Trial of the Natural Capital Protocol for land-based businesses

Glenlivet Estate
Natural Capital Assessment

March 2018

Version	Date	Version Details	Prepared by	Reviewed by
1.0	31/01/2018	First Draft Report	Paul Silcock	Paul Silcock
2.0	21/02/2018	Draft Report	Paul Silcock	Charlie Russ Paul Silcock
3.0	22/03/2018	Final Report	Paul Silcock	Charlie Russ Paul Silcock

Cumulus Consultants Ltd
1 Gainsborough House, Campden Business Park
Battle Brook Drive
Chipping Campden
Gloucestershire GL55 6JX

Telephone: +44 (0)1386 277970
Email: info@cumulus-consultants.co.uk
Web: www.cumulus-consultants.co.uk

Contents

EXECUTIVE SUMMARY

Glenlivet Estate is one of three-land based businesses participating in a trial to explore the degree to which the Natural Capital Protocol (the Protocol) is applicable and useful to land-based businesses in Scotland. Glenlivet Estate is a mixed upland estate with a range of enterprises including crop and livestock production, forestry, whisky distilling, water bottling, tourism, shooting and fishing.

These enterprises are dependent on natural capital (NC) assets and a range of ecosystem services (ESS). An overview of the Estate's key natural capital assets and trends over the current tenancy is given below:

Asset	Trend (2007 – 2017)	
	Extent	Condition
Arable land and temporary pasture (3,036 ha)	➔	↗
Permanent pasture (6,071 ha)	➔	↗
Coniferous woodland (3,472 ha)	➔	↗
Broadleaved woodland (497 ha)	↗	➔*
Mountains, moorlands and heaths (10,274 ha)	➔	↗
Water (rivers and streams, 168 km)	➔	↗
"↗" = Improving/growing "➔" = stable "↘" = deteriorating/shrinking		

* Condition is mixed across broadleaved woodlands on let holdings.

Natural capital dependencies

Some Estate enterprises (e.g. crop production, commercial forestry) are dependent on just one natural capital asset whereas other enterprises (e.g. livestock production, whisky distilling, water bottling, tourism) are dependent on a group of assets, some of which are not immediately obvious (for example hedges and woodland to provide shelter for livestock).

The Estate enterprises are dependent on provisioning services of crops, livestock, wild foods, water supply and timber and a number of key regulating and cultural services, including:

Local climate regulation – livestock production depends on shelterbelts, for example, to reduce exposure and mortality.

Water quality regulation – whisky distilling and water bottling are dependent on a plentiful supply of clean, fresh, spring water.

Disease and pest regulation – crop and livestock production, forestry, shooting and fishing all depend on disease and pest management services to minimise production losses.

Wild species diversity – tourism, shooting, fishing and forestry depend on a diversity of habitats and species.

Natural capital impacts

This report looks at both the 'gross' impacts of Glenlivet Estate's enterprises (i.e. the impact of enterprises compared to a benchmark of no management/natural state); and the impacts of specific activities undertaken during the period 2007 to the present day.

Against a benchmark of the natural state of the land, most enterprises cause some negative ecosystem service impacts, particularly on regulating services such as climate, flood, water quality, soil quality and disease and pest regulation.

By contrast, the impacts on natural capital and ecosystem services of Estate enterprises and activities over the past ten years have been positive. These include:

Climate regulation – peatland restoration and woodland creation and management has increased carbon storage and reduced carbon emissions.

Wild species diversity – a wide range of habitat and species conservation work has been undertaken by the Estate and farmers.

Recreation – The Estate has invested in waymarked footpaths and mountain bike trails, as well as signs, hides, picnic areas and car parks. Ski-ing, shooting and fishing also take place on the Estate.

Education - The Estate has worked with the RSPB and other organisations to raise awareness of environmental features on farm and supports research into sustainable land management.

Risks and opportunities

Risks include:

- Brexit, loss of Basic Payment Scheme and potential tariffs, resulting in a reduction in farm income and adaptation
- Input prices may rise and become more volatile
- Change in regulation and legislation
- Climate change and an increase in extreme weather events

Opportunities include:

- Production for the domestic market
- Building resilience and resource efficiency
- 'Public payments for public goods' schemes, with opportunities for future public funding
- Private funding for investment in carbon, water quality and flood management, for example.
- Continued diversification, including strengthening the Estate's brand
- Greater awareness of inter-dependencies and trade-offs between enterprises in terms of natural capital and ecosystem services.
- Developing a set of metrics for monitoring the Estate's natural capital assets.

Actions for consideration

Internal data and reporting:

- Improve natural capital and ecosystem service data for the Estate as a whole.
- Identify a few, key indicators to track natural capital e.g. soil organic matter, water quality, carbon, biodiversity index.
- Develop natural capital accounts for the Estate and integrate into reporting.

Working with partners and stakeholders:

- Raise awareness of natural capital and ecosystem services amongst tenants, communities and other stakeholders
- Incorporate natural capital into land use decisions
- Engage with partners/buyers to identify win-wins from integrating natural capital into production, supply chain and marketing.

Funding and investment:

- Identify priorities for natural capital investment.
- Incorporate natural capital into investment decisions.
- Engage with public and private buyers to secure funding for natural capital maintenance and enhancement.

FRAME STAGE: Why?

Step 01: Get started

Crown Estate Scotland and its partners in a coalition of organisations with an interest in land management in Scotland would like to explore the degree to which the Natural Capital Protocol (the Protocol) is applicable and useful to land-based businesses in Scotland.

Natural capital refers to the natural resources (or assets) that people use and gain benefit from. For Glenlivet Estate, this includes its soils, water, arable and pasture land, hedges, woodland, moorland and other habitats, see Table 2. More officially, natural capital can be defined as:

"…the stock of renewable and non-renewable natural resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits or 'services' to people"[1].

Figure 1 illustrates the relationship between natural capital and the flows of benefits (which can be ecosystem services or abiotic services) which provide value to people and businesses.

[1] Natural Capital Coalition (2016) Natural Capital Protocol [online] available at https://naturalcapitalcoalition.org/protocol/.

Figure 1: Natural capital stocks, flows and values

The Natural Capital Protocol[2], produced by the Natural Capital Coalition[3], is a standardised framework for businesses to identify, measure, and value their impacts and dependencies on natural capital. The framework is designed to help generate trusted, credible, and actionable information about how businesses interact with nature, or more specifically natural capital, that business managers need to inform decisions. This includes highlighting natural capital risks and opportunities for each business.

Glenlivet Estate's natural capital assets provide a range of ecosystem services, see Table 3. This framework has been adapted from the Millennium Ecosystem Assessment[4] which identifies four broad categories of ecosystem services:

[2] http://naturalcapitalcoalition.org/wp-content/uploads/2016/07/Framework_Book_2016-07-01-2.pdf

[3] http://naturalcapitalcoalition.org/

[4] Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis [online] available at https://www.millenniumassessment.org/documents/document.356.aspx.pdf

- Provisioning services; such as food supply, materials, energy, water supply, genetic resources.
- Regulating services; such as carbon sequestration and climate regulation, waste decomposition and detoxification, purification of water and air, pest and disease control.
- Cultural services; e.g. recreation, education and cultural heritage.
- Supporting services; regarded as the basis for the services listed above (note: these are not separated out in the ecosystem services tables). These include services such as nutrient recycling, primary production and soil formation. These services make it possible for the ecosystems to provide services such as food supply, flood regulation and water purification.

Glenlivet Estate is dependent on the continued supply of ecosystem services such as water supply, soil quality regulation, disease and pest regulation, local climate regulation and wild species diversity to support its various enterprises. Estate enterprises also have impacts – both positive and negative - on natural capital stocks and ecosystem services flows. Conducting a natural capital assessment of Glenlivet Estate can help to identify, measure and value the impacts and dependencies of Estate enterprises and outputs on natural capital.

SCOPE STAGE: What?

Step 02: Define the objective

Overall project objectives

The overall aim of the project is to explore the degree to which the Natural Capital Protocol (the Protocol) is applicable and useful to land-based businesses in Scotland through:

- completing pilot natural capital assessments for three land-based businesses, including Glenlivet Estate;
- developing businesses' understanding of natural capital and the Protocol through this pilot; and
- producing case studies to help communicate the value to the businesses of reducing natural capital impacts and managing dependencies to share with the steering group and promote more broadly.

This report sets out the key findings from the natural capital assessment of Glenlivet Estate, whilst a separate Overview Report presents the findings and lessons learnt from the wider project

Glenlivet Estate objectives

The objectives relating specifically to the Glenlivet Estate natural capital assessment are to:

- facilitate more informed decision-making in terms of land use and management, supporting enhanced environmental and economic performance and greater resilience in terms of primary production and other enterprises;
- systematically identify and assess natural capital risks and opportunities relating to the Estate; and
- support the business to be better prepared and informed to secure future public payments and identify potential new revenue streams.

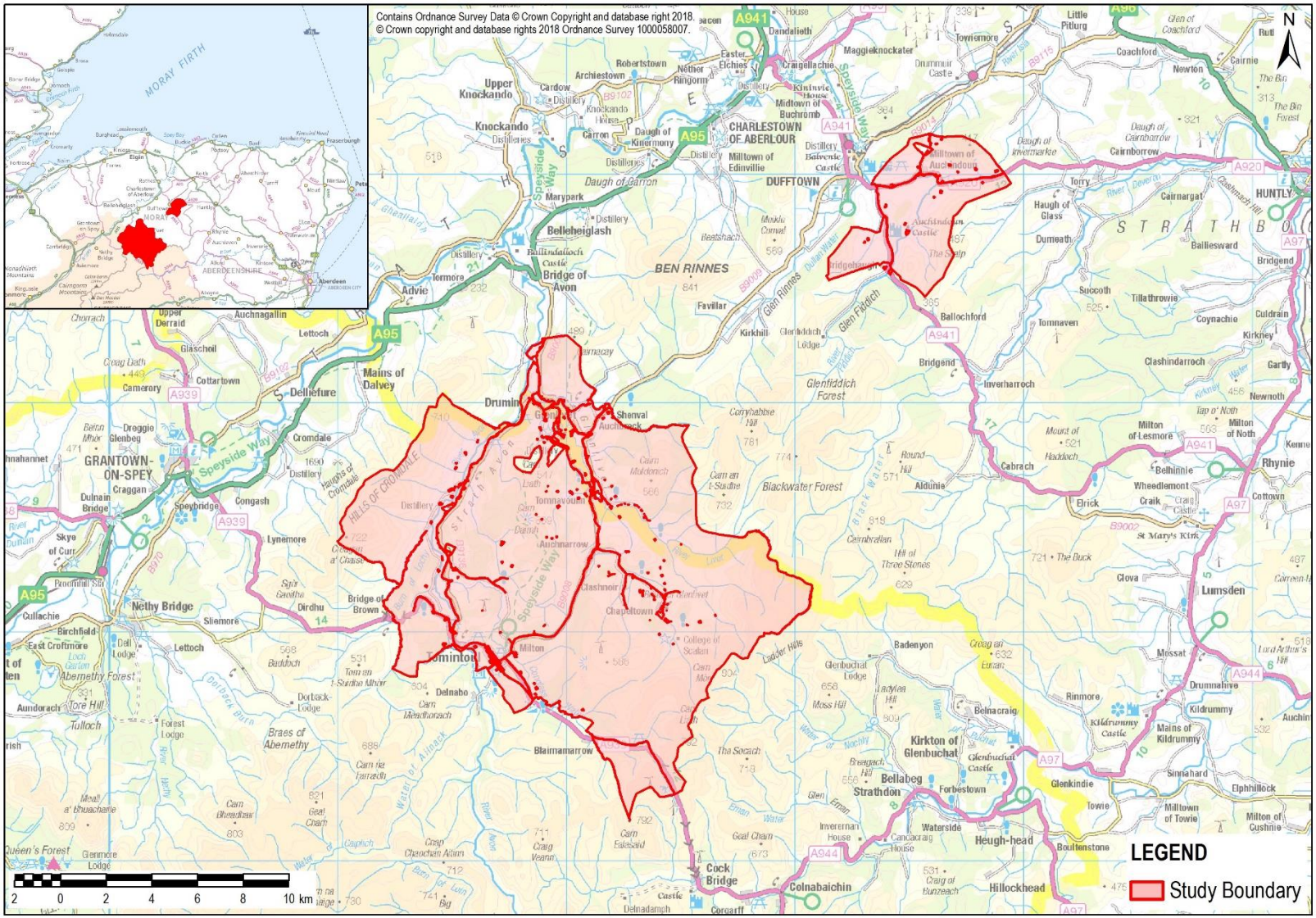
This has been done through a high level natural capital assessment for the whole Estate, assessing the key natural capital impacts and dependencies of the Estate's enterprises. In addition, a more detailed assessment of a peatland restoration project was undertaken to demonstrate how quantification and valuation of natural capital costs and benefits may be a useful input to business decision-making.

Step 03: Scope the assessment

Scope of assessment

- The assessment examines the **impacts and dependencies** of Estate enterprises on natural capital stocks and the benefits they provide.
- The assessment covers the impacts and dependencies of direct operations within the Estate boundaries (see Figure 2) only and does not include consideration of supply chain impacts or dependencies. However, account is taken of risks and opportunities beyond the 'farm gate' where these are relevant.
- We have assessed and valued impacts (positive and negative) from the perspectives of both the **business and society**.
- The assessment considers both impacts and dependencies of enterprises on the Estate in general (i.e. in any given period of time), as well the change in natural capital and ecosystem service flows over an indicative 10-year period from 2007 to the present day (2017).

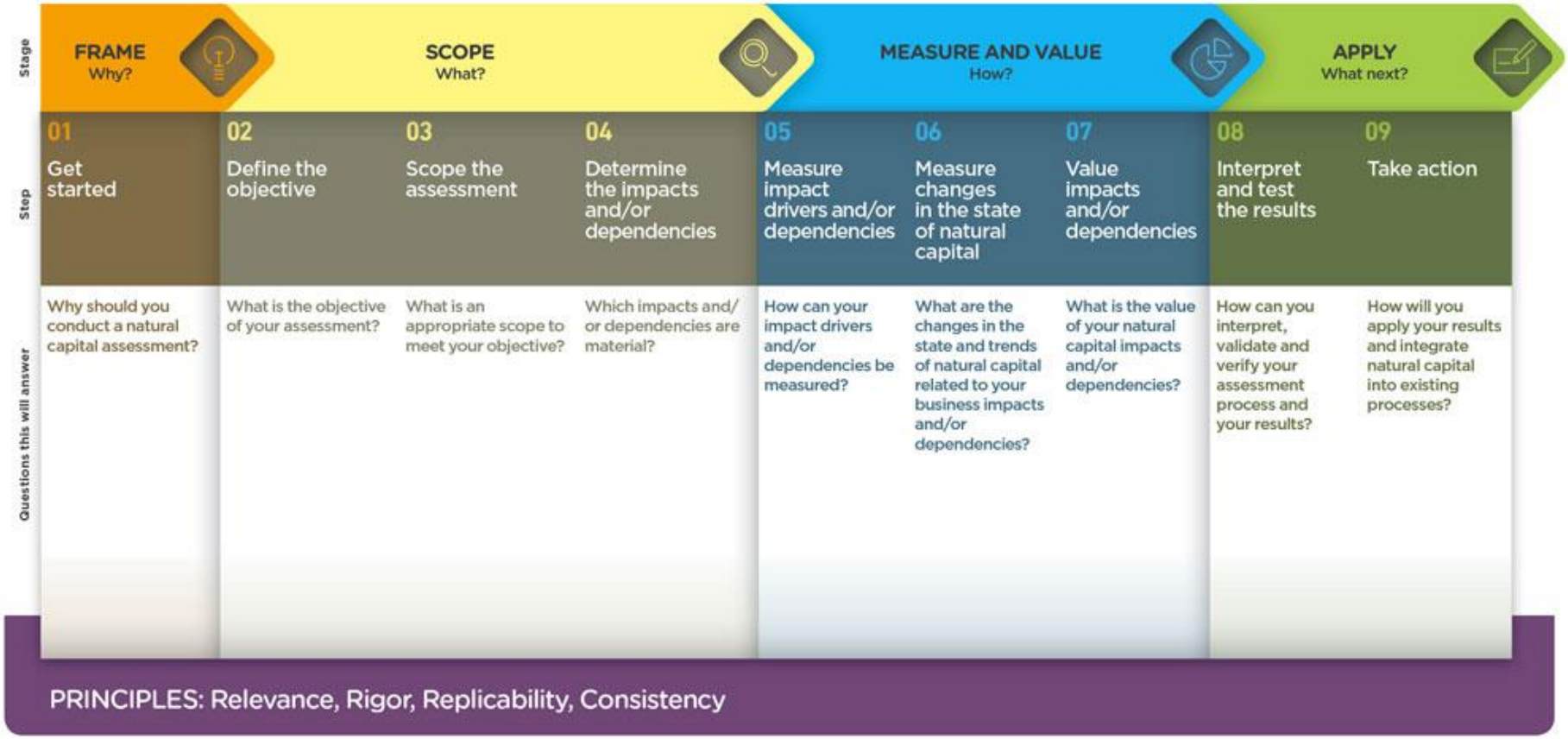
Figure 1: Map of Glenlivet Estate (red line boundary) and surrounding area



Approach

The work involved three meetings with Estate staff and the land agent over the period November 2017 to February 2018, a review of Estate data and documents, analysis and assessment. The work followed the steps laid out by the Protocol and this report reflects that process, illustrated in Figure 3 below.

Figure 3: Natural Capital Protocol Framework



Estate overview

Glenlivet Estate is owned by the Crown and managed by Crown Estate Scotland. It comprises approximately 23,350 hectares (57,700 acres) located in and around Tomintoul, Moray at the Northern fringe of the Cairngorms.

Glenlivet is a mixed upland estate. It includes large areas of moorland and rough grazing, together with in-bye land which is predominantly permanent pasture, with smaller areas of arable land and temporary grass. There are extensive conifer plantations and broadleaved woodland at lower level. There is a range of let and in-hand enterprises on the Estate, as set out in Table 1.

Table 1: Estate enterprises

31 let farms, ranging in size from 60-1,100 ha, with predominantly breeding suckler cow and sheep enterprises
3,500 ha of in-hand commercial forestry plantations
Let sporting rights – grouse, pheasant, deer and fishing
Let water rights for water bottling, whisky distilling and business/residential use
Let residential and commercial properties
Tourism, recreation and education activities
Let commercial leisure enterprises (e.g. mountain bike centre, ski centre etc.)

Crown Estate Scotland aims to manage the estate as an outstanding example of a sustainable highly integrated multiple-use upland estate, which provides a commercial return. The aims are to provide opportunities for sustained employment in agriculture, forestry, sporting and tourism while giving high priority to the long term development of the estate's community, it's recreational, educational and other resources. This is balanced with the need to protect, conserve and enhance the rich natural and cultural heritage of the estate. In the future, it is anticipated that there will be continued diversification of the estate.

Step 04: Determine the impacts and/or dependencies

Introduction

Every business impacts on and depends on natural capital and the ecosystem services it provides to some degree and will experience risks and/or opportunities associated with these relationships. Impacts can be negative, e.g., pollution, or positive, e.g., improved water quality.

There are many ecosystem services that flow from the different types of natural capital, not all of which will be relevant for this assessment. For upland estates, provisioning services such as crops, livestock, wild food and timber are highly significant while other services such as noise regulation may be less so.

This step in the process aims firstly to identify the natural capital stocks that are present on Glenlivet Estate and the ecosystem services that flow from these and secondly to determine which of the impacts and dependencies upon these are most significant and worth more detailed investigation.

Natural capital assets and ecosystem services on the Glenlivet Estate

Glenlivet Estate's **natural capital assets** can be viewed as a series of habitat types, set out in the form of an Asset Register in Table 2. This Asset Register lists the extent of the assets (e.g. hectares of land) and the condition, and identifies changes over time from 2007 to 2017. Note, the same areas have been used for 2007 as 2017, due to lack of more specific data, however it is acknowledged that in practice the area of some habitats (e.g. broadleaved woodland) has increased.

The land[5] comprises around 3,036 ha of arable land and temporary grassland, 6,071 ha of permanent pasture, 10,274 ha of moorland and other upland habitats, and 3,969 ha of coniferous and broadleaved woodland (including 520ha of native woodland). There are also hedges at lower level, providing shelter against the prevailing winds.

Soils on the Estate are mostly peaty gleys, peat podzols and brown forest soils at lower levels grading to blanket bogs and montane soils at high altitude. The Estate's farmland is also varied ranging from Land Capability for Agriculture (LCA) Class 4.1 (capable of producing a narrow range of crops) through to 7.0 (very limited agricultural value; restricted to very poor rough grazing).

Watercourses include the Rivers Avon and Livet and numerous streams, which are tributaries to the River Spey, a SAC (Special Area of Conservation). Where water quality is known, these watercourses are predominantly in good status (66%), although some are moderate (32%) and a minority are poor (2%).

Biodiversity on the Estate includes a wide range of habitats and species. There are six Sites of Special Scientific Interest (SSSI), mainly in favourable condition, albeit with parts of some sites in unfavourable condition. There are also three SACs and one Special Protection Area (SPA). The Estate supports over 100 UK Biodiversity Action Plan species including at least 23 'Priority Species of conservation concern'.

[5] Based on CES data, predominantly the Wildllife Estates Scotland (WES) return. This differs from land use data extracted from tenancy agreements, which is a partial dataset, and EUNIS data.

The Estate is in an Area of Great Landscape Value, being part of the Cairngorms Straths Environmentally Sensitive Area. Most of the Estate also lies within the Cairngorms National Park.

The Estate is relatively wild, with an average score of 75, with scores ranging from 19 to 161[6].

There is good public access across the Estate including 100 miles of waymarked walking and cycling routes. There are a number of historic features of interest including Drumnin Castle, The Scalan (seminary) and Lecht Mine.

It is estimated that over 50% of farms on the Estate participate in an agri-environment scheme and the in-hand woodland is certified under the UK Woodland Assurance Scheme. The Estate's game and wildlife management is accredited by Wildlife Estates Scotland.

A series of maps illustrating some of the above elements are included in Appendix 3 as a separate document.

The asset register shows a general improvement in the condition of Glenlivet Estate's natural capital assets, although comparable historic and current data on extent and condition is limited (judgements have therefore been made based on available data and discussions with Estate staff and the land agent). This trend includes habitat improvements on farms (such as Ruthven Farm), restructuring and diversification of conifer woodland, creation of new native woodland, peatland restoration (see the Case Study at the end of the report) and a wide range of other conservation work and access improvements.

[6] 'Relative Wildness' is a composite index based on four attributes naturalness of land cover, ruggedness, remoteness and the lack of built modern artefacts. The scale is 1 to 256; the lower the score the less 'wild' the area.

Glenlivet Estate's natural capital assets provide a range of **ecosystem services**. Table 3 provides an overview of the relative importance of different types of natural capital stocks on the Estate in delivering ecosystem service flows (shown by coloured cells) in 2017.

For example, cropland and temporary grass are relatively important for crop and livestock provisioning services but less so for most regulating and cultural services. In contrast, broadleaved woodland is important for a wide range of regulating and cultural services, as well as some provisioning services such as livestock, wild food and timber.

The information in Table 3 was compiled on the basis of information from the UK National Ecosystem Assessment (in terms of the relative importance of different habitat types for different ecosystem services) as well as from observations and discussions with Estate staff and the land agent.

Definitions for these services can be found in Appendix 2.

Key dependencies and impacts

The discussion and assessment outlined above helped us to identify where the key or 'material' dependencies and impacts lie and therefore which are likely to be most relevant to the Estate business and its stakeholders.

Given the range of enterprises on the Estate and the range of dependencies and impacts, all the ecosystem services outlined in Table 3 were considered key or 'material' and included in the subsequent stages of the assessment.

Table 2: Natural capital asset register

Assets (habitat types)	Unit of measure	2007		Current status 2017		Data source	Trends
		Extent	Condition	Extent	Condition		
Enclosed farmland:							
Cropland (arable & horticultural)	ha	3,036	n.d.	3,036	n.d.	WES return	Improving condition
Temporary pasture (temporary improved grassland)	ha		n.d.				
Permanent pasture (permanent improved grassland)	ha	6,071	n.d.	6,071	n.d.	WES return	Improving conditon
Permanent unimproved pasture (semi-natural grassland	ha		n.d.				
Field margins	ha of 3m field margins		n.d.	n.d.	n.d.		
Hedgerows	length of hedges in meters	150	n.d.	150	n.d.	WES return	Improving condition
Woodland:							
Coniferous (commercial)	ha	3,472	n.d.	3,472	UKWAS/Woodmark	Forest Plan 2013-32	Improving condition
Broadleaved (amenity)	ha	497	n.d.	497	n.d.	WES return	Mixed condition
Mountains, Moorlands and Heaths	ha	10,274	n.d.	10,274	n.d.	WES return	Improving conditon
Water (Openwaters, Wetlands & Floodplains)	length of streams in meters	168,876	n.d.	168,876	Mainly good status	OS Open Rivers	Improving condition

n.d.	no data

Table 3: Ecosystem services

Current status 2017			ECOSYSTEM SERVICES																	
			PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
Assets (habitat types)	Current asset?	Trend	Crops	Livestock	Wild foods (game birds)	Wild foods (venison)	Wild foods (fish)	Water Supply	Timber	Fibre	Climate regulation	Flood regulation	Water quality regulation	Soil quality & erosion regulation	Air quality regulation	Disease & pest regulation	Pollination	Wild Species Diversity	Recreation	Education	Cultural heritage
Enclosed farmland:																					
Cropland (arable & horticultural)	yes	Improving																			
Temporary pasture (temporary improved grassland)	yes																				
Permanent pasture (permanent improved grassland)	yes	Improving																			
Permanent unimproved pasture (semi-natural grasslands)	yes																				
Field margins	yes	n.d.																			
Hedgerows	yes	Improving																			
Woodland:																					
Coniferous (commercial)	yes	Improving																			
Broadleaved (amenity)	yes	Mixed																			
Mountains, Moorlands and Heaths	yes	Improving																			
Water (Openwaters, Wetlands & Floodplains)	yes	Improving																			

Relative importance:	
	high
	medium
	low
	not important

MEASURE AND VALUE STAGE: How?

Step 05: Measure impact drivers and dependencies

Step 06: Measure changes in the state of natural capital

Step 07: Value impacts and/or dependencies

This stage focuses on assessing the dependencies and impacts of Glenlivet Estate's enterprises on natural capital and ecosystem services in more detail. It starts by identifying the specific enterprises that are dependent on, or give rise to impacts on ecosystem services before describing the nature of these relationships and their implications both for the Estate itself and for others that may also benefit from the services provided. Some of the broad approaches to monetary valuation of the costs and benefits are described and are demonstrated in more detail in the case study at the end of the report.

Natural capital and ecosystem service dependencies

Table 4 highlights the extent to which the different enterprises on the Estate are dependent on natural capital. It can be seen that some enterprises (e.g. crop production, commercial forestry) are clearly dependent on just one asset, whereas others (e.g. livestock production, whisky distilling, water bottling, tourism) are dependent on a group of assets, some of which are not immediately obvious (for example hedges and woodland to provide shelter for livestock). Looking at it the other way round, some individual assets provide a range of services for different enterprises. For example, mountains, moorlands and heaths provide: grazing for livestock; support the supply of fresh, clean, spring water for whisky distilling and water bottling; provide space and tranquillity for walkers; and a place and habitat for grouse shooting.

Table 5 shows the dependency of enterprises on specific ecosystem services. Beyond the more obvious provisioning services of crops, livestock, wild foods, water supply and timber this highlights that the Estate depends on a number of key regulating and cultural services, including:

- local climate regulation;
- water quality regulation;
- disease and pest regulation; and
- wild species diversity.

Provisioning services

Crop production and livestock grazing are clearly highly dependent on food provisioning services, forestry is dependent on timber, and shooting and fishing are dependent on wild food. This is due to the management of land primarily for these purposes. Whisky distilling and water bottling are dependent on water supply, although not directly involved in associated land management. These benefits are supported by a range of regulating services.

Regulating services

It is no surprise that the majority of the Estate's dependencies are classified as regulating services. These are the services that regulate climate, flooding, water quality, soil quality and erosion, diseases and pests and so on. Three primary production enterprises and two sporting enterprises are dependent on disease and pest regulation provided by the natural environment; other regulating services are also important, albeit for fewer enterprises each.

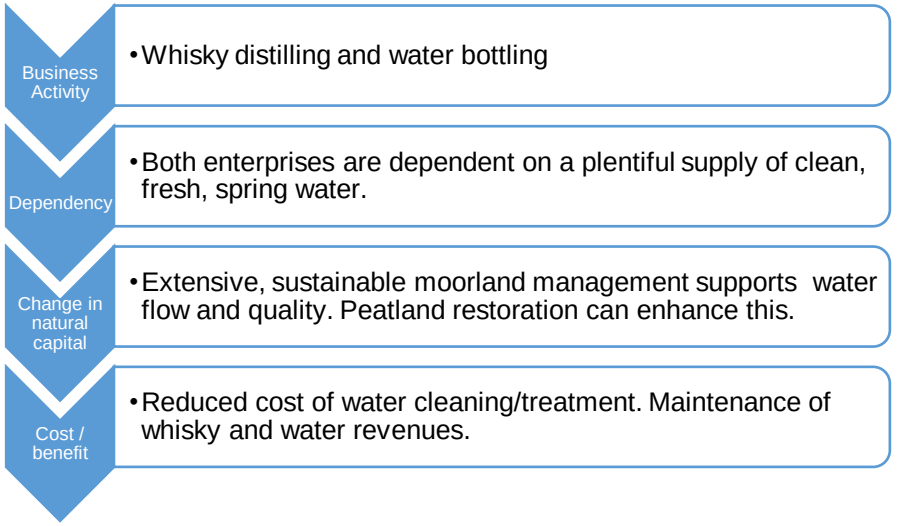
Cultural services

All of the Estate's enterprises have a high dependency on cultural heritage (which includes knowledge and understanding of land and its management built up over many years), with recreation and sporting enterprises also dependent on other cultural services such as wild species diversity and recreation.

Dependency pathways have been developed for some of the key dependencies identified in Tables 4 and 5. These pathways describe the ways in which a range of different enterprises depend on natural capital and ecosystem services and how changes in these may impact positively or negatively on the business.

Dependency pathways:

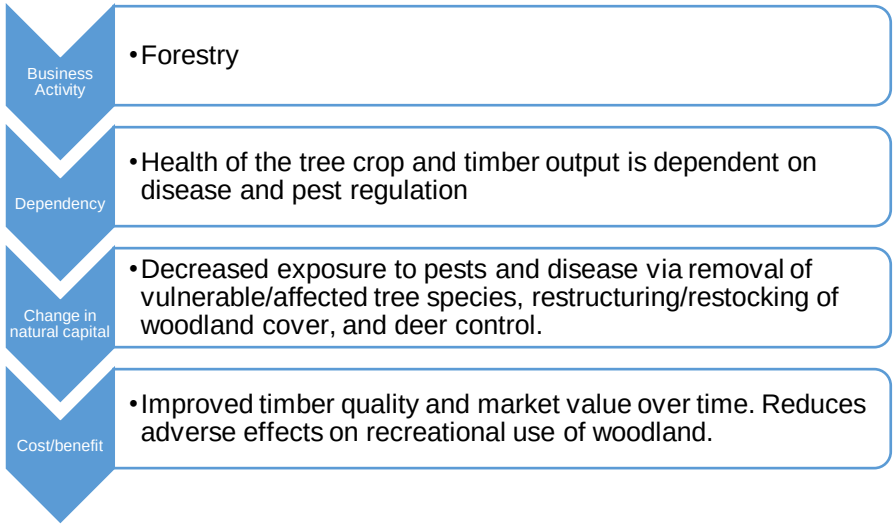
Water supply /water quality regulation



Moorland management is undertaken by the sporting tenant and livestock graziers under existing agreements. This indirectly maintains water supply and water quality for a number of enterprises, most notably whisky distilling and water bottling. The Estate restored an area of degraded peatland at Glenmullie in 2014 which amongst other benefits will help to maintain base flows during droughts and reduce loss of peat and associated discoloration of water.

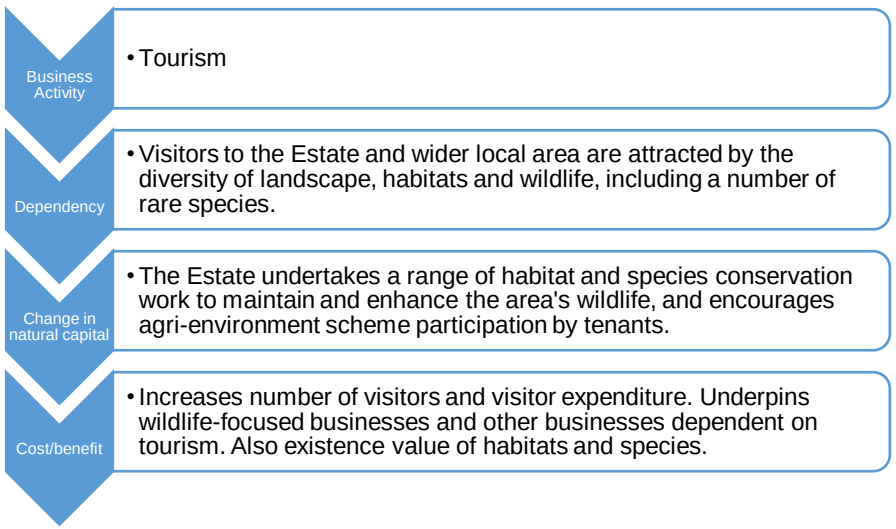
See the Case Study on Page 24 for further details.

Disease and pest regulation



Commercial forestry on the Estate is subject to a range of diseases and pests, most notably Red band needle blight (Lodgepole Pine, Scot's Pine), Pine weevil (various conifer species), deer and rabbit. The Estate is removing affected trees, restocking/restructuring to reduce exposure to disease risk as well as working with stalkers to control deer numbers. This is long term work which will help to improve forestry returns and resilience, and sustain the woodland's broader benefits.

Wild species diversity



In recent years the Estate has invested in a variety of projects and initiatives designed to enhance the area's natural environment and landscape. Examples include the creation of new native woodlands, the restructuring/restocking of commercial forestry, the restoration of blanket bog, and management to support specific species such as upland waders. This directly support the area's visitor economy, with tenanted, licenced and other businesses all benefiting.

Table 4: Natural capital dependencies

Enterprises	Assets (habitat types)								
	Enclosed farmland:								
	Cropland (arable & horticultural)	Temporary pasture (temporary improved grassland)	Permanent pasture (permanent improved grassland)	Permanent unimproved pasture (semi-natural Grasslands)	Field margins	Hedgerows	Woodland (includes farm woodlands)	Mountains, Moorlands and Heaths	Water (Openwaters, Wetlands & Floodplains)
Crop production									
Livestock grazing									
Forestry									
Whisky distilling									
Water bottling									
Tourism									
Shooting									
Fishing									

Table 5: Ecosystem service dependencies

Enterprises	% area of land of enterprise	ECOSYSTEM SERVICES																		
		PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
		Crops	Livestock	Wild foods (game)	Wild foods (venison)	Wild foods (fish)	Water Supply	Timber	Fibre	Climate regulation	Flood regulation	Water quality regulation	Soil quality & erosion	Air quality regulation	Disease & pest regulation	Pollination	Wild Species Diversity	Recreation	Education	Cultural heritage
Crop production	2																			
Livestock grazing	76																			
Whisky distilling																				
Water bottling																				
Forestry	20																			
Tourism																				
Shooting	95																			
Fishing																				

Dependency:	
	High
	Medium
	Low
	No dependency

Natural capital and ecosystem service impacts

The gross impacts (i.e. compared to a situation in which the land is not actively managed) of Glenlivet Estate's enterprises on natural capital assets and ecosystem services are highlighted in Tables 6 and 7.

Crop and livestock production positively impacts cropland and temporary pasture. Forestry has a positive impact on woodland and to a lesser extent water, through woodland creation and management. Whisky distilling and water bottling have negative impacts on water, specifically spring water, due to water abstraction.

The gross impacts of the Estate's enterprises on ecosystem services are summarised below:

- Crop and livestock production provide crops, livestock and fibre but adversely affect a range of regulating services, including water quality regulation, and wild species diversity. Cultural heritage is enhanced i.e. knowledge and understanding of land and its management.
- Whisky distilling and water bottling have a negative impact on water supply and certain regulatory services but positively impact recreation (visitors) and cultural heritage.
- Forestry has a wide range of positive impacts on timber, wild foods and most regulatory and cultural services. It has a mixed impact on soil quality and erosion regulation; positive for the most part, but negative when clear felling takes place.
- Tourism is beneficial in terms of recreation, education and cultural heritage, but can give rise to some negative impacts, for example in relation to water supply and climate regulation due to visitor activities and consumption.
- Shooting, which includes grouse, pheasant and deer shooting, has mixed impacts in terms of wild species, negative impacts on most regulatory impacts (primarily linked to moorland management activities), and positive impacts in terms of recreation and cultural heritage.
- Fishing has negative impacts on wild food and positive impacts on water quality regulation, recreation, education and cultural heritage.

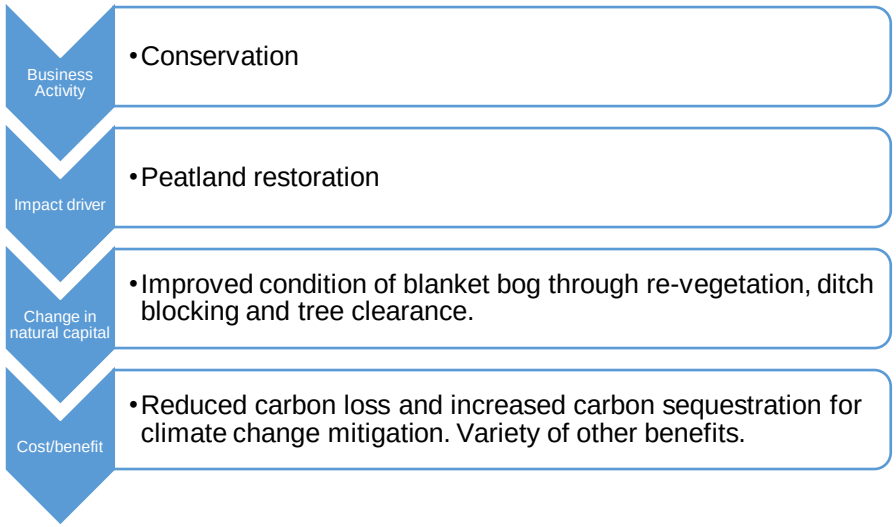
It is worth noting the general, positive impact of the Estate's enterprises on cultural services.

We have also examined the specific impacts on natural capital and ecosystem services arising from Estate enterprises and activities over the period from 2007 to present day (2017). These are shown in Tables 8 and 9 and indicate that there have been improvements in the extent and/or condition of woodland and peatland, and improvements in a range of regulatory services due to forestry and conservation work in particular. There have also been positive impacts on cultural services including wild species diversity, recreation, education and cultural heritage. Note, 'conservation' has been included as an enterprise in these tables given the specific work undertaken by Crown Estate Scotland in this area.

Similar to the dependency pathways, we have developed a selection of impact pathways showing the 'logic chain' from business activity to impacts on natural capital and the costs and benefits associated with these impacts.

Impact pathways:

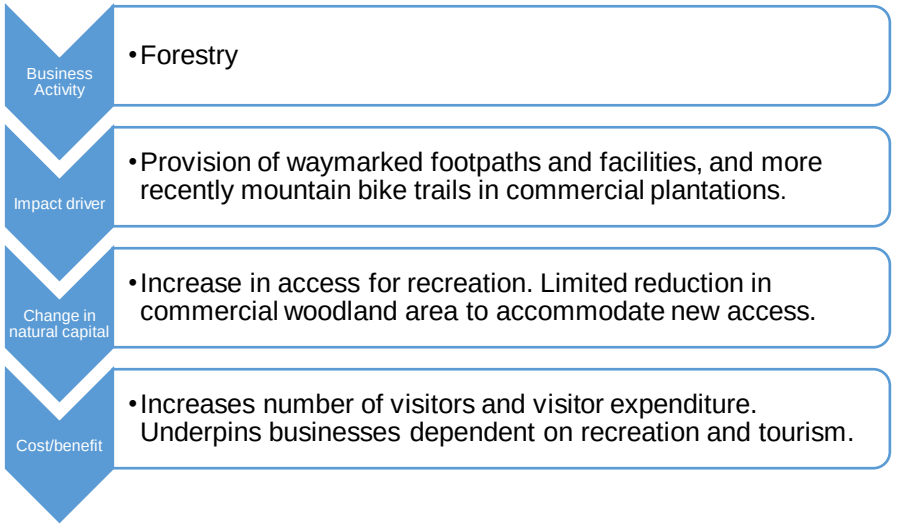
Climate regulation



The Glenmullie peatland restoration project undertaken in 2014 has helped restore 166ha of previously degraded blanket bog. A variety of work was undertaken to stabilise and revegetate bare peat, raise water levels and remove non-native conifers. This has had a positive impact on climate regulation through reduced carbon emissions, which will continue into the future. Additional benefits relate to soil quality/erosion regulation, water quality requlation and wild species diversity, as well as improved access for livestock grazing and grouse shooting.

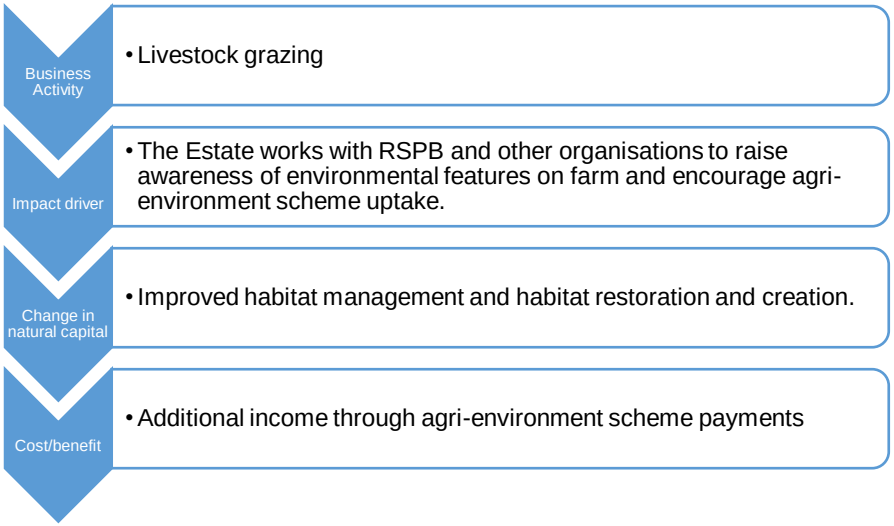
See the Case Study on Page 24 for further details.

Recreation



The Estate has invested in a comprehensive network of waymarked footpaths and associated infrastructure over the years and from 2012 onwards constructed, in commercial woodland, a series of mountain bike trails and a centre/café (run by a tenant) which has become increasingly popular. Pheasant and deer shooting also take place in the Estate's woodland.

Education



The Estate actively encourages tenant farmers to participate in agri-environment schemes and other projects enhancing landscape and wildlife. The Estate also supports a wide range of research into sustainable land management (including this trial of the Natural Capital Protocol).

Table 6: Natural capital impacts – gross impacts

Enterprises	Assets (habitat types)								
	Enclosed farmland:								
	Cropland (arable & horticultural)	Temporary pasture (temporary improved grassland)	Permanent pasture (permanent improved grassland)	Permanent unimproved pasture (semi-natural Grasslands)	Field margins	Hedgerows	Woodland (includes farm woodlands)	Mountains, Moorlands and Heaths	Water (Openwaters, Wetlands & Floodplains)
Crop production									
Livestock Grazing									
Forestry									
Whisky distilling									
Water bottling									
Tourism									
Shooting								+/-	
Fishing									

Table 7: Ecosystem service impacts – gross impacts

Enterprises	ECOSYSTEM SERVICES																		
	PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
	Crops	Livestock	Wild foods (game)	Wild foods (venison)	Wild foods (fish)	Water Supply	Timber	Fibre	Climate regulation	Flood regulation	Water quality regulation	Soil quality & erosion regulation	Air quality regulation	Disease & pest regulation	Pollination	Wild Species Diversity	Recreation	Education	Cultural heritage
Crop production																			
Livestock Grazing																			
Whisky distilling																			
Water bottling																			
Forestry												++/--							
Tourism																+/-			
Shooting			++/--	++/--												+/-			
Fishing																+/-			

Impact:	Positive	Negative
High		
Medium		
Low		
Mixed	+/-	
None		

Table 8: Natural capital impacts – impacts over 2007-2017

Enterprises	Assets (habitat types)								
	Enclosed farmland:								
	Cropland (arable & horticultural)	Temporary pasture (temporary improved grassland)	Permanent pasture (permanent improved grassland)	Permanent unimproved pasture (semi-natural Grasslands)	Field margins	Hedgerows	Woodland (includes farm woodlands)	Mountains, Moorlands and Heaths	Water (Openwaters, Wetlands & Floodplains)
Crop production									
Livestock grazing							+/-		
Forestry									
Whisky distilling									
Water bottling									
Tourism									
Shooting								+/-	
Fishing									
Conservation									

Table 9: Ecosystem service impacts – impacts over 2007-2017

Enterprises	ECOSYSTEM SERVICES																		
	PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
	Crops	Livestock	Wild foods (game)	Wild foods (venison)	Wild foods (fish)	Water Supply	Timber	Fibre	Climate regulation	Flood regulation	Water quality regulation	Soil quality & erosion regulation	Air quality regulation	Disease & pest regulation	Pollination	Wild Species Diversity	Recreation	Education	Cultural heritage
Crop production																			
Livestock grazing																			
Whisky distilling																			
Water bottling																			
Forestry												+/-							
Tourism																			
Shooting			+/-	+/-															
Fishing																			
Conservation																			

Impact:	Positive	Negative
High		
Medium		
Low		
Mixed	+/-	
None		

APPLY STAGE: So what?

Step 08: Interpret and use the results

This assessment has shown the dependencies and impacts on natural capital for Glenlivet Estate's let and in-hand enterprises. In the light of this assessment, the following risks and opportunities can be identified.

Risks

Brexit poses risks (but also opportunities) for the Estate. The loss of the Basic Payment Scheme will mean a reduction in income for farmers. It is currently unclear whether the UK can negotiate a favourable trade agreement with Europe. In the event of no agreement, trade might be conducted under World Trade Organisation rules; tariffs on lamb exports would significantly reduce sheep enterprise profitability. Downward pressure on rents can be expected. Trade liberalisation, with non-EU countries, would exacerbate the situation.

Some farm businesses can be expected to try to maintain profitability by **improving productivity and production**. This could involve reducing costs, improving efficiencies and scaling up. It could include a greater focus on productive land, with associated environmental risks, especially in terms of water quality. Other farms can be expected to target the delivery of public goods, or give up.

Input costs may rise due to a combination of supply limitations (e.g. Phosphorus), energy price rises and Brexit; continuing and potentially increasing price volatility can be expected.

Regulations and legislation can be expected to continue to change driven by consumer pressure and supermarkets for more sustainable products. The use of herbicides (e.g. glyphosate) is under constant review, and may limit the chemical options available for weed management. It is likely to become increasingly important to demonstrate not only best practice in animal health & welfare and crop production, but also the environmental footprint in terms of inputs (e.g. water use) and outputs (e.g. greenhouse gas emissions) is likely to be used for benchmarking suppliers. Grouse moor management (e.g. muirburn) can similarly be expected to come under greater scrutiny in future.

Climate change is expected to result in: higher temperatures; more extreme weather events, such as excessive rainfall, storm events and drought; and more/different pests and diseases. This will affect all enterprises on the Estate. Adaptation will be important.

Opportunities

Brexit provides an opportunity for farms to produce more for the **domestic market**. Added value can be obtained by strengthening supply chains and investment in processing infrastructure. Brexit opens up the possibility of a new support regime that is better tailored to British agriculture, as well as reducing regulations such as the 'three crop rule'.

Building resilience and resource efficiency will be key for farm businesses on the Estate. Soil analysis combined with more targeted, precise applications will help reduce costs and potential environmental risks. Improving soil quality by increasing organic matter will benefit crop/grass quality and mitigate against drought and water-logging. Similarly, forestry which is more resilient and less susceptible to risk (e.g. single species threats, clear fell risks) could be beneficial economically and environmentally.

Future policy is likely to be focused on **'public payments for public goods'** – and strongly aligned to the concept of natural

capital – in both agriculture and forestry. There will be a need to demonstrate the contribution that the Estate is making to 'public goods'. There is also likely to be a range of opportunities– on both let and in-hand land – to maintain and enhance biodiversity, water quality, climate regulation, access and other public goods. Examples include:

- Creation of new native woodland and diversification of existing woodland
- Riparian woodland establishment
- Montane scrub/juniper regeneration
- Management for wading birds
- Peatland restoration

Private funding could be sourced for investment in natural capital, supported by initiatives such as the Peatland Code and Woodland Carbon Code. Payments for Ecosystem Services, for example in relation to water quality and flood management, may also become available in future.

Continued diversification should strengthen the resilience, profitability and value of the Estate. Done in the right way, it should also enhance the Estate's natural capital assets. This may include encouraging enterprises which benefit from and support the area's high quality environment. It could also involve strengthening and developing the Crown Estate Scotland / Glenlivet Estate brand.

Greater awareness of inter-dependencies and trade-offs between enterprises (e.g. farming, forestry, sporting, tourism, commercial) in terms of natural capital and ecosystem services would be beneficial when considering new tenancies and land use change.

There is an opportunity to **develop a set of metrics** for monitoring the Estate's natural capital assets which would:

- Record the extent and the condition of natural capital assets of the Estate, such as soil health, water quality, carbon and biodiversity.
- Review these metrics as part of tenancy/enterprise review, and record the improvement in extent and condition (or deteriorations, if any) of the natural capital assets and any investments made. This could help facilitate broader conversations between landlord and tenant about future developments of the farm to ensure its long term sustainability.

Step 09: Take action

Actions for consideration:

Internal data and reporting:

- Improve natural capital and ecosystem service data for the Estate as a whole. Data is dispersed and there are gaps in terms of asset extent and condition as well as specific ecosystem services.
- Identify a few, key indicators to track natural capital e.g. soil organic matter, water quality, carbon, biodiversity index.
- Develop natural capital accounts for the Estate (building on work undertaken in this assessment) and integrate into reporting.

Working with partners and stakeholders:

- Raise awareness of natural capital and ecosystem services amongst tenants, communities and other stakeholders
- Incorporate natural capital into land use decisions
- Engage with partners/buyers to identify win-wins from integrating natural capital into production, supply chain and marketing.

Funding and investment:

- Identify priorities for natural capital investment.
- Incorporate natural capital into investment decisions.
- Engage with public and private buyers to secure funding for natural capital (maintenance) and enhancements.

CASE STUDY – Peatland restoration

This case study applies the Natural Capital Protocol to a practical example.

FRAME STAGE: Why?

Step 01: Get started

Crown Estate Scotland maintains and enhances a diverse range of habitats on Glenlivet Estate and, in 2014, identified an opportunity to restore an area of degraded peatland at Glenmullie, with funding from Peatland ACTION managed by Scottish Natural Heritage (SNH). The key issues on the site included:

- Large areas of bare peat cut down to the mineral layer, the result of historic peat cutting
- Eroded gullies, peat hags and bare peat areas
- Drainage ditches
- Establishment of non-native confers

Crown Estate Scotland undertook a variety of measures to restore the peatland in order to reduce carbon loss, increase carbon sequestration, enhance peatland ecosystem functions and make the site more resilient to climate change.

SCOPE STAGE: What?

Step 02: Define the objective

The objective of this case study is to understand what impact Crown Estate Scotland activities to restore the peatland at Glenmullie have had on natural capital, as well as providing a high level cost/benefit analysis (incorporating financial costs and natural capital costs/benefits).

Step 03: Scope the assessment

This case study assesses the impacts of restoring peatland habitat to deliver the benefits outlined above, including:

- Blocking and re-profiling ditches
- Re-profiling, stabilising and re-vegetating areas of bare or badly eroded peat
- Removing non-native conifers

Step 04: Determine the impacts and/or dependencies

Peatland restoration has material impacts on climate regulation, water quality regulation, soil quality and erosion regulation, and wild species diversity. It should also have positive impacts on water supply (maintaining base flow in times of drought), flood regulation and education (given the use of a range of restoration techniques and the potential for demonstration). Upland livestock grazing and grouse shooting enterprises are dependent on the extent and condition of natural capital assets, including peatland and other upland habitats, so should also benefit.

MEASURE AND VALUE STAGE: How?

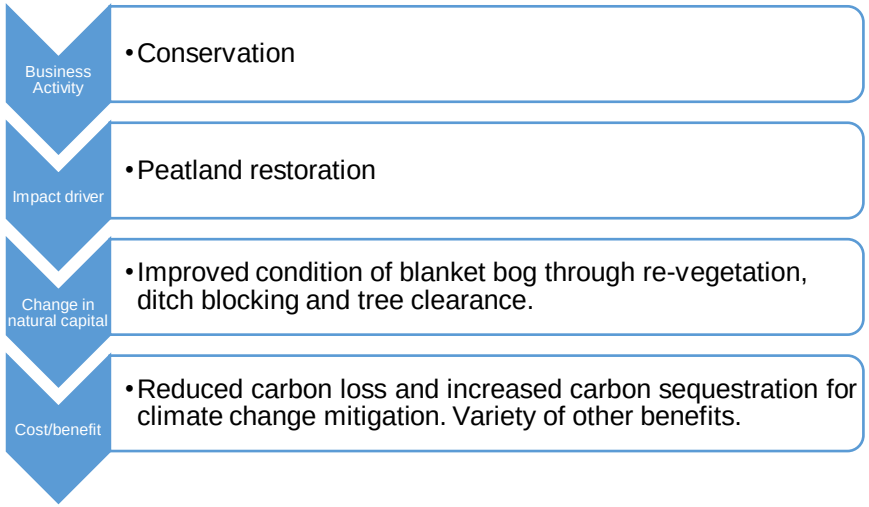
Step 05: Measure impact drivers

Climate regulation; the main impact driver for climate regulation is (peatland) habitat cover and condition, this in turn influences greenhouse gas emissions (GHGs). Degraded peat emits carbon dioxide and other GHGs, with carbon being lost through decay and shrinkage of peat as it dries. Restoration of peatland habitat and associated ecosystem functions maintains carbon stores, reduces carbon loss and encourages carbon sequestration over time. Habitat restoration practices include spreading heather brash and where necessary, re-profiling and stabilising with geotextile matting. Energy is required to operate the machinery involved in undertaking

the restoration work resulting in some additional GHG emissions. Estimates of changes in GHGs are set out in Step 07.

The impact pathway showing the 'logic chain' from business activity to impacts on natural capital and the costs and benefits associated with these impacts is shown below.

Climate regulation



Water quality regulation; habitat cover and changes in drainage, which influence the volume and type of water pollutants, are the impact drivers for water quality regulation. Eroding upland peatland can cause high levels of Dissolved Organic Carbon (DOC) and associated discoloration in watercourses. Water quality data was collected after the restoration work but no data is available yet on changes in water pollutants arising from the project.

Soil quality and erosion regulation; habitat cover and changes in drainage also influence soil quality and soil loss, and are therefore the impact drivers for soil quality and erosion regulation. There are linkages to both water quality and climate regulation. No data is available on changes in soil pollutants arising from peatland restoration at Glenmullie.

Wild species diversity; the restoration of peatland is beneficial for a range of flora and fauna associated with peatland habitat or habitat mosaic. The main impact driver for wild species diversity is therefore peatland habitat cover. It can also affect aquatic habitats and species affected by sedimentation resulting from eroding peatlands. Watercourses draining the area flow into the River Spey, designated SAC. No data is available on changes in wild species diversity arising from peatland restoration at Glenmullie.

Step 06: Measure changes in the state and trends of natural capital

Table A below sets out the asset register for this case study, detailing the interventions taken to restore peatland at Glenmullie and the resulting changes in the state of natural capital on this part of the Estate. It is important to note that there were a number of challenges experienced during the project including bad weather and time pressure, which affected the extent and quality of the restoration work. The restoration on the site is incomplete due to the failure of the mulch on the bare peat, the need to address water erosion in gullies and on the bare peat, and unsuccessful conifer removal work.

Table B sets out the impacts on natural capital assets. This reflects the information provided in the asset register, distilling it into a graded positive/negative (green or red scoring). The project has had a positive impact on the extent of blanket bog, which is included in both the 'moorland' and 'wetland' categories in this assessment.

Table C sets out the impact the project has had on ecosystem services. For example, the reduction in carbon emissions contributing to climate regulation. The project has had no (or negligible) negative natural capital or ecosystem service impacts.

Table A: Case study asset register

		2014		Management interventions	Current status 2017	
	Natural capital asset	**Hectares**	**Data source**	**Activities undertaken**	**Hectares**	**Data source**
Extent	Mountains, Moorlands and Heaths (Degraded upland blanket bog)	166	CNPA		0	CNPA
	Mountains, Moorlands and Heaths (Restored upland blanket bog)	0	CNPA	Peatland restoration through a variety of interventions (see below)	166	CNPA
Condition	**Condition Indicators**	**Status / Score**	**Data source**	**Activities undertaken**	**Status / Score**	**Data source**
	Peat depth	0.97m on average, but variable across site	CNPA	Various activities below will help increase peat depth in long term	0.97m on average, but variable across site	CNPA
	Bare peat area	4.75 ha	CNPA	Spreading heather brash and, where appropriate re-profiling and laying down geotextile matting	Bare peat partly re-vegetated.	CNPA
	Eroded gullies/haggs length	9,300m	CNPA	Re-profiling, laying down geotextile matting and spreading heather brah/turves	Eroded gullies/haggs partly restored.	CNPA
	Drainage ditches length	8,800m	CNPA	Re-profiling and blocking drainage ditches	0 m. Drainage ditches all blocked.	CNPA
	Invasive species coverage	45 ha	CNPA	Removal of non-native conifers	Conifers partly removed.	CNPA

Tables B & C: Key

Impact:	Positive	Negative
High		
Medium		
Low		
Mixed	+/-	
None		

Table B: Natural capital asset impacts

	Assets (habitat types)								
	Enclosed farmland:								
Activity	**Cropland (arable & horticultural)**	**Temporary pasture (temporary improved grassland)**	**Permanent pasture (permanent improved grassland)**	**Permanent unimproved pasture (semi-natural Grasslands)**	**Field margins**	**Hedgerows**	**Woodland (includes farm woodlands)**	**Mountains, Moorlands and Heaths**	**Water (Openwaters, Wetlands & Floodplains)**
Peatland restoration									

Table C: Ecosystem service impacts

	ECOSYSTEM SERVICES																		
	PROVISIONING SERVICES								REGULATING SERVICES							CULTURAL SERVICES			
Activity	**Crops**	**Livestock**	**Wild foods (game)**	**Wild foods (venison)**	**Wild foods (fish)**	**Water Supply**	**Timber**	**Fibre**	**Climate regulation**	**Flood regulation**	**Water quality regulation**	**Soil quality & erosion regulation**	**Air quality regulation**	**Disease & pest regulation**	**Pollination**	**Wild Species Diversity**	**Recreation**	**Education**	**Cultural heritage**
Peatland restoration																			

Step 07: Value impacts

The financial cost of the Glenmullie peatland restoration project was approximately **£120,000**. This was funded mainly from SNH's Peatland ACTION fund, with financial and in-kind contributions from CES.

The carbon emissions reduction of the project has been calculated using the methodology developed for the Peatland Code [7]and the Peatland Code Emissions Calculator[8], see Tables B and C. Based on the likely change in the different Assessment Units and an assumed project duration of 50 years, and no leakage (increased emissions on the Estate as a result of displacement of land management activities due to the restoration), then the project could result in a total cumulative saving of 8,919 tonnes of CO2 equivalents **(**tCO2e)[9].

Table B – Assessment units and pre- and post-restoration condition categories

Assessment Unit	Area (ha)	Pre-Restoration (Baseline) Condition Category	Post-Restoration Condition Category
AU1	4.75	Actively Eroding: Flat Bare	Drained: Re-Vegetated AE
AU2	1.86	Actively Eroding: Hagg/Gully	Drained: Re-Vegetated AE
AU3	52.80	Drained: Artificial	Modified
AU4	105.59	Modified	Modified
Total	**165.00**		

Table C – Cumulative emissions reduction over project duration (tCO2e)

Cumulative Emissions Reduction over project duration (tCo2e)					
Period (Year)	Gross Emissions Reduction (tCO2e)	Emissions Reduction less 10% model precision (tCO2e)	Net Emissions Reduction adjusted for Leakage (tCO2e)	Cumulative Risk Buffer Contribution (tCO2e)	Cumulative Claimable Emissions Reduction (tCO2e)
0-5	1166	1049	1049	157	**892**
5-10	2332	2099	2099	315	**1784**
10-15	3498	3148	3148	472	**2676**
15-20	4663	4197	4197	630	**3568**
20-25	5829	5246	5246	787	**4459**
25-30	6995	6296	6296	944	**5351**
30-35	8161	7345	7345	1102	**6243**
35-40	9327	8394	8394	1259	**7135**
40-45	10493	9444	9444	1417	**8027**
45-50	11659	10493	10493	1574	**8919**

The monetary value of the carbon emissions reduction can be estimated using non-traded carbon values which are calculated based on the abatement cost per tonne of carbon[10], with figures converted to £2014 using the latest HM Treasury GDP deflator series[11]. 8,919 tCO2e equates to a total value of £537,424; this averages out at £60.26/ tCO2e.

There is insufficient data available to measure and value other material impacts in terms of water quality regulation, soil quality and erosion regulation, and wild species diversity, nor other benefits relating to livestock production, wild food (game), flood regulation, recreation and education.

[7] http://www.iucn-uk-peatlandprogramme.org/peatland-code

[8] http://www.iucn-uk-peatlandprogramme.org/peatland-code/resources

[9] This figure could be higher depending on condition categories selected.

[10] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/484184/3136-guide-carbon-valuation-methodology.pdf

[11] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

APPLY STAGE: So what?

Step 08: Interpret and test results

A one-off investment of around £120,000 in 2014 will yield a considerable return with a present value of £537,000, through reducing carbon emissions over a 50 year timescale; this represents an approximate benefit-cost ratio of 4.5:1 over 50 years. The return can be expected to continue to increase beyond the initial period. This is broadly in line with a similar assessment of the potential emissions savings at North Sanquhar Moor, carried out by the Crichton Carbon Centre[12] on behalf of Buccleuch Estates Ltd. In addition, the project will yield a wide range of other market and non-market benefits which it has not been possible to value at this stage.

Step 09: Take action

Lessons have been learned from the project and funding will be sought for remedial work to address the restoration issues identified above.

There is an opportunity to measure and value other impacts from the project to get a more complete picture of the net benefits. A better understanding of the before and after position in respect of water quality and other areas would help in this regard. This work would add value to Glenmullie as a site for education and demonstration. Future monitoring of peatland condition and its associated services would also be beneficial to track progress.

Peatland restoration could be extended to other areas on the Estate, subject to site suitability. Third party funding could potentially be sourced using Peatland Code verification.

[12] Crichton Carbon Centre (2017) North Sanquhar Moors Peatland Restoration – Restoration Potential and Carbon Savings

Appendix 1: Glossary

Where available, definitions are taken directly from the Natural Capital Protocol[13].

Baseline	In the Protocol, the starting point or benchmark against which changes in natural capital attributed to your business' activities can be compared.
Biodiversity	The variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems (UN 1992).
Ecosystem services	The Millennium Ecosystem Assessment defines these as "benefits people obtain from ecosystems".
Natural capital	The stock of renewable and non-renewable natural resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people.
Natural capital dependency	A business reliance on or use of natural capital.
Natural capital impact	The negative or positive effect of business activity on natural capital.

[13] Natural Capital Coalition. 2016. "Natural Capital Protocol". (Online) Available at: www.naturalcapitalcoalition.org/protocol

Appendix 2: Ecosystem service descriptions

These are not intended to set definitive or exclusive interpretations of the listed ecosystem services, but can be used as an indication of the range of services to which this report refers, and the general meaning of those terms.

Air quality regulation	The regulation of air quality by ecosystems (e.g. the absorption of air pollutant particles by tree leaves)
Climate regulation	The capacity of ecosystems to influence the climate to improve local conditions (e.g. through a tree's shade) or mitigate global climate change (e.g. through the fixing of atmospheric carbon in woodlands)
Crops	The capacity of the ecosystem to support crop production
Cultural heritage	The value of cultural heritage arising from a community's historic relationship with its surrounding ecosystem
Disease & pest regulation	The capacity of ecosystems to regulate and control native or introduced pest and disease (e.g. slug predation by amphibians, or parasite exclusion through microclimatic conditions)
Education	The capacity of ecosystems to invoke interest and curiosity about the natural world
Fibre	The production of fibres and materials such as wood, skin, wax or flax for use as inputs for manufacturing or in their unprocessed forms
Flood regulation	The regulation, by upstream ecosystems, of water flows to prevent or mitigate flooding events downstream
Fuel	The provision of wood or other natural materials which are burnt or otherwise broken down to release energy, usually as heat.
Genetic materials	Genetic material (e.g. DNA), from all living organisms used, for example, in medicine, breeding programmes and research
Livestock	The capacity of the ecosystem to support livestock growth
Pollination	The service provided by wild pollinators in pollinating dependent crops and thereby enhancing yields
Recreation	The provision of views and experiences that promote and enhance recreation
Soil quality & erosion regulation	The capacity of ecosystems to stabilise, build and enhance soils
Timber	The provision of timber for use in construction and manufacturing
Water quality regulation	The regulation, through the filtering of sediment and the use of nutrients and pollutants, of ecosystems to improve water quality for human use
Water Supply	The provision of freshwater from ground or surface waters
Wild foods (fish)	The provision of wild freshwater and marine fish for food
Wild foods (game)	The provision of game animals for food
Wild foods (venison)	The provision of wild deer populations for food
Wild Species Diversity	The range of species which provide benefits to people through their aesthetic, natural history and existence. Biodiversity also contributes to the health and functions of ecosystems.

Appendix 3: Supplementary maps

See separate document