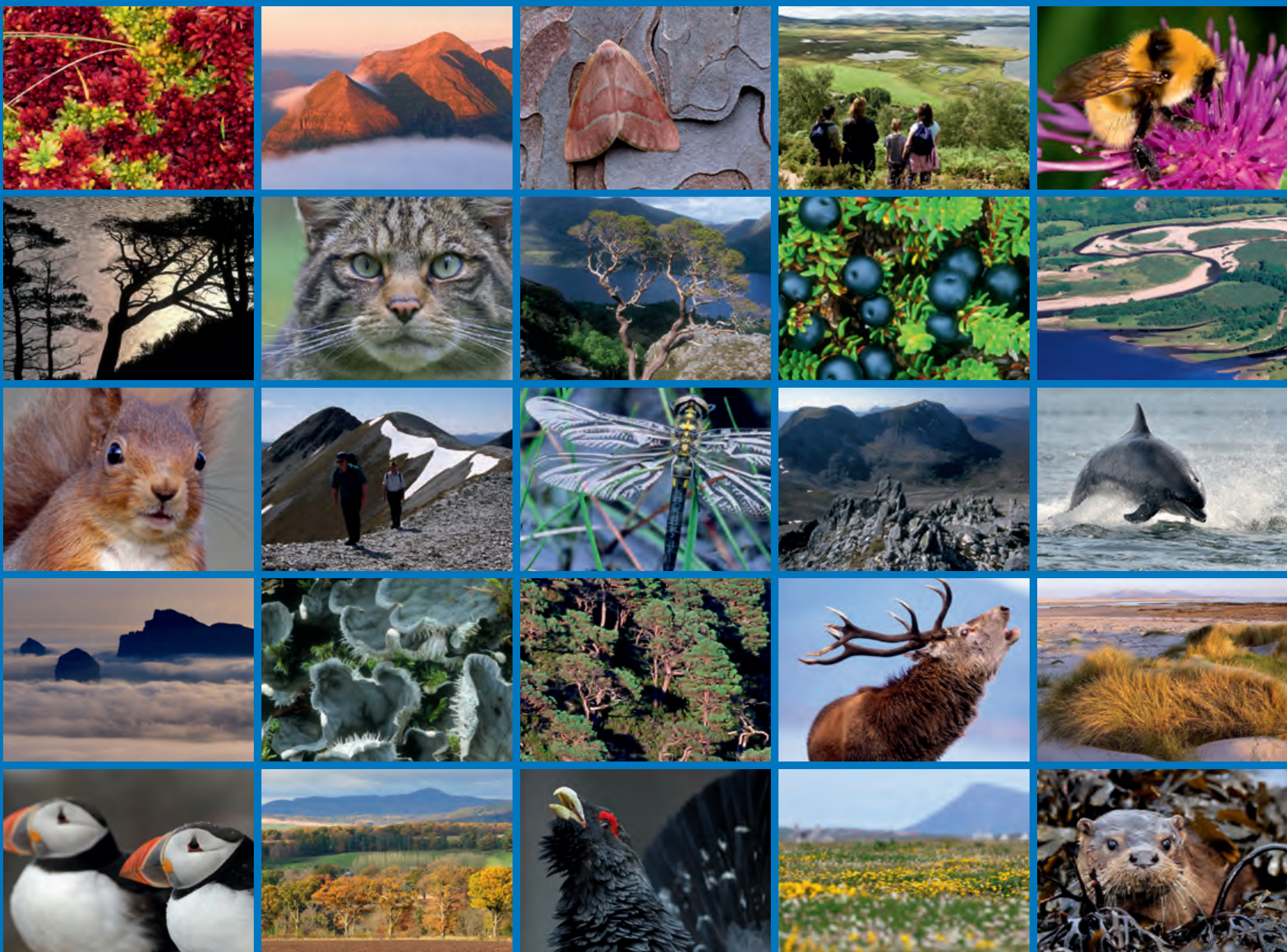
Scottish Natural Heritage
Commissioned Report No. 613

The Scottish Beaver Trial: Woodland monitoring 2012



COMMISSIONED REPORT

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Summary

The Scottish Beaver Trial: Woodland monitoring 2012

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Keywords

Eurasian beaver; Knapdale; Scottish Beaver Trial; browsing in woodland; woodland regeneration; woodland monitoring.

Background

In 2008, the Scottish Government approved a licence to the Scottish Wildlife Trust (SWT) and the Royal Zoological Society of Scotland (RZSS), to undertake a five-year trial reintroduction of the European beaver (*Castor fiber*) to Scotland after an absence of more than 400 years. In May 2009, three beaver family groups were introduced to Loch Coille-Bharr, Loch Linne/Loch Fidhle and Creagmhor Loch/Un-named Loch (North) on land managed by Forest Enterprise Scotland (FES) at Knapdale, Argyll. Since 2009, additional releases have also taken place, and by November 2010, beaver groups were established in these three lochs and Lochan Buic. This is the fourth annual report that describes the effects of beavers on riparian woodland at Knapdale, and summarises effects observed up until November 2012. In this report we attempt to identify trends that are emerging with increasing time since the trial reintroduction process began.

Main findings

- 31 transects each comprising up to four permanent (4m×10m) vegetation plots were established between the water's edge and 30m from the water's edge, on five lochs at Knapdale.
- Of the initial total of 111 plots, two have since been completely excluded from monitoring, another is no longer monitored for ground vegetation and the effects on trees are no longer monitored in a fourth. There are thus 108 sampling plots for each of the sets of measurements. Two plots became inaccessible due to beaver-induced flooding, and a further two were affected by road-widening for forestry purposes. A total of 4,452 tree stems have been individually marked, along with 139 marked logs or natural stumps. Any beaver-induced changes are being monitored on these marked trees and logs.
- Downy birch was the dominant tree species on most plots, although alder, hazel, ash, rowan and willow also occurred as co-dominants or dominants with restricted distributions.
- In November 2012, 42 months after their release, beavers had directly affected trees in 48 (44.4%) out of the 108 continuously monitored vegetation plots. Of the individual trees marked in all plots, 15.7% had been gnawed or felled.
- Plots used by beavers included more birch and willow, but less alder, than an average plot.

- Although the beaver effects on trees recorded during the first year of the trial were mainly within 10m of the water's edge, at November 2012, any trees newly affected by beavers were distributed quite evenly in relation to the distance of the plots from the water.
- There has been a slight decrease in the mean stem diameter of trees affected by beavers from 5.53cm in November 2010 to 5.18cm in November 2011 and to 4.98cm by November 2012.
- A comparison of the tree species used by beavers with their abundance indicates that willow and rowan are preferred species whereas alder and hazel tend to be avoided. Birch is both the most abundant species and the species most often used by beavers, but is used at a frequency commensurate with its abundance. There have been no detectable changes in beaver tree species preferences.
- The degree of browsing, its characteristics and any subsequent re-sprouting of beaver-cut stumps, are all important for the long-term dynamics and sustainability of the beaver interaction with woodland. An initial flush of re-sprouting from the stumps of trees that had been directly affected by beavers has now declined. Of those stumps affected by beavers in 2010, 56% had re-sprouting shoots, but by 2011 this had fallen to 42% of stumps that had been affected previously; only 26% of trees affected by beavers up to 2012, had re-sprouted shoots at the time of survey. However, despite initial mortality of the re-sprouting shoots, the shoots that remained in 2012 were longer than previously, suggesting good growth of survivors.
- The most vigorous re-sprouting was observed on ash and willow; poorer re-sprouting was observed on birch, hazel and rowan and very poor re-sprouting was observed on alder, although this latter species is rarely affected by beavers.
- In general the trees, except for birch and rowan, appear to be more affected by beavers in the summer months (April – October) than in the winter months (November – March).

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This project is part of the independent monitoring programme for the Scottish Beaver Trial coordinated by SNH in collaboration with a number of independent monitoring partners. For further information go to:
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Acknowledgements

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1. BACKGROUND

1.1 Overall background to the trial release of beavers

The European beaver, *Castor fiber*, became extinct in Scotland by the end of the 16th century as a result of hunting combined with habitat loss (Kitchener and Conroy, 1997). Over recent years the potential for restoring this species to the natural fauna has been investigated. These investigations have resulted in a suite of information about the scientific feasibility and desirability of conducting such a reintroduction. Relevant documents published by Scottish Natural Heritage (SNH) can be viewed at the 'Other work on beavers' page at:
http://www.snh.gov.uk/protecting-scotlands-nature/safeguarding-biodiversity/reintroducing-native-species/scottish-beaver-trial/other-work-on-beavers/

Article 22 of the European Council Directive 92/43/EEC *on the Conservation of Natural Habitats and of Wild Flora and Fauna* (the 'Habitats Directive') requires the UK government to consider the desirability of reintroducing certain species (listed on Annex IV), including European beaver.

The Species Action Framework, launched in 2007 by Scottish Ministers, sets out a strategic approach to species management in Scotland. In addition, 32 species, including the European beaver, were identified as the focus of new management action for five years from 2007. SNH works with a range of partners in developing this work and further information can be found at:
http://www.snh.gov.uk/protecting-scotlands-nature/species-action-framework/

In May 2008, the Minister for Environment approved a licence to allow a trial reintroduction of up to four families of European beaver to Knapdale Forest, mid-Argyll. The licence was granted to the Scottish Wildlife Trust (SWT) and the Royal Zoological Society of Scotland (RZSS), who are working on behalf of the 'Scottish Beaver Trial' partnership. The trial site, Knapdale Forest in Argyll, is managed by Forest Enterprise Scotland (FES). Animals were caught in Norway in 2008, quarantined for six months and released in spring 2009. The initial release sites were Loch Coille-Bharr, Loch Linne/ Loch Fidhle and Creagmhor Loch/ Un-named Loch (North) (also known as Loch Beag), immediately to the west of Creagmhor Loch. Further releases took place during 2010 at Lochan Buic/Un-named Loch (South).

One condition of the licence is that SNH coordinates an independently conducted monitoring programme in collaboration with the project partners. The trial will therefore involve a number of independent monitoring sub-projects in order to address the primary aims, and at the end of the trial the outputs of the monitoring will be assessed and a decision made by Scottish Government on the next stage. This is a progress report on the woodland monitoring sub-project, which is being conducted by The James Hutton Institute (formerly Macaulay Land Use Research Institute) in partnership with Scottish Natural Heritage.

1.2 Summary of likely beaver impacts on woodland

Beavers are ecosystem engineers and can produce both direct and indirect effects upon woodlands. The most obvious direct effect is felling of trees. In other parts of their range, particularly during autumn and winter, beavers gnaw and fell trees for food and to obtain timber for the construction of lodges and dams. In the short term at least, tree felling can reduce the biomass of standing, living trees and change the age and size structure of woodlands. Longer-term changes may involve a shift in tree species composition. Many riparian tree species in Europe and North America evolved in the presence of beavers and other browsing herbivores and, given suitable conditions, respond to browsing of woody stems by producing abundant new growth. This can lead to the development of denser stands of woody vegetation producing abundant foliage, which can offer a valuable food resource not only to beavers but also to browsing ungulates and herbivorous insects (Jones *et al.* 2009). However, the recovery of vegetation from beaver browsing and felling will be dependent upon the interaction of new shoots with subsequent browsing by both beavers and sympatric ungulate browsers (Hood and Bayley, 2009). Some woody species may also respond to browsing by altering the nutritional and anti-herbivore defensive chemistry of new growth, which can alter the food quality of this plant material for herbivores, sometimes in unpredictable ways (Veraart *et al.* 2006).

Because plant species differ in their tolerance of browsing and their competitive abilities, as well as their palatability to herbivores, sustained browsing of riparian woodlands by beavers may also alter their floristic composition. As well as herbivorous animals, human interests can also be influenced by changes in the structure and floristic composition of riparian woodlands: the appearance of loch and river shores can change, with significant aesthetic consequences, and access to the water from land may be hindered or facilitated. If shading at ground level changes then this may influence water temperatures, particularly in smaller watercourses, which in turn might affect the reproduction and survival of commercially and recreationally valuable fish species.

Many internationally important species of lichen rely on a continuity of old tree stems in open woodland. By maintaining a cycle of felling and re-growth, beaver activity may result in a loss of this habitat in riparian zones, or at least suppress future development of such habitat.

The most obvious indirect effect of beaver activity on lochside woodlands is flooding caused by beaver dams. Beavers build dams to raise the water level of lochs and watercourses but also to expand their potential foraging area into inundated woodlands and other habitats. Most tree species are intolerant of sustained flooding, and so flooding can increase the amount of standing dead timber but possibly also favour flood-tolerant species such as willows.

2. AIMS AND OBJECTIVES

The overall aim of this work is to monitor the effect of the introduced beavers on woodland in the area of the trial release, in order to inform any future decisions and plans for the species in Scotland.

The objectives of this monitoring work are to:

1. Carry out a sample-based assessment of the composition and structure of the loch-side woodlands around the beaver release site;
2. Assess the nature and extent of beaver effects on the loch-side woodlands, again based on a representative sample of survey plots;
3. Assess seasonal variation in the effect of beavers on woody vegetation.

In addition to these objectives, we will ultimately identify any changes in the nature of the beavers' effects on the woodland that become apparent during the course of the monitoring program from 2009-2014. It is particularly relevant to identify temporal shifts in:

i) The nature of foraging activity and impact as compared to that observed immediately after colonisation (i.e. changing preferences for tree species and size classes within locations.
ii) The spatial location of impacts
iii) The appearance of and use of sprouts from previously beaver-affected trees by beavers and other herbivores.

This report covers the monitoring of beaver effects on woodlands undertaken at two sampling times (April 2012 and November 2012), and quantifies the effects of beavers since the previous monitoring visit in November 2011 (Moore *et al.* 2013), up to a point 42 months after the release of beavers. Where possible, comparisons will be drawn between recent beaver effects and those observed during previous monitoring periods. Most comparisons are made between the results in November 2012, November 2011 (Moore et al. 2013) and November 2010 (Moore *et al*. 2011), which were collected on a common standardised set of plots which was sampled on all occasions.

It is not intended to try to assess the effect of beavers on the woodland ground flora or on epiphytic species. It is likely that the presence of beavers will affect these species – either directly through grazing or indirectly through changing the woodland structure – but confidently demonstrating such an effect was considered to be extremely difficult or impossible and would have demanded greater resources than were available. Much of the loch-side vegetation in the trial area had been managed prior to the reintroduction to improve the habitat in preparation for the trial beaver release. As a result, the ground flora was already developing in response to this management. Distinguishing any change which may result from beaver activity from this background change is likely to be extremely challenging – especially over such a short period as five years.

3. METHODS

3.1 Site description and beaver releases

The loch-side and riparian woodland at Knapdale has been described by Armstrong *et al.* (2004) (Loch Linne and Loch Fidhle) and Brandon-Jones *et al.* (2005) (all loch-side and riparian woodland within the FES land at Knapdale). Most of the release sites (excluding Lochan Buic and Un-named Loch (South)) lie within the Taynish and Knapdale Woods Special Area of Conservation (SAC, EU code UK0012682), which comprises 44% broadleaf woodland as well as water bodies, extensive conifer plantations and smaller areas of bogs, marshes, water-fringed vegetation, fens, heath and scrub. One main reason for the designation of the area as an SAC is the presence of old sessile oak (*Quercus petraea*) woods with holly *(Ilex aquifolium)* and hard fern *(Blechnum spicant)*. In the years leading up to the Scottish Beaver Trial, extensive areas of conifer plantation have been cleared from Knapdale, particularly near the lochs, and in most places, dense downy birch (*Betula pubsecens*) regrowth has taken their place.

A decision was taken to restrict woodland monitoring with permanent plots to the strip of woodland within 30 m of loch shores, as it was anticipated, based on other studies of *C. fiber*, that most beaver effects would occur in this zone (Haarberg & Rosell 2006). Most woodlands in this zone at Knapdale are dominated by mature and regenerating birch and common alder (A*lnus glutinosa*). In many areas, willow species, particularly goat willow (*Salix caprea*) are abundant and rowan (*Sorbus aucuparia*) is widespread throughout the area, both as mature and sapling trees. Hazel (*Corylus avellana*) and ash (*Fraxinus excelsior*) are also common in some areas around the loch shores. Aspen (*Populus tremula*) is highly favoured by European beavers elsewhere, but is very rare at Knapdale and only occurs on rocky terrain, where it would be largely inaccessible to beavers. Sessile oak is common and widespread at Knapdale, but within 30 m of the water it is limited to steep, often rocky terrain where the shore is precipitous and unsuitable for beavers.

Three family groups, comprising eleven beavers, were released at Knapdale in late May 2009. One group was released in each of Loch Coille-Bharr (four animals), Loch Linne/Loch Fidhle (four animals; these lochs are continuous with one another) and Creagmhor Loch (three animals). Beavers were released into artificial straw bale lodges situated in areas that were expected to provide suitable browsing habitat nearby and minimise the likelihood of disturbance to the animals. These artificial lodges were located at the southern ends of Loch Coille-Bharr and Creagmhor Loch and on the island in Loch Linne/Fidhle. Subsequently, one Loch Linne beaver died, and all three beavers disappeared from Creagmhor Loch, although the adult male was subsequently recaptured and returned to the site. Prior to April 2010, the male at Creagmhor Loch was removed on welfare grounds because of ill health, and subsequently died at Edinburgh Zoo. By this time, the family from Loch Coille-Bharr had established themselves in a lodge on the eastern shore of the small Dubh Loch to the east of Loch Coille-Bharr. These animals had also dammed the point where Dubh Loch naturally drains to Loch Collie-Bharr, flooding the surrounding broadleaf woodland and significantly expanding the area of Dubh Loch.

To reach the trial's aims of having established four pairs of beavers at Knapdale, two new pairs were released in 2010: in May one pair was released onto the Un-named Loch (South) (British National Grid coordinates NR 78908 88570) just to the south of Lochan Buic, also called Lily Loch. This loch lies out-with the Taynish and Knapdale SAC but within the Forest Enterprise Scotland land-holding. In June 2010 a further pair was released onto Creagmhor Loch. The male from the Un-named Loch (South) pair died a few days later and the female moved herself to the nearby Lochan Buic. Another male beaver was released into that loch in September 2010. In anticipation of the 2010 releases, a number of additional monitoring transects were established around Un-named Loch (South) and Lochan Buic in April 2010, but no new sampling areas have been established since (see 3.2.1 below).

As at November 2010, there were beaver pairs/families established on four loch complexes at Knapdale: Loch Coille-Bharr/Dubh Loch, Loch Linne/Loch Fidhle, Creagmhor Loch/Un-named Loch (North) and Lochan Buic/Un-named Loch (South). The first two families each successfully produced at least one kit in 2010. These same families have also produced a further kit each during the summer of 2011, although only that produced by the Loch Linne/Loch Fidhle pair has survived. During the summer of 2011 the pair of non-breeding beavers on Creagmhor Loch built a further lodge at the south-eastern end of the small loch to the west of Creagmhor Loch; this Un-named Loch (North) is now known as Loch Beag (Figure 1). In the summer of 2012 the pairs/families at Loch Linne/Loch Fidhle and Lochan Buic/Un-named Loch (South) produced one kit each and remarkably the pair at Loch Coille-Bharr/Dubh Loch produced three kits. The only kit known to have definitely survived is that at Lochan Buic/Un-named Loch (South); the kit born at Loch Linne/Loch Fidhle has been found dead and the three born at Loch Coille-Bharr/Dubh Loch have not been seen since autumn 2012.

3.2 Field methods

3.2.1 Location of transects

Field sampling of the vegetation in the broad area designated for beaver release could not feasibly be established prior to the release, since their range locations or sizes could not be predicted. Seventeen transects, each comprising from one to four plots, with 65 plots in total, were established at Knapdale in November 2009 (Moore *et al.* 2010). Those transects were positioned, radiating perpendicularly from the water's edge, around all lochs known to have been used by beavers at that time, so that all shores, other than those considered to be too steep to be readily accessible by beavers, were included. By November 2009, the lack of beaver field signs suggested that some of these areas were yet to be visited by beavers. To increase the likelihood that a reasonable number of transects would subsequently be visited by beavers, and to provide the opportunity to monitor their local effects, the choice of locations of further transects was guided by the position of active beaver lodges and the distribution of existing signs of beaver herbivory. A further 13 transects (43 plots) were established in April 2010, and one further transect (3 plots) established in November 2010, making a total of 111 plots across 31 transects. Most transects established in 2010 were positioned to monitor the impact of the newly released beavers at Un-named Loch (South)/Lochan Buic. Two of the 111 plots, including a single plot transect, have since been accidentally destroyed or otherwise affected by human road-building activity, and two more have been flooded due to the activity of beavers. These losses (specified by plot in Appendix 4), have led to the reduction of the number of plots such that the sampling of impacts on trees and on ground vegetation characteristics is now reduced to 108 plots, although not precisely the same 108 plots for both tree and vegetation monitoring. The 108 tree monitoring plots contained a total of 4454 marked stems and 139 marked logs or natural stumps (Appendix 2). Plot locations are indicated in Figures 1 and 2.

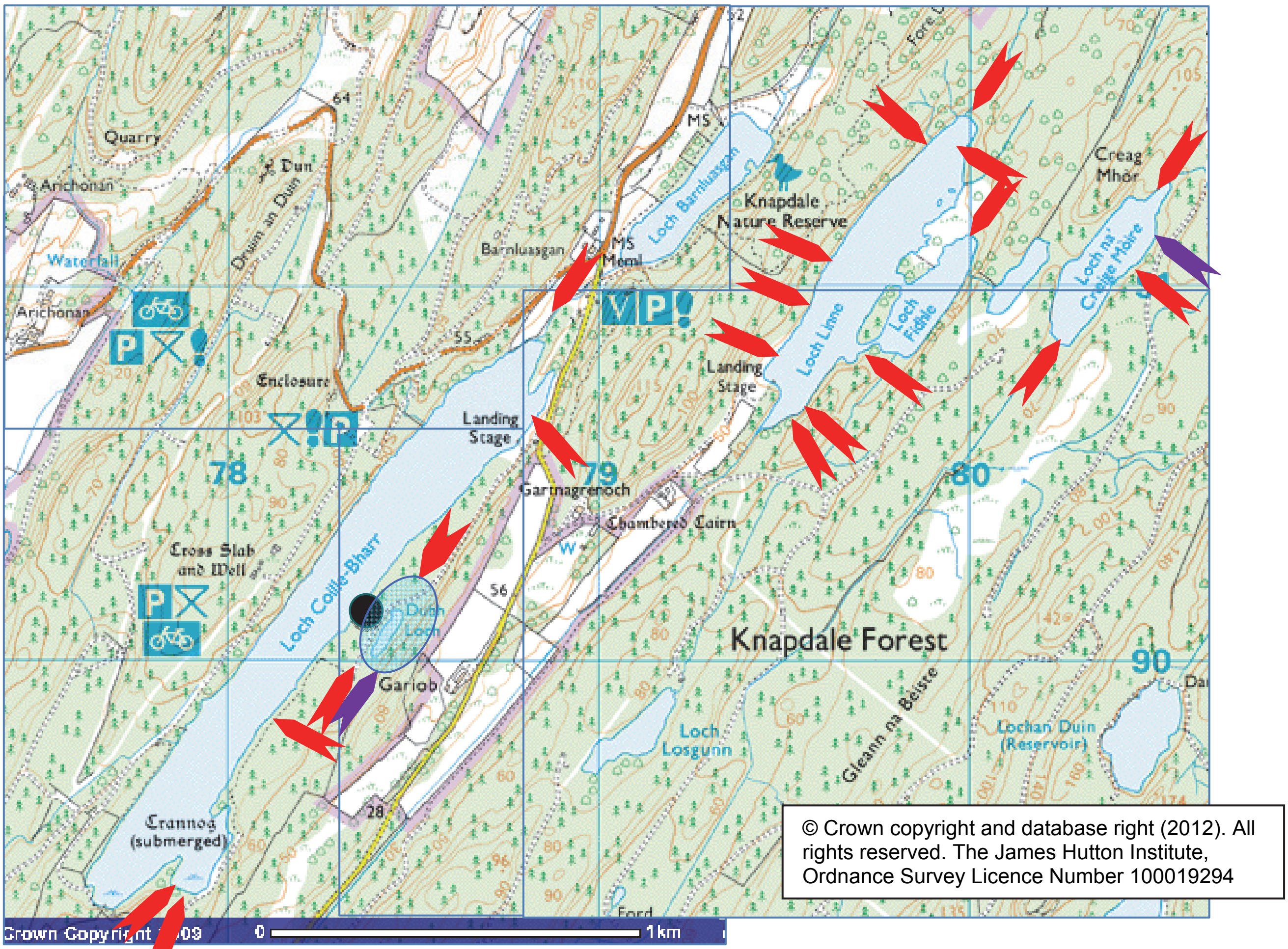


Figure 1. Locations of monitoring transects (red arrows) around Loch Coille-Bharr/Dubh Loch, Loch Linne/Loch Fidhle and Creagmhor Loch/Un-named Loch (North) in November 2012.The excluded transect is shown as a black dot and the two transects with excluded plots are shown in purple. No further sampling plots have been added since November 2010.

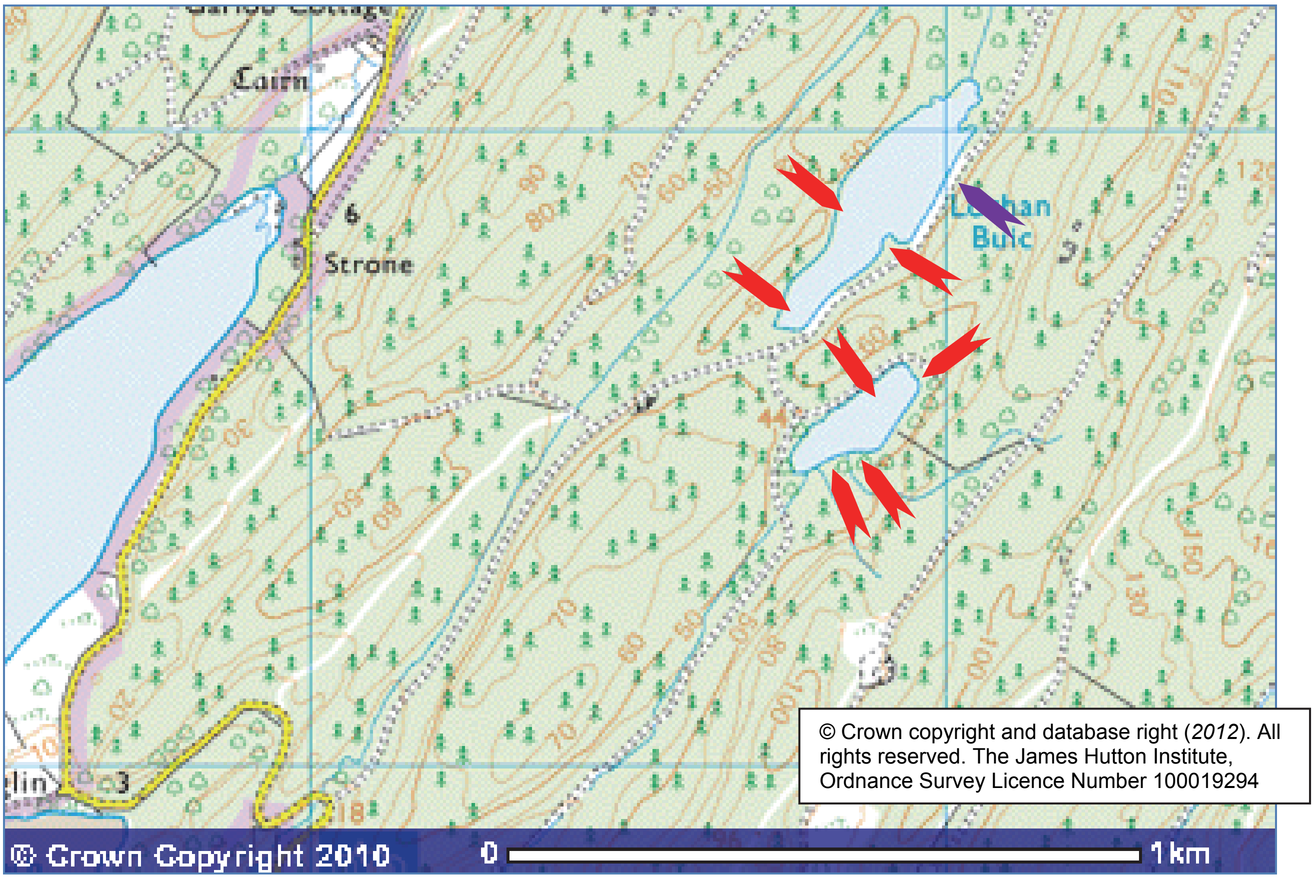


Figure 2. Locations of monitoring transects around Lochan Buic/Un-named Loch (South) in November 2012.See text for explanation of symbols. The transect with excluded plots is shown in purple.

Complete transects extend perpendicularly from the water's edge for 30 m (Figures 3a and 3b). In most cases, four rectangular plots are positioned along each transect, each 10 m long (along the side parallel to the water's edge) and 4 m wide (along the side parallel to the transect and perpendicular to the water's edge). Plots are placed along the transect from 0 – 4 m, 6 – 10 m, 16 – 20 m and 26 – 30 m from the water. All four corners of each plot are marked with permanent wooden posts, and one post is marked with a numbered aluminium tag (at point A, Figure 4). The geographic coordinates of each plot are also recorded at this point using a global positioning system (GPS). Where the loch shore is indented or projects into the loch beyond a straight line along the edge of the first plot, all land and trees up to the water's edge is considered to be part of the plot, and if necessary the position of the plot is adjusted such that its total area remains 40 m^2 (e.g. Figure 4). In sites where the woodland is flooded, it is not always possible to access, or to identify the edge of the loch. In these instances, the transect is started at the closest point to the water body that allows safe working.

On some sections of loch shore, deciduous broadleaf woodland extends for less than 30 m from the water before conifer plantations, paths, roads or inaccessible terrain are encountered. In these cases, transects included fewer than four plots. Where transects crossed small paths, it was occasionally necessary to shift a plot one or two metres towards or away from the water.

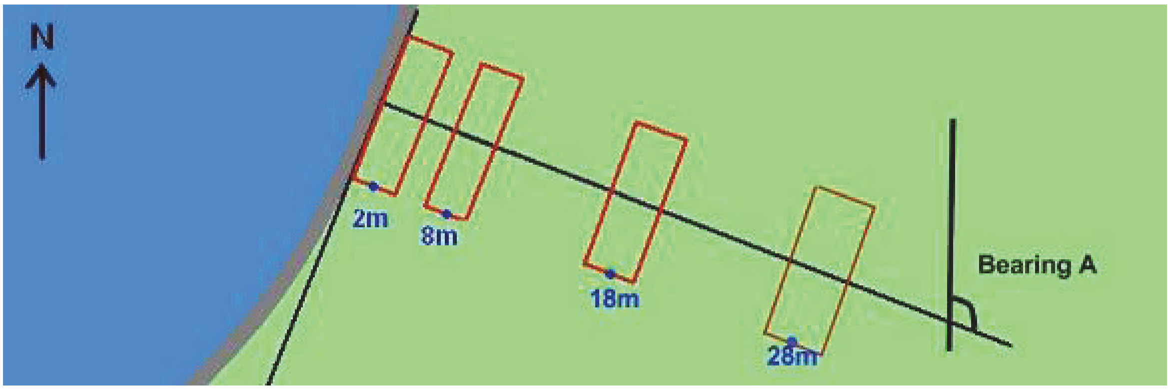


Figure 3a. Schematic illustration of the arrangement of survey plots (red rectangles) along a transect, relative to a nearby loch (blue shading). Blue text indicates the distance of the midpoint of each plot from the water's edge. (Not to scale).

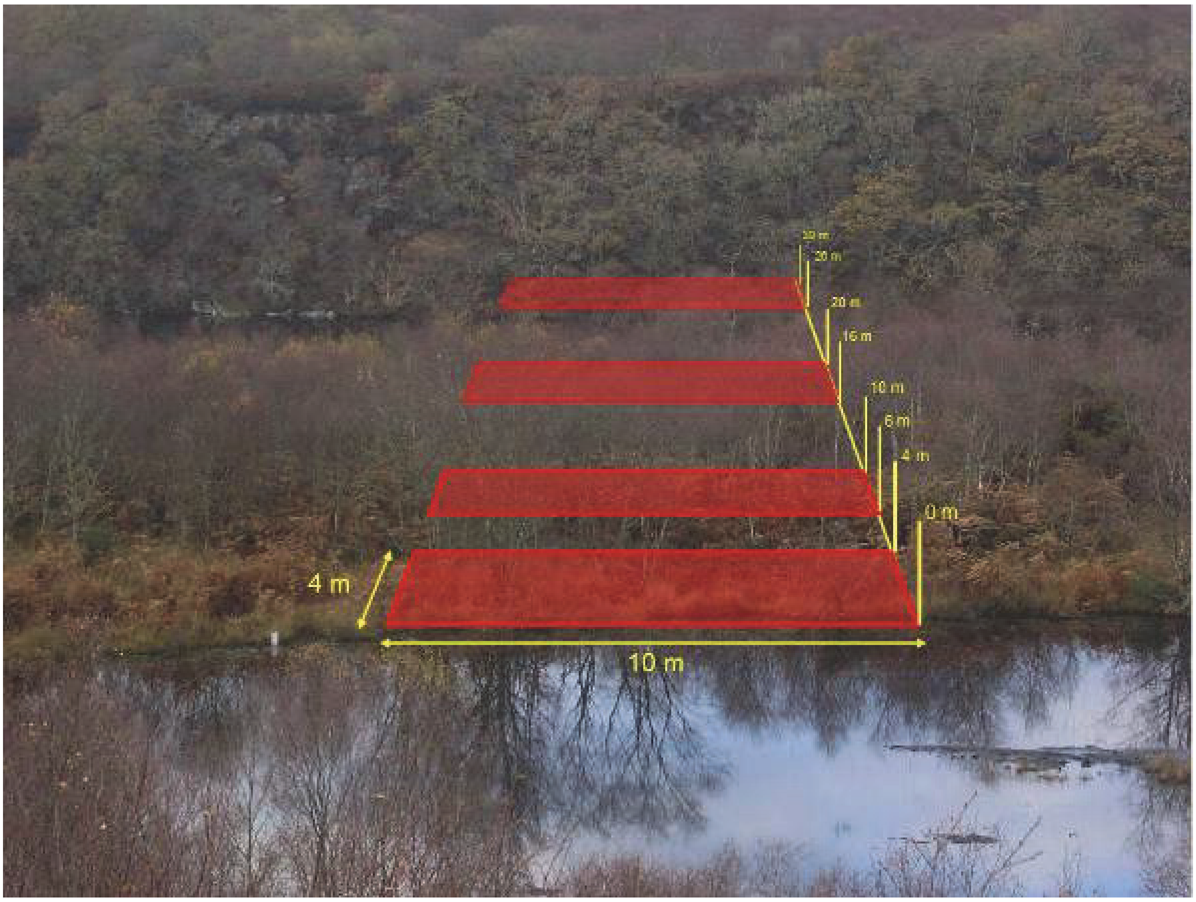


Figure 3b. Photograph showing a typical monitoring transect.

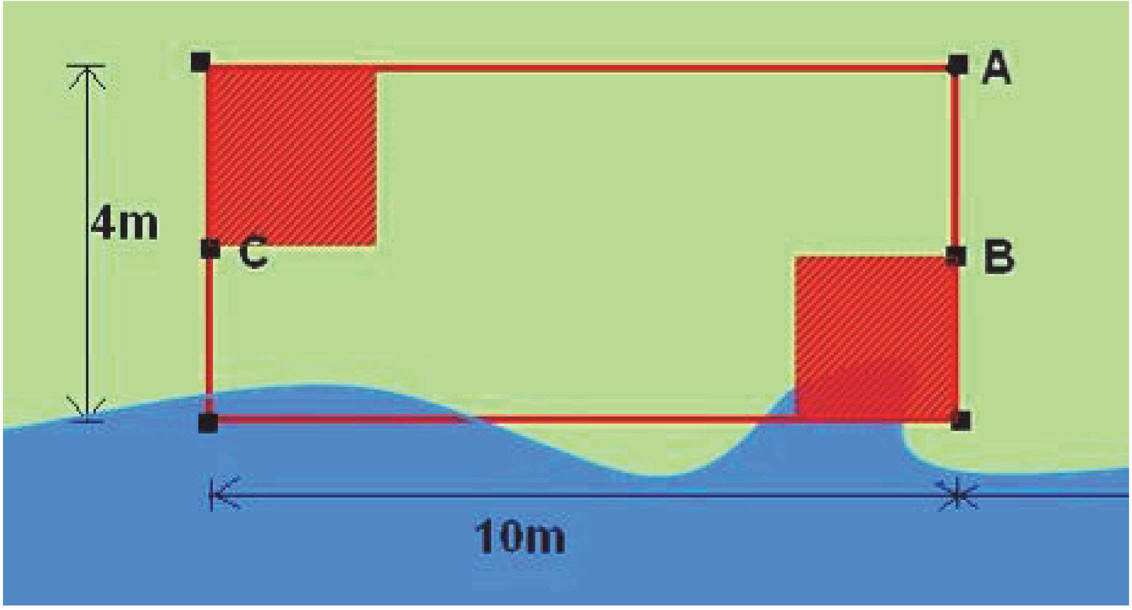


Figure 4. Dimensions of permanent vegetation plot, position of subplots for ground cover description within the plot (solid red squares) and several point locations referred to in the text.

3.2.2 Plot measurements

Each plot was delineated with a line extended around its four corner posts while observers were on site. The slope of each plot, from its lowest to highest point, was measured using a clinometer, and where this was greater than zero, the aspect of the slope was also measured using a compass. Percentage vertical canopy cover and ground surface area covered by standing water were estimated to the nearest 5 % and recorded for each plot. Several measurements were taken from a point midway along the right hand side of the plot when viewed from the waterside (point B, Figure 4). Percentage horizontal vegetation density was measured across the plot from point B by estimating the percentage area obscured of a 50 cm × 50 cm white board held by an assistant facing the observer from point C (Figure 4). This was repeated with both the board and the observer's eyes at four different levels above the ground: 0 – 50 cm, 50 – 100 cm, 100 – 150 cm and 150 – 200 cm. At each visit, in each plot, one photograph was taken from point B, facing across the plot towards point C, with a camera supported 1.6 m above the ground by a monopod. The camera used was a Nikon Coolpix 5400, with its zoom set to the widest lens angle possible (28 mm). All photographs are archived at The James Hutton Institute and will form a sequence of photographs describing visual changes to the plots over the course of the Scottish Beaver Trial.

3.2.3 Subplot measurements of ground cover

Ground cover was described in two subplots within each plot. Subplots measured 2 m × 2 m and were positioned in the front right-hand corner and back left-hand corner of the plot (when facing the plot from the water) as illustrated in Figure 4. For each plot, percentage cover of the following was estimated to the nearest 5 %:

- standing water
- rock
- bare earth or mud
- grasses, sedges or rushes

- leaf litter
- woody litter (from small twigs to logs)
- ferns (including browned-off bracken)
- bryophytes
- dwarf shrubs (primarily *Calluna vulgaris, Myrica gale* and *Vaccinium* spp.)
- herbs

Because litter, for example, could overlie an area of grass which might overlap a layer of moss, the sum of all estimates in a plot was allowed to exceed 100 %. Tree seedlings less than 1.3 m in height were also counted in each subplot.

3.2.4 Measurements of woodland and beaver effects

All trees greater than 1.3 m in height, regardless of stem diameter, were marked and recorded in each plot, along with stumps and fallen timber from trees which would originally have met this criterion. Working from one end of the plot to the other, each stem or, in the case of easily grouped clumps of smaller stems of a single species, each clump of stems, was permanently marked with a uniquely numbered aluminium tag. Tags were affixed as close to the ground as possible, using either a small aluminium nail or, for some smaller stems, a length of wire encircling the stem. For each stem, stump or group of stems, an observer recorded the species; measured the diameter at a height of 20 cm (or lower if a bifurcation occurred at 20 cm or if beavers had severed the stem below 20 cm) using callipers, recorded whether the stem or stump was alive, dead or indeterminate, and assigned the stem(s) to one of 13 status categories:

1. Upright tree, unaffected by beaver gnawing, NB trees need not be vertical to qualify, some ‘upright trees’ are inclined at angles as low as 10 degrees from the ground (Up)
2. Stump of a tree felled by beavers (BStump)
3. Upright stems growing from a log or horizontal tree trunk previously felled by beavers (LogUp)
4. The base of a multi-stemmed tree, above which one or more of the multiple stems have been affected by beavers (Base)
5. Tree partially felled by beavers i.e. the xylem has been incompletely severed, some phloem remains continuous between the stump and the upper part of the tree, but the upper part of the tree has fallen over and is resting on the ground or on other trees (BP)
6. Naturally fallen log (NLog)
7. Upright tree gnawed by beavers; this included trees with a single bite-mark through to trees that are near toppling (BUp)
8. Large log felled by beavers (BLog)
9. Natural’ tree stump – resulting from windfall or decay, but also including stumps sawn by humans (NStump)
10. Trees that have been pushed over by part of a beaver felled or partially felled tree. (Bent)
11. Site on a tree where a minor branch has been removed by beavers, typically overhanging the water (BCut)
12. Naturally partially fallen tree (NP)
13. Trees that had previously been tagged but which could not be found on subsequent visits (Gone).

See Appendix 1 for examples of categories.

In a number of cases, trees branched at a point closer to the ground than the height at which stem diameters were measured (20 cm); in these cases diameters were recorded for all stems at that height. Instances were also observed where trees branched at a point higher than 20 cm, but beavers severed the branched stems above the branching point. In those cases, in addition to the 20 cm diameter, observers also measured the diameter where the stem was severed by beavers, and recorded this hierarchy of branching (see Appendix 1 for details). In some instances, secondary and even tertiary branching events were recorded below beaver gnawing.

Some tree stems and logs were leaning, either naturally, or because they had been incompletely gnawed and partially felled by beavers, or because they had been completely severed by beavers but were still supported above the ground by surrounding vegetation. The angle these stems made with the ground was recorded. From trees and stumps that had been gnawed by beavers, observers recorded the percentage of the circumference of the stem that had been gnawed. In the case of stumps of trees felled by beavers, this was almost always 100%. From stumps felled by beavers, and partially felled and upright trees gnawed by beavers, observers also recorded the height above the ground at which gnawing had occurred. For stumps, this was measured at the highest part of the stump remaining, and for upright trees, at the vertical midpoint of the gnawing. The lengths and diameters of any logs lying within the plot were also recorded, but only that part of the log lying within the plot boundary was included.

Observers also recorded any coppice re-sprouting from stumps or trees gnawed by beavers. All new shoots were counted and recorded separately as:

- “low shoots”: shoots originating from stumps or below the gnawing damage on trees gnawed but not felled by beavers, or
- “high shoots”: shoots originating from logs or above the gnawing damage on the stems of upright or partially felled trees gnawed by beavers.

The average and maximum shoot lengths were both recorded, and whether or not the longest shoot had been browsed. Where coppice re-sprouting had occurred and it had subsequently been browsed, observers recorded the extent of browsing effects on these shoots attributable to deer (roe deer *Capreolus capreolus*, red deer *Cervus elaphus* and sika deer *Cervus nippon* are present at Knapdale) and/or to beavers on a three-point scale: 0 = none; 1 = detectable, less than half of shoots browsed; 2 = substantial, more than half of shoots browsed. Previous bark stripping by deer was evident on the trunks of many willows throughout Knapdale.

A series of illustrations of trees that have experienced a variety of beaver effects and an example datasheet recording all required data about these trees was produced for observers’ reference in the field. Many permutations of tree growth form and beaver effect are more easily described by these illustrations than in text. This sheet is included as Appendix 1 at the end of this report.

3.2.5 Timing of measurements

The fieldwork reported here was conducted in April and November 2012, and includes the cumulative effects of previous beaver activity. Field visits have been planned for two time periods in each year of the monitoring programme so that observers are able to assess the full extent of coppice re-sprouting throughout the growing season from trees and stumps felled by beavers, as well as any beaver and deer herbivory that these shoots have suffered. This timing of survey also allows partitioning of the intensity of beaver gnawing between the two periods: November-April and April-November. These periods coincide approximately to the periods of dormancy and growth of trees respectively. It is anticipated that spring fieldwork will reveal the full extent of tree felling and bark feeding that has occurred on dormant trees through the preceding winter and that autumn fieldwork will also allow the determination of the net biomass gain of new shoots resulting from the interaction of growth and browsing.

3.3 Analysis and presentation of results

The abundance of trees within plots was considered in two ways. First, the number of stems were counted, and second, the basal area of each stem was calculated (basal area = π × stem radius^2) and these were summed to give a total stem basal area (at height 20 cm) for each plot. These totals included the stumps of trees recently felled by beavers, and by back-dating to provide a very close approximation of the plot structure and availability of trees prior to the release of the beavers, but exclude branches and logs felled by beavers and naturally felled logs and natural stumps.

Where comparisons were made between trees directly affected by beavers and the total tree sample, the former category included all trees gnawed by beavers, whether they were still standing or whether only a stump remained.

Where possible, data are analysed in order to provide a comparison with previous time periods, in order to document temporal changes in the effects of beavers.

4. RESULTS

4.1 Details of transects and plots

The locations of the 31 transects and 111 plots established by November 2010 are listed in Table 1, and their locations are illustrated in Figures 1 and 2. The plots which have been excluded from all monitoring are Transect 25 Plot 2102 and Transect 27 Plot 2705. Ground cover measurements are no longer recorded in Transect 13 Plot 261, and tree measurements are no longer recorded in Transect 6 Plot 232. Seven different species were recorded as dominant or co-dominant species in at least one plot, however it should be noted that plot 244, which was dominated by *Q. petraea*, included only a single tree. Also two of the marked plots, plots 285 and 290, did not contain any trees, although the other plots in those transects did. *B. pubescens* was dominant in the majority of vegetation plots. Note that species dominance in Table 1 has been determined on the basis of number of stem diameters recorded, which may overestimate the abundance of *C. avellana* and to a lesser extent *Salix spp.*, because many stems may have been recorded from a single stool or plant.

Table 1. Numbers and date of establishment of each transect/plot and the permanent tag numbers, British National Grid reference, distance from the water's edge, dominant woody species and presence or absence of beaver browsing in each plot within each transect in 2010, 2011 and 2012

Transect and Loch	Date	Plot tag	Grid reference	Dist. to water*	Dominant species‡	Beaver sign# 2010	2011	2012
1. Dubh N	11/09	211	NR 78494 90138	0 m	BETPUB	Y	Y	Y
		212	NR 78500 90140	6 m	BETPUB	Y	Y	Y
		213	NR 78509 90139	16 m	BETPUB	N	N	N
		214	NR 78512 90162	26 m	BETPUB/SORAUC	N	N	Y
2. Linne SW	11/09	3015	NR 79461 90798	0 m	BETPUB	Y	Y	Y
		3016	NR 79457 90799	6 m	ALNGLU/BETPUB	Y	Y	Y
		217	NR 79450 90808	18 m	ALNGLU/BETPUB	Y	Y	Y
		218	NR 79445 90814	26 m	BETPUB	N	Y	Y
3. Coille-Bharr SE	11/09	219	NR 77900 89380	0 m	BETPUB/ALNGLU	N	N	N
		220	NR 77899 89375	6 m	BETPUB	N	N	N
		221	NR 77892 89369	16 m	BETPUB	N	N	N

Transect and Loch	Date	Plot tag	Grid reference	Dist. to water*	Dominant species‡	Beaver sign# 2010	2011	2012
		222	NR 77885 89361	26 m	BETPUB	N	N	N
4. Creagmhor S	11/09	223	NR 80271 90836	0 m	BETPUB	N	N	N
		224	NR 80272 90834	6 m	BETPUB	Y	Y	Y
		225	NR 80265 90823	16 m	BETPUB	N	N	N
		226	NR 80258 90815	26 m	BETPUB	N	N	N
5. Fidhle N	11/09	227	NR 80014 91133	0 m	BETPUB	N	N	N
		228	NR 80018 91141	6 m	BETPUB	N	N	N
		229	NR 80021 91149	16 m	BETPUB	N	N	N
		230	NR 80027 91157	26 m	BETPUB	N	N	N
6. Dubh S	11/09	231	NR 78360 89946	0 m	BETPUB	N	N	N
		232	NR 78359 89946	6 m	Salix/BETPUB	Y [note a]	[note a]	[note a]
		233	NR 78353 89929	16 m	Salix/BETPUB	Y	Y	Y
		234	NR 78355 89924	26 m	Salix/BETPUB	Y	Y	Y
7. Linne SW	11/09	235	NR 79588 91016	0 m	BETPUB/ALNGLU	Y	Y	Y
		236	NR 79576 91020	6 m	Salix/BETPUB	Y	Y	Y
		237	NR 79575 91022	16 m	Salix/BETPUB	Y	Y	Y
		238	NR 79592 91033	26 m	BETPUB	N	N	N
8. Linne W	11/09	239	NR 79665 91103	0 m	CORAVE	Y	Y	Y
		240	NR 79665 91097	6 m	CORAVE	N	Y	Y
		241	NR 79645 91126	16 m	CORAVE	N	N	N
		242	NR 79640 91118	26 m	CORAVE	N	Y	Y
9. Coille-Bharr SSE	11/09	243	NR 77851 89397	0 m	ALNGLU/BETPUB	N	Y	Y
		244	NR 77846 89391	6 m	QUEPET	N	N	N
		245	NR 77843 89387	16 m	BETPUB	N	N	N
		246	NR 77823 89384	26 m	BETPUB	N	N	N
10. Creagmhor E	11/09	247	NR 80471 91047	0 m	BETPUB/FRAEXC	Y	Y	Y
		248	NR 80472 91039	6 m	BETPUB	Y	Y	Y
		249	NR 80475 91031	16 m	BETPUB	Y	Y	Y
		250	NR 80484 91026	26 m	BETPUB	N	N	N
11. Coille- Bharr E	11/09	251	NR 78195 89908	0 m	ALNGLU/SORAUC	N	N	N
		252	NR 78202 89905	10 m	BETPUB/SORAUC	N	N	N
		253	NR 78209 89899	20 m	BETPUB/SORAUC	N	N	N
12. Creagmhor N	11/09	254	NR 80555 91267	0 m	BETPUB	N	N	N
		255	NR 80561 91273	6 m	BETPUB	Y	Y	Y
		256	NR 80567 91281	16 m	ALNGLU/BETPUB	Y	Y	Y
		257	NR 80574 91285	26 m	BETPUB	N	N	N
13. Creagmhor NE	11/09	258	NR 80492 91072	0 m	BETPUB/SORAUC	Y	Y	Y
		259	NR 80493 91073	6 m	BETPUB	N	N	N
		260	NR 80501 91064	16 m	BETPUB	N	N	N
		261	NR 80510 91058	26 m	BETPUB	N	N	N [note c]
14. Linne N	11/09	262	NR 80026 91434	0 m	ALNGLU	N	N	N
		263	NR 80029 91439	6 m	BETPUB	N	N	N
		264	NR 80037 91451	16 m	ALNGLU/BETPUB	N	N	N
		265	NR 80043 91459	26 m	BETPUB	N	N	N
15. Linne SE	11/09	269	NR 79466 90614	0 m	ALNGLU/BETPUB	Y	Y	Y
		270	NR 79463 90611	6 m	BETPUB	Y	Y	Y
16. Linne SE	11/09	271	NR 79503 90635	0 m	BETPUB	Y	Y	Y
		272	NR 79506 90626	6 m	BETPUB	Y	Y	Y
		273	NR 79512 90619	16 m	BETPUB	Y	Y	Y
		266	NR 79518 90614	26 m	BETPUB	Y	Y	Y
17. Coille- Bharr	11/09	276	NR 78867 90853	0 m	ALNGLU	N	N	N

Transect and Loch	Date	Plot tag	Grid reference	Dist. to water*	Dominant species‡	Beaver sign# 2010	2011	2012
N		277	NR 78873 90863	6 m	ALNGLU	N	N	N
		278	NR 78877 90863	16 m	ALNGLU/Salix	N	N	N
		279	NR 78882 90873	26 m	BETPUB	N	N	N
18.Lilly NW	4/10	201	NR 78851 88572	0 m	ALNGLU/Salix	N	Y	Y
		202	NR 78849 88578	6 m	ALNGLU	N	Y	Y
		203	NR 78844 88583	16 m	BETPUB	N	N	N
19.Linne NE	4/10	204	NR 79994 91278	0 m	BETPUB	Y	Y	Y
		205	NR 79998 91276	6 m	BETPUB	Y	Y	Y
		206	NR 80007 91276	16 m	BETPUB	N	N	N
		207	NR 80017 91276	26 m	BETPUB	N	N	N
20.Lilly N End	4/10	280	NR 78965 88611	0 m	ALNGLU	N	N	N
		281	NR 78968 88615	6 m	ALNGLU/BETPUB	N	Y	Y
		282	NR 78975 88619	16 m	ALNGLU	N	N	N
		283	NR 78986 88623	26 m	BETPUB	N	N	N
21.Linne NW	4/10	284	NR 79879 91366	0 m	ALNGLU/CORAVE	Y	Y	Y
		285	NR 79877 91369	6 m	-	note d	note d	note d
		286	NR 79870 91374	16 m	CORAVE	N	N	N
		287	NR 79864 91381	26 m	CORAVE	N	N	N
22.Lilly SE	4/10	288	NR 78879 88477	0 m	Salix	N	N	N
		289	NR 78884 88473	6 m	ALNGLU	N	N	N
		290	NR 78881 88462	16 m	-	note d	note d	note d
		291	NR 78885 88451	26 m	BETPUB	N	N	N
23.Lilly SSE	4/10	292	NR 78798 88455	0 m	ALNGLU/Salix	N	N	N
		293	NR 78798 88450	6 m	BETPUB	N	N	N
		294	NR 78803 88441	16 m	BETPUB	N	N	N
		295	NR 78809 88430	26 m	BETPUB	N	N	N
24.Lochan Buic SW	4/10	296	NR 78747 88723	0 m	BETPUB/Salix	N	Y	Y
		297	NR 78738 88715	6 m	BETPUB	N	N	Y
		298	NR 78730 88719	16 m	BETPUB	N	N	Y
		299	NR 78726 88719	26 m	BETPUB	N	N	N
25.Lochan Buic NE	4/10	2101	NR 79040 88975	0 m	BETPUB/ALNGLU/ CORAVE	Y	Y	Y
		2102	NR 79054 88964	6 m	ALNGLU/BETPUB	N note b	note b	note b
		2103	NR 79067 88965	16 m	CORAVE	N	N	Y
		2104	NR 79063 88977	26 m	BETPUB/CORAVE	N	N	N
26.Linne E	4/10	274	NR 79699 90798	0 m	BETPUB	Y	Y	Y
		275	NR 79705 90794	6 m	BETPUB	Y	Y	Y
		300	NR 79710 90785	16 m	BETPUB	Y	Y	Y
		2105	NR 79718 90780	26 m	BETPUB	Y	Y	Y
27.Dubh W	4/10	2705	NR 78346 90062	0 m	BETPUB/SORAUC	Y note a	note a	note a
28.Dubh SW	4/10	2706	NR 78338 90049	0 m	BETPUB/SORAUC	Y	Y	Y
29.Coille-Bharr NE	4/10	2894	NR 78665 90445	0 m	ALNGLU/CORAVE	N	Y	Y
		2895	NR 78670 90441	6 m	ALNGLU	N	N	N
		2896	NR 78675 90437	16 m	ALNGLU/SORAUC	N	N	N
		2897	NR 78703 90399	26 m	BETPUB/SORAUC	N	N	N
30.Lochan Buic E	4/10	2921	NR 78914 88790	0 m	BETPUB/Salix	N	N	Y
		2922	NR 78915 88785	6 m	BETPUB/CORAVE	N	N	N
31.Lochan Buic W.	11/10	3221	NR 78832 88864	0 m	ANLGLU/BETPUB	N	Y	Y
		3222	NR 78828 88863	6 m	BETPUB	N	Y	Y
		3223	NR 78817 88862	16 m	BETPUB	N	N	N

Footnote to Table 1: * From nearest edge to water. ‡Species codes are listed in Table 2.
Beaver sign includes any gnawing or felling of woody vegetation up until Nov 2010, Nov 2011 or Nov 2012 respectively.
Notes: a – Plot now flooded and not monitored due to beaver activity,
b – Track through plot not monitored,
c – Track through plot and ground cover measurements no longer taken,
d – No trees in plot.

4.2 Ground cover in subplots

Results for ground cover estimates and seedling counts in the two subplots in each vegetation plot in November 2012 are presented in Appendix 2. It was not anticipated that any major changes in ground vegetation would take place across any single year but these data are presented for completeness. Towards the end of the trial, a full statistical comparison will be made of changes in ground cover, in order to quantify any effects of beaver activity. It should be borne in mind that the results of these ground cover surveys are very season-specific, and quite different results might be returned at other times of the year. Only 51 seedlings of woody plants were recorded across all plots.

4.3 Vegetation composition and structure in plots

The numbers of stems of tree and shrub species, and their basal areas, in the final set of plots that were established by November 2010, are shown in Table 2. These represent a consistent baseline data-set of availability of trees to beavers, against which future comparisons can be made. Fourteen tree species were identified in the vegetation plots. However, because trees were not in leaf during fieldwork, willows could only be identified to genus, meaning that tree species diversity has been underestimated. However, most *Salix* at Knapdale is believed to be *Salix caprea*. Numerically, *B. pubescens* is clearly dominant, and only *A. glutinosa, C. avellana, Salix* spp. and *S. aucuparia* can also be considered abundant. When total basal area was considered however, the dominance of *B. pubescens* over *A. glutinosa* was less marked. This result can be largely explained by the widespread occurrence of dense thickets of young, small birch trees which have grown in place of recently cleared conifer plantations throughout Knapdale. The substantial contribution made by *A. glutinosa* to the total basal area despite its more modest stem count, reflects the fact that this species most commonly occurs as large trees at the water's edge.

The tree species codes given in Table 2 are used to annotate the figures throughout this report.

Table 2. Total number of upright stems and total basal area of all tree and shrub species recorded in the 108 plots prior to reintroduction. Asterisked rows indicate species categories that were summed and treated as a single category in most data summaries and analyses.

	Common name	Code	Species	Stem Count	Total basal area (cm^2)	Median diameter (cm)
*	Sycamore	ACEPSE	*Acer pseudoplatanus*	2	4	1.5
	Black alder	ALNGLU	*Alnus glutinosa*	518	113,175	5.0
	Downy birch	BETPUB	*Betula pubescens*	2791	117,280	3.0
	Hazel	CORAVE	*Corylus avellana*	374	11,534	3.0
*	Hawthorn	CRAMON	*Crataegus monogyna*	5	162	2.0
*	Douglas fir	PSEMEN	*Pseudotsuga menziesii*	1	3	2.0
	Ash	FRAEXC	*Fraxinus excelsior*	58	10,862	7.0
*	Holly	ILEAQU	*Ilex aquifolium*	1	79	10.0
*	Bog myrtle	MYRGAL	*Myrica gale*	11	37	2.0
*	Sitka spruce	PICSIT	*Picea sitchensis*	23	7,091	5.0
*	Sessile oak	QUEPET	*Quercus petraea*	6	1,444	2.0
*	Wild rose	ROSACI	*Rosa acicularis*	1	1	1.0
	Willow	Salix	*Salix* spp.	372	10,930	3.0
	Rowan	SORAUC	*Sorbus aucuparia*	284	6,242	2.0
	Unidentified	-	-	5	15	2.0
	TOTAL			4,452	278,859	

Because beavers are expected to have the greatest effect on woodland near to the water's edge, different tree species may vary in their susceptibility to beaver herbivory if their distributions differ in relation to distance from water. Figure 5 shows how the abundance of each tree species differs with distance from the water. The density of *A. glutinosa, C. avellana* and *F. excelsior* decrease and the density of *B. pubescens* increases with distance from water. It is clear that the greatest number of large *A. glutinosa* were found near the water's edge. *S. aucuparia* was most abundant within 4 m of the water.

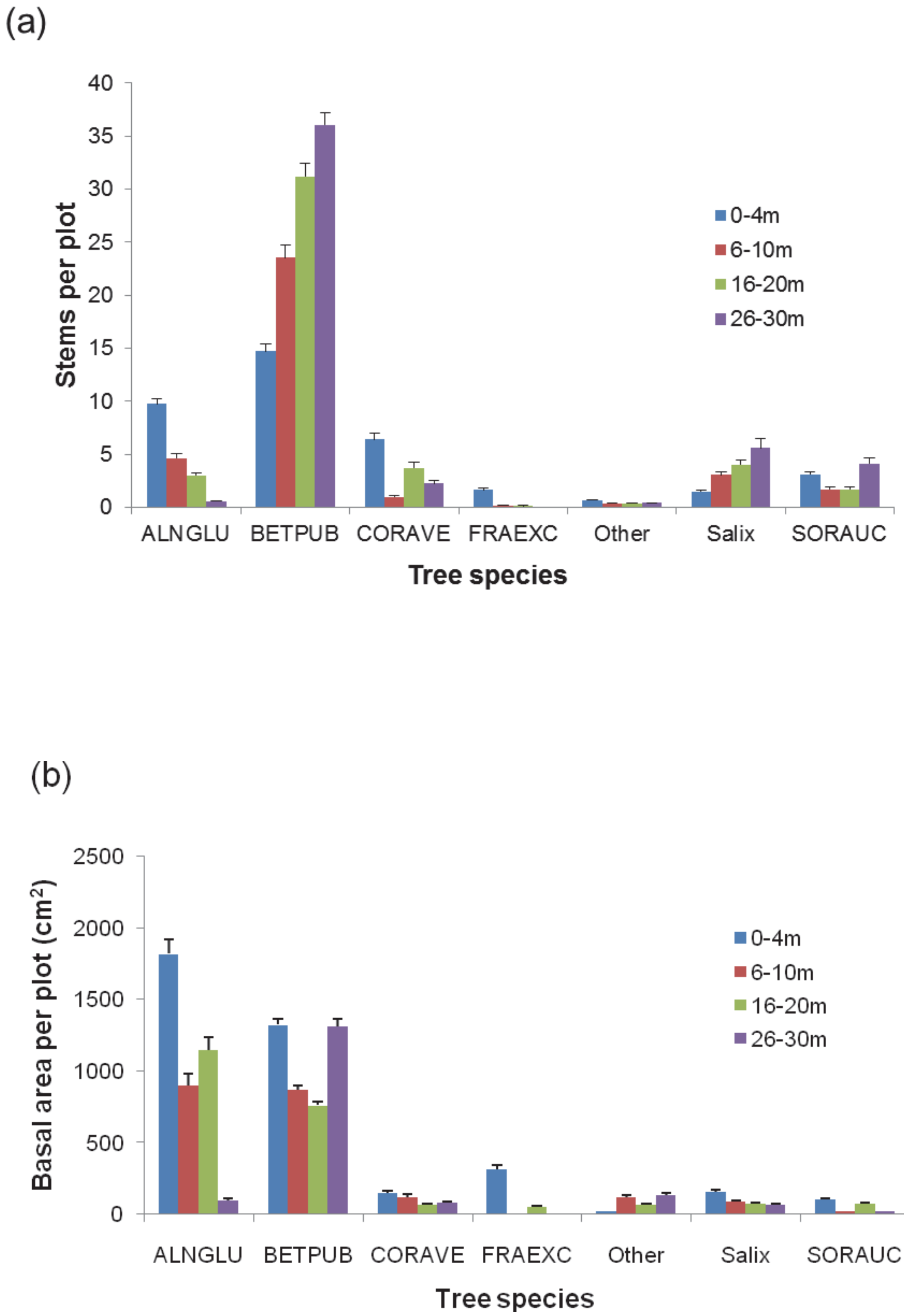


Figure 5. (a) Mean number of stems per plot and (b) mean total basal area per plot for seven common tree species in plots located at increasing distances from the water's edge. Error bars indicate one standard error.

4.4 Beaver effects

4.4.1 Use of transects by beavers

The establishment of transects was partly guided by existing beaver effects, making these data unsuitable for a formal analysis of the factors influencing beaver preferences for vegetation communities present in different transects. However, up to November 2010, 16 of the 30 (53.3%) transects included trees that had been gnawed by beavers and a further six hitherto unused transects had been used by November 2011, meaning that 73.3% had been used by that time. Only one hitherto unused transect had been further used by November 2012, meaning that 76.7% had been used. The intensity of beaver effects on each transect remains variable.

4.4.2 Use of plots by beavers

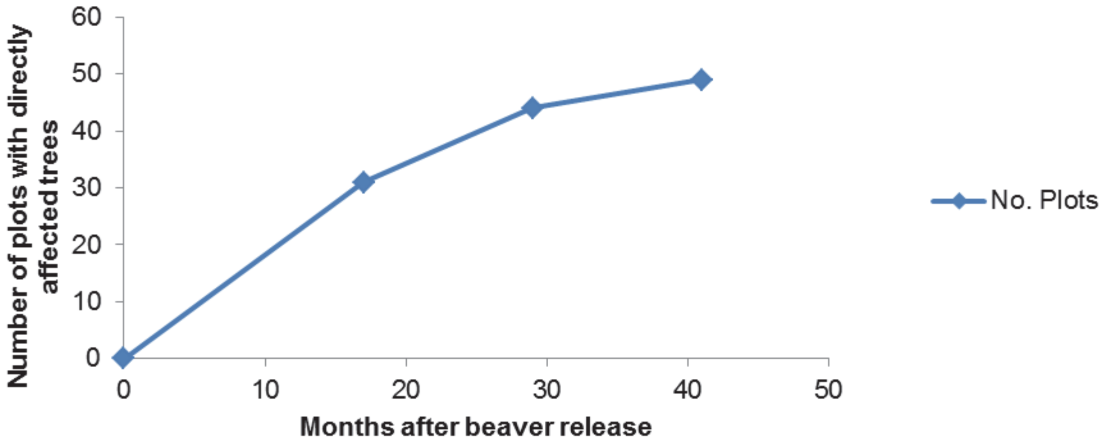


Figure 6. Number of plots with trees directly affected by beavers since release November 2012.

Approximately one and a half years after their release, beavers had directly affected trees in 31 of the 108 (28.7%) vegetation plots, after two and a half years that had risen to 44 (40.7%) and after three and half years (by November 2012) to 49 (45.3%) (Table 1, Figure 6).

The dam at Dubh Loch has substantially expanded the area of that water body into the surrounding woodland and across a nearby Forestry Commission road and walking track. Since November 2009, the beavers had continued to improve the dam, consequently expanding the flooded area as reported previously (Moore *et al.* 2010, 2011, 2013). This flooding has prevented access to some of the plots established in that area (Table 1).

The effects of beavers varied with the plots' proximity to water and this spatial distribution of effects has changed between years (Figure 7). It was reported previously (Moore *et al*. 2011, 2013), that between 2009 and 2011 there had been a slight tendency for beaver effects on trees to be occurring slightly further from the water's edge. This would be expected because although beavers would prefer to forage close to water, which permits escape from predators, as the beavers deplete their preferred food sources at these locations they might be forced to forage elsewhere. A comparison of the incidences of new beaver herbivory per plot up to November 2010, between November 2010 and November 2011, and between November 2011 and November 2012 showed that this pattern had continued. However, there was a large variability in the new incidences of herbivory among plots and this putative spatial shift in beaver activity is not yet statistically proven, as the interaction between year of measurement and incidences per plot is not statistically significant.

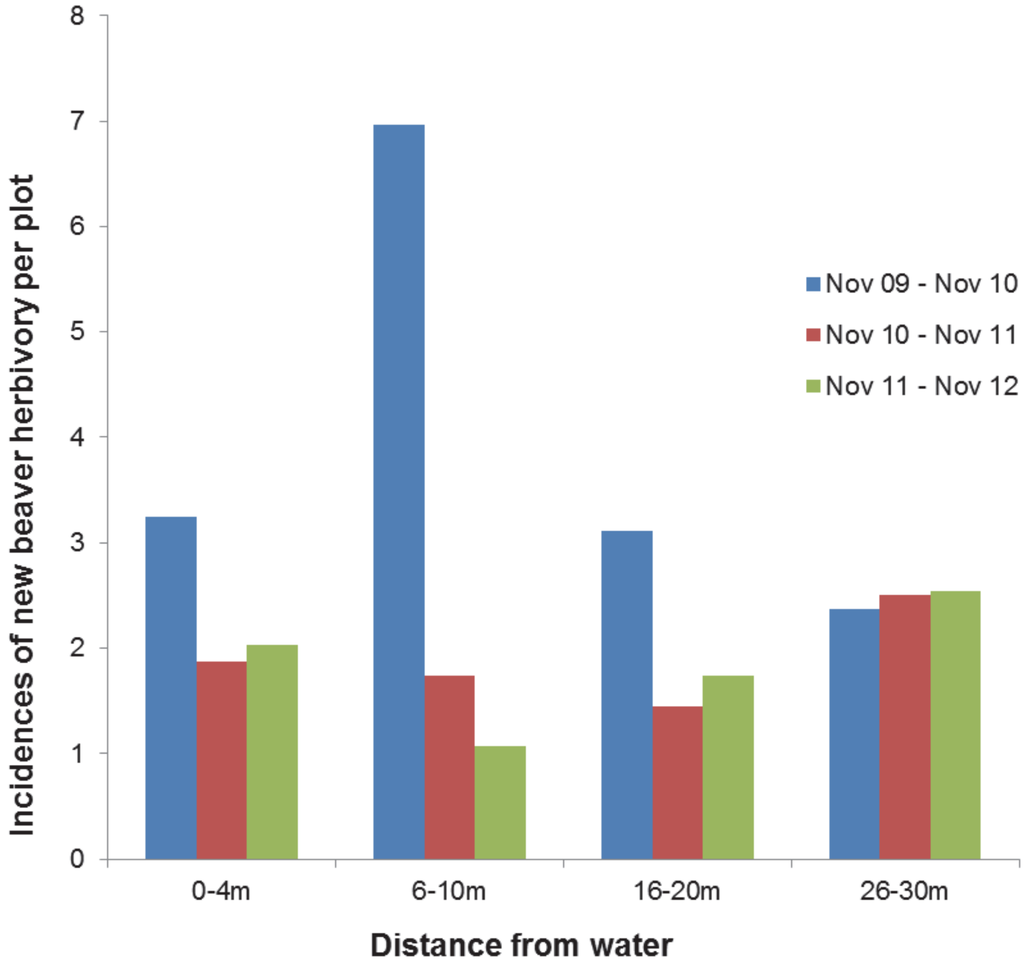


Figure 7. Distribution of beaver effects, expressed as mean number of new incidences per plot, with plot distance from water's edge, occurring in the period up to and including November 2010 (blue bars), the period November 2010-November 2011 (red bars) and the period November 2011-November 2012 (green bars).

A second important aspect of the spatial distribution of beavers' effects on trees is the possibility that the distance they forage from their lodges might increase as they deplete their preferred food types closer to them. The consistent recording of the set of plots at Loch Linne/Loch Fidhle, Loch Dubh and Lochan Buic in November 2010, November 2011 and November 2012 permits a comparison of the distance of beaver foraging from the nearest beaver lodges, how this has changed over time and in relation to the plot characteristics. The construction of a new lodge on Un-named Loch (North) and the subsequent movement of the beavers into this lodge from their previous one on Creagmhor Loch means that they were excluded from this aspect of the report. Figure 8 shows that beavers exploit the woodland resources by using plots containing preferred species that are closer to their lodges.

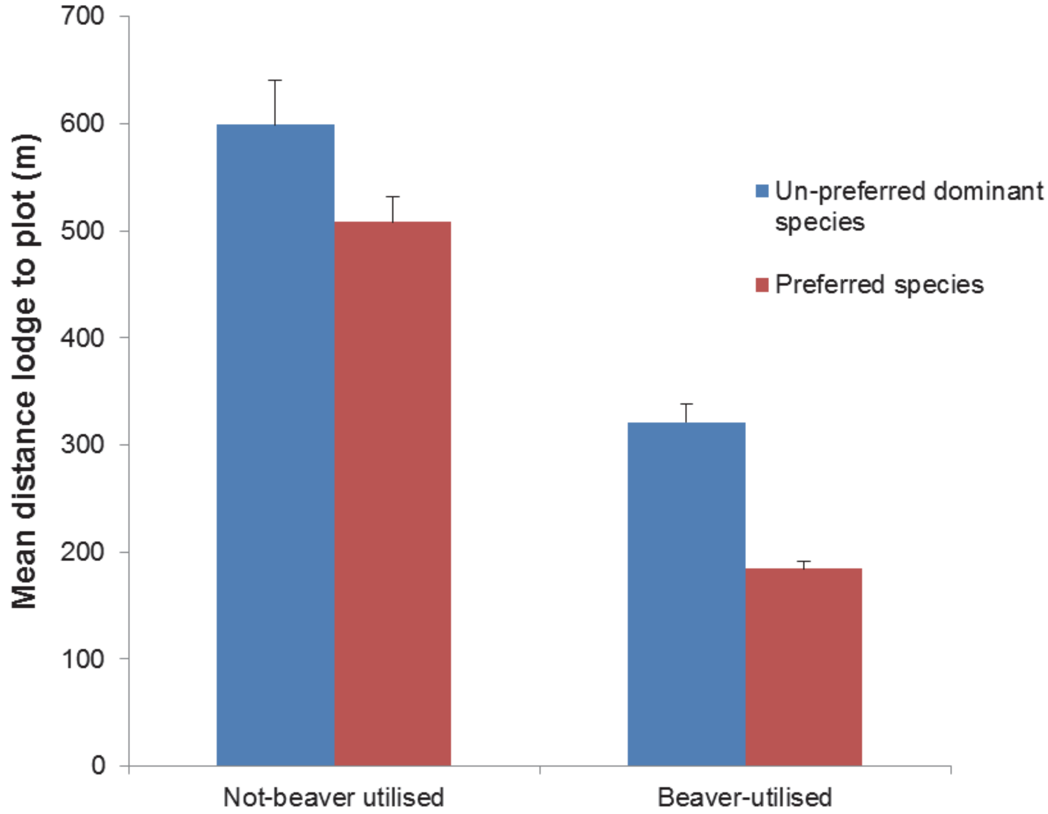


Figure 8. The mean distance from the three main beaver lodges to their corresponding monitoring plots in relation to whether or not the plots were utilised by beavers and whether the plot consisted of a dominant tree species that was un-preferred (blue bars) or preferred (red bars). The data cover the periods up to November 2012.

4.4.3 Use of tree species by beavers

Different tree species differ in their abundance and spatial distribution at Knapdale but also in their suitability as food sources, or construction materials for beavers. Consequently, it is expected that the proportional use of preferred species should be greater than their proportional availability and conversely that of avoided species should be less than their availability. It is clear that the majority of direct beaver effects so far observed at Knapdale have been on *B. pubescens* and *Salix spp.* (Figure 9).

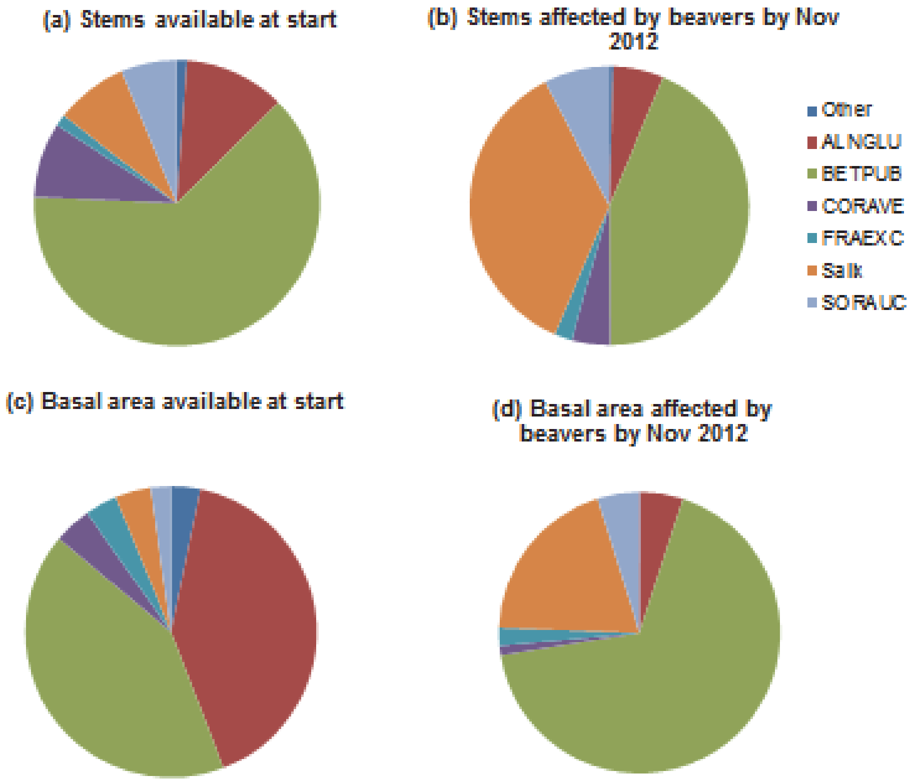


Figure 9. Proportional composition by species of (a) total number of stems in the standard set of 108 plots at Knapdale prior to the trial and (b) total number of these stems gnawed by beavers, and proportions of (c) total summed basal area of stems in plots at Knapdale and (d) total summed basal area of these trees directly affected by beavers. These data include all trees recorded up to and including November 2012. Species codes can be found in Table 2.

Figure 9 shows that although fewer individual stems of *B. pubescens* were browsed than suggested by its availability, the total basal area of browsed *B. pubescens* was greater than expected. This finding suggests that beavers tended to favour large birch trees over the small birch trees typical of dense stands of birch growth. Figure 9 also strongly suggests that *A. glutinosa,* and large trees in particular, were avoided by beavers, while *Salix* was fairly strongly preferred relative to its availability, both on the basis of tree numbers and basal area. *F. excelsior* and *S. aucuparia* were used in approximate proportion to their abundance, while *C. avellana* was used much less than its abundance would suggest, and when it was used, only very small stems were gnawed. It should be noted however that the availability of *C. avellana* is somewhat misleading, because it is less widespread than other tree species. Where it occurs, very large numbers of small stems were often recorded growing from only a small number of stools. This overall pattern of tree selection relative to availability is similar to the conclusions of previous reports (Moore *et al*. 2011, Moore *et al*. 2013), but a fuller analysis based on foraging in individual years, rather than effects accumulated across years, will be undertaken towards the end of the trial reintroduction.

4.4.4 Use of individual trees by beavers

The majority of marked and measured stems in the plots in November 2012 were standing trees unaffected by beavers. However, stems, stumps and branches were recorded in all 12 status categories (Section 3.2.4, above). By November 2010, 8.8 % of trees in the plots had been directly affected by beavers, however these accounted for only 5.7% of the total basal area. By November 2011 the figures had increased to 12.2% and 8.3% respectively and by November 2012 they had further increased to 15.5% and 9.8% respectively (Table 3, Figure 10).

Table 3. Thirteen status classes used to classify trees and tree parts in the plots, codes used to record them, and the numbers of each class recorded in vegetation plots in November 2010 and changes recorded in 2011 and 2012.

Status	Code	Count			Difference		Total Basal Area (cm^2)		
		2010	2011	2012	2010-2011	2011-2012	2010	2011	2012
Upright tree, unaffected by beavers	Up	4148	3955	3816	-193	-139	265143	259222	255443
Stump of tree felled by beavers	BStump	300	415	524	+115	+109	7318	9032	11130
Upright stems growing from a log	LogUp	103	98	98	-5	0	2703	2657	2657
Base of Affected Tree	Base	21	39	61	+18	+22	1737	5350	6447
Tree partially felled by beavers	BP	32	39	56	+7	+17	3642	4206	5259
Naturally fallen log	NLog	39	44	47	+5	+3	13074	12047	12119
Upright tree gnawed by beavers	BUp	24	38	43	+14	+5	2125	3797	4163
Log felled by beavers	Blog	31	35	37	+8	+2	2406	2553	2590
Natural tree stump	NStump	7	26	31	+20	5	223	558	618
Tree pushed down by beaver tree	Bent	13	13	22	0	+9	82	82	112
Site where a minor branch removed from standing tree	BCut	7	10	13	+3	+3	5	35	71
Naturally partially fallen tree	NP	1	2	2	+1	0	1810	1829	1829
Tagged 2009, 2010 missing 2011	Gone	20	68	123	+48	+55	498	738	856
Total trees affected by beavers		428	589	756	+161	+167	17315	25055	29772
TOTAL (excl. 'Gone')		4726	4714	4750			300268	301368	302438

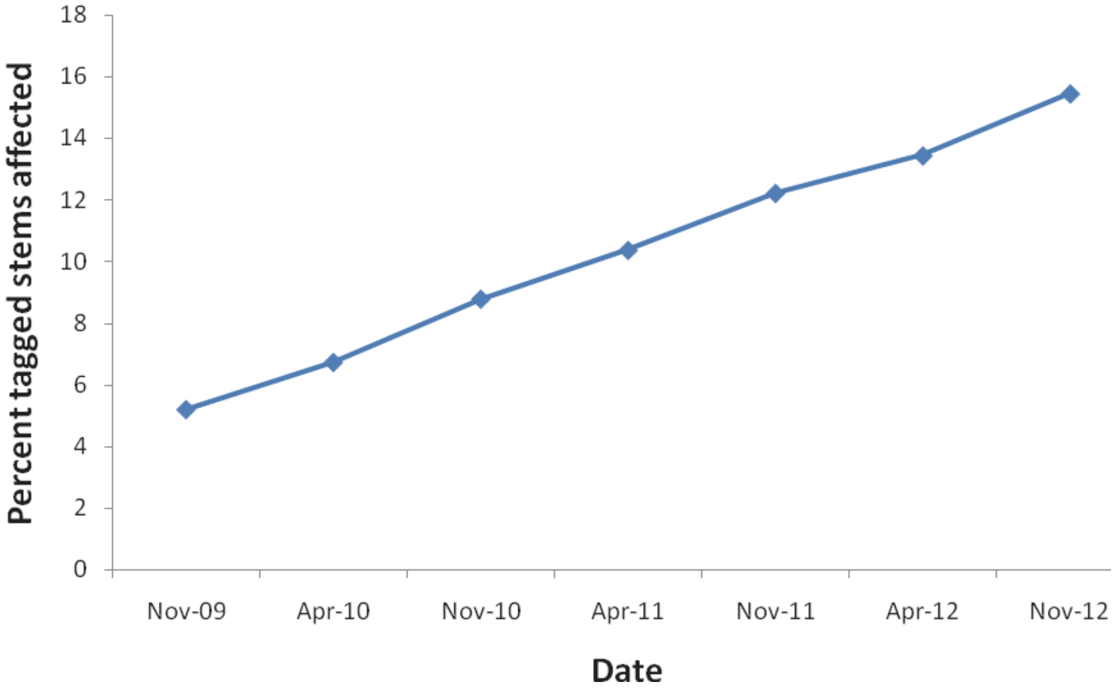
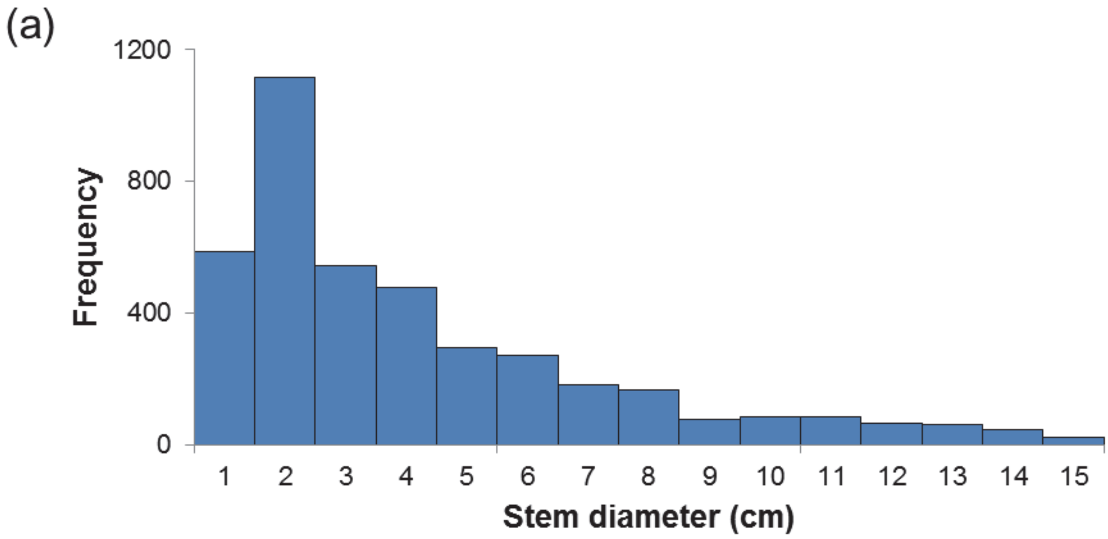


Figure 10. The cumulative percentage of individually marked stems affected by beaver activity since their reintroduction.

The ultimate effect of beavers on woodland structure at Knapdale will be strongly influenced by which individual trees beavers fell. Figure 11 compares the distribution of stem diameters available at the start of the reintroduction amongst all trees measured in the vegetation plots and amongst trees gnawed or felled by beavers in the three years November 2009 to November 2010, November 2010 to November 2011 and November 2011 to November 2012. Numerically, the vegetation surrounding the lochs at Knapdale is dominated by small trees, reflecting the extensive areas of recent regrowth of birch, in particular, described by Brandon-Jones *et al.* (2005).

It seems that beavers use very small trees (diameter ≤ 2 cm) less than their availability would predict, and mostly use trees of diameter 2 – 6 cm. The distribution of sizes of stems gnawed by beavers as measured in November 2012, was approximately the same as measured in November 2010 (Figure 10, Moore *et al*. 2011 and Figure 10, Moore *et al.* 2013), but there was a continuing slight reduction in the mean diameter of the gnawed trees (2010: Mean = 5.50cm, SE = 0.294; 2011: Mean = 5.18cm SE = 0.380; 2012 Mean = 4.98, SE = 0.255). Trees larger than 6 cm diameter were gnawed approximately in proportion to their abundance. In our sampling plots, very few trees of diameter ≥ 20 cm were observed to have been directly affected by beavers. However trees of this size and considerably larger were commonly observed both as stumps and partially felled trees throughout the trial area more widely, particularly close to the water.



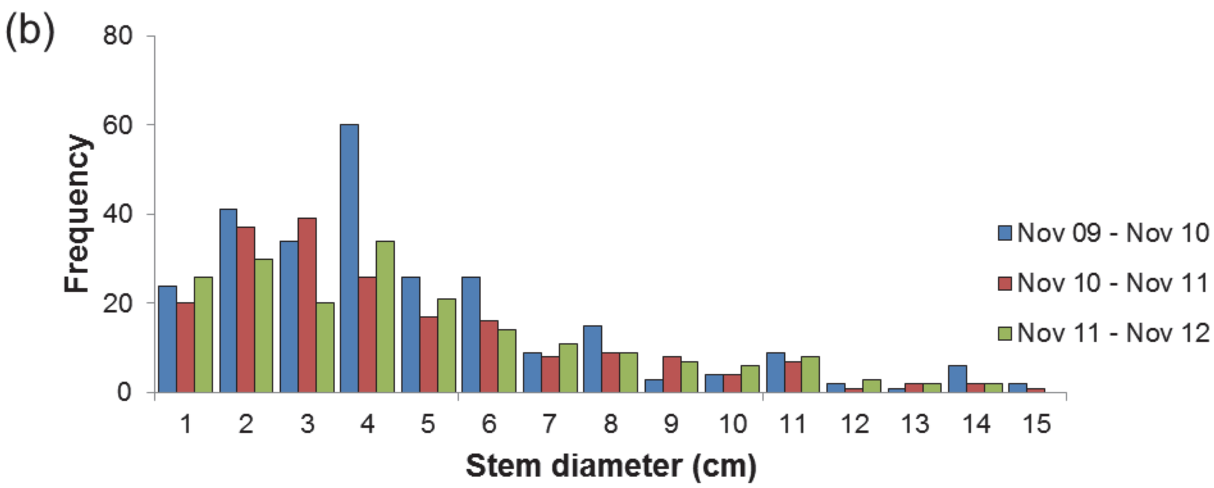
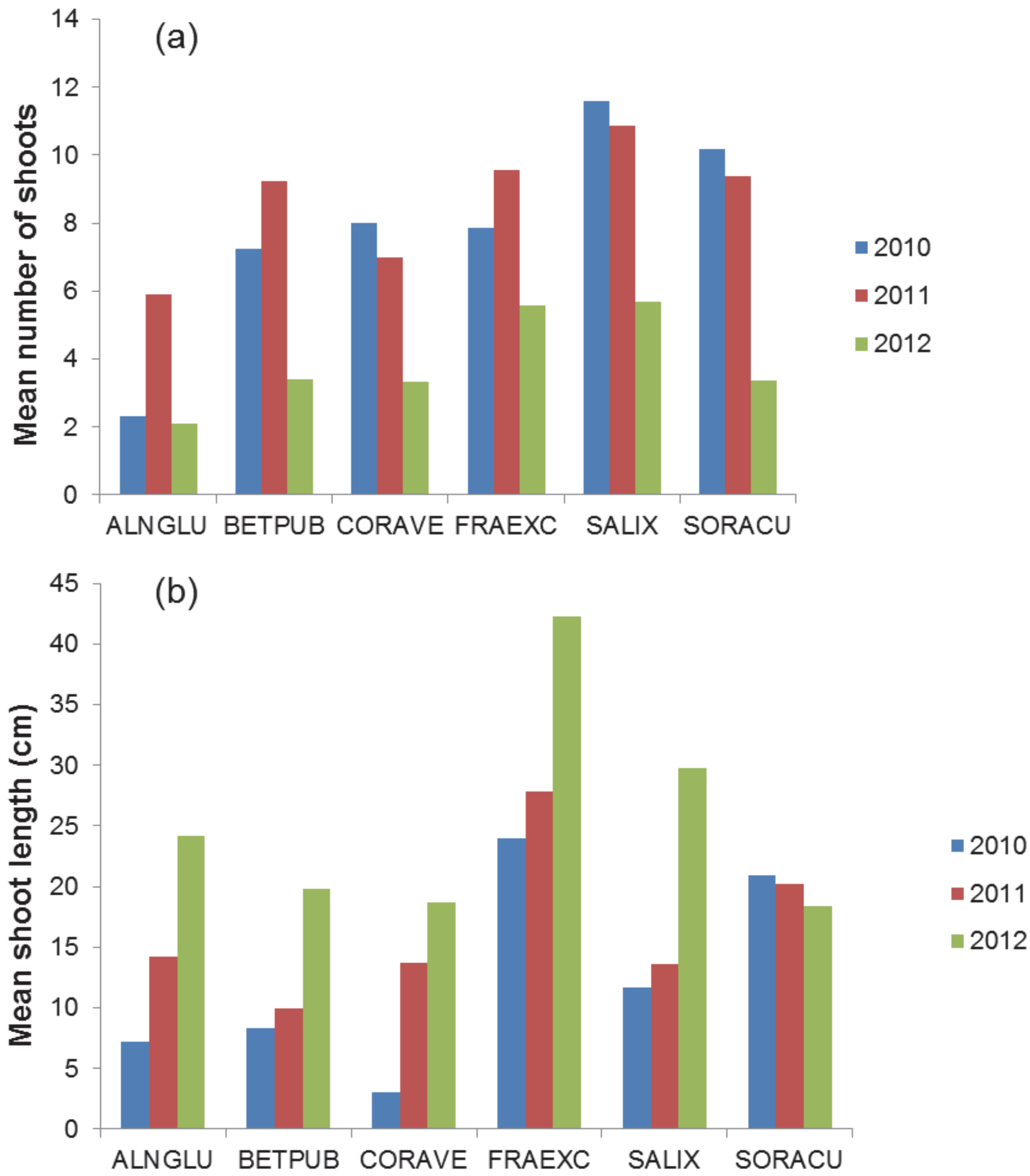


Figure 11. Frequency histograms illustrating (a) the distribution of stem diameters of all trees recorded in plots at Knapdale at the start of the reintroduction of beavers, and b) the distribution of stem diameters of trees gnawed or felled by beavers in the three periods November 2009 to November 2010, November 2010 to November 2011 and November 2011 to November 2012 in the plots. These histograms are truncated; beavers also use some trees larger than 15 cm diameter.

4.5 Re-sprouting and subsequent deer and beaver browsing

An important factor likely to influence the effects of beavers on riparian woodland in the medium to long-term is the re-sprouting of stumps of felled trees. The key rationale for conducting two monitoring sessions in the woodland each year is to estimate both rates of browsing by deer and beavers on new shoots during the non-growing season as well as rates of browsing and net growth during the growing season. In November 2009, no new sprouts were observed on beaver stumps in the permanent plots, and little significant re-sprouting was observed elsewhere in the trial site (Moore *et al.* 2010). As expected this situation had changed little by April 2010, as the intervening winter period was not favourable for plant growth. During 2010, a reasonably high proportion of the beaver damaged trees showed signs of re-sprouting (Moore *et al.* 2011, 2013), but the proportion of beaver damaged stumps with re-sprouted shoots had declined by November 2012 (Figure 12c). In the first and second years of assessment, the number of shoots on trees that had re-sprouted increased, but this had declined by November 2012 (Figure 12a). However, the re-sprouted shoots remaining at November 2012 had grown to a longer length (Figure 12b). The re-sprouting of beaver-damaged trees is strongly species dependent; Ash, willow and rowan are reliable re-sprouters (Rackham 2001) which generally produce large numbers of thick shoots. Fewer stumps of most species had shoots that had re-sprouted when assessed in 2011, and this trend continued in 2012.



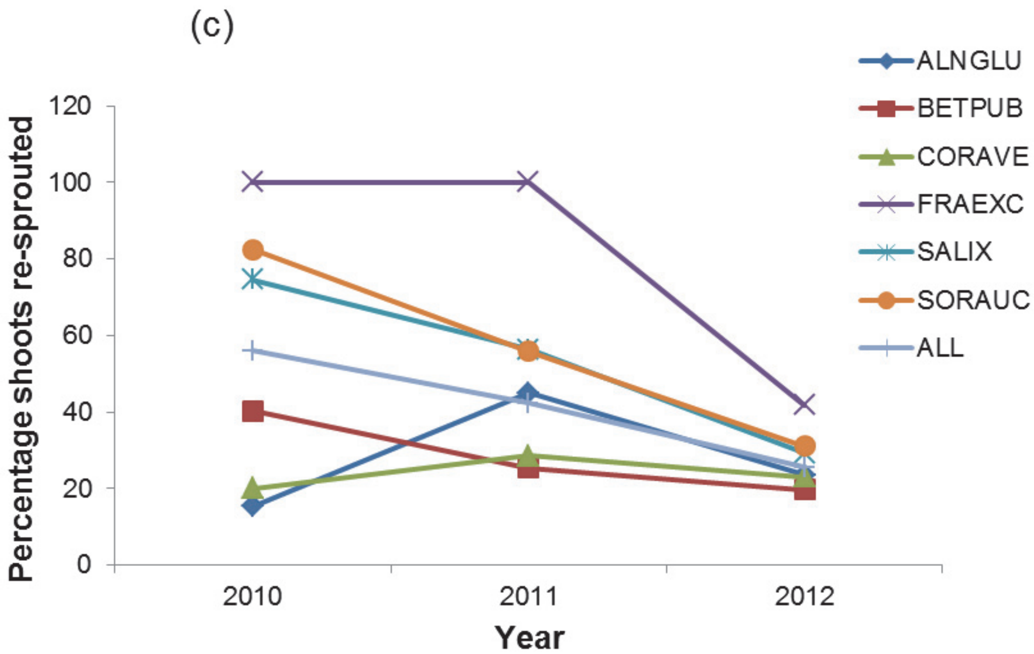


Figure 12. (a) Mean number of shoots on trees that had re-sprouted after being affected by beavers by November 2010, November 2011 and November 2012 and (b) mean length of extant living shoots (in mm) growing from the stumps and base of trees gnawed by beavers at the same times as in (a), and (c) percentage of stumps resulting from beaver activity that had new re-sprouting shoots at the same times. Tree species codes are in Table 2.

4.6 Seasonal differences in beaver effects

Because trees in the plots are individually permanently marked and monitored for the duration of this study, all beaver effects that occur after initial marking of these trees can be detected.

Because of the constancy of the composition of the sample of plots recorded in April and November 2010, 2011 and 2012, the seasonal variation in the effects of beavers on the trees can now be assessed by comparing the frequency of effects of beavers between these dates. During summer and autumn, beavers are expected to feed more on forbs and aquatic macrophytes in addition to the foliage of deciduous trees and to direct their diet more towards the bark and small twigs of woody vegetation as other foods become less available through winter (Krojerová-Prokešová *et al.* 2010). November-April coincides with the period of winter dormancy of the vegetation and April-November represents the summer growth period. A greater proportion of the trees changed status during the summer period than the winter period for most species, the exceptions being *S. aucuparia* and *B. pubescens* (Figure 13). This result may be due to the felling and browsing of trees by beavers during the summer months to provide cached food resources and material for lodge-building.

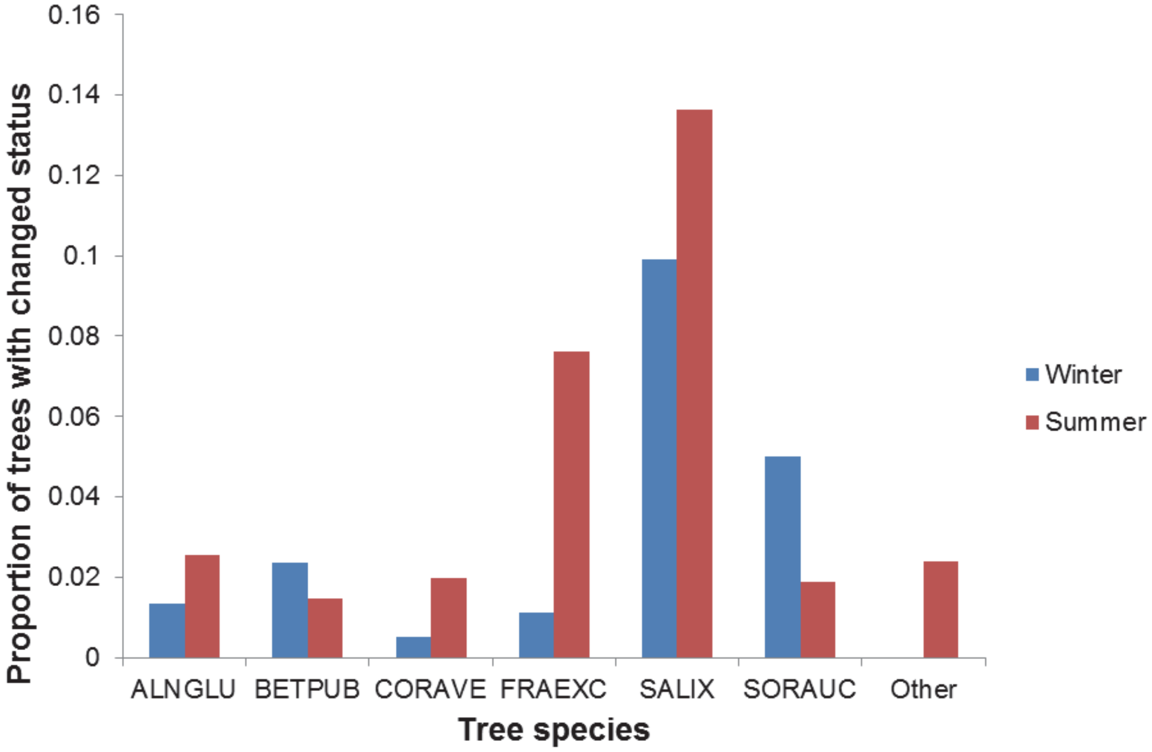


Figure 13. The proportion of stems of each species that changed status (i.e. were affected by beavers) between monitoring sessions in winter (November-April) and summer (April-November). The descriptions of status are in Table 4. Species codes and the numbers of trees of each species are summarised in Table 3. Data are combined across the three years of study November 2009-November 2012.

4.7 Visual changes in plot structure

Plot structure has been assessed visually and photographic records have been taken in each April and November over the 42 months of monitoring. These pictures have provided an interesting visual record of how horizontal vegetation structure has changed as a result of the effects the beavers have had on the plots. Examples of these are illustrated in Appendix 3a.

Visual assessments of changes in plot structure undertaken in April and November provide only a limited impression of the effects of beavers, because at these times of year, the trees are not in leaf and consequently a clear view across the plot is obtainable. The measurements were repeated during the summer of 2012, and will be repeated again in the summer of 2013, in order to contrast with the winter measurements for each plot, and help us investigate more fully the beaver effects on both horizontal vegetation density and plot canopy cover.

The visible contrast between seasons is illustrated in Appendix 3b.

5. DISCUSSION

The effect of beavers on the woodlands of Knapdale already extends beyond the direct effects of gnawing and felling of trees. A substantial area has been flooded by a beaver dam at Dubh Loch and vegetation changes can be expected in the flooded woodland. Flood-tolerant species such as willows and alder may survive, while less flood tolerant species may die but persist for some time as standing dead timber. Ultimately, the vegetation may shift from broadleaf deciduous woodland to swamp or bog.

5.1 Woody vegetation at Knapdale

Since the initial survey undertaken in November 2009 (Moore *et al.* 2010), the number of monitoring plots at Knapdale has been almost doubled, however the mixture of woodland types included in the sample has not changed substantially. The set of plots onto which all comparisons will be standardised show that the most numerous tree species in vegetation plots, by a considerable margin, was *B. pubescens*. Dense stands of young regrowth of this species, as well as larger, old trees, occur throughout the area. In many places birch has rapidly colonised areas from which conifer plantations were removed to meet Natura Special Area of Conservation obligations in earlier years. These early successional woodlands are dynamic communities and it is likely that the presence of beavers will alter the trajectory of their development. *A. glutinosa* is also widespread and common at Knapdale, but in contrast to *B. pubescens*, it occurs primarily as large trees at the water's edge, and thus accounts for a large proportion of total tree basal area. *Salix* spp., *C. avellana, F. excelsior* and *S. aucuparia* were also common in plots and have previously been identified as important components of European beaver habitat elsewhere in Europe (Haarberg & Rosell, 2006, Macdonald *et al.* 1997).

5.2 Beaver browsing preferences and effects

Because the positioning of transects was partially guided by pre-existing beaver herbivory, the plots selected are not an entirely unbiased sample of loch shore. They do however permit a thorough analysis of local selection of tree sizes and species by beavers. The number of transects established at Knapdale is now such that all vegetation types are represented and a clear picture of beaver preferences is emerging. From November 2010-November 2012 the beavers have affected a progressively increasing number of the 108 standard monitoring plots (28.7%, 40.7% to 45.3%), and now 15.7% of trees in those plots have been affected.

Based upon a comparison of the sizes of trees used by beavers with those available, the preferred tree size for beavers was from 3 – 6 cm diameter, and smaller trees were less preferred, although still commonly used. A study of foraging by beavers in Telemark, Norway (the source of the reintroduced beavers) found that beavers there tended to use smaller trees than is the case at Knapdale to date (Haarberg & Rosell, 2006). The mean diameter of stems eaten by beavers has decreased slightly across the three years of monitoring up to November 2012, consistent with what would be expected if an optimum size of tree was selected initially but then depleted in supply. Outwith the plots many still larger trees were also observed to have been affected by beavers. This has some implications for the woodland structure. First, beavers may not, at least so far, be playing a strong direct role in thinning the dense birch stands around the lochs which often comprise very small (diameter 1-2 cm) trees, and second, their focus on larger trees may significantly reduce the standing biomass of these communities and increase the amount of light reaching smaller trees and the ground. Despite felling mainly small stemmed trees, it is clear that beavers will fell or attempt to fell even very large trees.

There have been no major changes in the tree species utilised by beavers at Knapdale. Results show that beavers continue to exhibit a strong preference for *Salix*, (the willows) but that although earlier reports showed that *S. aucuparia* was preferred, since the beginning of the trial and up to November 2012, it has been eaten in proportion to its initial availability of numbers of stems. However, due to the felling of a few large trees, it appears to be selected when considered on the basis of basal area. *Fraxinus excelsior* and *B. pubescens* are used approximately in proportion to their availability in the environment, but birch remains easily the species that is most utilised by beavers, due to its abundance, whilst ash is only a very minor component of the species used. Overall, since the beginning of the trial, *A. glutinosa* and *C. avellana* have been avoided relative to their availability in the environment. Factors that may change the selection of tree species across time include the depletion of preferred species, reducing their availability and encouraging utilisation of other species, and changes in the preponderance of felling for building materials versus foraging. Haarberg & Rosell (2006) found in Telemark that beavers' species preferences could be ordered willow > rowan > birch >*Prunus*> others > alder > conifers, which is almost perfectly consistent with patterns observed at Knapdale. Note that the alder present in Telemark was *Alnus incana,* not *A. glutinosa*.

The monitoring up to and including November 2012 supports results from the previous years that suggested that beavers at Knapdale affected a greater proportion of the available trees during the summer months than during the winter months, for almost all tree species. Herbivory of the upper parts of trees would be expected to yield greater energy and nutrient gains during the summer when they are in leaf. Some of the harvested material is likely to have been cached underwater by beavers. Food caching is a behavioural characteristic that is advantageous to beavers that regularly experience harsh winters, when access to food resources or travel opportunities may be restricted by ice for long periods, or the costs of swimming at low temperatures may become too high (Nolet and Rosell 1994). The proportion of the beaver's diet that comprises food from other sources such as grasses, forbs and shrubs, or aquatic vegetation is unknown, but likely to be higher during the summer. During the period of this study, and since their initial colonisation, beavers have continued to actively enhance their lodges and a dam, both of which use mainly poles from harvested stems, rather than large tree trunks. The decision of where to locate a lodge would seem to be very important to beavers; as they are central-place foragers, its location determines proximity to food of the required quality and thus future costs of foraging . There was no indication from comparisons of the plot monitoring data between years that plots further from beaver lodges were being increasingly used with time since the release of beavers, although the Creagmhor beavers moved to another lodge in 2011, and this may have been a response to initially choosing a sub-optimal habitat.

In the first year following release of beavers the majority of beaver effects on trees were within 10 m of the water's edge. These results to date confirm observations from other populations that beaver effects are confined to areas close to water, primarily within 10 m of the shore. However, beaver effects were distributed slightly further inland in the November 2011 monitoring period compared with the previous year, and this trend towards the evening out of trees newly affected by beavers at slightly greater distances from water has continued. Where conditions allow, beavers will feed from the water on overhanging branches and trees growing right at the water's edge. Opportunities for this type of feeding seem to be limited at Knapdale, as loch shores are sometimes steep or rocky and often are vegetated with large mature trees such as birch and alder rather than by dense thickets of preferred tree species such as willow or aspen. Many parts of Knapdale are not suitable for assessing how far beavers forage from the water, because the narrow strip of broadleaf woodland along the edges of the lochs is hemmed in by dense conifer plantation. The persistence of this and other shifts in the activity of beavers should be revealed by further monitoring, particularly in response to local depletion of preferred species, and expansion of the beaver population. In most areas, the majority of felled biomass has been removed for construction, caching or eating elsewhere, or consumed on the spot by beavers. Even some very large trees have been almost entirely removed. As a consequence, the riparian woodland is not generally becoming cluttered with dead wood, and indeed in parts it is beginning to feel more open, particularly when larger, spreading, waterside trees are removed.

Re-sprouting after felling or other forms of beaver damage is a characteristic that varies strongly among tree-species, with rowan, ash and willow being the strongest re-sprouters. The overall pattern of dynamics of re-sprouted shoots is that following browsing an initial flush of re-sprouting shoots grows, and many of these subsequently die, often showing signs of frost damage (Figure 14a). Those growing on birch appear to be very thin and wispy and suffer a high mortality. The possible role of re-browsing of these newly appearing re-sprouts by other herbivores, mainly deer, will be assessed at the end of the four years of data collection after November 2013. A further factor influencing the re-sprouting from beaver damaged trees is the mortality of the remaining stumps, which despite initially re-sprouting, subsequently die and/or become rapidly colonised by moss (Figure 14b). In contrast to ash, willow and rowan, hazel and alder appear to be fairly poor re-sprouters, although for some species, relatively few trees were present at Knapdale, or were not commonly browsed by beavers. Consequently for those species (particularly *F. excelsior*) the results in Figure 12 are based on small sample sizes and should be interpreted with caution. There were, as yet, rather few incidences of beaver or deer re-browsing on these re-sprouted shoots, but the final field surveys in April and November 2013 will assess the extent of this re-browsing.

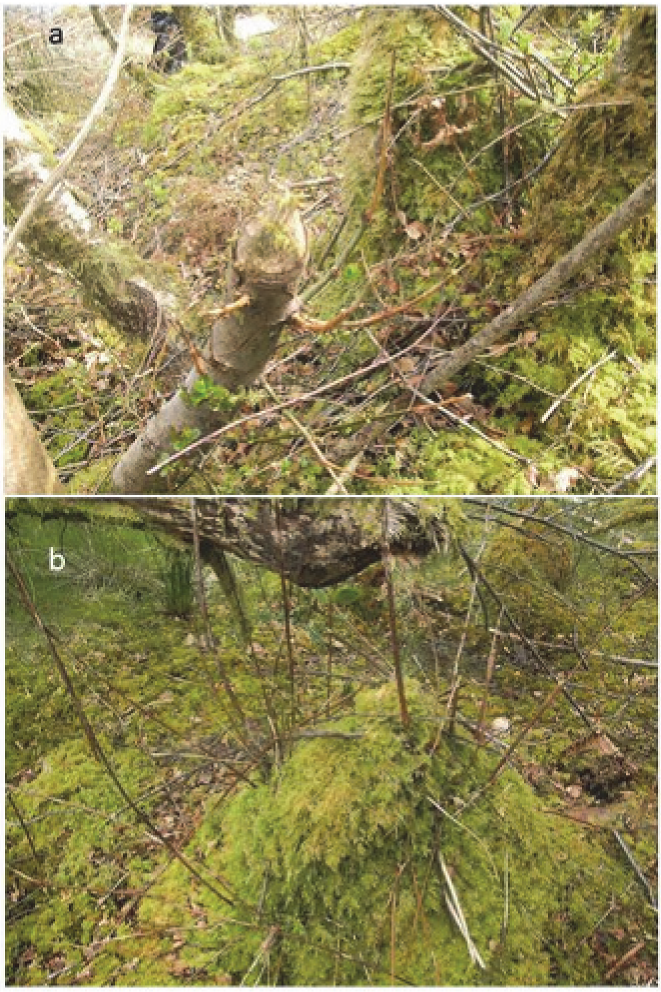


Figure 14. a) frost damage causing browning to re-sprouting shoots and b) a stump over-grown by moss.

5.3 Assessment of monitoring methodology and future monitoring plans

The fieldwork reported here was conducted 35 and 42 months after the initial reintroduction of beavers to Knapdale in early summer 2009. Over the period of study there has been some instability in the numbers and locations of beavers, so any interpretation of trends in beaver foraging patterns should still be treated with some caution, and considered in relation to the number of beavers that forage in that locality. The tree sampling plots contributing results to this report represent a sub-sample that comprises most of the plots established, with the exception of a few which have been destroyed by routine forestry activity or have become impossible to access due to flooding caused by beavers. The results presented here have been standardised to the same sample plots across all years, and within these plots, the tree species and size composition at the outset of the trial, have been estimated. Ideally, this woodland monitoring program would have commenced with a survey of baseline vegetation conditions in the plots before beavers were reintroduced. However, uncertainty surrounding several aspects of the releases made this impractical. For example, the precise locations of the artificial lodges used for the releases was not known long in advance and the use of space by beavers post release could not be confidently predicted, making the prior siting of transects too speculative to be justified. The initial location of the sampling plots does not provide an unbiased reflection of the use of habitat by beavers as they were located at the lochs on which beavers were initially established or were considered likely to establish subsequently. The proportion of trees affected (15.7%) reflects the use of trees by beavers locally in the plots and in the areas in which they are established rather than their selection from a wider population of all available trees.

Despite the absence of such baseline data prior to release, the persistence of stumps of trees felled by beavers prior to the first survey has allowed the reconstruction of an almost complete picture of woodland structure and species composition prior to the release. All stumps of trees felled by beavers in vegetation plots were identified, tagged and measured. Estimates of stem density and total basal area in each plot will only differ from the true baseline figures if trees branched above the site of beaver gnawing but below 20 cm. Other measures that may have changed from their baseline values since the beavers' introduction include estimates of canopy cover, estimates of horizontal vegetation density and estimates of ground cover, particularly where beavers had caused flooding or canalisation. Any direct effects of beavers on trees that have occurred since monitoring plots were established will have been detected.

Overall, the permanent woodland monitoring plot methodology is serving its purpose well. Tree tags and plot markers have proven robust and durable. Some transects established on Un-named Loch (South) (also known as Lily Loch) and Loch Coille-Bharr are arguably of marginal interest now that beavers have established patterns of movement focussed on other lochs, however low-level beaver activity continues to be detected on these lochs (as of April 2011) and they will continue to be monitored for the duration of the Scottish Beaver Trial.

6. CONCLUSIONS

The results reported here cover three years of monitoring beaver impacts following their trial release. There have been no major changes to the patterns of tree use since the report for 2010. However, there does seem to have been a minor shift of beaver activity to plots further from the water's edge .There appears to have been no detectable shift by beavers towards using plots that are farther from their lodges, except for the Creagmhor beavers, which have built a new lodge on a neighbouring loch. Most effects were observed on transects less than 500m from active beaver lodges. The utilisation of different species by beavers remains similar to that previously observed, with a preferences for willow, but the preference for rowan has waned. Only six species occurred in plots in substantial numbers; *B. pubescens, A. glutinosa, C. avellana, F. excelsior, S. aucuparia* and *Salix* spp. Most plots were dominated by *B. pubescens*, often in conjunction with one or more other species, and the birches remain numerically the most used by beavers.

By November 2012, beavers had been present at Knapdale for 42 months and had produced noticeable effects on woody vegetation. Trees had been gnawed or felled by beavers in 45.3% of the 108 plots that could be monitored. Up to November 2010 10.2% of trees within our sample plots had been affected by beavers and this had increased to 12.2% by November 2011, and to 15.8% a year later in November 2012. Within the plots that were used by beavers, the number of stems affected varied from only one or two stems to over 60% of those stems present. Plots used by beavers included more *B. pubescens* and *Salix*, but less *A. glutinosa* than an average plot. Beaver effects were, by November 2012 still being detected at on average slightly greater distances from the shore than previously recorded, and beavers continue to favour trees of diameter 3 - 6 cm.

Twenty five per cent of trees felled by beavers were re-sprouting with new shoots in November 2011. *Salix*, *F. excelsior* and *S. aucuparia* were particularly vigorous re-sprouters. The structure of riparian woodland at Knapdale in future will be strongly influenced by the interaction between the growth of new shoots from beaver stumps and subsequent browsing of these shoots by deer and beaver. However, results to date suggest that although re-sprouting may initially be profuse, it may take longer than anticipated for it to generate regrown stems that may be utilised by beavers. The continued monitoring of re-sprouting is an important component of future work.

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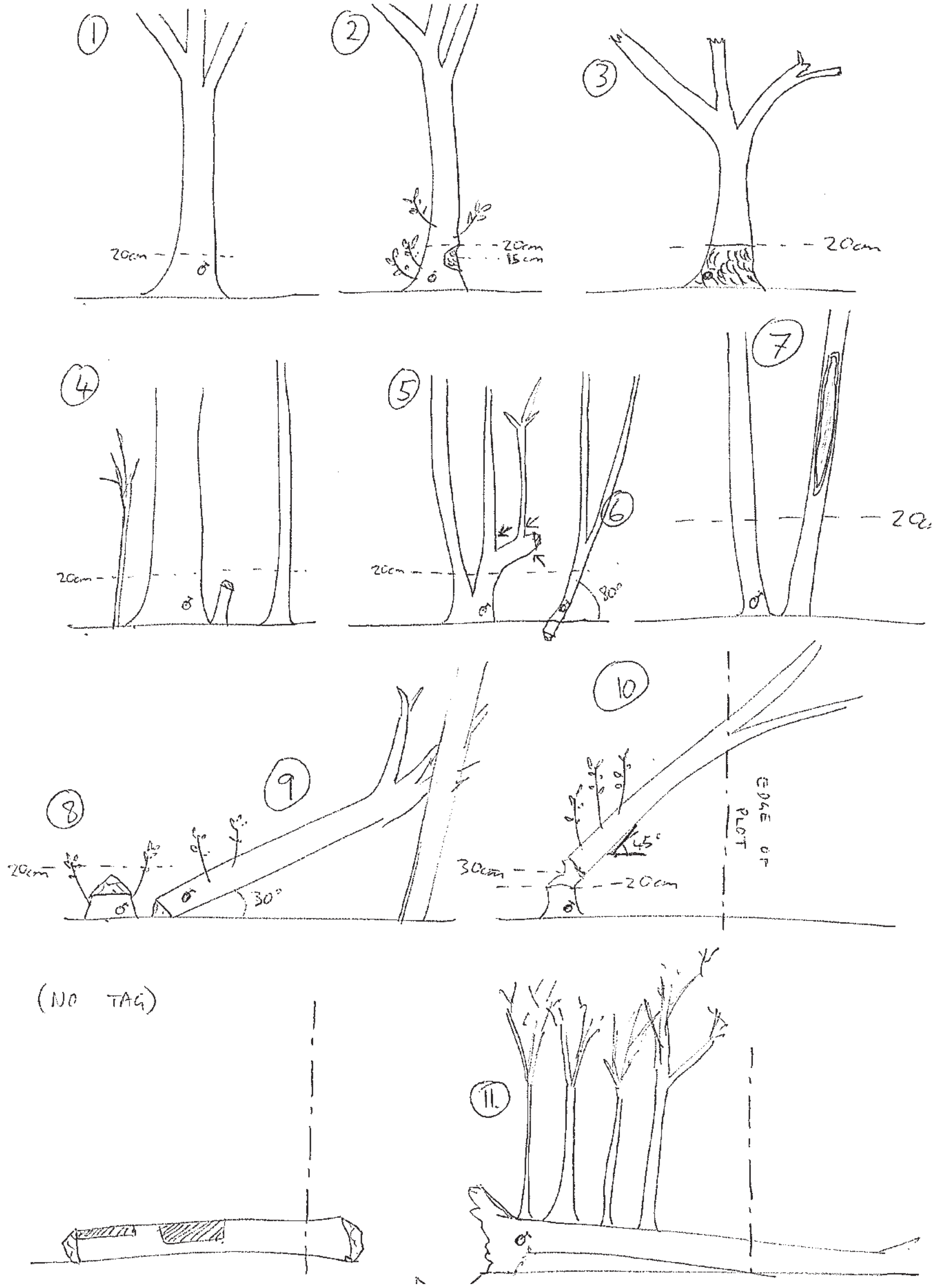
APPENDIX 1. REFERENCE ILLUSTRATIONS USED IN THE FIELD

Reference illustrations used in the field encompassing most tree, stump and log forms encountered with various types of beaver effect. Accompanying example datasheet with entries corresponding to numbered illustrations



The James Hutton Institute, Craigiebuckler, Aberdeen AB15 8QH tel: 01224 395000

Scottish Beaver Trial: Woodland Monitoring. 302-460. Version 3. Date: 10/4/2013

Loch:______________________________ Transect:____________ Distance: ____to____m. Page_____of_____
Plot Tag:

Tag No.	Species or count	Diam.(20cm)	Status	Angle	Alive Y/?/N	bark rmvd	low shoot	high shoot	avge. shoot	Deer	Beav	Height chopped	log length
#[a]	CODE	cm	[b]	deg	Y/?/N	%[c]	count[d]	count[e]	cm	0/1/2[f]	0/1/2[f]	cm	m[g]
1	SORACU	15	Up		Y	0	0	0	--	--	--	--	--
2	BETPUB	10	B, Up		Y	50	2	2	20	0	0	15	--
3	QUEPET	20	B, Up		N	100	0	0	0	0	0	20	--
4 ¦	BETPUB	15,3,1	Up		Y	0	0	0	0	0	0	--	--
¦	"	2	B, St		Y	100	0	0	0	0	0	15	--
5	Salix	5	Up		Y	0	0	0	0	0	0	--	--
	"	8 ¦	Base										
	"	¦ 5, 3	Up		Y	0	0	0	0	0	0	--	--
	"	¦ 6	B, St		Y	100	0	0	0	0	0	30	--
6	"	4	B, Br	80	Y	0	0	0	0	0	0	--	3
7	SORACU	4	Up		?	0	0	0	0	0	0	--	--
		4	Up		?	deer	0	0	0	0	0	--	--
8	ALNGLU	15	B, St		Y	100	2	--	20	1	0	15	--
9	"	15	B, Log	30	Y	0	--	2	20	1	0	--	3
10	SORACU	20	B, P	45	Y	100	0	3	50	0	0	30	2
	BETPUB	25	B, Log	0	?	20	--	0	0	0	0	--	2
11	SALCAP	30 ¦	N, Log	0	Y	0	0	0	0	0	0	--	4
		¦3,3,4,5	Up		Y	0	0	0	0	0	0	--	--

a: bracket paired stumps & logs; **b:** For stumps, logs & partially felled, indicate B (beaver) or N (natural) then Up=upright; St=stump; P=partially felled; Log; Branch **c:** % of circumference or % of log w/in plot, "deer" for old deer bark stripping; **d:** <30cm; **e:** >30cm; **f:** 0=none, 1=detectable, 2=significant; **g:** within plot boundaries.

APPENDIX 2. MEAN PER CENT GROUND COVER OF TEN CATEGORIES ESTIMATED IN NOVEMBER 2012 IN TWO 2 M × 2 M SUBPLOTS IN EACH PLOT, AND THE MEAN NUMBER OF WOODY SEEDLINGS PER SUBPLOT

	Per cent Cover										
Transect, plot	Water	Rock	Bare ground	Grass / sedge	Leaf litter	Woody litter	Ferns	Bryophytes	Dwarf shrubs	Herb	Seedlings
1, 0m	70	0	5	5	20	2.5	1.25	15	1.25	2.5	0
1, 6m	20	0	2.5	16.25	45	2.5	13.75	32.5	3.75	1.25	0
1, 16m	0	0	0	1.25	75	6.25	42.5	25	2.5	2.5	0
1, 26m	0	0	0	2.5	80	8.75	17.5	25	1.25	3.75	0
2, 0m	2.5	0	2.5	70	22.5	3.75	2.5	20	15	1.25	0
2, 6m	7.5	0	0	27.5	52.5	5	2.5	40	2.5	2.5	0.5
2, 18m	1.25	0	1.25	31.25	70	3.75	2.5	55	1.25	1.25	0
2, 26m	2.5	5	1.25	21.25	75	6.25	2.5	67.5	0	2.5	0
3, 0m	0	0	0	50	50	2.5	5	15	15	0	1
3, 6m	0	0	0	62.5	35	1.25	7.5	25	2.5	0	0
3, 16m	0	0	0	52.5	52.5	3.75	16.25	25	2.5	2.5	0
3, 26m	7.5	0	0	50	60	3.75	5	40	1.25	6.25	0
4, 0m	10	0	0	80	7.5	1.25	0	17.5	8.75	0	0
4, 6m	2.5	0	0	97.5	2.5	1.25	1.25	11.25	0	1.25	0
4, 16m	0	0	0	11.25	55	3.75	1.25	70	1.25	0	0
4, 26m	1.25	0	0	16.25	60	12.5	1.25	67.5	0	0	0
5, 0m	0	0	0	100	5	1.25	2.5	1.25	15	0	0
5, 6m	2.5	0	0	97.5	12.5	1.25	12.5	2.5	0	0	0
5, 16m	1.25	0	0	45	62.5	1.25	17.5	17.5	2.5	1.25	0.5
5, 26m	1.25	0	0	52.5	37.5	2.5	1.25	16.25	27.5	2.5	0
6, 0m	100	0	0	57.5	2.5	0	0	0	0	2.5	0
6, 6m	100	0	0	57.5	2.5	5	0	1.25	0	5	0
6, 16m	55	0	1.25	55	11.25	1.25	0	22.5	0	5	0
6, 26m	2.5	0	10	40	10	6.25	2.5	35	2.5	7.5	0
7, 0m	0	2.5	1.25	10	50	5	77.5	45	37.5	0	0
7, 7m	0	12.5	2.5	2.5	72.5	11.25	11.25	55	16.25	0	0
7, 16m	0	25	0	1.25	70	3.75	2.5	45	30	0	0
7, 26m	0	37.5	0	1.25	40	2.5	46.25	52.5	62.5	0	0
8, 0m	0	0	0	60	90	1.25	0	2.5	0	0	0
8, 6m	0	0	0	70	87.5	1.25	3.75	2.5	0	0	0
8, 16m	0	0	0	50	75	3.75	2.5	17.5	1.25	3.75	0
8, 26m	0	0	0	40	80	1.25	1.25	17.5	1.25	2.5	0
9, 0m	2.5	0	0	65	40	2.5	1.25	20	3.75	17.5	0
9, 6m	0	0	2.5	77.5	45	2.5	0	2.5	3.75	3.75	0
9, 16m	2.5	0	1.25	45	37.5	1.25	1.25	42.5	2.5	3.75	0
9, 26m	0	0	0	8.75	82.5	3.75	6.25	52.5	2.5	2.5	0
10, 0m	2.5	0	1.25	85	7.5	6.25	3.75	25	0	0	0
10, 6m	0	0	1.25	70	45	2.5	18.75	17.5	2.5	13.75	0
10, 16m	1.25	0	2.5	70	72.5	1.25	1.25	47.5	0	3.75	0
10, 26m	1.25	0	1.25	60	50	0	3.75	26.25	0	16.25	0

Transect, plot	Per cent Cover										
	Water	Rock	Bare ground	Grass / sedge	Leaf litter	Woody litter	Ferns	Bryophytes	Dwarf shrubs	Herb	Seedlings
11, 0m	1.25	0	7.5	27.5	35	1.25	2.5	50	1.25	1.25	0
11, 10m	0	0	0	31.25	40	2.5	16.25	60	2.5	0	0
11, 20m	0	0	0	36.25	42.5	2.5	1.25	25	12.5	0	3
12, 0m	42.5	0	0	77.5	8.75	1.25	0	2.5	0	5	0
12, 6m	5	0	0	85	2.5	10	20	32.5	1.25	1.25	0
12, 16m	25	0	1.25	31.25	25	3.75	35	45	17.5	2.5	0
12, 26m	5	0	0	47.5	5	2.5	31.25	45	11.25	1.25	0
13, 0m	1.25	0	0	57.5	35	6.25	7.5	50	22.5	2.5	0
13, 6m	0	0	0	62.5	32.5	2.5	1.25	7.5	45	0	0
13, 16m	0	0	0	3.75	77.5	6.25	13.75	50	1.25	2.5	0
13, 26m*	*	*	*	*	*	*	*	*	*	*	*
14, 0m	0	6.25	1.25	72.5	30	1.25	6.25	8.75	0	2.5	0
14, 6m	0	15	0	80	45	2.5	7.5	1.25	0	1.25	0
14, 16m	0	0	0	55	65	2.5	17.5	2.5	0	12.5	0
14, 26m	0	0	0	80	45	2.5	2.5	1.25	0	5	0
15, 0m	5	0	1.25	52.5	15	3.75	0	50	0	0	0
15, 6m	12.5	0	1.25	65	10	8.75	0	40	0	1.25	0
16, 0m	1.25	0	1.25	55	40	3.75	20	52.5	17.5	1.25	0.5
16, 6m	0	0	0	32.5	10	2.5	42.5	32.5	10	1.25	0
16, 16m	0	0	0	85	2.5	11.25	22.5	50	0	0	0
16, 26m	0	0	0	70	6.25	2.5	17.5	52.5	0	0	0
17, 0m	40	0	0	65	35	5	1.25	5	1.25	2.5	1.5
17, 6m	40	0	5	70	10	0	5	3.75	2.5	2.5	5.5
17, 16m	30	0	7.5	67.5	12.5	1.25	1.25	3.75	2.5	2.5	0
17, 26m	0	0	0	32.5	65	2.5	11.25	22.5	3.75	2.5	0.5
18, 0m	30	0	1.25	22.5	75	3.75	1.25	13.75	0	1.25	3
18, 6m	0	0	5	47.5	52.5	2.5	0	33.75	1.25	3.75	1.5
18, 16m	11.25	0	20	25	45	2.5	1.25	16.25	1.25	5	0
19, 0m	2.5	1.25	0	46.25	15	1.25	52.5	6.25	0	0	0
19, 6m	0	0	0	72.5	22.5	3.75	2.5	20	2.5	0	0
19, 16m	0	0	0	70	30	1.25	30	21.25	2.5	0	0
19, 26m	0	10	0	5	55	3.75	10	45	45	0	1
20, 0m	90	0	0	52.5	21.25	1.25	0	1.25	0	5	0
20, 6m	12.5	0	0	52.5	37.5	2.5	0	8.75	0	6.25	0
20, 16m	8.75	0	1.25	67.5	35	2.5	0	1.25	0	7.5	0
20, 26m	1.25	0	15	26.25	35	2.5	1.25	37.5	0	1.25	0
21, 0m	2.5	0	0	72.5	55	2.5	2.25	7.5	3.75	2.5	0
21, 6m	0	0	0	11.25	10	0	77.5	12.5	0	2.5	0
21, 16m	0	0	0	10	87.5	1.25	27.5	7.5	0	2.5	0
21, 26m	0	0	0	6.25	90	1.25	30	3.75	0	2.5	0
22, 0m	5	0	0	25	85	1.25	0	1.25	0	1.25	0
22, 6m	0	0	0	62.5	65	2.5	0	2.5	0	5	0
22, 16m	1.25	0	0	97.5	30	1.25	1.25	3.75	0	17.5	0
22, 26m	5	0	2.5	55	45	2.5	5	8.75	0	30	0

Transect, plot	Per cent Cover: Water	Rock	Bare ground	Grass / sedge	Leaf litter	Woody litter	Ferns	Bryophytes	Dwarf shrubs	Herb	Seedlings
23, 0m	85	0	0	65	3.75	0	0	1.25	0	1.25	1
23, 7m	0	0	0	85	70	1.25	0	20	0	1.25	0
23, 16m	0	0	0	2.5	60	2.5	3.75	87.5	0	0	0
23, 26m	0	0	0	17.5	50	7.5	0	80	0	0	0
24, 0m	0	0	2.5	20	55	1.25	0	90	0	0	0
24, 6m	0	0	0	80	50	2.5	1.25	17.5	1.25	1.25	0
24, 16m	0	0	0	8.75	75	11.25	0	57.5	2.5	0	0
24, 26m	0	0	1.25	5	85	3.75	2.5	15	0	1.25	0
25, 0m	0	32.5	0	27.5	72.5	2.5	1.25	17.5	1.25	1.25	0
25, 6m **	-	-	-	-	-	-	-	-	-	-	-
25, 16m	0	0	0	70	65	1.25	2.5	2.5	1.25	2.5	0
25, 26m	0	0	0	67.5	42.5	2.5	2.5	20	6.25	2.5	1
26, 0m	15	0	1.25	25	20	6.25	41.25	15	3.75	0	0
26, 6m	0	0	0	40	30	2.5	40	55	2.5	0	0
26, 16m	0	0	0	6.25	22.5	22.5	17.5	80	5	0	0
26, 26m	0	0	0	2.5	62.5	12.5	2.5	65	2.5	0	0
27, 0m***	-	-	-	-	-	-	-	-	-	-	-
28, 0m	92.5	1.25	2.5	3.75	2.5	2.5	0	8.75	0	1.25	0
29, 0m	0	10	0	32.5	85	1.25	2.5	12.5	0	1.25	1.5
29, 6m	0	0	0	55	55	1.25	3.75	1.25	2.5	2.5	1.5
29, 16m	0	0	0	50	30	5	22.5	22.5	1.25	16.25	0
29, 26m	3.75	0	2.5	8.75	72.5	2.5	12.5	25	1.25	13.75	0
30, 0m	0	1.25	0	35	60	1.25	8.75	32.5	2.5	3.75	0
30, 6m	0	0	0	27.5	75	5	1.25	36.25	3.75	2.5	1.5
31, 0m	0	0	0	65	35	2.5	25	27.5	2.5	0	0
31, 6m	0	0	0	57.5	50	5	2.5	42.5	0	0	0.5
31, 0m	0	0	0	0	50	6.25	8.75	77.5	16.25	0	0

* Edge of plot bulldozed in 2011

** Track through centre of plot

*** Plot now completely submerged

APPENDIX 3. PHOTOGRAPHS

Appendix 3a: Figures a – d. Photographs showing horizontal vegetation changes since introduction of beavers

November 2009

November 2010

November 2011

November 2012

Figure a. Plot 211


November 2009 November 2010


November 2011 November 2012

Figure b. Plot 234

April 2010

November 2010

November 2011

November 2012

Figure c. Plot 300

November 2009

November 2010

November 2011

November 2012

Figure d. Plot 272

Appendix 3b: Figures e – h. Photographs showing horizontal vegetation difference between summer and winter

July 2012 November 2012

Figure e. Plot 251

July 2012 November 2012

Figure f. Plot 256

July 2012 November 2012

Figure g. Plot 285

July 2012 November 2012

Figure h. Plot 2895

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