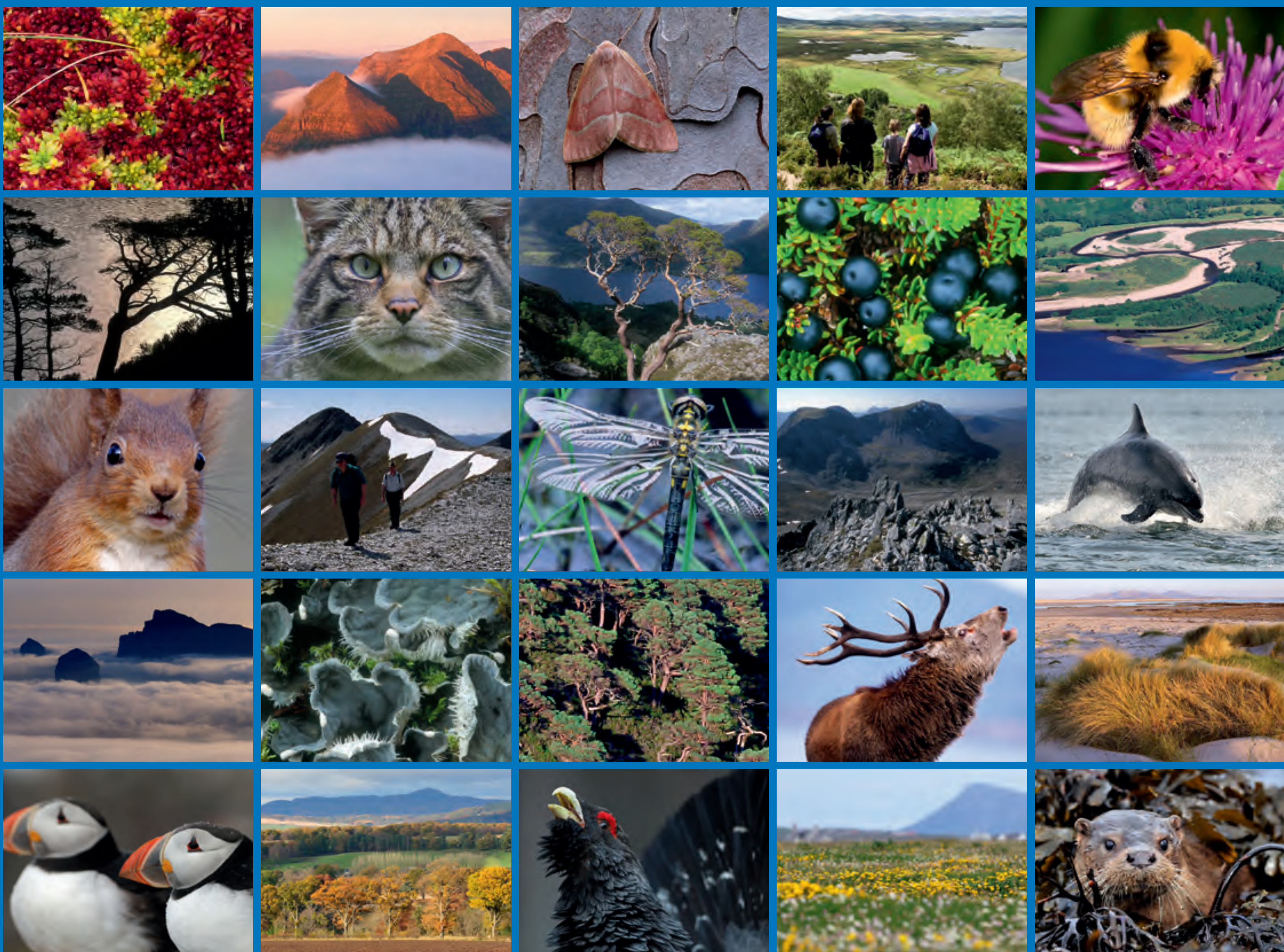
Scottish Natural Heritage
Commissioned Report No. 694

The Scottish Beaver Trial: Lichen impact assessment 2010-2014, final report



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COMMISSIONED REPORT

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The Scottish Beaver Trial: Lichen impact assessment 2010-2014, final report

For further information on this report please contact:

David Genney or Martin Gaywood
Scottish Natural Heritage
Great Glen House
INVERNESS
IV3 8NW
Telephone: 01463 725000
E-mail: beavers@snh.gov.uk

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COMMISSIONED REPORT

Summary

The Scottish Beaver Trial: Lichen impact assessment 2010-2014, final report

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Keywords

Castor fiber; Atlantic hazel; micro-habitat continuity; impacts; *Corylus*; *Lobarion*; *Graphidion*; Knapdale.

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 owned by Forestry Commission Scotland (FCS) 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 report describes work by Scottish Natural Heritage (SNH) to examine the observed and potential impacts of beavers on lichen communities within the trial area with particular emphasis on Taynish and Knapdale Woods Special Area of Conservation (SAC). The report also assesses wider potential impacts of beavers on lichens should a wider reintroduction be implemented.

Main findings

- The national and international importance of oceanic lichen communities at Taynish and Knapdale Woods SAC is described before summarising the potential impacts that beavers may have on them. Particular attention is paid to the impact on the diversity and temporal continuity of woodland lichen micro-habitats.

- After assessing the initial impact of the released beavers, a risk assessment was carried out that identified hazelwoods (termed ‘Atlantic hazel’ in western Scotland due to the strong influence of the oceanic climate on associated lichen diversity) as the most vulnerable lichen habitat within the trial area. Atlantic hazel supports two globally restricted lichen communities called the *Lobarion* and *Graphidion*. Other lichen habitats were scoped out of detailed monitoring because the risk of beaver impact was judged to be low.

- Indirect assessment of the impact of beaver on these Atlantic hazel lichens was carried out between July 2013 and April 2014 by quantifying the direct impact on hazel in all stands continuous with beaver-inhabited water bodies.

- Out of a total of 12,810 stems from 1,417 hazel stools (individual hazel plants), 8.6 % had either been felled or partially felled from 19.5 % of the stools. Thirty three stools had been completely felled resulting in localised loss of lichen habitat continuity at the stool scale. Even short breaks in lichen habitat continuity can result in loss of lichen species that may take many years to recolonise.

- The impact was restricted to a maximum of *c*. 60 m from a loch and within woodland on gentler, less bouldery slopes. Within this utilised zone 24.4 % of stems had been felled impacting just over half of the stools. There was no observable impact on lichens beyond areas where felling had occurred. Most felled stems supported oceanic lichen communities including a number of species that are of national and/or international conservation concern.

- The beavers utilised just under 8 % of Atlantic hazel-dominated woodland area across the Taynish and Knapdale SAC. Given the relatively high rate of stems felled within the trial period, high levels of browsing of sun-shoots (the next generation of hazel stems), and other observed factors, concern is raised for the long-term viability of Atlantic hazel lichen habitat (under current conditions) around water bodies occupied by beavers. However, there is uncertainty about whether beavers will eventually fell all hazel stems and how beaver and other browsing patterns will vary over time. There is a possibility that some lichen species of conservation concern will become locally extinct (extirpated) in beaver-occupied habitat.

- So far, the SBT is not considered to have had an unacceptable adverse impact on the quality of SAC qualifying woodland habitat (with lichens as typical species) within the Taynish and Knapdale SAC, however this assessment will have to be periodically reviewed should beavers remain within the site.

- Given these impacts, the overlap between Scotland's entire Atlantic hazel habitat on the Native Woodland Survey of Scotland with a national model of potential beaver habitat was calculated. If beavers were to be introduced or otherwise spread throughout all suitable habitat it is expected that a maximum of 27 % of Scotland's Atlantic hazel habitat could be impacted. This is a significant proportion given the restricted global range of the associated lichen communities. However, wider monitoring over a longer period of time will be required to fully assess the impact within areas where Atlantic hazel lichen and beaver habitat overlap.

- The potential impact of beavers on other important woodland lichen habitats is considered, with particular attention given to aspen and riparian trees in central and eastern Scotland. Aspen has a restricted distribution in Scotland, supports a diverse range of lichens of conservation concern and is preferentially felled by beavers. The conservation of aspen would need to be addressed in any future beaver management strategy if there is a decision to allow further beaver reintroduction, together with further necessary research.

- Depending on circumstances, fencing may not be an appropriate method to locally protect trees or shrubs that provide important lichen habitat. The long-term absence of grazing can be as damaging as over-grazing due to thicket regeneration and shading of light demanding lichens. Management of beaver populations at an achievable scale in areas supporting diverse lichen habitat is recommended until the wider impact of beavers can be determined.

- Compensatory expansion of affected woodland lichen habitat should be considered, although this would be a long-term strategy, requiring prior or early implementation given the very long time period over which ancient woodland lichen micro-habitats are thought to develop and poor dispersal capabilities of many lichen species. Every effort should also be made to reduce the impact of other pressures on important woodland lichen habitat e.g. invasive non-native species such as rhododendron, air pollution or inappropriate grazing levels.

For further information on this project contact:
David Genney or Martin Gaywood, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or beavers@snh.gov.uk
For further information on the SNH Research & Technical Support Programme contact:
Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725000 or research@snh.gov.uk

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:
www.snh.gov.uk/scottishbeavertrial
or contact:
Martin Gaywood, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.
Tel: 01463 725230 or beavers@snh.gov.uk

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We would also like to thank SBT staff and Forestry Commission Scotland for facilitating access to the study site and members of the British Lichen Society for access to their species distribution database.

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 & 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 (SAF), launched in 2007 by Scottish Ministers, set 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 worked 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 beavers to Knapdale Forest, mid-Argyll (hereafter referred to as the Scottish Beaver Trial (SBT)). The licence was granted to the Scottish Wildlife Trust (SWT) and the Royal Zoological Society of Scotland (RZSS) 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 (Loch na' Creige Mòire)/ Un-named Loch (North), 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 was that SNH should coordinate an independent monitoring programme in collaboration with the project partners. The trial therefore involved 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 report by Scottish Natural Heritage considers the impact of beaver on lichens at Taynish and Knapdale Woods SAC/Knapdale Woods SSSI. It also considers the potential national impact on lichens should beavers be released more widely throughout Scotland.

2. AIMS AND OBJECTIVES

The overall aim of the SBT, as set out in the licence application submitted by RZSS and SWT was:

"*To undertake a scientifically monitored trial re-introduction of the European beaver to Knapdale, mid-Argyll, for a five year period in order to:*

- *Study the ecology and biology of the European beaver in the Scottish environment;*

- *Assess the effects of beaver activities on the natural and socioeconomic environment;*
- *Generate information during the proposed trial release that will inform a potential further release of beavers at other sites with different habitat characteristics;*
- *Determine the extent and impact of any increased tourism generated through the presence of beaver;*
- *Explore the environmental education opportunities that may arise from the trial itself and the scope for a wider programme should the trial be successful*".

The aim of the work reported here is to assess the effect of the introduced beavers on lichen habitat in the area of the trial release. Since the majority of important lichen habitat within Taynish and Knapdale SAC is woodland, this report draws heavily on, and complements the wider woodland habitat monitoring carried out by Iason *et al*. (2014). In doing so, this report helps address the second and third overall aims of the trial, and will help to inform any future decisions and plans for beavers in Scotland.

The specific objectives of this report are to:

- Outline the importance of lichens in Scotland and within Taynish and Knapdale Woods SAC;
- Describe the potential impacts of beavers on lichens;
- Summarise which important lichen habitats are at risk from negative impacts due to beaver activity within Taynish and Knapdale Woods SAC;
- Assess the impact of beavers on Atlantic hazel (*Corylus avellana*) lichen habitat within Taynish and Knapdale Woods SAC;
- Extrapolate these findings to predict the impact of beavers on Atlantic hazel lichen habitat at the national and European level should further reintroductions take place;
- Identify gaps in our understanding of the impact of beaver on lichens following the Knapdale trial.

3. LICHENS AND THE POTENTIAL IMPACT OF BEAVERS

3.1 The importance of Scottish lichen populations

With over 1500 species, Scotland has a large diversity of lichens and is home to many species that are rare or absent from the rest of Europe. The west of Scotland, where the climate is strongly oceanic (characterised by relatively mild wet winters and cool wet summers), supports lichen communities of particular international importance (e.g. see section 5.1). Relatively clean air, geo-diversity and a rich tapestry of habitat types from lowland woodland to exposed mountain summits also contribute to this abundance and diversity. The international significance of Scottish lichen populations cannot be overstated and they attract the interest of lichenologists from around the world.

Lichen habitat requirements are also diverse. For example some grow on rocks, others on trees and some directly on the ground. Most are terrestrial but some grow submerged in rivers and streams, while others are marine. Within these broad habitat types, there is further variation in species' habitat requirements. For example, many woodland lichens grow only on particular species of tree, and then further differentiate between twigs or trunks, dead or live trees, young or old trees, bark or bare wood, and open or sheltered aspects. This diversity of ecological requirements makes it difficult to provide a simple assessment of the impact of beavers on lichens. However, it is possible to focus on species of greatest national and international importance (as defined by their rarity within Scotland and/or within Europe), and within these on woodland species that are most likely to be impacted by beaver activity.

3.2 Lichen ecology and potential impact of beavers

The following woodland characteristics are the main drivers of lichen diversity in woodland, and the potential impacts of beavers are briefly discussed for each:

3.2.1 Diverse micro-habitats

Lichens respond to small-scale habitat variability, so in addition to allocating species to broad habitats, e.g. to oak woodland, lichenologists also assign species to micro-habitats. Lichen diversity is directly related to the diversity of these micro-habitats (Ellis, 2012). Different micro-habitats can be found on different tree species and on different ages of tree. While young and smooth-barked trees support communities of crust-like lichen species, old trees with rougher bark and more complex structure provide a much greater range of micro-habitats, e.g. wound tracks, water seepage lines, dead branches and sheltered fissures within the bark. Old trees therefore support a particularly high diversity of species compared to young trees, including crust-like, leafy and powdery lichen forms. Different tree species also produce bark with contrasting chemical properties. Some lichens are adapted to acid, low nutrient bark, while others grow only on trees with neutral, nutrient-rich bark. Tree diversity is therefore another important driver of lichen diversity.

Beavers have the potential to reduce the abundance and diversity of woodland micro-habitats, particularly those normally associated with ancient woodland. This is because they can maintain woodland in a state of coppice dominated by younger stems (Donkor & Fryxell, 2000) which does not support a wide range of lichen micro-habitats. Beavers also prefer to use some species of tree over others, and are therefore likely to affect the diversity or relative abundance of trees (Donkor, 2007), and therefore lichens, within a woodland. Lichens that are strongly associated with tree species preferred by beavers may be particularly threatened.

3.2.2 Ecological continuity

Lichens grow relatively slowly compared to vascular plants and many ancient woodland associated lichens are also thought to be dispersal-limited (e.g. Sillett *et al*., 2000). It is therefore thought to take many years for new or disturbed woodland to be colonised by ancient woodland lichen species. The high diversity of lichens in ancient woodlands is therefore not only a function of their high micro-habitat diversity (3.2.1), but also their temporal ecological continuity. Observations that many lichen species are restricted to ancient woodland led Coppins and Coppins (2002) to develop tables of lichens that indicate long periods of ecological continuity (IEC), and these are widely used to assess the relative quality of woodland habitat for lichens across the British Isles. If a suite of micro-habitats is lost from a woodland, even temporarily, for example through the loss of old trees or of all of a particular tree species, there is a high chance that associated lichen species will be extirpated. If, and how quickly, species re-colonise is thought to depend on a number of factors, such as whether the micro-habitats recover and the proximity and abundance of donor lichen populations in the surrounding landscape (e.g. (Ellis & Hope, 2012; Scheidegger & Werth, 2009). Based on the current understanding of lichen dispersal, establishment and the time taken for ancient woodland micro-habitats to recover, the perceived wisdom is that, following a break in micro-habitat continuity, recolonisation may take many decades and some species, particularly those that are already rare in the landscape, may not return. To emphasise, from a lichen perspective, ancient woodland is woodland with a long history of micro-habitat continuity rather than continuity of trees *per se*. For example, Ellis and Hope (2012) found little difference in the lichen diversity associated with micro habitats on oak trees in ancient versus recent woodland. They hypothesised that this was due to intensive management of oak within ancient woodland sites in the late-18th and early 19th Century, resulting in similar micro-habitat continuity between old and new woodland.

The temporary or permanent loss of lichen micro-habitats due to beaver activity (3.2.1) may break a long history of ecological continuity in some woodland. The potential for beavers to break the continuity of micro-habitats associated with old-growth woodland is of particular concern since this may result in the loss of species that are typical of ancient woodland and that have poor recolonisation potential. Even short breaks in continuity may result in long-term losses, so the recovery of trees between successive cycles of felling is unlikely to result in ancient woodland lichen recovery. The stand-level impact of beavers will depend upon a number of factors including the proportion of the stand that is utilised by the animals and within utilised areas, the proportion of a particular micro-habitat that is lost. Many species of oceanic lichen, for which Scotland frequently holds the bulk of the European population, are associated with old tree micro-habitats, so it will be important to assess impacts on these species in a European context following the trial.

3.2.3 Light and shelter

Although there is a large amount of variation in the light requirements of different species of lichen, as photosynthetic organisms, they all require a minimum level of light. Most species do not tolerate heavy shade. The health of lichen populations can therefore be severely impacted by the shade cast by e.g. dense thickets of young trees, or by invasive non-native species such as *Rhododendron ponticum* and certain commercial conifers. Shelter is another important determinant of woodland lichen diversity, with some species only thriving when protected from desiccating wind and direct sunlight. Changes in the balance between light and shelter can therefore alter the suitability of woodland habitat for many lichen species.

Woodland monitoring within the SBT has demonstrated that beavers influenced the structure of the woodland causing an opening up of the canopy, and a reduction in the vertical density of vegetation. This is likely to alter the composition of lichen communities within affected woodland, but this has not been monitored during the current trial.

In addition to the impacts described above, it should be noted that most epiphytic lichens die when the trees or stems they grow on are felled to the ground.

3.3 Historical perspective

The Scottish landscape has changed significantly in the 400 years since the extirpation of the beaver. In this time habitats have been subject to significant habitat disturbance through often drastic changes in land use (e.g. conversion to conifer plantations). Hence, many areas, such as Knapdale, have suffered severe habitat reduction and lichen populations here could be described as remnants, only now beginning to recover. Beavers have the potential to reintroduce a further source of habitat disturbance, albeit one that occurred as a natural component of the landscape in the past. Whether habitats, particularly those that support species such as lichens that are sensitive to breaks in micro-habitat continuity, have the resilience to withstand additional disturbance should be a key consideration when interpreting the findings of the SBT and associated monitoring.

3.4 Important lichen habitats within Taynish and Knapdale Woods SAC

Lichens are considered typical species of the qualifying woodland habitat within Taynish and Knapdale Woods SAC. More detail on the type and distribution of important lichen habitat and communities within the SBT area is provided in the Knapdale Woods SSSI citation. This states (additions in square brackets inserted by Griffith (2011)):

> *'Lichen assemblages of international and national importance occur within the wide range of habitats and topographical features which make up Knapdale Woods SSSI. [By 2004] over 440 lichen taxa [had been] recorded, with 10 nationally-rare species*

including Bactrospora dryina *(Red Data Book (RDB) critically-endangered), and 17 species listed as RDB near-threatened [85 Nationally Scarce species have also been recorded.]. The presence of 40 lichenicolous fungi further emphasises the biodiversity importance of the site, these fungi being numerous only within old, long-established and species-rich lichen communities. There are 67 lichen taxa of international-responsibility, mostly indicative of the well-developed Lobarion community, which includes all four British species of the genus* Lobaria*, as well as four species of* Pseudocyphellaria*, including* P. lacerata *(RDB vulnerable) and* P. norvegica *(BAP species). The* Lobarion *community generally is well-represented, and in healthy, viable populations. Around the Faery Isles and Port Lunna, this community is richly developed in characteristic habitat features for this part of Knapdale. These habitats are under dappled tree canopy on sheltered base-rich rocks above the coast in sheltered inlets. The more exposed rocky ridges with oak and birch as are found above Port Lunna, between Loch Barnluasgan and Loch Linne, and around Loch Coille-Bharr, support notable assemblages of the* Parmelietum laevigatae*. The sheltered, humid Atlantic hazelwoods of Barnluasgan are important for luxuriant* Lobarion *lichens, together with a nationally important smooth-bark community of the* Graphidion *on hazel, rowan and holly. Rocks and boulders within the SSSI are an integral part of the overall habitat, and lichens on mossy rocks contribute to the overall species diversity.'*

For the purposes of Site Condition Monitoring (SCM), the cycle of monitoring used to assess the condition of notified features on SSSIs and SACs, the following lichen habitats are assessed (see Annex 1 for detailed descriptions):

- Oceanic, sheltered birch-oak woodlands on rocky ridges and knolls (Figure 1)
- Oceanic coastal cliffs and gullies (terrestrial zone) (Figure 2)
- Oceanic mixed deciduous woods on base-rich soils
- Atlantic hazelwoods (Figure 4)

The Taynish Woods SSSI component of the Taynish and Knapdale Woods SAC is also important for its lichen assemblages, but is not considered further in this report because of the very low risk that beavers would colonise or utilise woodland in this part of the SAC.

3.4.1 Risk assessment of the impact of beavers on important lichen habitat within Taynish and Knapdale Woods SAC

Because lichens are typical species of the SAC qualifying woodland habitat, it was important to regularly monitor and assess the impact of the beavers on the woodland lichen interest.

Early in the trial SNH's lichen advisor, David Genney and woodland ecologist, Jeanette Hall, conducted a number of site visits to rapidly assess the initial impact of beavers on lichen and woodland features across the Knapdale Woods SSSI component of the SAC. This was supplemented in 2010 by a full assessment of the lichen interest of Knapdale Woods SSSI for SCM by Griffith (2011). Based on these early observations the following risk assessments of the impact of the SBT on important lichen habitats were made:

- Oceanic, sheltered birch-oak woodlands on rocky ridges and knolls are common and widespread at Knapdale, but tend to occur either away from water bodies or on steep boulder terrain that is unlikely to be accessed by beavers (Figure 1). Although the impact of beavers on lichens associated with this habitat could be high, the likelihood of this happening was assessed as very low and therefore the overall a risk was also considered to be low.

- Beavers are species of freshwater habitats, well away from lichen communities on coastal rocks (Figure 2) within the SAC. The overall risk was considered to be low.
- Mixed deciduous woods on base-rich soils are relatively rare within the SAC. The main area identified as important lichen habitat occurs well away from beaver-inhabited water bodies so although a watching brief was required, the risk to this habitat was considered low.
- Atlantic hazelwood (or Atlantic hazel) occurs frequently around loch margins within the SAC and produces many stems within the size range frequently felled by beavers. It is also one of the richest habitats for internationally important populations of oceanic epiphytic lichens due to its structural diversity (Section 5.1 and also see Coppins & Coppins (2012)). As a result of the high likelihood of impact and the importance of hazel as a lichen habitat, the risk was considered to be high.

Based on this risk assessment, further monitoring concentrated on the impact of beavers on Atlantic hazelwood lichen habitat within the SAC (see Section 4).

Figure 1. Mature oak trees growing on steep or rocky ridges (here along the east shore of Loch Coille-Bharr) support rich examples of the internationally important oceanic Parmelietum laevigatae *lichen community.*

Figure 2. Sheltered rocks and trees in woodland along the extensive coastline within Taynish and Knapdale Woods SAC support luxuriant communities of oceanic lichens. Large colonies of Lobaria scrobiculata *(leafy grey lichen top-left) and* L. amplissima *(large green and black colony across the middle) festoon this coastal boulder in dappled shade.*

4. IMPACT OF BEAVERS ON ATLANTIC HAZEL LICHEN HABITAT WITHIN TAYNISH AND KNAPDALE WOODS SAC

4.1 Introduction

According to the Native Woodland Survey of Scotland (NWSS) (Forestry Commission Scotland, 2014), Taynish and Knapdale Woods SAC contains six discrete stands of woodland where hazel contributes 80 % or more to canopy cover (*Figure 3*). This accounts for 10.8 ha of woodland or 1 % of the area of the SAC. Most of this woodland occurs in the north of the site around lochs that could be utilised by beavers.

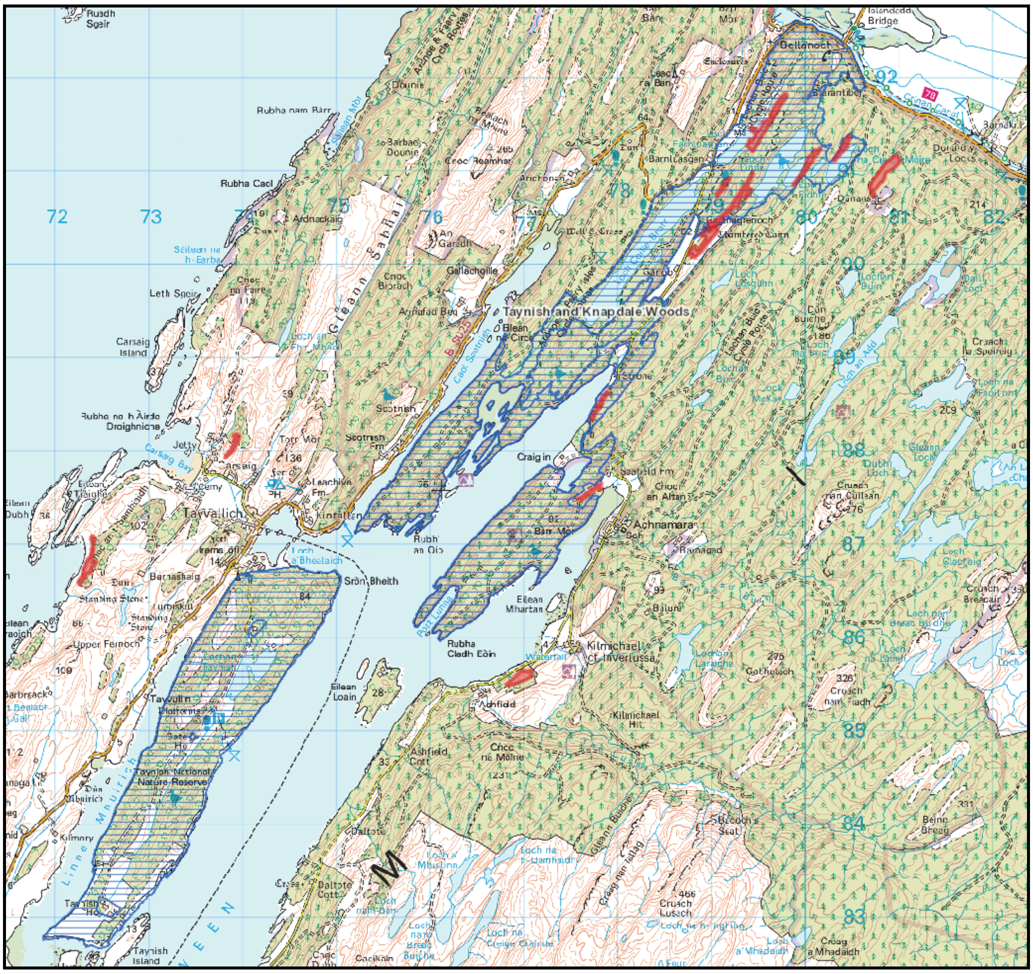

Figure 3. Distribution of NWSS polygons with at least 80 % hazel canopy cover (red shaded areas) in relation to the Taynish and Knapdale Woods SAC (blue horizontal lines). © Crown copyright and database right 2015. Ordnance Survey 100017908.

Atlantic hazel provides habitat for a diverse assemblage of oceanic lichens. A community of crust-like lichens called the *Graphidion* grows on young smooth-barked stems while older, rougher stems support a community dominated by larger, leafy lichens called the *Lobarion* (Figure 4). The coexistence of these two lichen communities, along with the equitable oceanic climate, stand structure and the long temporal continuity of many Atlantic hazelwoods, all contribute to the ability of Atlantic hazel to support a high diversity of lichens. The national and international significance of these communities is described in Section 5.1.

Figure 4. Atlantic hazel supports two distinct oceanic communities of lichens. Young smooth-barked stems support a community of crust-like lichens called the Graphidion *(left) while older, rougher stems support a community dominated by larger, leafy lichens called the* Lobarion*.*

Under natural conditions, hazel is a multi-stemmed shrub. Despite this growth form being similar to hazel that has been coppiced, there is no evidence that species-rich stands of Atlantic hazel were ever coppiced in the past (Coppins & Coppins, 2012). An individual is referred to as a 'stool', with each stool normally supporting a range of stem ages from thin, young stems (often called 'sun-shoots') to large old rough-barked stems. As the largest and oldest stems die or snap off under their own weight, they create a gap that allows replacement by young hazel stems from the bank of sun-shoots at the stool base. A single naturally self-perpetuating hazel stool can therefore be ancient and, while individual stems have a finite life, they provide long periods of ecological continuity of both young, smooth-barked and old rough-barked stems. As described in Section 3.2.2, this temporal micro-habitat continuity is an important determinant of lichen diversity. The loss of all, or a particular age-class, of stems from a stool, either through coppicing by humans or felling by beavers, can result in the loss of long-term habitat continuity and thereby loss or deterioration of ancient woodland lichens assemblages (Coppins & Coppins, 2012).

In a sample-based assessment of the impact of the SBT on woodland composition and structure, Iason *et al*. (2014) set up 31 transects perpendicular to beaver-occupied water-bodies. However, because the woodland monitoring was not designed to specifically monitor hazel, only two of these transects (8 and 21) occurred within hazel-dominated stands. This was not thought sufficient to assess the SAC-scale impact of beavers on Atlantic hazel lichen habitat, one of the conditions of the SBT licence. For this purpose, two methods were considered; the first was to directly monitor lichens, and the second to indirectly monitor the impact on lichens by measuring the impact on lichen habitat. While direct lichen monitoring would have given the most accurate local measure of impact on individual species and communities, the indirect monitoring approach was chosen for the following reasons:

1) A number of important habitat variables (indirect attributes) could be monitored relatively rapidly allowing a complete survey of all beaver-affected hazel stands. This was important both to assess the impact on lichens as typical species of the SAC, and also to allow extrapolation of the impacts beyond the SBT.

2) Direct lichen monitoring would have been too time-consuming to cover the whole site and sub-sampling would have been difficult to implement without prior knowledge of the areas affected by beavers. A similar conclusion was drawn by Armstrong *et al*. (2004) in their assessment of methods to determine the impacts of beaver on woodland vegetation.

3) Lichens occupy a complex three-dimensional suite of micro-habitats within a hazel stool. Direct monitoring was therefore thought likely to introduce significant surveyor error, e.g. in the establishment and subsequent re-monitoring of baseline data (as subsequently demonstrated by Britton *et al*. (2013). This, combined with the low frequency and patchy distribution of some lichen species within hazel stands, would have made it difficult to identify statistically significant changes attributable to beavers within the timeframe of the SBT.

Indirect monitoring had the following specific aims:

- Identify the area of Atlantic hazel lichen habitat utilised by beavers within Taynish and Knapdale SAC.
- Measure the impact of beaver activity on stools and stems within beaver-affected hazel stands.
- Assess the potential for hazel stools to recover following beaver activity
- Determine the current and future likely impact on lichen micro-habitat continuity within affected stands.

4.2 Methods

Stands of hazel were located by querying the Native Woodland Survey of Scotland (NWSS) and aerial imagery, and confirmed by walking the perimeter of each beaver-inhabited water body. The walk-over identified three additional stands, all around Loch Linne, that were not identified by the NWSS. The five stands that were continuous with water bodies occupied by beavers (Loch Linne, Loch Fidhle and Creagmhor Loch) were included in the detailed survey (Figure 5).

All stools within the five selected stands were surveyed over five days. This took place in two stages, the first on the 23rd and 24th July 2013 (covering Loch Linne (West), Loch Linne (North-west), Loch Linne (North-east) and Creagmhor Loch stands but not the Loch Fidhle stand due to time constraints) and the second between the 28th and 30th April 2014 (50 and 59 months after the beavers were released respectively). The 2014 survey followed the same methodology as in 2013 but also assessed grazing levels of sun-shoots and differentiated between partially and totally felled stems (see the assessed attributes below). Again, with such a large area to cover in 2014, time prevented a full survey of all five stands. Effort focussed on collecting baseline data for the Loch Fidhle stand and from beaver-affected areas within the Loch Linne (West) and Creagmhor Loch stands. Re-survey of the latter two stands was carried out to expand coverage of the 2014 sun-shoot grazing assessment and to gauge whether an apparent increase in beaver activity in hazel stands had continued through the final autumn and winter of the trial.

The following attributes were recorded from each stool:

1. Date recorded
2. Eight figure grid reference (10 m square)
3. Number of unaffected stems > 1 cm diameter at breast height (dbh)
4. Number of stems > 1 cm dbh partially felled (>1/4 diameter gnawed) (2014 only[1])
5. Number of stems > 1 cm dbh fully felled
6. Diameter of largest unaffected stem (to nearest 5 cm dbh category)
7. Diameter of largest felled stem (to nearest 5 cm category at stump level)
8. Grazing impact on sun-shoots (see below)

By restricting stem counts to those with > 1 cm dbh, sun shoots were not counted. However, grazing pressure on sun shoots was recorded in the 2014 survey to assess the likelihood that stools would recovery after being felled. To aid rapid survey of a large area, the shoots on each stool were assigned to the following broad categories:

0 = ungrazed
1 = 1-50 % shoots grazed
2 = 51-99 % shoots grazed
3 = 100 % shoots grazed
4 = no sun shoots on stool

Representative photographs were taken and casual notes made on the distribution of typical *Lobarion* and *Graphidion*-associated lichens throughout the study area.

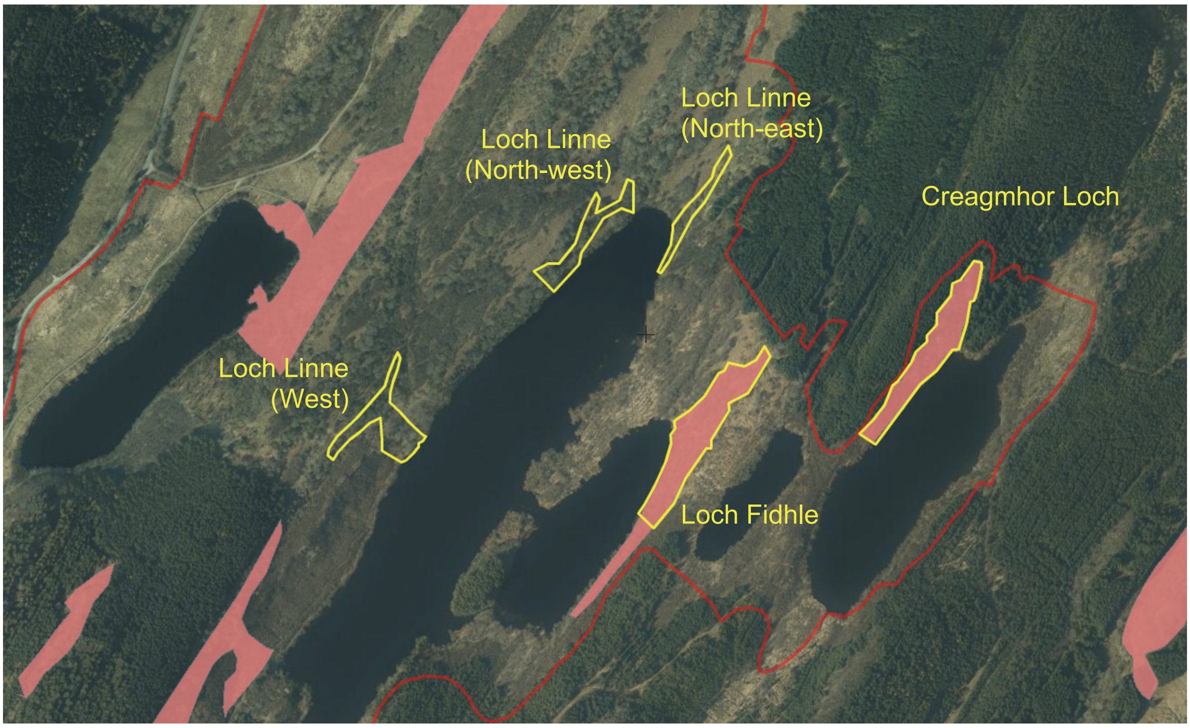

Figure 5. Approximate location of the five main hazel stands continuous with beaver inhabited water bodies (yellow border). NWSS polygons containing 80 % or more hazel in the canopy are shaded pink. Base layer © Getmapping plc.

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[1] Due to time constraints in 2013, partially felled stems and fully felled stems were recorded as felled (beaver impacted). Felled and partially felled stems were recorded separately in 2014 for Loch Fidhle, Creagmhor Loch and Loch Linne (West) stands only.

4.3 Results

In total, 1,417 hazel stools were recorded in the five stands, of which 261 (19.5 %) had been directly impacted (Figure 6). This amounted to 12,810 individual stems of which 1,106 (8.6 %) had been felled or partially felled. The distribution of hazel stems and relative impact by beavers across all assessed stands is shown in Figure 7. Thirty three stools had been completely felled (e.g. Figure 8), including stools in all stands except for Loch Linne (North-west) with the majority (14) in the Creagmhor Loch stand. The completely felled stools were amongst the smaller stools in the stands with the largest originally having 11 stems. The maximum number of stems impacted per stool was 16, and stools with 21 to 44 (the largest stool surveyed) stems had fewer than 50 % of stems felled.

Five hundred and four stools (35.6 %) occurred within the 113 10 m squares with beaver activity. Within these squares, 24.4 % of stems had been either felled or partially felled from 53.6 % of the stools. For the Loch Fidhle, Loch Linne (West) and Creagmhor Loch stands, surveyed in 2014, it was possible to calculate values for felled and partially felled stems independently. This demonstrated that 88 % of the beaver impacted stems were fully felled (23 % of all stems within beaver impacted 10 m squares).

A more detailed look at the Loch Linne (West) stand illustrates the spatial distribution of beaver activity (Figure 10). Felled stems were detected up to 60 m from the edge of the loch, although felling at this distance seems to be entirely exploratory with less than 10 % of stems felled. There was no indication that stems were preferentially felled from hazel stools along the loch margin. Most stems were felled from areas supporting the greatest density of stems between 10 and 20 m into the stand. It was also at these distances that the greatest proportion of stems were felled from individual stools, with up to 80 % of stems being fully felled in some 10 m squares. Similar patterns of utilisation were observed in the other four stands (see ANNEX 2: Detailed beaver impact Charts not included in main text), although impacted stools were not found as far from the water's edge.

As expected, felled stems resulted in the loss of lichens from the *Graphidion* and *Lobarion* communities (Figure 9). From casual observations of the most rapidly recognisable members of these communities, there was no indication that they were any better or worse developed within and outwith areas affected by beavers. *Graphidion*-community lichens were more abundant on stems <10 cm diameter while *Lobarion*-community lichens were more prevalent on larger stems.

There was no appreciable difference in the total number of stems (felled and standing) recorded in beaver-impacted 10 m squares that were monitored in both 2013 and 2014 (1589 and 1613 stems respectively). There was some indication that the number of stems felled and partially felled had increased (counts of 447 and 502 respectively – an apparent 12 % increase), however variation in GPS signal prevented pairwise comparisons between 10 m squares so it was not possible to determine whether this increase was due to further beaver activity or minor counting errors. The surveyors did not notice many freshly gnawed stems in 2014, suggesting that the difference was most likely due to counting error.

The maximum stem diameter in each beaver impact class was analysed for stools that were impacted by beavers[2]. Most of the largest felled stems were between 1 and 10 cm diameter (dbh) with a mean diameter of 8.2 cm (Figure 11). The largest partially felled stems tended to be larger in diameter than felled stems (mean diameter = 10.4 cm) with more attempts at stems greater than 10 cm diameter compared to felled stems. Beavers did not attempt to fell stems greater than 20 cm, although very few larger stems were available.

[2] Only 2014 data were used because this allowed discrimination between fully and partially felled stems.

Figure 6. Examples of beaver-browsed hazel stools within Taynish and Knapdale Woods SAC. Bottom right photo demonstrates typical level of sun-shoot browsing across the site (most shoots browsed).

The mean maximum diameter of remaining standing stems was 12.7 cm with the largest recorded stem between 30 and 35 cm diameter. The largest felled stem on 66 % of stools was in a lower diameter class than the largest remaining stem on the stool. However, only 5 % of stools had at least one stem larger than the largest felled stem diameter class. The mean values presented here must be treated with caution because they are calculated from categorical data – they merely serve to describe the relative size-class distribution between beaver impact categories. It should also be noted that, as a total local population dataset there is no replication, so while the data give an accurate impression of the impact within the SBT area, it is not possible to assign statistical significance to the observed differences or to extrapolate beyond the trial without caution.

The level of sun-shoot grazing within each of the three assessed stands is illustrated in Figure 12. Across all stands[3], 75.7 % of hazel stools with sun-shoots had high levels (>50 %) of browsing, presumably by deer. Many sun-shoots were recorded as ungrazed on the basis that they had new, spring growth from the tips of previously grazed shoots.

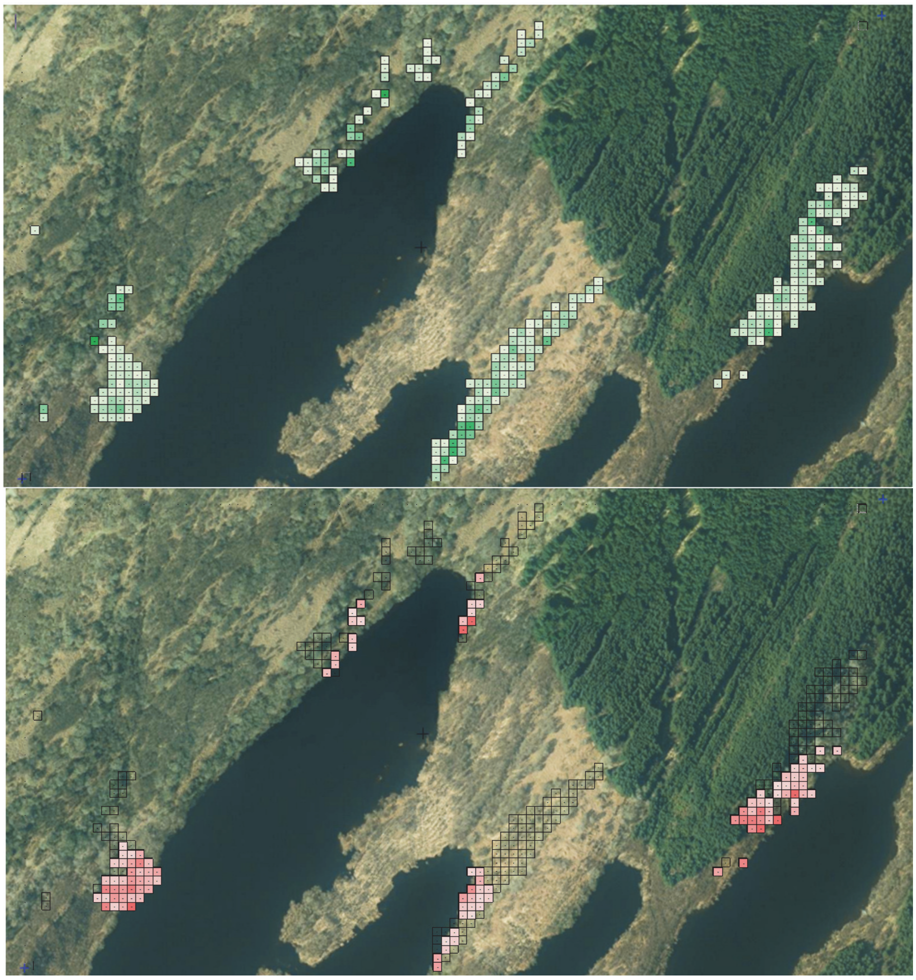

Figure 7. Relative hazel stem distribution (upper image) and proportion of stems felled or partially felled (lower image) per 10 m OS grid square (see Figure 10 and Annex 2 for values). Data shown for all continuous beaver browsed hazel stands within Taynish and Knapdale Woods SAC (bottom left grid = NR79519100). Base layer © Getmapping plc.

[3] Note that lack of time prevented sun shoot assessment of all stools in the large Loch Fidhle stand, so only a random sub-sample of stools were assessed in some areas of the stands not impacted by beavers.

Figure 8. Completely felled hazel stool at NE end of Loch Linne (NR800914) (2013).

Figure 9. Lobarion *lichens on a felled hazel stem. Most lichens will subsequently die as stems decay, light and humidity conditions change or bark is stripped by the beavers.*

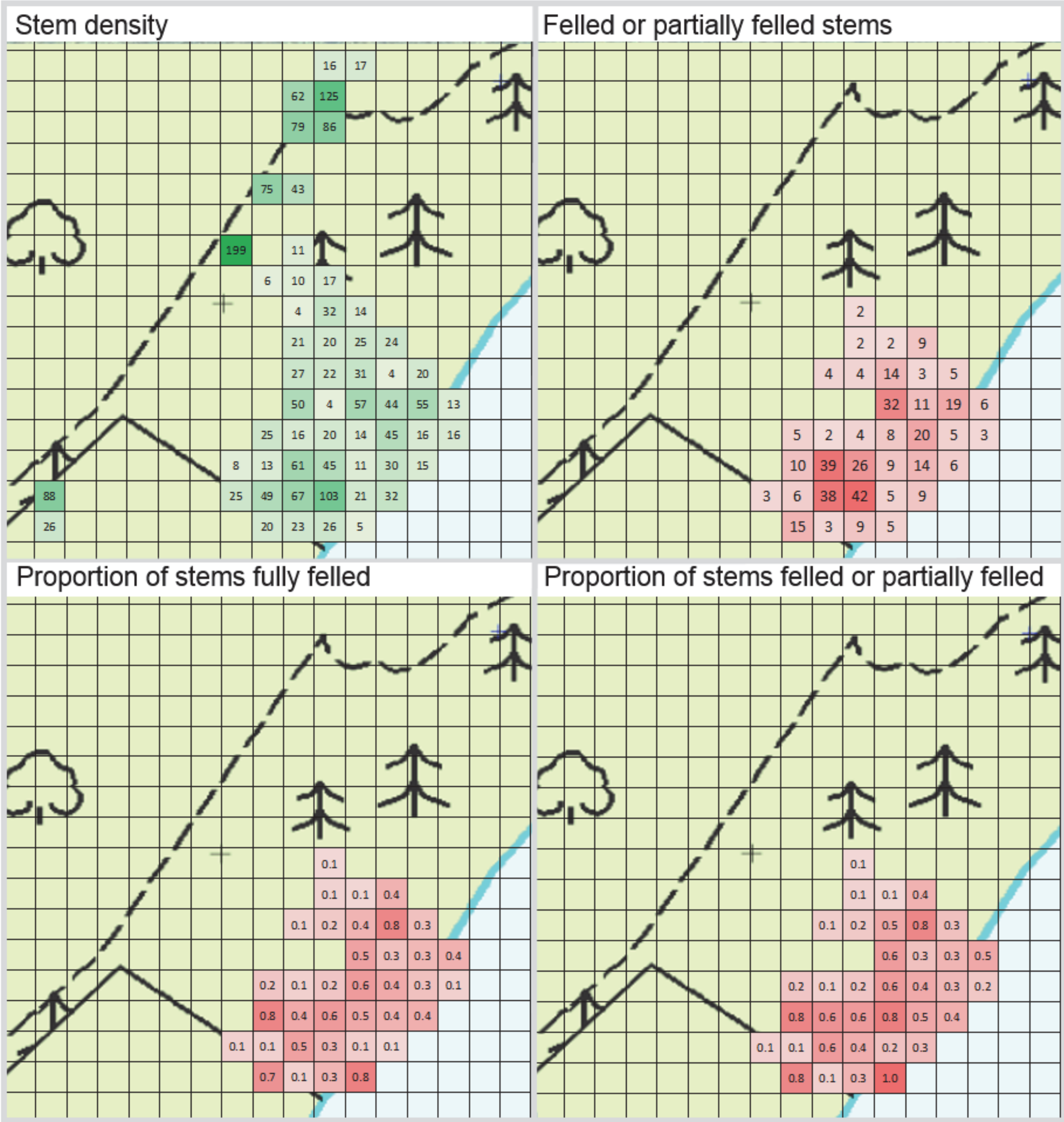

Figure 10. Hazel stem density[4] (top-left); proportion of stems felled (bottom-left); total number of stems fully or partially felled (top-right); and proportion of stems fully felled or partially felled (bottom-right) by beavers in the Loch Linne (West) hazel stand (bottom left grid = NR79529106). Grid spaced at 10 m National Grid intervals. © Crown copyright and database right 2015. Ordnance Survey 100017908.

[4] The 10 m square with 199 stems actually represents stools growing along a ridge between that point and the bottom left of the depicted area. This was due to a poor GPS signal below the ridge which precluded clear allocation of stems to an individual 10 m square.

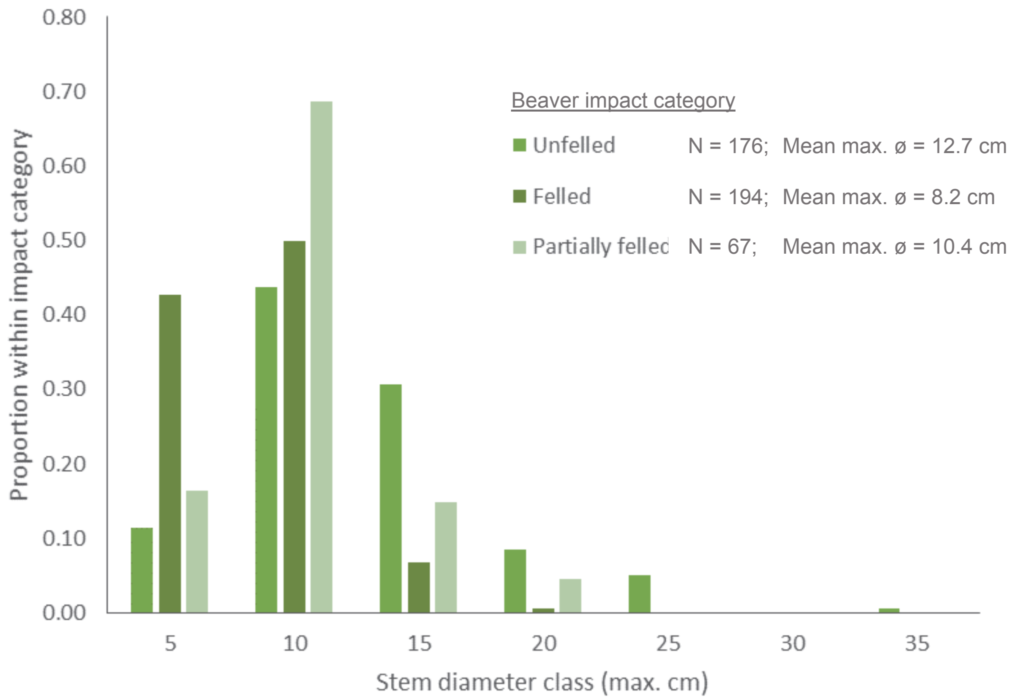

Figure 11. Maximum diameter of stems on beaver-impacted stools that were either felled, partially felled or unfelled (from stands surveyed in 2014 only). Diameter classes are represented by the maximum diameter in each class and the first class is >1 – 5 cm.

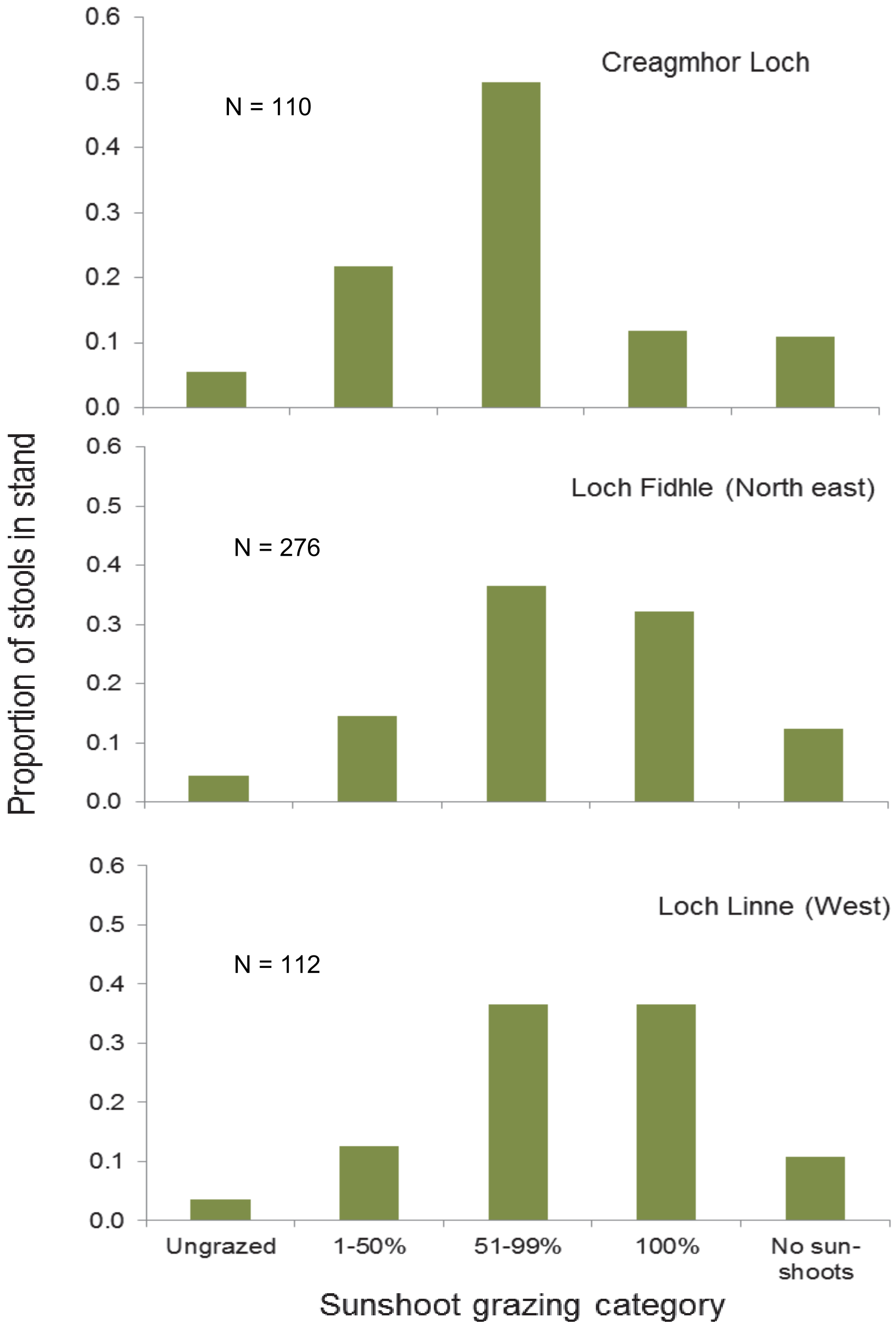

Figure 12. Percentage of sun-shoots grazed on stools in 2014.

4.4 Discussion

This section of the report focusses on Atlantic hazel habitat where beaver impact was both predicted and observed. It is important to note however that there was no detectable impact of beavers on lichen communities associated with other important lichen habitats within the SBT trial area (outlined in 3.4). This was primarily because these habitats were not adjacent to beaver-occupied lochs and therefore did not overlap with beaver-utilised habitat.

As described in Section 3.2, the most likely impact of beavers on Atlantic hazel lichens will be through intermittent or permanent loss of micro-habitat, e.g. all of a particular age-class of stem, or through localised loss of broad habitat if all hazel is lost from an area. From a lichen perspective short-term loss of ecological continuity, at any scale, is likely to result in medium to long-term loss of species, even if hazel subsequently re-grows from basal shoots. The magnitude of impact at the lichen community scale will be related to the proportion of habitat affected and the degree to which micro-habitat continuity can be maintained through replacement of young and old hazel stems. This assessment of the impact of the SBT on Atlantic hazel lichen habitat focusses on the site-scale impact on the habitat rather than directly on the response of lichens.

After 50 to 59 months the beavers had impacted just under a fifth of all hazel stools in stands continuous with beaver-occupied lochs. However, impact was localised because the beavers did not utilise hazel beyond a maximum of 60 m from a loch margin. Iason *et al*. (2014) demonstrated that most effects of beavers, across all tree species, were detected within 10 m of a water body. While this was broadly true for hazel habitat around loch Fidhle and the two stands at the north end of Loch Linne, beaver were utilising more stems beyond 10 m in the Loch Linne (West) and Creagmhor Loch stands with no clear relationship between the number and proportion of stems felled and distance from the loch edge. For hazel stands at least, the variation in impact with distance from a loch may have more to do with the angle of slope and occurrence of boulders that beavers find difficult to negotiate (Figure 13 & Figure 14). The majority of the Taynish and Knapdale Woods SAC Atlantic hazel habitat is beyond 60 m from a loch or on steep uneven ground is therefore not likely to be significantly affected by beavers based on current observations.

In the areas were beavers were active, about half of the stools had been impacted from which almost a quarter of stems had been felled or partially felled. While this does not yet represent a break in ecological continuity, a significant proportion of the habitat has been removed over a relatively short period of time. There is also a risk of extirpation of locally rare species within these impacted areas, although only further detailed monitoring would be able to quantify this risk for a particular species.

In a cursory survey of the Creagmhor Loch stand, Acton (2013) recorded 18 species of lichen considered to be indicators of long periods of micro-habitat continuity in woodland in the west of Scotland (Coppins & Coppins, 2002). He also noted instances of direct loss of lichens of conservation concern on felled stems, for example *Parmeliella testacea*, which is nationally scarce, a priority species on the Scottish Biodiversity List and a species for which Scotland is considered to have international responsibility (Woods & Coppins, 2012). Such losses from individual stems are to be expected, although the local, national and international significance of these losses must be put into context with the extent and magnitude of impact on the habitat at each of these assessment scales.

In the areas surveyed in 2014 the largest diameter felled stem on each stool was normally less than 10 cm diameter, although larger stems up to 20 cm diameter had either been partially or entirely felled on some stools. Because only the largest diameter stem was recorded on each stool, it is not possible to describe the full diameter class distribution of each beaver impact category, however it is clear from maximum values that smaller, and hence normally younger, smooth barked stems were preferentially felled over larger, rough-barked older stems. This means that lichens associated with the *Graphidion* community (typically occupying the smooth bark micro-habitat) will have been impacted to a greater extent relative to species typical of the *Lobarion* community (typically occupying the rough bark stem micro-habitat). Many of the larger, and some of the smaller, older, felled stems did however support luxuriant populations of *Lobarion* species.

Figure 13. Hazel stools on steep boulder ground at the NE end of Loch Fidhle (NR800910) have been subject to very little beaver activity.

Figure 14. Beaver-felled stems were found up to 60 m from the shore in the hazel stand on gently sloping ground on the west shore of Loch Linne (2011). Woodland monitoring Transect 8 (Iason et al.*, 2014) runs up-slope from the bottom-left of this photograph.*

It is too early to say for certain what the fate of hazel and associated lichen habitat within beaver habitat will be, but it is possible to predict what will happen if beavers continue to utilise hazel at the current rate. In a detailed survey of beaver impacts around Creagmhor Loch in November 2010, Moore *et al*. (2011) recorded 63 beaver-impacted hazel stems. Subsequent complete survey for the lichen habitat assessment found this had risen to 239 by July 2013 and 367 by April 2014 (Figure 15). Beavers have therefore impacted an average of 62 stems per year since their release in this area. This equates to approximately 5 % of the stems originally present in the area utilised by beavers per year. No information has been found on the growth rate of individual hazel stems, but numerous observations in western Scotland suggest a typical increase in stem circumference of 1 cm per year (Sandy Coppins and Gordon Gray Stephens, pers. com.). So a 1 cm diameter stem, the threshold for recording in this study, is likely to be approximately three years old. Similarly stems that support the *Graphidion* lichen community (typically 5 to 10 cm diameter) are likely to be in the region of 16 to 31 years old respectively. Stems supporting lichens from the *Lobarion* community are more likely to be in the 10 to 20 cm diameter category and are therefore likely to be between 31 and 63 years old. Given the current rate of stems being felled by beavers in this area, there is a high risk that there will be a loss of lichen habitat continuity. If the beavers continue to utilise stems up to 5 and 10 cm diameter at a rate close to 5 % per annum, it seems likely that few stems will survive more than 20 years. These impacts may be mitigated however if larger stems are never felled (although only 5 % of stools had stems with greater diameter than the largest felled stem), if a proportion of smaller stems are protected by rocks or by being in the centre of large stools, or if stems regenerate from large stems above beaver browsing height. Beaver activity may also vary over time with stands being left to regenerate for longer periods than current observations suggest.

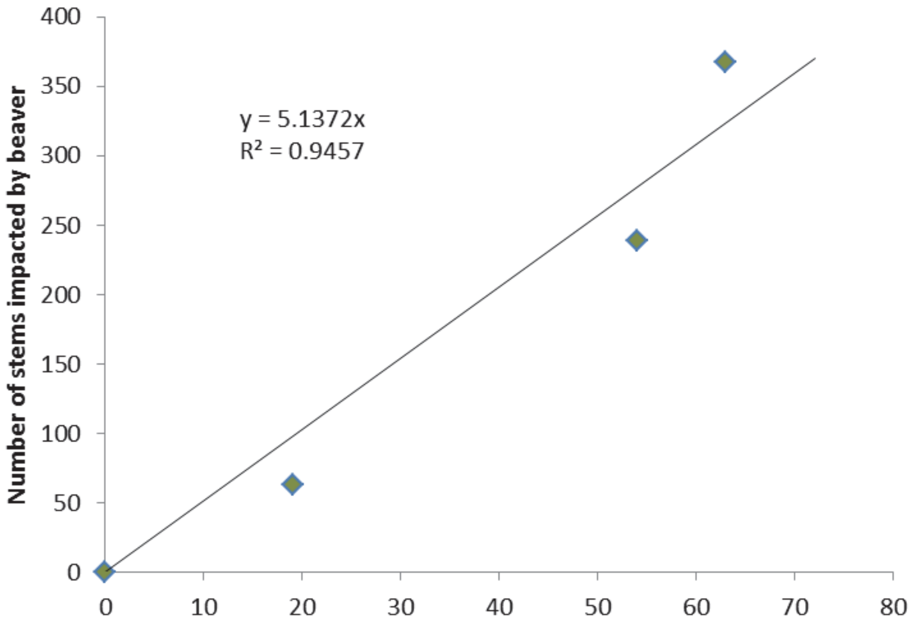

Figure 15. Number of beaver-impacted hazel stems around Creagmhor Loch since beavers were first released into this loch.

Whether young and old stem micro-habitat continuity is maintained will be strongly dependent on recruitment of new stems from the pool of sun-shoots normally present at the base of mature hazel stools. Observations demonstrate that, throughout the SBT area, there are high levels of sun-shoot browsing with at least half of shoots browsed on two thirds of stools. A further 10.6 % of stools did not have sun-shoots. It was also evident that many sun-shoots were repeatedly re-browsed with many previously browsed shoots showing early season re-growth in April 2014. This indicates that the number of unbrowsed shoots may be overestimated in April compared to an assessment later in the year, but also demonstrates that shoots remain viable following grazing and should be able to respond to a future cessation in grazing levels. The number of felled hazels that had re-sprouting shoots within the wider woodland monitoring woodland plots increased between 2010 and 2013, although there was a year on year decline in the mean number of shoots per stool from *c*. 8 to *c*. 3 (Iason *et al*., 2014). If the 5 % beaver felling rate estimated in beaver habitat around Creagmhor Loch is typical, and the average stool there has between eight and nine stems, sun-shoots will have to be recruited at a rate of about one every 2.3 years to maintain the current density of hazel stems. This is possible based on current estimations, but Figure 12 shows that sun-shoot browsing varies between stands, with between 10 and 35 % of individual stools having no unbrowsed sun-shoots. The ability of hazel to be maintained through recruitment from basal sun-shoots is therefore in doubt and it is likely that the number of stems felled with be greater than the number replaced, at least in some areas. Hazel has the ability to produce new shoots above browsing height (Coppins & Coppins, 2012), so there is a possibility that this could maintain the continuity of stems if stools are not completely felled. However, casual observations indicate that young stems that sprout higher in the canopy are less likely to support the important *Graphidion* lichen community (Sandy Coppins, pers. comm.). Given the level of browsing and trend towards fewer re-sprouting sun-shoots, it is recommended that, if the decision is made to retain beavers at Knapdale, browsing and stem recruitment continue to be monitored beyond the period of the SBT.

The total area of Atlantic hazel habitat (> 80 % canopy) within the SAC is estimated to be 13 ha. The total area of hazelwood affected by beavers (calculated as the sum of 10 m squares with beaver impacted stems) was 1.13 ha, or 7.8 % of the SAC's hazel resource by area. While the density of hazel within these areas varied, this analysis gives some indication of the overall extent of impact of the SBT on hazel-dominated woodland within the SAC. It is too early to determine the significance of this impact for lichens as typical species of the wider SAC qualifying woodland habitat. While impact has certainly occurred, further monitoring beyond the time-frame of the SBT will be required.

The ability of lichen populations to recover following any localised loss of ecological continuity within beaver-utilised areas is likely to depend on two factors. Firstly, on whether lichen micro-habitats area able to recover and secondly on the health and abundance of adjacent unaffected Atlantic hazel lichen communities (e.g. Ellis & Hope, 2012; Scheidegger & Werth, 2009). It is therefore recommended that, should beavers remain on the SBT site, every effort is made to maintain the condition of adjoining hazelwoods, to improve condition where possible (e.g. remove adjacent conifer plantations and rhododendrons that are currently shading the fringes of a number of Atlantic hazel stands and to ensure browsing levels by deer are managed), to seek opportunities to increase the extent of Atlantic hazel within the SAC, and to put in place appropriate beaver management measures if necessary.

5. NATIONAL IMPACT ON ATLANTIC HAZEL LICHENS IF BEAVERS ARE RELEASED THROUGHOUT SCOTLAND

5.1 Introduction

The risk assessment of important lichen habitats within the SBT area highlighted the relatively large overlap with potential beaver habitat. While other important lichen habitats may overlap beaver habitat outwith the SBT area, given the national and international importance of Atlantic hazel-associated lichen communities and the potential impacts described in Section 4, this habitat was selected for an assessment of its Scotland-wide overlap with potential beaver habitat.

5.2 The wider importance of Atlantic hazel as a lichen habitat

Atlantic hazel occurs in oceanic areas in western Britain (Coppins & Coppins, 2012). This climatic association, and other attributes associated with hazel (as described in Section 4.1), result in high diversity of lichens (e.g. Figure 17). While the strength of association between Atlantic hazel and a particular lichen varies, many species are of high conservation value (e.g. Table 1). When assessing the costs and benefits of a potential wider beaver reintroduction programme, the relative international importance of Scotland to species such as these (which have a restricted global and European distribution), should be considered. For many Atlantic hazel associates, Scotland is their European headquarters (e.g. see examples in Figure 18). One endemic species, *Graphis alboscripta*, occurs nowhere else on earth other than in Scottish Atlantic hazelwoods (Figure 16).

Table 1. Notable lichens associated with Atlantic hazelwoods showing strength of association, lichen community type and conservation status/priority (adapted from Coppins & Coppins, 2012).

Notable lichens	Strength of association [1]	Community type [2]	IUCN [3]	Rarity/Scarcity in the UK [4]	IR [5]
Arthonia cohabitans	***	Graphidion	VU	Rare	IR
Arthonia excipienda	**	Graphidion	NT	Rare	
Arthonia ilicinella	**	Graphidion	NT	Scarce	IR
Arthothelium dictyosporum	*	Graphidion	NT	Rare	IR
Arthothelium macounii	***	Graphidion	VU	Rare	IR
Arthothelium norvegicum	*	Graphidion	NT	Rare	
Arthothelium orbilliferum	**	Graphidion	LC	Scarce	IR
Bactrospora homalotropa	**	Graphidion	LC	Scarce	IR
Collema fasciculare	**	Lobarion	NT	Scarce	IR
Eopyrenula septemseptata	***	Graphidion	NT	Rare	IR
Fuscopannaria sampaiana	**	Lobarion	NT	Scarce	IR
Gomphillus calycioides	**	Lobarion	NT	Scarce	IR
Graphis alboscripta	***	Graphidion	NT	Rare	IR
Lecanora cinereofusca	**	Graphidion	VU	Rare	
Lecidea erythrophaea	*	Graphidion	VU	Rare	
Leptogium brebissonii	**	Lobarion	NT	Scarce	IR
Leptogium cochleatum	**	Lobarion	VU	Scarce	IR
Leptogium hibernicum	**	Lobarion	NT	Rare	IR
Melaspilea atroides	***	Graphidion	LC	Scarce	IR
Mycomicrothelia atlantica	**	Graphidion	NT	Rare	
Parmeliella testacea	**	Lobarion	NT	Scarce	IR
Polychidium dendriscum	*	Lobarion	VU	Rare	IR
Porina hibernica	*	Lobarion	NT	Scarce	IR
Pseudocyphellaria intricata	**	Lobarion	NT	Scarce	IR

Notable lichens	Strength of association[1]	Community type[2]	IUCN[3]	Rarity/Scarcity in the UK[4]	IR[5]
Pseudocyphellaria norvegica	**	Lobarion	LC	Scarce	IR
Pyrenula coryli	***	Graphidion	VU	Rare	
Pyrenula hibernica	***	Graphidion	VU	Rare	IR
Pyrenula laevigata	**	Graphidion	LC	Scarce	IR
Sticta canariensis	*	Lobarion	VU	Rare	IR
Thelotrema macrosporum	***	Graphidion	LC	Scarce	IR

[1] Degree of strength of association with Atlantic hazelwoods, with *** being exclusively associated; ** closely associated; * mildly associated.
[2] *Graphidion* community lichens are mostly associated with smooth young stems while *Lobarion* community lichens are mostly associated with rough older stems.
[3] IUCN = Conservation evaluation against IUCN red listing criteria (Woods & Coppins, 2012). LC = Least Concern, NT = Near Threatened, VU = Vulnerable. All lichens listed are also included on the Scottish Biodiversity List.
[4] Nationally Rare species have been recorded in 1-15 10 km squares and Nationally Scarce species have been recorded in 16-100 10 km squares in Britain.
[1] IR = species for which the UK (more particularly, Scotland) has International Responsibility (Woods & Coppins, 2012).

Figure 16. Graphis alboscripta *(syn.* Fissurina alboscripta*), a Scottish endemic that only grows on smooth-barked stems in Atlantic hazelwoods (Ballachuan Hazelwood. NM761144)*

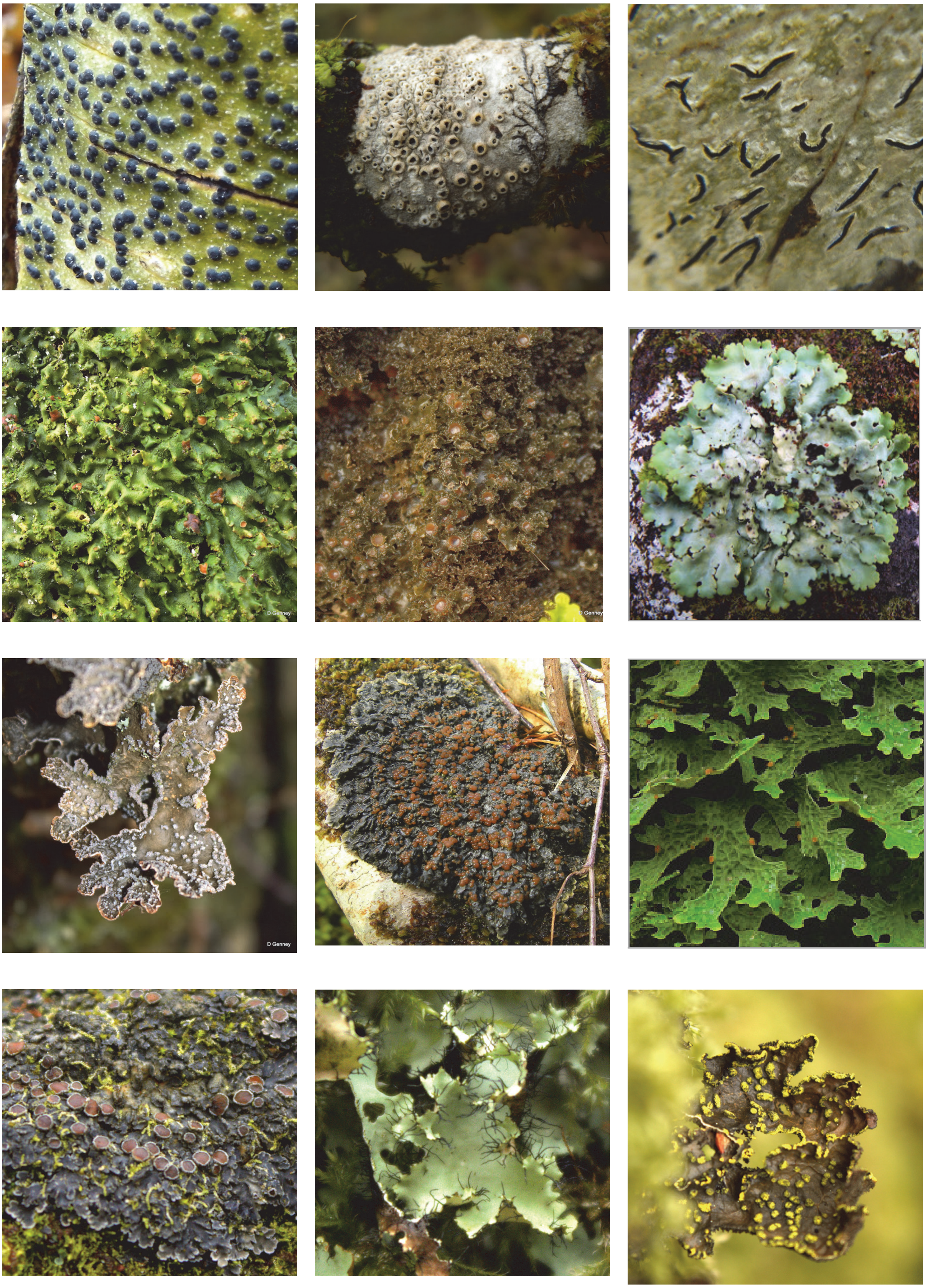

Figure 17. Typical lichens associated with Atlantic hazelwoods. (top left to bottom right) Pyrenula macrospora*,* Thelotrema lepadinum*,* Graphis scripta*,* Lobaria virens*,* Leptogium burgessii*,* Lobaria amplissima*,* Pseudocyphellaria norvegica*,* Degelia plumbea*,* Lobaria pulmonaria*,* Pannaria rubiginosa*,* Parmotrema crinitum *and* Pseudocyphellaria crocata*.*

Fuscopannaria sampaiana

Pseudocyphellaria norvegica

Thelotrema petractoides

Degelia atlantica

Bactrospora homalotropa

Arthothelium macounii

Figure 18. Distribution of six Atlantic hazel lichen species (1960 – present) to show their limited British and European distribution (The Global Biodiversity Information Facility, 2014).

5.3 Methods

The Native Woodland Survey of Scotland (NWSS) was interrogated to extract an Atlantic hazel layer. In order to allow comparison between woodland where Atlantic hazel is a subdominant understory tree and woodland where hazel is the dominant canopy species (as used to define Atlantic hazel stands in Section 3), polygons where hazel accounted for >= 25 %, >= 50 % and >= 80 % of the total canopy cover were extracted. Each of these hazel layers was then clipped to exclude polygons outwith the oceanic climate zone (broadly the area where the mean annual number of wet days (>1 mm) divided by the range of monthly temperatures (˚C) is greater than 20 (Averis *et al.*, 2004)). A 5 km buffer around this oceanic climate layer was used to ensure that NWSS polygons that overlapped the boundary of the oceanic zone were included in the Atlantic hazel layer. Each layer was then intersected with Local Authority boundaries to allow summary statistics to be broken down by area. While this analysis provides a detailed and useful assessment of the area of Atlantic hazel, it was not possible to determine whether the extracted polygons were ancient and/or rich in oceanic lichen communities. However, hazel that is currently of low biodiversity value has the potential to become diverse with time so it should be assumed that all of the identified woodland has potential, if not current, biodiversity value.

Each Atlantic hazel layer was then intersected with a model that predicts potential beaver habitat based on distance from water body (50 m), angle of slope (<15 %) and occurrence of suitable native woodland for mainland Scotland and islands within 6 km of the coast (see SNH final beaver report to Scottish Government for full details of this model, in prep.). A visual example of the analysis is provided in Figure 19. Because beavers are unlikely to permanently colonise areas with small areas of fragmented and isolated woodland, the analysis was repeated to include only core areas of potential habitat where it was predicted beaver territories may be established. Core habitat excluded isolated woodland polygons that are unlikely to support permanent beaver populations in order to provide a more realistic indication of the amount of Atlantic hazel that could be impacted. Both layers were again intersected with Local Authority boundaries to allow regional assessment of potential beaver / Atlantic hazel overlap. The detailed GIS methodology is retained within SNH as GIS job 67562.

5.4 Results

Outputs of the GIS analysis are presented in Table 2. More than half of Scotland’s Atlantic hazel habitat occurs in Argyll and Bute, irrespective of the contribution of hazel to woodland canopy cover. The total area of hazel-dominated Atlantic hazel (>80 % hazel canopy) is less than 1000 ha, which highlights the restricted nature of this internationally important habitat. North Ayrshire and Stirling contain relatively little Atlantic hazel habitat, largely due to their boundaries being outwith the oceanic climatic zone.

For hazel dominated (>80 % canopy cover) Atlantic hazel, the greatest absolute overlap with suitable beaver habitat is in Argyll and Bute (147 ha), with the highest proportional overlap in Highland (32 %). There is slightly less overlap when isolated fragments of potential beaver habitat are excluded (19 %). This overlap increases slightly as the threshold for the proportion of hazel in the canopy is reduced, but this is not likely to be a significant trend.

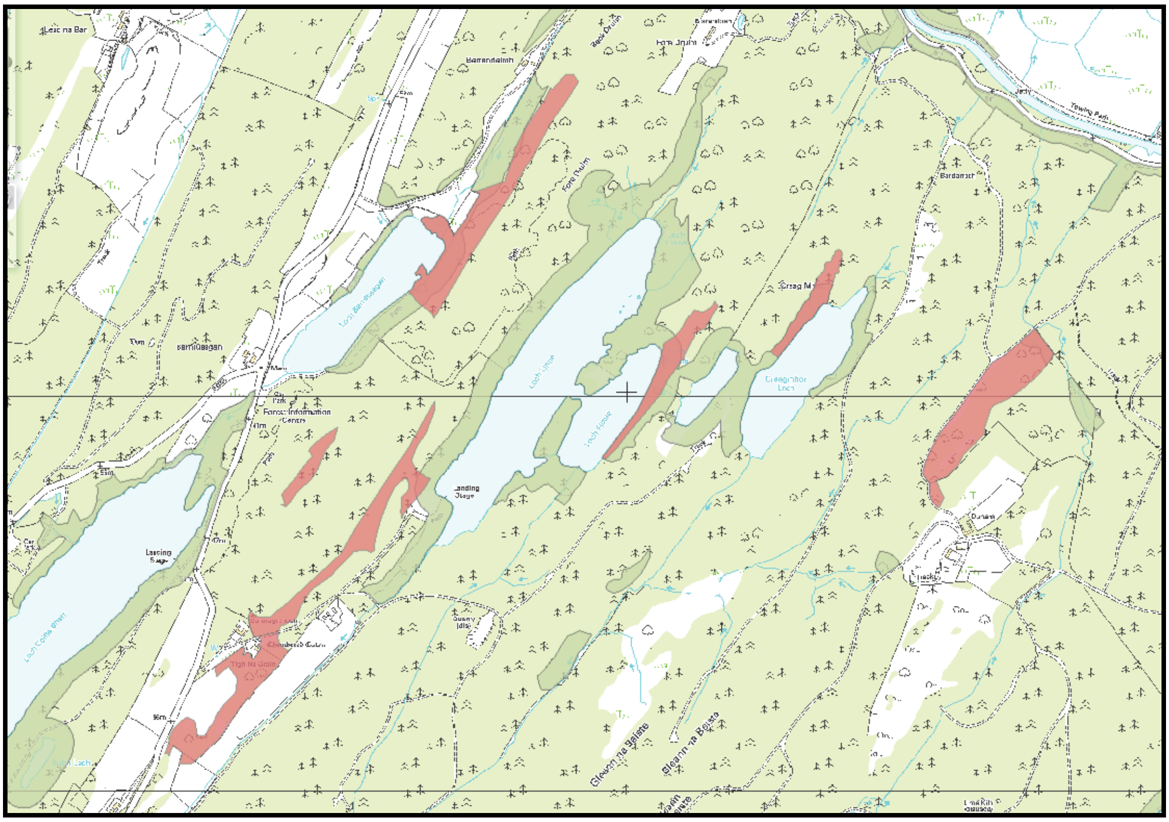

Figure 19. Example comparison between potential core beaver habitat (dark-green shading) and woodland with 80 % or more hazel canopy cover (solid red shading) at Knapdale. © Crown copyright and database right 2015. Ordnance Survey 100017908.

Table 2. Overlap of all and core potential beaver habitat with Atlantic hazelwood. Values are provided for three thresholds of hazel as % of the woodland canopy within an NWSS woodland polygon.

	Atlantic hazel ≥ 80 %				
Local Authority	**Total area (ha)**	**Beaver habitat Overlap (ha (%))**		**Beaver core habitat overlap (ha (%))**	
Argyll and Bute	603	147	(24%)	105	(17%)
Highland	319	101	(32%)	70	(22%)
North Ayrshire	13	4	(31%)	1	(8%)
Stirling	0	0	-	0	-
Total	**934**	**252**	**(27%)**	**176**	**(19%)**

	Atlantic hazel ≥ 50 %				
Local Authority	**Total area (ha)**	**Beaver habitat overlap (ha (%))**		**Beaver core habitat overlap (ha (%))**	
Argyll and Bute	1,775	490	(28%)	367	(21%)
Highland	850	256	(30%)	173	(20%)
North Ayrshire	21	6	(29%)	3	(14%)
Stirling	14	1	(7%)	1	(7%)
Total	**2,660**	**753**	**(28%)**	**544**	**(20%)**

	Atlantic hazel ≥ 25 %				
Local Authority	**Total area (ha)**	**Beaver habitat overlap (ha (%))**		**Beaver core habitat overlap (ha (%))**	
Argyll and Bute	4,865	1,395	(29%)	1,163	(24%)
Highland	2,195	774	(35%)	600	(27%)
North Ayrshire	110	35	(32%)	22	(20%)
Stirling	36	11	(31%)	11	(31%)
Total	**7,207**	**2,215**	**(31%)**	**1,796**	**(25%)**

5.5 Discussion

This analysis has demonstrated a significant overlap between Atlantic hazel lichen habitat and potential beaver habitat. Twenty seven percent overlap between hazel-dominated (>80 % canopy) woodland is a large proportion, particularly when this represents the majority of Europe's resource for many of the associated lichen populations. The proportion of habitat affected is reduced when isolated woodland fragments are excluded from the beaver habitat model, but still represents a large proportion of Atlantic hazel lichen habitat.

As with many such exercises the degree and scale of uncertainties increases with extrapolation. Section 4 of this report concludes that there is a risk to the long-term viability of hazel in habitat occupied by beavers, but also identifies uncertainties that will require further study. Similarly, the modelled potential distribution of beaver habitat has inherent uncertainties, not least about the rate and extent to which beavers occupy areas over time and between regions. The values calculated here should be considered the worst case scenario and used to identify regions where more effort will be required to manage and monitor potential conflicts between beavers and lichens. For example, Argyll and Bute is clearly the Local Authority area where the majority of Atlantic hazel occurs and where the greatest overlap with potential beaver habitat occurs. Other spatial scales of assessment could be used and the most appropriate scale will probably be determined by the beaver management options available e.g. at the catchment level.

The woodland monitoring report (Iason *et al*., 2014) concludes that:

> '*The outcome of the beaver-woodland interaction is dependent upon the species composition of the woodland. Consequently any prediction of the effects of beavers on woodland in any area of Scotland or the remainder of the UK that they may colonise, would need to be tailored in the light of the woodland resources present. This means that the predictability of the beaver-woodland interaction elsewhere is low relative to our knowledge of the possible woodland vegetation responses at Knapdale*.'

This statement will undoubtedly hold true for Atlantic hazel and should be borne in mind when making the important decision as to whether beavers should remain in Argyll and/or be reintroduced into other areas of Scotland.

6. IMPACT OF BEAVERS ON OTHER IMPORTANT LICHEN HABITATS, AND MITIGATION

6.1 Aspen

Aspen (*Populus tremula*) is an important habitat for lichens[5], particularly in the central Highlands where it one of the few tree species able to support lichens that require trees with a high bark pH (Davies, 2008). Three hundred and eighty species of lichen and lichenicolous fungi have been recorded from aspen (British Lichen Society database queried on the 2nd January 2015), including 14 species assessed as Endangered, ten as Vulnerable and 15 as Near Threatened against IUCN Red Listing criteria (Woods & Coppins, 2012). Britain is considered to have international responsibility for 42 of these species because of the relatively high proportion of their global population that occurs here (Woods & Coppins, 2012). Lichen diversity on aspen is related to a number of factors but tends to be higher in areas with high historic woodland cover and a range of tree ages (Ellis, 2008). However, aspen is highly favoured by European beavers and the observations of beaver activity in Sweden demonstrate that beaver will fell even mature trees in order to access the nutrient-rich bark (Figure 20 & Figure 21).

Aspen is very rare at Knapdale and only occurs on rocky terrain, where it was assumed that it would be largely inaccessible to beavers. The SBT therefore does not provide evidence to inform the impact of a wider release of beavers on aspen. However, Griffith (2011) recorded felled aspen saplings on the steep rocky bank above Loch Fidhle (NR79909085).

[5] Mature aspen is also an important habitat for a number of other scarce species e.g. epiphytic bryophytes in central and eastern Scotland e.g. bristle mosses (*Orthotrichum* species) (Rothero, 2008).

Figure 20. Beaver will fell large mature aspen (Ekenäs, Sweden, 2008).

Figure 21. Large aspen felled by beaver to provide access to bark (Ekenäs, Sweden, 2008).

Relatively speaking, aspen is less important for lichen species of conservation concern in western Scotland than it is in central and eastern Scotland. Indeed, as a woodland type, aspen is mainly a species of the Highlands with particular local abundance in parts of Badenoch and Strathspey (Cosgrove & Amphlett, 2001). The impact on lichens, and other species associated with aspen, and in particular those associated with large old aspen trees, will have to be carefully considered before beavers are released or allowed to colonise these central Highland aspen strongholds.

Batty (2001) considered options to manage the threat to aspen from beavers. He proposes three approaches:

1. Identify and fence off aspen in areas at high risk from beavers with low stock-proof fencing (possibly with an apron of netting on the ground to deter burrowing);
2. Exclude beavers from catchments that support high concentrations of aspen;
3. Increase the quantity and quality of the aspen resource so that there is sufficient habitat for beaver.

Each of these options requires further consideration, particularly if beavers are introduced into high-risk areas such as Badenoch and Strathspey. For example, as discussed above in relation to hazel, fencing may protect trees but negatively impact lichens if it results in dense regeneration and shade around mature trees. Increasing the quantity and quality of aspen in areas likely to be colonised by beavers may provide mitigation, but a careful assessment of the impact on aspen, particularly on the continuity of mature or ancient aspen, will be required. It is recommended that research into the relative impacts on aspen and associated biodiversity is needed before allowing beavers to colonise aspen-rich catchments.

6.2 Other lichen habitats

Other woodland lichen habitats, even those that were not considered at risk from beaver impact within the SBT, could clearly be impacted by beaver to a greater or lesser extent should a wider reintroduction programme be implemented. A full assessment of these habitats is beyond the scope of this report. However it is reasonable to assume that riparian woodland types will be subject to the greatest impacts e.g. willow carr, birch car and alder woodland. Willow, birch and alder occur more widely and are not restricted to riparian habitats. The main lichen community found on these trees (the *Parmelietum laevigatae*) also occurs outwith the riparian habitat, but is rarely as well-developed there. The composition of the community varies accordingly with some species that occur predominantly within the shelter and humidity of the riparian zone and others only in more open exposed locations (Sandy Coppins, pers. comm.). Research should be encouraged to further elucidate the relationship between water bodies and lichen community composition in order to better understand the impacts of beaver and other riparian pressures.

Particular concern has been expressed about the potential impact of beaver on trees by rivers and burns in drier parts of Scotland, e.g. Perthshire, Speyside, Morayshire, Aberdeenshire, East Sutherland and eastern Easterness (Brian Coppins, pers. comm.). Many sites of high lichen importance are typified by trees on river-banks, or low lying strips of alluvial ground (often where rivers bend or at confluences). The main tree species in such places is ash, but willow (*Salix caprea*) and hazel are also important. It is recommended that catchment-level assessments are made on the relative impact that beavers may have on riparian tree-dependent species, particularly where water bodies run through SSSIs notified for their lichen interest e.g. Cawdor Woods, Lower Findhorn Woods and Moniack Gorge. It is also possible to assess the vulnerability of particular species of lichen of conservation concern where they are known to occupy mature trees in possible beaver habitat. For example, Figure 22 shows how the Nationally Rare lichen *Fuscopannaria ignobilis* (listed on Schedule 8 of the Wildlife and Countryside Act (1981) and considered Vulnerable to extinction against IUCN Red Listing criteria (Woods & Coppins, 2012)), which is predominantly found on mature ash trees, may potentially be threatened by beaver activity in some catchments but not in others. Such assessments are limited by the availability of accurate lichen survey data and should only be used to identify known areas of vulnerability rather than to demonstrate low vulnerability. In the latter case, further detailed local survey would be required to make an accurate assessment

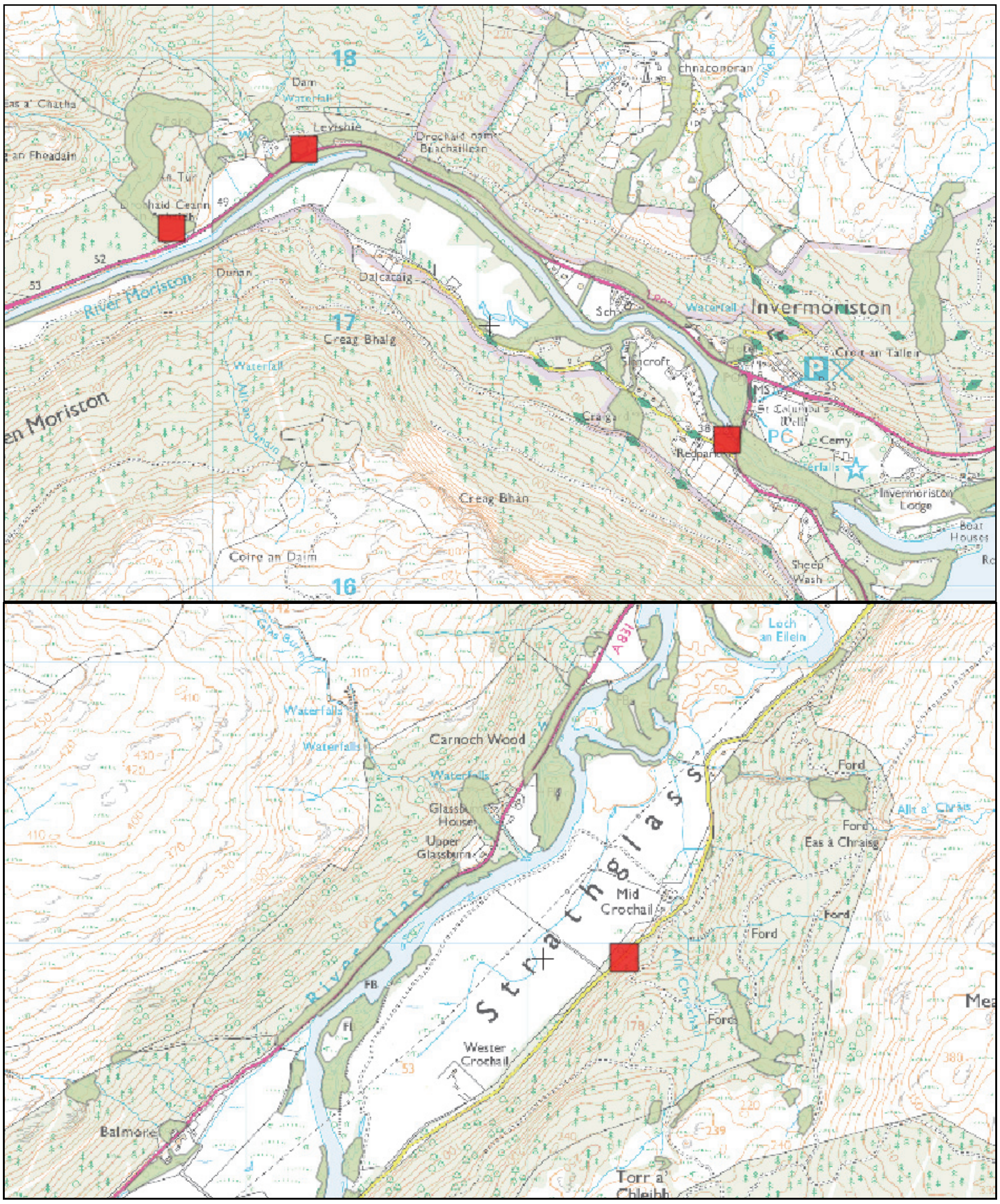

Figure 22. The threatened lichen Fuscopannaria ignobilis *may be impacted in some catchments but not in others. The upper map of lower Glen Moriston shows significant overlap between recorded locations (100 m resolution points only, red squares) and potential core beaver habitat (green shaded areas from SNH beaver habitat model), while the lower map of Strathglass demonstrates an area where the local population of the lichen may not overlap with potential beaver habitat. © Crown copyright and database right 2015. Ordnance Survey 100017908. Species data extracted from the NBN Gateway on 6/1/15.*

The wider woodland impacts described by Iason *et al*. (2014) should be used when considering the likelihood of local impacts, with particular attention being paid to the impacts on lichen micro-habitat diversity and ecological continuity as described in Section 3.2. It is also recommended that the Tayside beaver population is used as a starting point to quantify the impact on lichen habitat in an eastern, riparian environment.

6.3 Mitigation

If a decision is made to retain the current beaver populations and/or allow further releases, there will inevitably be circumstances when it is necessary to locally manage beavers where their impacts on other biodiversity interests are considered negative (e.g. see recommendations in 5.5 & 6.1). One option, as previously discussed, is to manage beaver populations at an appropriate landscape scale in order to avoid species conflicts, at least until further research into long-term impacts has been conducted. A number of beaver exclusion options were laid out in Section 7.5.1 of the Scottish Beaver Trial licence application to the Scottish Government, including physical barriers (such as fencing), habitat manipulation and capture and removal of animals from sensitive areas.

Fencing is not recommended as the primary method to locally protect trees or shrubs that provide important lichen habitat. The long-term absence of grazing can be as damaging as over-grazing due to thicket regeneration and shading of light demanding lichens. It may however be possible, with careful monitoring, to exclude beavers from areas without excluding other grazers, for example the SBT used low electric fences and open ended fencing across watercourses as deterrents (rather than hard barriers) (Jones & Campbell-Palmer, 2014).

At the scale of the trial, the SBT partners considered that the only reliable and efficient method of excluding animals from sensitive areas was the recapture and removal method (Jones & Campbell-Palmer, 2014). Whether this is a viable management option if beavers become more widely established requires further assessment.

Compensatory expansion of affected woodland lichen habitat within and beyond potential beaver habitat will be an essential mitigation measure should beavers be released more widely. The aim of this mitigation would be to expand important lichen populations such that the relative impact of beavers is reduced to an acceptable level. While such expansion could provide great benefits to lichen populations, it should not be seen as a quick solution because it will take many years for old-growth woodland micro-habitats to develop and for lichens to colonise them. Ideally such compensatory mitigation should form part of a long-term national strategy with habitat expansion preceding beaver reintroduction by a number of decades at least. In practice, a complementary programme of, for example, Atlantic hazel habitat expansion should be implemented in tandem with any decision to release beavers on a wider scale.

Where it is not possible to expand habitat in advance of beaver colonisation, in addition to a complementary programme of habitat expansion, the condition of existing woodland lichen habitat should be improved. This may include effective control of rhododendron and other non-native invasive species, reducing sources of atmospheric pollution, or by controlling deer numbers to allow pulses of tree regeneration within a landscape of open and closed canopy woodland.

7. CONCLUSIONS

Based on observations of Atlantic hazel lichen habitat within the Knapdale SBT area:

- Beavers have the potential to negatively impact nationally and internationally important lichen populations by reducing areas of woodland with ancient woodland characteristics or by breaking the ecological continuity of important lichen micro-habitats. However, the risk varies greatly between lichen habitat types, mainly due to differential overlap with potential or occupied beaver habitat. The risk to some lichen habitats is low.

- Detailed monitoring of Atlantic hazel habitat within the Knapdale SBT area has already demonstrated relatively high impacts that may eventually result in the permanent or temporary localised loss of a globally restricted lichen habitat.

- Deer browsing of sun-shoots may prevent recovery of hazel stools. This represents an important interaction between beavers and other herbivores that will require careful monitoring and management.

- These impacts have to be considered against the majority of Atlantic hazel habitat within the SAC that is unlikely ever to be impacted by beaver.

- Further monitoring over a longer period of time is required to clarify uncertainties as to the long-term impact on Atlantic hazel habitat. Particular attention should be given to continuity of hazel stems that provide habitat for *Graphidon* and *Lobarion* lichen communities against the current rate of beaver felling, slow rate of hazel growth and high current levels of sun-shoot browsing.

- So far, the SBT is not considered to have had an unacceptable adverse impact on the quality of SAC qualifying woodland habitat (with lichens as typical species) within the Taynish and Knapdale SAC. However this assessment should be periodically reviewed should beavers remain within the site.

Beyond the SBT there is significant overlap between important woodland lichen habitat and potential beaver habitat. This is clearly demonstrated by the analysis of overlap between Atlantic hazel and potential for beaver habitat presented here. The impacts observed within the SBT should only be scaled up with caution.

The potential impact on other important lichen habitats requires further study, with a focus on aspen and other riparian trees known to support important lichen populations. Further research into impacts and possible mitigation or avoidance strategies is recommended should the beaver reintroduction trial be expanded into other areas.

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ANNEX 1: DESCRIPTION OF IMPORTANT LICHEN HABITAT TYPES AND LICHEN COMMUNITIES WITHIN KNAPDALE WOODS SSSI

The following unpublished generic lichen habitat descriptions were written by lichenologist Sandy Coppins in 2003 to support SNH's Site Condition Monitoring programme. They detail the community and habitat characteristics that are important for lichens within each habitat type.

1) Oceanic, sheltered birch-oak woods on rocky ridges and knolls

Native deciduous woodlands associated with the undulating terrain of rocky ridges or knolls with small, damp valleys are characteristic of Knapdale and the foothills of Lochaber, and are notable for supporting species-rich lichen assemblages. Where these habitats fringe sheltered coastal inlets, the maritime climate exerts a considerable benign influence, leading to a particularly luxuriant development of *Lobarion* lichens on trees, shrubs and rocks. The classic Knapdale topography is of series of parallel rocky ridges and alternating valleys running SW-NE. The ridges (and occasional knolls) provide a diversity of habitat features, with variation of aspect and steepness of slope, and are frequently characterised by scattered boulders or rock outcrops. Trees present can include oak, birch, with hazel and willow, occasionally alder, holly, ash and elm. Tree cover tends to be fairly open or gladed, and dominated by mature or senescent trees. Such woodlands are traditionally used as sheltered grazing, although oak and birch may have been coppiced in the past, with oak later selected to develop into standards. Dead wood is often present. Regeneration of trees tends to be infrequent, sometimes limited to 'phoenix' trees (wind-blown trees which regenerate from canopy boughs or shoots springing from along the horizontal trunk, all above browsing height). A species-rich *Lobarion* community is often present on oak and hazel, as well as ash and elm if present. On more inland or exposed situations, there is a gradation to the *Parmelietum laevigatae*, especially on oak and birch. In some very humid and sheltered situations, there can be a well-developed *Lobarion* lichen community associated with boulders or cliffs, especially close to trees and shrubs. The *Graphidion* community will be found on hazel, holly, rowan and smooth bark areas of ash and oak. Boulders and rock outcrops will carry additional lichen assemblages associated with particular niche and habitat diversity.

Unfavourable condition indicators: severe reduction in tree and shrub cover, leading to loss of habitat and niches for lichens on both tree and boulders.

2) Western coastal cliffs and gullies (terrestrial zone)

For lichens, the various maritime zones are roughly equated with habitat and prevailing environmental factors which affect colonization and development of the lichen flora. The lower maritime zones are usually quite visually distinctive as linear black, orange and grey bands on rocky coasts, the colouration derived from the dominant colour of the various lichen thalli found in the zones (littoral zone = "black zone"; mesic-supralittoral zone = "orange zone"; xeric-supralittoral = "grey zone"). Above these is the terrestrial zone; this is a difficult zone to define, in that the species occurring within it are not necessarily confined to maritime conditions; indeed, the majority being found in landward habitats, and often on trees. However, where an assemblage of lichens occurs within a well-defined zone above the xeric-supralittoral, and this assemblage appears to be confined to a distinct linear band, then this may be described within the terrestrial zone of the maritime habitat. Where low coastal cliffs, gullies, outcrops and boulders are present at the back of sheltered to moderately-exposed shores, a particularly species-rich lichen habitat can be present, by virtue of complex niche availability, shelter, warm maritime conditions, moisture and humidity from the prevailing climate, sea-mists and seepage from rock crevices and turf cappings. Geology can influence the range of lichen species present, but acid rocks will be subject to amelioration from small accumulations of wind-blown sand lodging in crevices, and the ingress of salt spray. This results in lichens associated with acidic, calcareous and intermediate habitat preferences being present. Particularly notable can be a luxuriant development of the *Lobarion* community, especially in damp, shaded gullies. Vertical (or slightly under-inclined) rock and cliff faces will support lichen assemblages associated with either dry, shaded conditions (where moisture is derived solely from localized humidity), or faces that receive direct wetting by rain, but dry rapidly due to an open, sunny aspect. Intermediate are lichen assemblages occurring on rock faces that receive gradual water-seepage from capping of vegetation mats. Crevices and ledges provide additional niches. Low outcrops and boulders also present a wide range of niches derived from inclination of the faces, degree of exposure, or localized shading from summer vegetation.

Unfavourable condition indicators: overgrazing (trampling, dunging, loss of vegetation mats, etc.), under grazing (scrub development); disturbance from trampling, burning, illegal dumping or oil spills.

3) Oceanic mixed deciduous woods on base-rich soils

Although subject to oceanic climatic conditions, these woods are not directly influenced by a mild, maritime climate as experienced by woods fringing the coastlines of very sheltered coasts or inlets of sea-lochs. Often on steep to moderately-steep slopes, grading into valley woodlands, with occasional exposed rock outcrops or boulders. Stand structure and composition will vary with topography but with hazel being a consistent presence throughout, and in some areas forming extensive stands of hazel scrub. Trees present can include ash, elm, oak, birch, holly, rowan, bird cherry with hawthorn not infrequent in more open areas. Patches of willow scrub (or more mature areas of willow carr) can be present in flush habitats, or damp valley bottoms. Away from extensive stands of hazel, tree cover tends to be fairly open or gladed, and dominated by mature or senescent trees. Such woodlands are traditionally used as sheltered grazing, although oak and birch may have been coppiced in the past, with oak later selected to develop into standards. Dead wood is often present. Regeneration of trees tends to be infrequent, sometimes limited to ‘phoenix’ trees (wind-blown trees which regenerate from canopy boughs or shoots springing from along the horizontal trunk, all above browsing height). Where these woods are extensive with varied topography, they provide niche-rich habitats and will support significantly important and diverse lichen assemblages. The basicity of the soils favours species-rich *Lobarion* communities especially on ash, elm, oak and hazel in sheltered and/or humid habitats. In well-lit but sheltered situations, mature wayside trees (ash and oak) beside roads or tracks, often support luxuriant lichen cover, the assemblages influenced by dust-impregnated bark. The *Graphidion* community will be found on hazel, holly, rowan and smooth bark areas of ash and oak. The *Parmelietum laevigatae* will also be well represented, particularly on oak and birch, and mature willow carr. Rock outcrops within the woodland will carry additional lichen assemblages associated with niche diversity.

Unfavourable condition indicators: severe reduction in tree and shrub cover, leading to loss of habitat and niches for lichens on both tree and rocks.

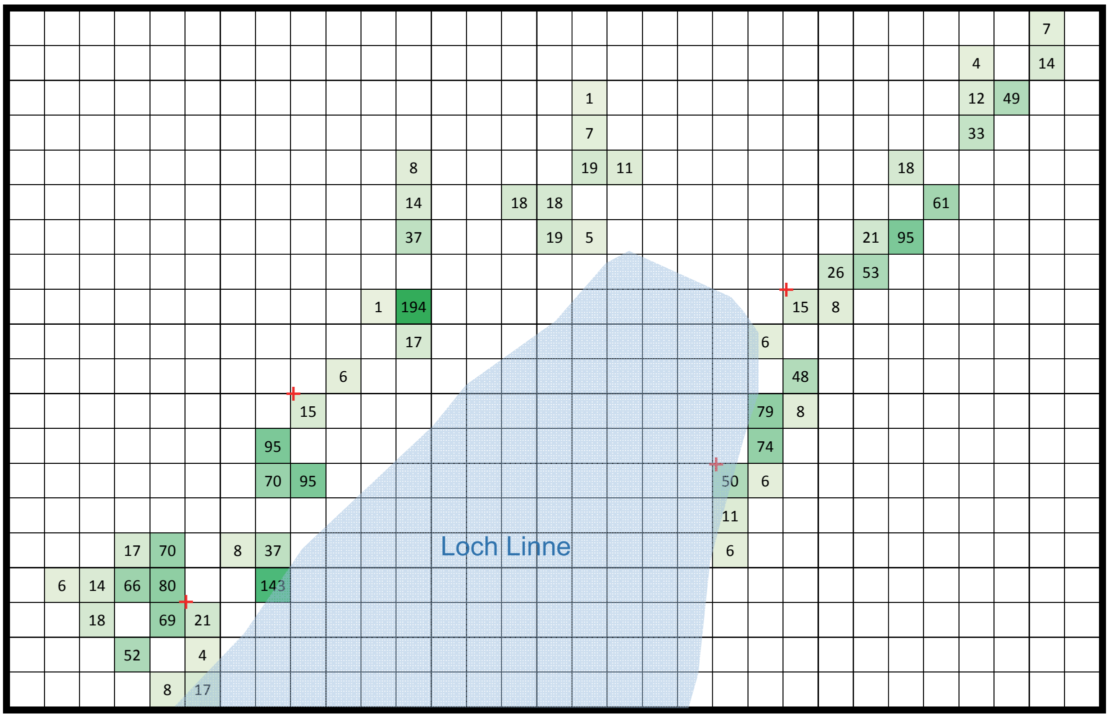
4) Atlantic Hazelwoods

Extensive areas of pure stands of hazel (*Corylus avellanae*) with few (if any) other tree or shrub species present. There must be a range of different-aged stems within individual stools, indicating viability of the stool and continuity of habitat. The stand may be dense, with closely-grouped stools consisting of relatively few stems per stool, with a closed canopy, and canopy height ranging from 1.0–2.5 m (usually in exposed, coastal situations, or over thin soils on rocky slopes). Alternatively, in more sheltered locations over deep soils and gentle terrain, the individual stools may be large, high and widely-spaced, with many stems per stool, often with several large, thick and leaning stems. *Graphidion* communities tend to be better represented on young stems in better-lit situations. *Lobarion* communities are more frequent in sheltered, humid situations, especially on leaning, larger stems.

Unfavourable condition indicators: hazel stools reduced to one or a few thick stems (hazel ‘trees’), with basal regeneration consistently browsed.

ANNEX 2: DETAILED BEAVER IMPACT CHARTS NOT INCLUDED IN MAIN TEXT

Stem density and proportion felled or partially felled for Loch Linne (North-west) and Loch Linne (North-east) hazel stands (Figure 23), Loch Fidhle (Figure 24), and Creagmhor Loch (Figure 25).



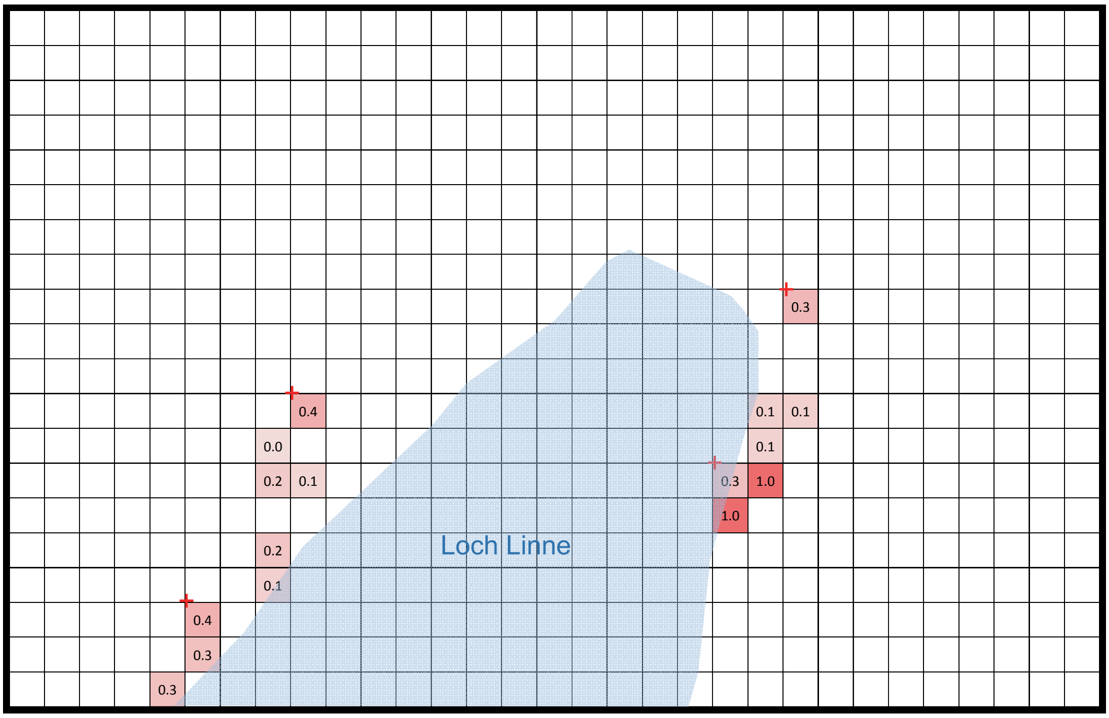


Figure 23. Hazel stem density (top) and proportion of stems felled or partially felled by beaver (bottom) in the Loch Linne (North-west) and Loch Linne (North-east) hazel stands. Grid spaced at 10 m National Grid intervals and bottom-left grid = NR79809134. Red crosses to aid comparison between charts.

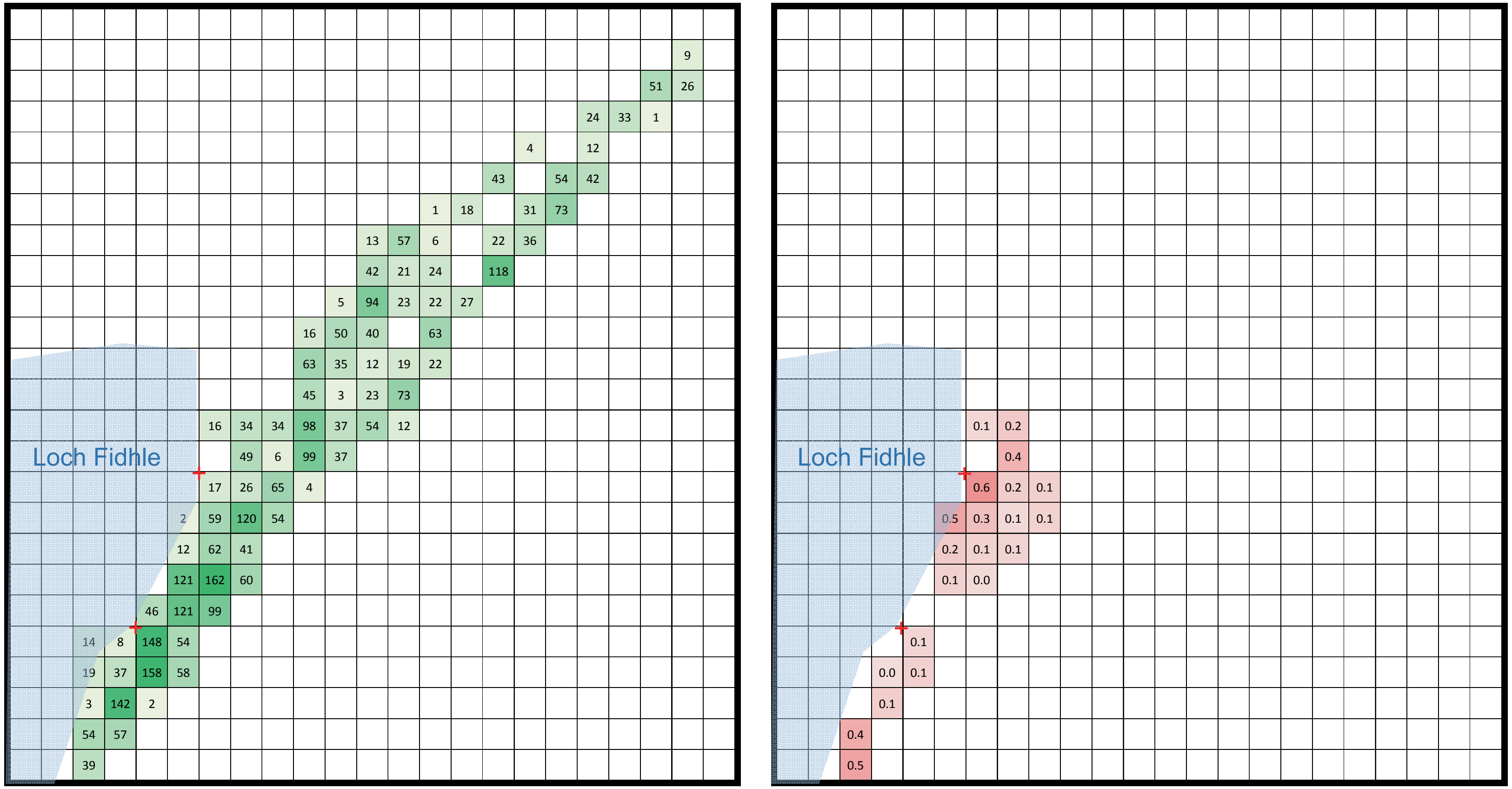


Figure 24. Hazel stem density (left) and proportion of stems felled or partially felled by beaver (right) in the Loch Fidhle hazel stand. Grid spaced at 10 m National Grid intervals and bottom-left grid = NR79979100. Red crosses to aid comparison between charts.

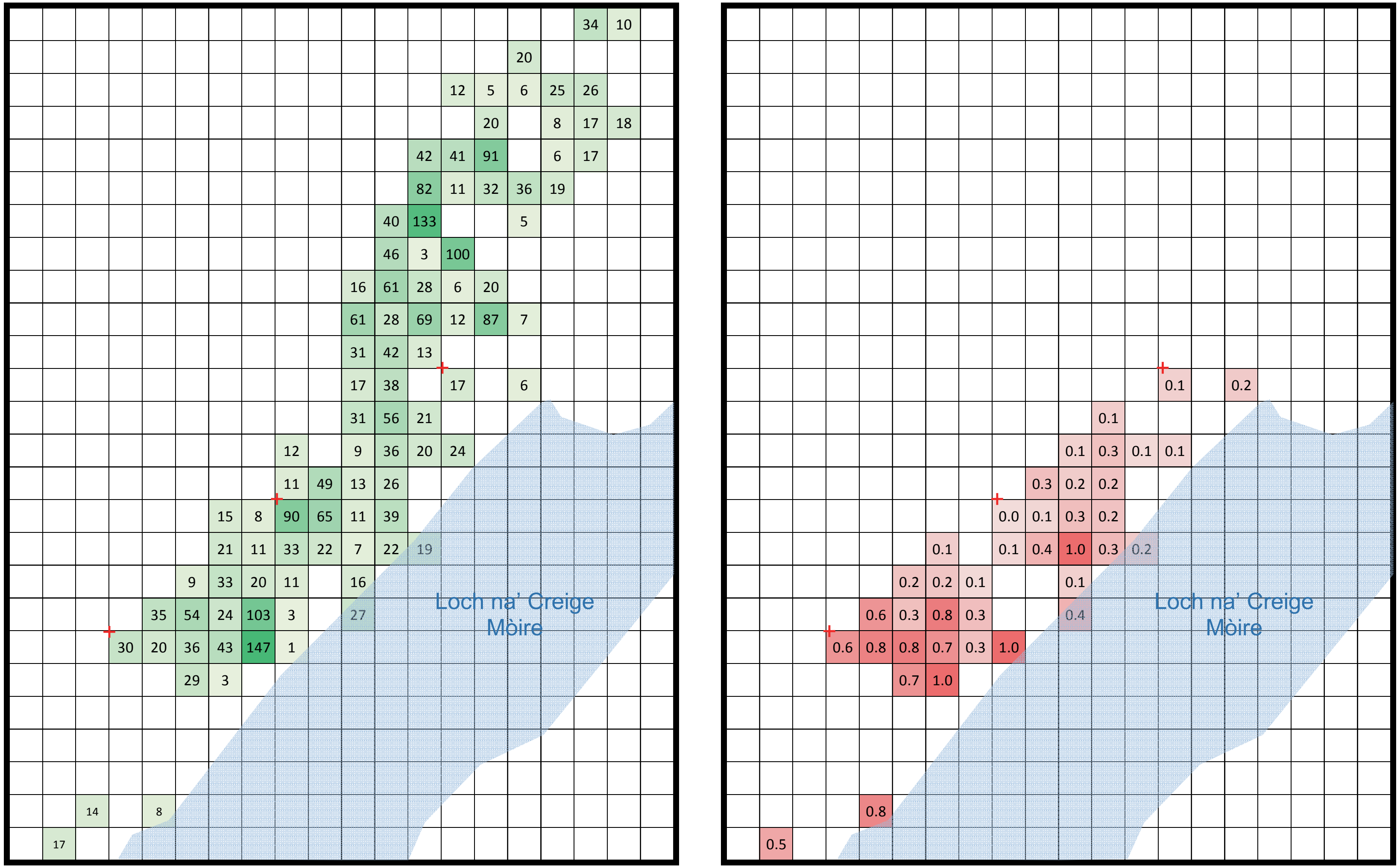


Figure 25. Hazel stem density (left) and proportion of stems felled or partially felled by beaver (right) in the Creagmhor Loch hazel stand. Grid spaced at 10 m National Grid intervals and bottom left grid = NR80319111. Red crosses to aid comparison between charts.

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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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