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Balancing conservation and climate change – a methodology using existing data demonstrated for twelve UK priority habitats

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ABSTRACT

Mitigation of climate change (CC) is a regulating ecosystem service provided by priority habitats that is often co-delivered alongside their conservation of biodiversity. Carefully planned conservation management is thought necessary to support biodiversity adaptation to CC, but could also contribute to CC mitigation. This paper presents a methodology for assessing direct emissions of greenhouse gases (GHG: CO_2, CH_4 and N_2O) from 12 UK priority habitats in 26 Special Areas of Conservation (SAC) using readily available data. Background emissions are estimated on the basis of published field research. The contribution of conservation management to GHG emission reduction is estimated using the IPCC GHG accounting methodology and other methods. Management Data Acquisition surveys carried out at selected SACs provided data on management practises for Scotland and Wales. Climate change mitigation actions identified in this study for priority habitats included livestock removal or change in stocking density, with GHG reduction potential of up to 3 tCO_2e/animal/year, afforestation of acid grasslands—up to 19.4 tCO_2e/ha/year, wetland restoration—0.3–0.8 tCO_2e/ha/year and cessation of moorland burning—6.9 tCO_2e/ha/year. Estimated GHG emissions from priority habitats can be used to identify win:win management options that co-deliver GHG mitigation, climate adaptation and conservation benefits for consideration by policy makers and conservation managers.

1. Introduction

The Convention on Biological Diversity in 1992 committed the signatory countries, including the UK, to "the conservation of biological diversity and the sustainable use of its components". In response, the UK Biodiversity Action Plan (UKBAP) proposed a list of priority habitats (PHs) that are under direct threat, or that support species that are threatened and requiring conservation. Priority habitats represent a variety of semi-natural ecosystems in different bioclimatic conditions and some are potentially threatened by climate change. They occur within a network of protected areas (PAs) established to support UK biodiversity and to maximise ecosystem functions with best conservation management measures. Conservation efforts are quite complex due to the need to address several threats. These include habitat loss and fragmentation due to urban, industrial and agricultural development, drainage of wetlands, invasion by non-native flora and fauna, and most recently, accelerating climate change.

Climate change, exacerbated by habitat fragmentation, is increasingly recognized as a major threat to biodiversity. As a global process it is very difficult to control, and its effects on UK biodiversity are not yet fully understood, particularly at a local level. One of the most valued ecosystem services provided by semi-natural habitats is their role in climate regulation, and it is possible that this role could be enhanced through appropriate management (Smith et al., 2013, 2014). Designing appropriate management interventions to optimise regulation of climate change impacts without detriment to the biodiversity requires an ability to quantify emissions of

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Table 1
UKBAP Priority Habitats (PHs) selected for the CC mitigation study.

Priority habitat	Ecosystem type
Blanket bog	Wetland
Coastal sand dunes	Other
Lowland beech and yew woodland	Woodland
Lowland calcareous grassland	Grassland
Lowland heathland	Wetland
Lowland mixed deciduous woodland	Woodland
Lowland raised bog	Wetland
Native pine woodland	Woodland
Purple moor grass and rush pasture	Grassland
Saltmarsh	Other
Upland heathland	Wetland
Wet woodland	Woodland

greenhouse gases under different conditions. This paper presents a methodology that utilises existing management data to assess baseline direct emissions of greenhouse gases (GHGs: carbon dioxide [CO_2], methane [CH_4] and nitrous oxide [N_2O]) and the potential effects of conservation management on current and future GHG emissions, with a view to identify management options to limit them. We demonstrate the utility of the methodology by applying it to twelve representative terrestrial PHs in the UK (Table 1, Carey et al., 2015).

In natural habitats, soils and soil carbon (C) stocks are expected to be at equilibrium. Changes in environmental conditions, such as alterations in climate or plant communities, disturb this biological balance in soils, and can release considerable quantities of C into the atmosphere. There are two large sources of direct GHG emissions from natural habitats: (1) disturbed plant-soil ecosystems and (2) grazing; both are affected by human intervention. Introduction of livestock provides large inputs of excreta, disturbing the C:N soil ratios and speeding methanogenesis, decomposition or denitrification. C storage capacity is controlled by soil properties and environmental conditions, which also influence the bacterial processes of decomposition, methane production, oxidation and denitrification. These processes affect emissions of CH_4, CO_2 and N_2O, that in turn can be predicted by their relationships with the environmental controllers.

2. Field research into GHG emissions from priority habitats

GHGs emissions have been measured in the three semi-natural environments (wetlands, woodlands and grasslands), into which all of the PHs considered here fit (Table A1).

2.1. Wetlands

In this category of PHs, the soil pool is responsible for the majority of GHG emissions. Soils are considered the largest global terrestrial sink of C (Ostle et al., 2009) and in the UK the majority of that C is found in upland blanket bogs, lowland raised bogs and fen peat habitats (Ostle et al., 2009; Emmett et al., 2010). These habitats have similar soil characteristics: shallow water table depth or presence of surface water (blanket bogs), high %C and soil acidity, that control soil processes responsible for GHG emissions. In blanket bogs, thick organic layers have been accumulated through the continuous supply of plant debris, which decomposes slowly in the conditions of low pH and long-term waterlogging. Decomposition in these habitats is very slow, hence they store large quantities of C. The main source of GHG emissions from these habitats is methanogens, responsible for the production of CH_4 which is subsequently released into the atmosphere from the peat surface or through vascular plants (MacDonald et al., 1998). Water table level is generally considered to be the main controller of CH_4 emissions. These emissions can range from 24.6 to 246 kg CH_4/ha/y (MacDonald et al., 1998) and 0.2 to 51.4 kg CH_4/ha/y (Dinsmore et al., 2009). In drier areas such as heathlands, or blanket bog hummocks, methanotrophic bacteria oxidise CH_4 to CO_2, and this can lead to an uptake of atmospheric CH_4 (MacDonald et al., 1997). At a moorland site in Scotland, MacDonald et al. (1997) measured an uptake of CH_4 due to oxidation that amounted to −1.8 kg CH_4/ha/y. A strong relationship, observed between water table depth and CH_4 emissions, has been included in a number of mathematical models (Worrall et al., 2009; Nayak et al., 2010).

Nitrous oxide (N_2O) emissions from these PHs are very small. This is a result of a very high soil water content that promotes full denitrification and production of dinitrogen (N_2), (Davidson, 1991; Bouwman, 1990), coupled with historically low N system inputs (no fertilization). In some areas, however, localised conditions can be more suitable for N_2O emissions. MacDonald et al. (1997) measured N_2O volatilisation of 0.3 kg N/ha/y at Dunslair Heights in Scotland. At Auchencorth Moss, N_2O emissions ranged from a slight uptake of −0.1 to emissions of 0.34 kg N/ha/y (Dinsmore et al., 2009). Those results were in the range of mean N_2O emissions from main land cover types in Scotland of 0.1–0.53 kg N/ha/y (Skiba et al., 1996). The emission rates are very sensitive to N enrichment of the soil from atmospheric deposition (in the vicinity of industrial or agricultural sources). IPCC (2007) prescribes the uniform emission factor of 1% for deposited N emitted from semi-natural soils as N_2O–N.

2.2. Woodlands

Biomass in woodlands and forests represents the second largest terrestrial C sink in semi-natural habitats, which store 60–130 tC/ha (Lal, 2004) and sequester around 110 kg C/ha/y in the UK (Ostle et al., 2009). C dynamics in living biomass depend on the age and type of tree canopy. The maximum storage capacity is reached at maturity, which is after approximately 25–30 years, but it can be longer for some deciduous woodlands (Cannell, 1996). The exchange of C between the vegetation and soil C pools occurs in the forest floor and root zone, from which CO_2 is lost into the atmosphere. Field studies measuring CO_2 emissions from plantations on organic soils showed that C losses can range from 1.2 tC/ha/y for spruce plantations, to 1.9 tC/ha/y for birch woodlands (Von Arnold et al., 2005).

Predicting GHG emissions with environmental factors is not always straightforward as field studies show conflicting results. The level of water Table is regarded as an important environmental controller of CO_2 emissions as it defines the volume of soil suitable for autotrophic and heterotrophic respiration. Von Arnold et al. (2005) found that emissions were 0.7 tC/ha/y lower from undrained than drained alder woodland. In contrast, Makiranta et al. (2008) found a limited effect of water table on CO_2 flux compared with soil temperature. Their findings could be affected by a different organic soil composition due to previous agricultural use. Forest soils, with large inputs of organic matter and deep oxic horizons, do not encourage methanogenesis. Woodlands act as CH_4 sinks with net fluxes ranging from −0.8 to −8.8 kg CH_4/ha/y (Dobbie & Smith, 1996), for mixed woodlands of spruce, beech and sycamore. In summer, net fluxes can increase to −10 kg CH_4/ha/y.

N_2O emissions are also very small compared to CO_2, and largely depend on N content in soils, as observed by experimental field studies into effects of atmospheric deposition or fertilisation. In areas of higher N deposition, N_2O emissions from spruce forest increased to 0.45 kg N/ha/y for N addition of 35 kg N/ha/y (Butterbach-Bahl et al., 1997), and to 0.64 kg N/ ha/y for N deposition of 46 kg N/ha/y (MacDonald et al., 1997). The background level emissions range from 0.11 to 0.35 kg N/ha/y for spruce and beech; higher emissions were measured from birch/sycamore – 0.6 kg N/ha/y and alder – 1.32 kg N/ha/y. High N_2O emissions from