TECHNICAL REPORT

LONDON climate change PARTNERSHIP

Adapting to climate change

Creating natural resilience

October 2009

NATURAL ENGLAND

London Biodiversity Partnership

SUPPORTED BY LONDON DEVELOPMENT AGENCY WORKING FOR THE MAYOR OF LONDON

Adapting to climate change

Creating natural resilience

Technical Report

Prepared for a partnership comprising:
Mayor of London, Natural England, London Climate Change Partnership, London Development Agency and London Biodiversity Partnership

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INTRODUCTION

1.1. As London's climate changes, so too will its biodiversity. We are already seeing differences in London's biodiversity compared with the surrounding countryside, for example differences in phenology which are likely to become more pronounced with climate change. There are also many other pressures facing London's biodiversity which must be managed, including pollution, habitat loss to development and increased visitor pressures on sites. In many instances, measures to respond to these wider pressures can, if well designed and executed, also help to respond to the pressures of climate change on biodiversity. In response to this, the Mayor's Biodiversity Strategy includes a proposal that 'The Mayor will consider biodiversity effects as part of an overall appraisal of the impacts of climate change in London'. A key question which this study therefore seeks to address is how London's biodiversity might change in the face of climate change and how we might respond to such change most effectively (what we have termed 'direct' impacts of climate change on biodiversity).

1.2. London must also respond to the impacts of climate change on many other sectors and services, including flood management, water supply, the transport system, public health and the economy. This will require a raft of adaptation measures to be implemented, some of which could benefit biodiversity (e.g. restoration of flood plains to help respond to increased risks of flooding) (which we have termed 'knock-on' impacts of climate change on biodiversity). The terms adaptation and mitigation, as they apply to climate change, are defined in the box below.

A definition of climate change adaptation vs. mitigation

Climate change adaptation is defined as the process of preparing for extreme weather and changes to our climate. Meteorologists know that there is a 'time lag' in the climate system between CO_2 being emitted and climate change happening. Given CO_2 emissions which have already been emitted we know that we are already committed to a certain level of climate change to which we will have to learn to adapt.

Mitigation is the process of reducing CO_2 emissions, for example, through energy efficiency measures and renewable energy generation. This is an essential activity to ensure we minimise future climate change.

This research focused on biodiversity opportunities associated with measures to adapt to climate change.

Climate change in London could affect biodiversity in two distinct ways:

1. Direct effects e.g. changes in species composition due to higher temperatures.
2. 'Knock-on' effects resulting from climate change adaptation actions to address overheating, flooding and drought.

Decision makers should work together to ensure:

1. Biodiversity is managed in such a way as to be as resilient as possible to climate change.

2. Opportunities to benefit biodiversity through climate change adaptation measures are optimised, and any threats minimised.

1.3. A study Steering Group came together in October 2008 to commission Land Use Consultants, in association with Susannah Gill at the Mersey Forest, to undertake this study into Climate Change and Biodiversity in London. The Steering Group was made up of representatives from the following organisations:

- GLA Environment Team
- Natural England
- London Climate Change Partnership
- London Development Agency
- London Biodiversity Partnership.

1.4. Key stakeholders were involved in the research process via two main consultation stages, as follows:

- Consultation with a focussed group of expert stakeholders on the research methodology and data sources via a consultation report.
- Consultation with a wider group of stakeholders from organisations working across London to plan and deliver biodiversity protection and enhancement and climate change adaptation. This took the form of a workshop in March 2009 which sought to identify how climate change adaptation options to respond to flooding, overheating and drought could maximise benefits and minimise threats for biodiversity.

AIMS AND OBJECTIVES OF THE STUDY

1.5. The aim of the study was:

To understand how London's valued plants and animals and the green spaces they inhabit may be affected by climate change and proposed climate change adaptation measures and to identify policy and other responses to maximise benefits for wildlife and green spaces.

1.6. The aim is supported by the following objectives:

- To review and synthesise available research on the likely (direct) effects of climate change on London's biodiversity, focussing on:
    - Seven key habitat types.

    - Species or green spaces of particular cultural significance or public resonance.
    - The particular issues faced by biodiversity in a densely developed urban area.

- To identify opportunities for delivering 'biodiversity friendly' climate change adaptation in London i.e. opportunities to integrate biodiversity conservation and enhancement (including climate change resilience) into The London Climate Change Adaptation Strategy and other relevant adaptation strategies, with a particular focus on adaptation measures relating to flood risk management, drought and the urban heat island effect (i.e. responding to 'knock-on' impacts of climate change on biodiversity).
- To make recommendations for policy and practice in London, including support for specified demonstration projects, to maximise the delivery of improved ecological resilience to climate change.

AUDIENCE

1.7. The intended audience for this report and accompanying summary document includes:

- Politicians.
- Planners and other officers within local authorities e.g. those involved in the urban regeneration or management of sites.
- Those involved in implementation of the Mayor's draft Climate Change Adaptation Strategy, in particular the Green London proposals within that Strategy.
- Those involved in strategic planning for green space and biodiversity e.g. those involved in the review of the Mayor's Biodiversity Strategy, borough biodiversity groups and those formulating and implementing green infrastructure strategies.
- Managers of London's green spaces.
- Other organisations, such as consultancies and academic institutions, involved in the planning and delivery of climate change adaptation and biodiversity enhancement.

STRUCTURE OF RESEARCH REPORT

1.8. The research has been structured around the DPSIR framework[a], as illustrated overleaf, and the report is structured into two main sections as follows:

- **Sections 2 to 4 (Part A)** set out the study **'baseline'** i.e. information on how London's climate will change and climate change impacts on biodiversity.

[a] European Environment Agency's DPSIR framework: Driving forces of environmental change, Pressures on the environment, State of the environment, Impacts and Response of society

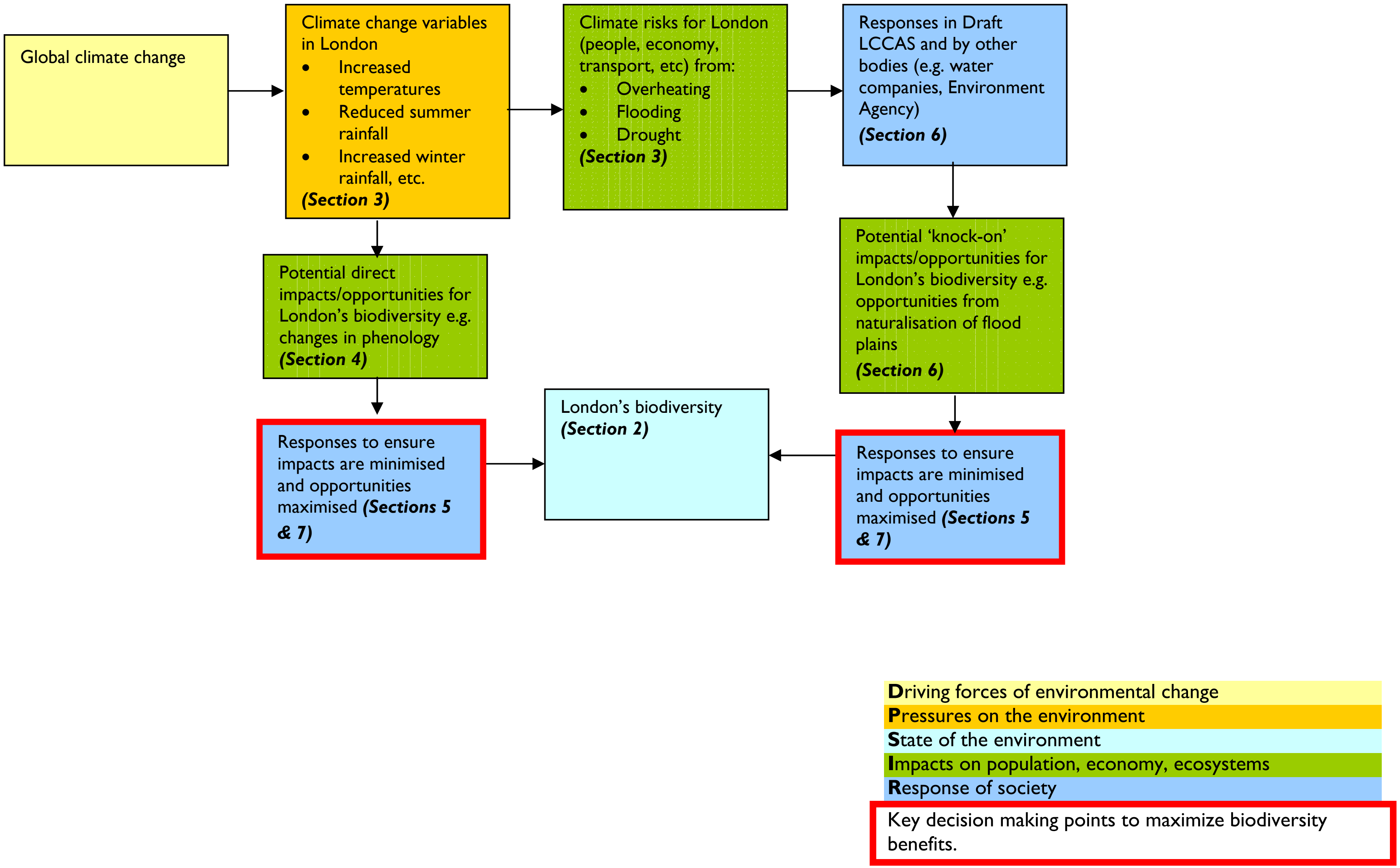
- **Sections 5 to 7 (Part B)** set out the **'way forward'** for ensuring benefits for biodiversity are maximised when implementing a wide range of climate change adaptation measures in London.

1.9. Principles identified through research by Defra (Conserving biodiversity in changing climate: guidance on building capacity to adapt) have been used to categorise the nature of opportunities for London's biodiversity when responding to the direct[b] and 'knock on'[c] impacts of climate change on biodiversity. The principles are defined in Section 5 and their applicability to and deliverability in London considered through Sections 5 to 7.

[b] Direct impacts on biodiversity include issues such as changes in species composition resulting from changing climatic variables such as higher summer temperatures.

[c] 'Knock-on' impacts on biodiversity include the 'side effects' (positive and negative) of climate change adaptation measures aimed at responding to overheating, flooding and drought e.g. naturalisation of flood plains to respond to increased risk of flooding could have benefits for biodiversity.

Figure 1.1: The research framework



PART A: THE STUDY BASELINE

2. WHY IS BIODIVERSITY IMPORTANT IN LONDON?

2.1. This section describes how London's biodiversity provides ecosystem services, contributes to health and wellbeing, business and the economy, education and social cohesion, and has cultural resonance. It then outlines key features on London's biodiversity assets before describing the policy support for their conservation and enhancement.

WHY IS BIODIVERSITY IMPORTANT?

Ecosystem services

2.2. Conservation of biodiversity is key to the continued functioning of complex ecosystem interactions which underpin the habitability of the planet and provide a host of services to humans. Examples of ecosystem services include provision of food, fuel and fibre; purification of air and water; provision of a 'bank' of genetic resources which are a key input to new crop varieties and medicines; maintenance of soil fertility through nutrient cycling and decomposition of wastes.[1]

2.3. In London, wetland systems in the Thames Estuary, for example, assist with flood regulation by providing storage capacity and reducing run-off. This contributes to increased human wellbeing by reducing the risk of death, disease and the psychological impacts of flooding, as well as risks to property and protected landscapes.

2.4. Biodiversity is also an indicator of the health of London's natural environment since thriving biodiversity is only possible when water resources, water quality, air quality and soil fertility are in good condition.

Health and wellbeing

2.5. Natural greenspace can contribute to health and a feeling of wellbeing by providing places:

- For relaxation and contemplation which can benefit mental health.
- To encounter wildlife such as deer in Richmond Park or valued historic landscapes such as those of Rainham Marshes and the Thames.
- For physical exercise though informal recreation activities such as walking and cycling.

2.6. There is research to suggest that viewing a natural scene provides a pleasurable and calming distraction which can rapidly lower anxiety and produce measurable improvements in stress-related physiological symptoms and may even improve the recovery of hospital patients[2,3].

2.7. There is also compelling scientific evidence that inadequate physical exercise has a significant negative impact on the health and wellbeing of the UK population[4]. Research suggests that the provision of "green gyms", schemes which promote physical exercise whilst carrying out valuable conservation or gardening work, can deliver important health benefits to local residents[5]. Forestry Commission research into the benefits that may result from improved physical and mental health associated with access to greenspace[6] found that accessible, attractive greenspace is also associated with increased autonomous physical activity. Access to natural greenspace must be carefully planned and managed, however, to ensure that users are directed towards areas of biodiversity which have a relatively low sensitivity to human disturbance.

2.8. There is also evidence[7,8,9] that natural greenspace can provide health benefits by helping to tackle local air pollution problems, whether by providing screening, by promoting dilution and dispersal, or in the case of certain plant species by actually absorbing airborne pollutants. The Urban Greenspace Taskforce reported that the presence of mature trees and woodland reduces air pollutants such as sulphur dioxide and nitrogen oxide and contributes to the reduction of ozone production and the filtering of dust and organic compounds emitted by vehicles and industry[10]. The London Biodiversity Strategy[11] also highlights the benefits of trees in improving air quality.

Business and the economy

2.9. The Government's Sustainable Development Strategy acknowledges the important contribution biodiversity makes towards local economies and communities. Consultation undertaken by the GLA[12] shows that the public values London's green environment, with the range of parks and open spaces frequently mentioned as one of the best things about living in London. As well as providing a public benefit, the value that people place on London's high quality natural environment also helps to support its tourist industry, while businesses wishing to base themselves in London will be assisted in attracting high quality employees. Research by CABE Space has demonstrated the economic value of green spaces which arise because businesses and residents value locations in close proximity to green spaces. As noted under 'Ecosystem services', ecosystems can provide a range of services to society which have significant economic value, for instance flood alleviation or improving water quality through natural processes of filtration, sedimentation and bio-degradation.

Education and social cohesion

2.10. Providing easy and regular access to the natural environment can encourage a more positive relationship with nature.[13] It can also provide an 'outdoor classroom' for more formal education on natural environment or health topics. One example of an organisation providing these types of educational opportunities in London is the Thames Explorer Trust. This educational charity runs river visits for schools, community groups and adults; provides training for educators; and makes available educational materials about the Thames Basin.

2.11. Community volunteering on biodiversity conservation and enhancement projects promotes a sense of involvement in and ownership of natural areas and supports social cohesion. Activities that volunteers might take on include tree planting, ongoing management and acting as guides. There are numerous community groups that are involved in environmental work in London, for instance:

- Thames 21, an environmental charity which mobilises thousands of volunteers every year to clean up waterside litter, remove graffiti and create new habitats for wildlife.
- The Wandle Trust, an environmental charity dedicated to restoring and maintaining the health of the River Wandle catchment in South West London, through community volunteer cleanups.

Cultural resonance

2.12. Many habitats and species in London also have particular cultural resonance. For example, some habitats are the product of historic land management practices, such as Bushy Park in south west London which historically formed part of the deer park linked to Hampton Court Palace used by Henry VIII. Others have literary connotations, for example, the landscape of the river Thames is vividly portrayed in the novels of Charles Dickens.

2.13. Many spaces rich in biodiversity value are well loved for their landscapes and the scope they provide for recreation, for example the Royal Parks in central London and Hampstead Heath in north London. Similarly many species are well known and loved by Londoners – for example, deer in the Royal Parks, bluebells in Hainault Forest and the rich bird life of the Thames Estuary.

WHAT DOES LONDON'S BIODIVERSITY CONSIST OF?

2.14. Whilst containing a densely populated urban area, London enjoys a remarkable amount of space for nature with two-thirds of its area occupied by green spaces or water. Of this about a third is private gardens, a third parks or sports grounds and the remaining third a variety of habitats, including grassland, woodland and rivers.[14] A number of these habitats are connected in functional networks, for instance along the Thames and the Lee Valley.

2.15. Natural England has identified Natural Areas which provide a useful, high level description of variations in wildlife, natural features and land use patterns.[15] Most of London falls within the London Basin area which is characterised by the following habitats:

- Fresh and saltwater – extensive networks of rivers and streams (the Thames and its tributaries); numerous canals; series of flooded gravel pits; man-made lakes in Royal Parks; and state of the art habitat creation schemes such as the London Wetland Centre.
- Woodland – extensive areas of lowland beech and yew woodland; significant areas of lowland mixed deciduous woodland, including oak-hornbeam woods; small areas of wet woodland (mostly alder) in wet gullies; numerous large lowland wood pastures and parklands.
- Lowland grassland and heath – notable areas of lowland dry heath and lowland wet heath; wet and acid grasslands; neutral grasslands in river valleys; extensive floodplain and coastal grazing marshes; small area of lowland calcareous grassland.

2.16. In addition, London contains parts of the Greater Thames Estuary, North Kent Plain and North Downs Natural Areas.

2.17. London contains a large number of sites which are designated for their biodiversity importance. Five of London's designated sites are of international importance as follows:

- *Richmond Park SAC* – This south-west London Royal Park contains a mixture of habitats, primarily heathland, broad-leaved deciduous woodland and grassland. Its European designation as a Special Area of Conservation (SAC) is for stag beetle since it is at the heart of the south London centre of distribution of this species. It is also a site of national importance for invertebrates associated with the decaying timber of its ancient trees.

- *Wimbledon Common SAC* – This SAC is dominated by broad-leaved deciduous woodland and dry grassland habitats but is designated for its areas of wet and dry heath as well as the stag beetle population associated with its standing and fallen deadwood.

- *South West London Waterbodies SPA, Ramsar*– A collection of reservoirs, two of which lie within London's boundary at Kempton Park have Special Protection Area (SPA) and Ramsar designation on account of supporting internationally important numbers of wintering gadwall and northern shoveller.

- *Lee Valley SPA, Ramsar* – In east London's Lee Valley, a number of embanked water supply reservoirs, sewage treatment lagoons and former gravel pits have SPA and Ramsar designation for the internationally important populations of wildfowl their habitats support.

- *Epping Forest SAC* – To the east of the Lee Valley, Epping Forest stretches 12 miles from Manor Park in East London out beyond London's borders to Epping in Essex and provides almost 6,000 acres of public open space. Whilst dominated by ancient broadleaved woodland, it also contains dry grassland, water bodies, heath and fen. Its designation as an SAC reflects the importance of its acid-loving beech forest and associated rare epiphytes and the fungi and dead wood invertebrates associated with the large number of veteran trees, including the stag beetle. Its wet and dry heaths are also significant.

2.18. London also contains 38 nationally protected Sites of Special Scientific Interest (SSSIs). The largest are Richmond Park and the Inner Thames Marshes, whilst others, including the London Wetland Centre, are no more than a few kilometres from Westminster. The London boroughs have also identified Sites of Importance for Nature Conservation (SINCs). These comprise 140 Sites of Metropolitan Importance covering 10% of London's land area (16,000 ha), 470 Sites of Borough Importance and 460 Sites of Local Importance.

2.19. **Section 4** provides more detailed information on the seven habitat types and 11 species which have been identified as the focus for this research.

POLICY TO CONSERVE AND ENHANCE LONDON'S BIODIVERSITY

2.20. London's biodiversity receives a high level of protection through policy which also seeks to enhance this resource.

2.21. As a signatory to the **Convention on Biological Diversity**, the UK Government is legally bound to its objectives which include '*the conservation of biological diversity [and] the sustainable use of its components*'. This is reflected in a range of national policies.

2.22. The **Natural Environment and Rural Communities Act (2006)** introduces the 'biodiversity duty' which stipulates that: '*Every public authority must, in exercising its functions, have regard, so far as is consistent with the proper exercise of those functions, to the purpose of conserving biodiversity.*' **Planning Policy Statement 9 (PPS9): Biodiversity and Geological Conservation** requires that regional and local planning policies reflect, and are consistent with, national, regional and local biodiversity priorities and objectives including those agreed by local biodiversity partnerships. **PPS1: Sustainable Development**, states that: '*The condition of our surroundings has a direct impact on the quality of life and the conservation and improvement of the natural and built environment brings social and economic benefit for local communities*'[16]. **Planning Policy Guidance 17 (PPG17): Planning for Open Space, Sport and Recreation** recognises the value of natural and semi-natural spaces in terms of both access to nature and also the visual amenity of such sites within the urban area.

2.23. The **Mayor's Biodiversity Strategy**[17] recognises the importance of London's biodiversity and commits to maintaining at least the current level of biodiversity. Besides achieving no overall loss of London's biodiversity, the other overarching goal of The Mayor's Biodiversity Strategy is to ensure that all Londoners are within walking distance of a high quality natural open space. The policies of the **London Plan**[18] protect London's open space network and recognise the wide variety of benefits it delivers, including for health, wellbeing and quality of life. The London Plan calls for:

- Development and regeneration to deliver positive gains for conservation, including habitat creation that delivers BAP priority habitats.
- Identification and protection of Sites of Metropolitan Importance (SMIs).
- Development to be resisted where it threatens protected species or BAP priority habitats or species.

2.24. London contains a number of biodiversity sites protected by borough, national and even international designations, as described in **Section 4**, and the **London Biodiversity Action Plan** sets out plans to conserve and enhance 26 habitats and species that are important in London. The importance of London's biodiversity stems as much from the benefits that biodiversity provides to Londoners as from its intrinsic value. As discussed above, biodiversity provides a range of 'ecosystem services' which are beneficial to humans and also contribute to the health and wellbeing of local communities.

2.25. In recognition of the benefits of ecosystems and their biodiversity, as well as the wider range of functions that green spaces can provide (for example routes for sustainable transport), the concept of 'green infrastructure' has gained increasing support in regional and local plans and strategies. The term refers to multi-functional networks of green space and is referred to in Policy 3D.8 of the **London Plan**. This policy cites as an example of the green infrastructure approach, the East London Green Grid, which will form a network of interlinked, high quality open spaces that connect town centres with public transport nodes, the Green Belt, the Thames, and major employment and residential areas.

3. HOW IS LONDON'S CLIMATE LIKELY TO CHANGE?

CLIMATE CHANGE VARIABLES

3.1. The London Climate Change Adaptation Strategy[19] sets out climate projections for the UK and the south-east[20] of England, the latter representing the best available data for Greater London. These are drawn from the Hadley Centre's modelling of four emissions scenarios (assuming low, medium-low, medium-high or high CO_2 emissions) which in turn give rise to four climate scenarios known as the UKCIP02 scenarios[21]. For the south-east, all four scenarios predict warmer, wetter winters, hotter, drier summers and an increase in the frequency and intensity of extreme weather. The quantitative projections for the south-east in relation to four key climatic variables are summarised in **Table 3.1**

Table 3.1: Selected UKCIP02 climate scenarios for the south-east against the 1961-1990 baseline

Period	Emissions scenario	Average summer temperature (°C)	Total summer rainfall (%)	Average winter temperature (°C)	Total winter rainfall (%)
2020s	Low	+1.0 to +1.5	-10 to -20	+0.5 to +1.0	0 to +10
	High	+1.0 to +1.5	-10 to -20	+0.5 to +1.0	0 to +10
2050s	Low	+2.0 to 2.5	-20 to -30	+1.0 to 1.5	+10 to 15
	High	+3.0 to 3.5	-30 to -40	+1.5 to 2.0	+15 to 20
2080s	Low	+2.5 to 3.0	-20 to -30	+1.5 to 2.0	+10 to 15
	High	>4.5	>-50	+3.0 to 3.5	+25 to 30

Source: Adapted from UKCIP02

3.2. Further projections for London and the south-east[22] which have particular implications for biodiversity include:

- A reduction in summer soil moisture – UKCIP02 projects a reduction of 40% or more against the 1961-1990 baseline by 2080.
- Earlier springs, longer frost-free seasons, and reduced snowfall in south-east England.

3.3. In addition to the variations in average climate described above, UKCIP02 also provides projections for extreme weather in the south-east compared to the 1961-1990 baseline period, including:

- Almost double the number of days in December-February with heavy rainfall by 2080 under a high emissions scenario.

- An increase in the average number of summer days with temperatures exceeding 25oC from nine per annum to 28-45 (depending on scenario) per annum by the 2050s.

- An increased frequency and height of tidal surges in the Thames Estuary such that a one in fifty year surge will be 1.4 m higher than by the 2080s (under Medium-High scenario).

- An increased frequency and intensity of windstorms, although the UKCIP02 projections for this variable are subject to a high degree of uncertainty.

KEY CLIMATE CHANGE RISKS FOR LONDON

3.4. The changes in climate variables described above will impact on London in a variety of ways. The Draft London Climate Change Adaptation Strategy identifies three key areas of increased risk for London: flooding, drought and overheating. These risks have wide-ranging implications for a range of sectors including the economy, health, transport infrastructure, and the built and natural environments. The potential impact of climate change on biodiversity is explored further in **Section 4**. In addition to direct climate change impacts on biodiversity, adaptation responses to flooding, drought and overheating are also likely to give rise to threats to biodiversity and create opportunities for conservation and enhancement (discussed further in **Section 5**). Before we consider these biodiversity implications in subsequent sections of this report, each of the three climate risks is described below, drawing on the Draft London Climate Change Adaptation Strategy.

Implications of climate change for flood risk

3.5. The Thames is tidal up to Teddington Weir in west London and as a result, much of central London would flood twice a day and nearly 15% of London would be flooded by an extreme flood event were it not for an extensive system of flood defences. The Thames Tidal Defences are an integrated system comprising the Thames Barrier, 185 miles of floodwalls, 35 major flood gates and over 400 minor gates. These defences protect London and the Thames Estuary from tidal surges[d] and the Thames Barrier can also be closed to keep out a high tide and provide additional upstream capacity for freshwater flows when river levels are high following heavy rain (known as a 'fluvial dominated closure').[23]

3.6. Even with these flood defences, it is estimated that 100,000 properties are located in areas with a greater than 1 in 200 year risk of flooding whilst a significant proportion of social (e.g. schools and hospitals) and civil (e.g. emergency services bases, public transport stations) infrastructure is located in Flood Zone 3[24]. The most deprived people in London are more likely to live in areas of tidal flood risk and less likely to have flood risk insurance.[25] Even without climate change, exposure to flood risk is likely to increase as the floodplain becomes ever more densely developed. Climate change is expected to further increase these risks.

[d] An uncommon meteorological event occurring when a deep low pressure system originating in the Atlantic moves down the North Sea to be funnelled in the bottleneck between the UK east coast and continental Europe. When the associated raised sea levels combine with a spring tide and winds blowing up the Thames Estuary, water levels can be more than 3 metres higher than normal.

Tidal Thames downstream of the Thames Barrier

3.7. The Thames Tidal Defences currently provide very high standards of flood protection, being designed to protect against a tidal surge that might be expected only once every 2,000 years. With climate change, the combination of rising sea levels[26] and increasing tidal surges means that the standard of protection is expected to drop to 1 in 100 years by the end of this century. The Thames Estuary 2100 Project is identifying future risks and responses and indicates that the following actions are likely to be necessary over the next 20-30 years:

- Raising the height of the defences downstream of the Thames Barrier and adjustments to the barrier itself.
- Identifying a new alignment for flood defences in the future to provide more sustainable flood risk management.
- Identifying riverside open space or industrial sites with the potential to be used for flood storage.
- Encouraging high vulnerability land users in high flood risk locations to swap places with low vulnerability users through the spatial planning system.

Tidal Thames upstream of the Thames Barrier

3.8. Flood defences are around two metres lower along the tidal Thames upstream of the Thames Barrier because the barrier was considered to provide adequate protection, but this picture will alter as climate changes. Projected rising sea levels and increasing tidal surges mean that the barrier is likely to have to close more frequently to keep out extreme high tides. Since the barrier has a maximum reliable operating capacity of only 70 closures per year, this may reduce the number of times the barrier can be closed during 'normal' high tides to provide additional upstream capacity for freshwater flows when river levels are high following heavy rain. This would increase fluvial flood risk in the tidal Thames upstream of the barrier. Options for additional flood storage in this stretch of the Thames are very limited due to development right up to the flood defences, meaning that flood defences may need to be raised, which could impede access to and views of this stretch of river. Some less developed areas offering the potential for flood storage do exist, however, for example the Old Deer Park in Richmond.

Non-tidal Thames

3.9. Upstream of Teddington Weir, flood risk is fluvial rather than tidal. Increases in rainfall due to climate change are expected to cause peak river levels in the Thames to rise by up to 20% by 2115[27]. There is insufficient flood storage in the upper catchment of the Thames to significantly reduce downstream fluvial flood risk in west London. Riverside development limits opportunities to set back flood defences and increase the capacity of the river channel in many areas.

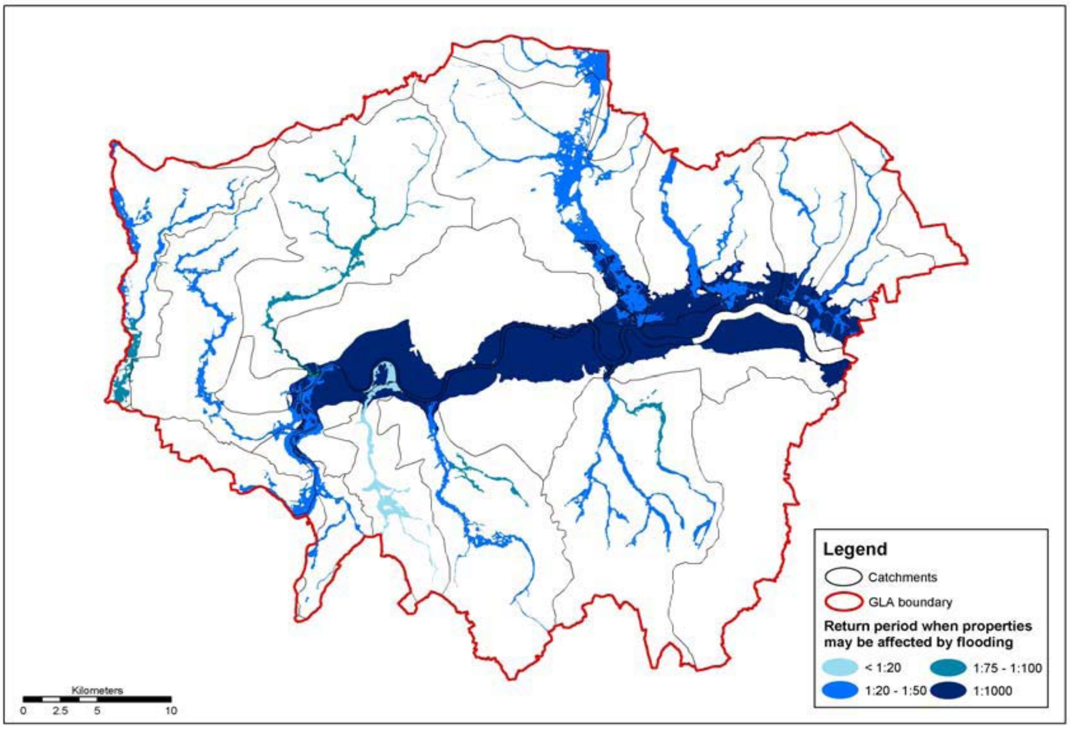
Tributaries to the Thames

3.10. The Thames has 11 tributaries within London. There are also a number of 'lost rivers' that were used as sewers and then partially or completely built over during

London's Victorian expansion. Increasing development has reduced surface permeability and thus increased surface run-off and related flash flooding. Flood defences have traditionally comprised hard engineering solutions, for example straightening and culverting river channels to convey water more rapidly downstream. This has had a negative impact on biodiversity and amenity, as well as encouraging development right up to the flood defences, restricting the ability to maintain or upgrade defences. The standard of flood protection on some stretches is relatively low.

3.11. **Figure 3.1** shows the current probability of flooding along the Thames and its tributaries, demonstrating that many areas of relatively high flood risk already exist. Climate change may increase peak flows in the tributaries of the Thames by up to 30% by 2115.[28]

Figure 3.1: Current probability of flood risk from the Thames and its tributaries



Source: Mayor of London (2008) The London Climate Change Adaptation Strategy: Draft report.

Storm drainage and surface water flooding

3.12. London, like most major urban areas, has a large area of impermeable built surfaces which prevent infiltration of rainfall and necessitate drainage systems to manage runoff. The probability of surface water flooding in London is much higher than tidal flooding[29].

3.13. High intensity rainfall, even when of relatively short duration, can quickly overwhelm the capacity of London's drainage systems, especially since most are designed for high frequency, low volume rainfall. This was demonstrated in July 2007, during which two and half times the normal monthly rainfall fell in the Thames catchment, much of it on just two days. The extremely intense rainfall, along with the low soil moisture deficits for the time of year and high groundwater recharge over the previous winter, caused flooding at many locations, including 1,100 homes and 300 businesses in London. In the wider Thames catchment, 4,000 properties were flooded, 60% by surface water flooding and the remainder from flooded rivers[30,31].

3.14. Continued development will further increase the extent of impermeable surfaces and associated surface water flooding risk. A study for the London Assembly[32] which compared historic land use maps with 2003 aerial photography suggested that 32 km^2 of London's front gardens has been paved over since 2003, an area 22 times the size of Hyde Park. Climate change will increase the frequency and severity of extreme rainfall events and the risk from surface water flooding is therefore set to increase.

Potential threats, opportunities and drivers for changes to biodiversity

Threats

Hard flood defences/channels limiting natural functioning of water courses.

Scouring of channel caused by stormwater flows.

Coastal squeeze as sea levels rise.

Increased flooding of sewers could lead to increased pollution of watercourses.

Opportunities

'Naturalise' rivers and allow space for functional floodplains.

Increase area of natural or vegetated surfaces to manage surface runoff.

Drivers for change

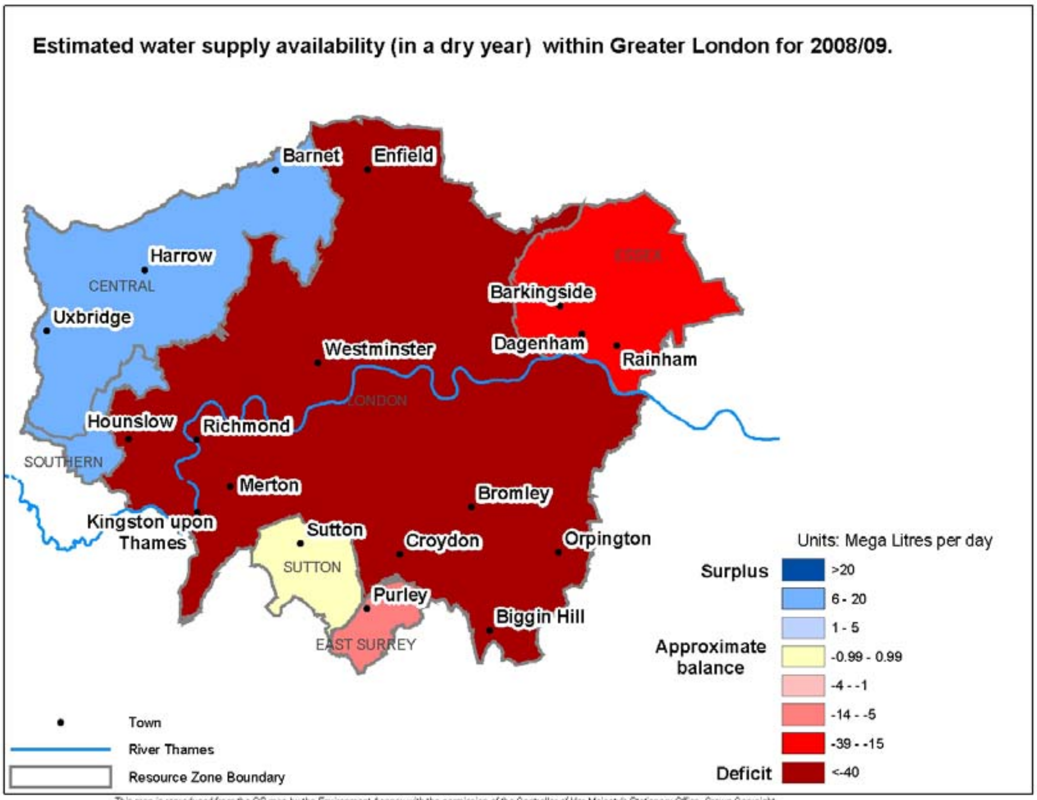
Managed retreat and restoration of functional floodplains could lead to a change in habitats e.g. from grazing land to salt marsh.

Implications of climate change for water resources

3.15. Eighty percent of London's water comes from the Thames and River Lee and is stored in reservoirs around the region whilst the remainder is abstracted from groundwater in chalk aquifers. Both sources are fed by rainfall, with winter rainfall particularly important in recharging the aquifers and reservoirs. Of the rain that falls in the Thames catchment, 66% is lost through evaporation or used by plants and 55% of the remainder is then abstracted, a higher proportion than in any other region in England and Wales. Only 15% of rainfall is available for rivers and wetlands.[33]

3.16. A high population density and low rainfall in London and the south-east means that water availability per person in the Thames region is just 20% of the England and Wales average[34]. London also has a relatively high water usage per capita because of its affluence, its low average household size and high levels of leakage in the distribution network. Extended periods of low rainfall mean that demand can exceed supply, leading to drought management measures and/or insufficient water for the environment ('water stress'). The Environment Agency classifies London as an area of serious water stress[35] and as **Figure 3.2** shows, only one of its six 'water resource zones' had a surplus in its supply-demand balance in 2008/09.

Figure 3.2: London's estimated water supply availability in a dry year for 2008/09



Source: Environment Agency

3.17. Climate change is expected to put further pressure on London's already limited water resources due to:

- Reduced river flows in summer.
- Reduced groundwater recharge due to more intense rainfall saturating soils and increasing surface runoff.
- Increased evaporation and transpiration during hotter summers with more cloud-free days.
- Increased leakage due to increased seasonal changes in soil moisture damaging infrastructure.
- Increased water demand during hot, dry summers.

Potential threats, opportunities and drivers for changes to biodiversity

Threats

Lack of water to irrigate sites of nature conservation importance and other green spaces.

Competition for water between users and between habitats.

Opportunities

Biodiversity value associated with water resource management e.g. infiltration systems, rain-gardens, decommissioned reservoirs.

Opportunities for more drought tolerant species.

Potential use of grey water and harvested/captured/stored rainwater to irrigate sites of nature conservation importance and other green spaces. This would also maintain their 'evaporative cooling' function when it is most needed hence helping to respond to the urban heat island phenomenon.

Drivers for change

Change in species composition in river/wetland habitats due to decreased water levels in summer.

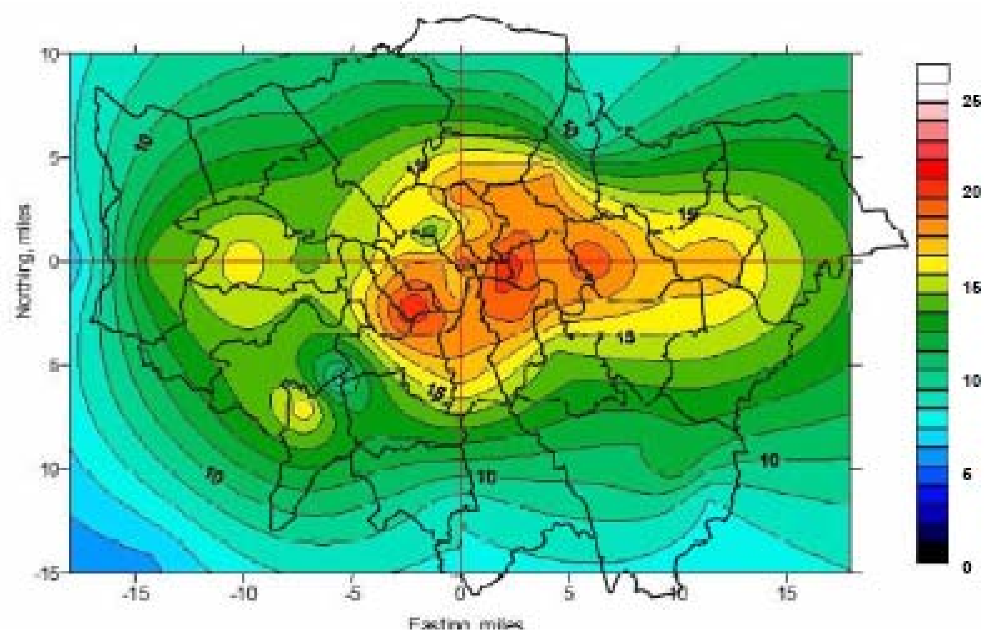
Changes in species composition in other habitats due to more frequent drought conditions.

Implications of climate change for overheating

3.18. High summer temperatures can adversely affect the health and comfort of Londoners, as well as damaging infrastructure, increasing water usage and increasing energy demand for cooling. Although London's summer weather is comparatively mild, we have already witnessed the effects of extreme weather events. It is estimated that the August 2003 heatwave increased underlying mortality rates by 40% in London, with the elderly most severely affected.[36]

3.19. Urban areas typically have warmer surfaces and air temperatures than the surrounding countryside, an effect known as the 'urban heat island'. This is due to the heat of the sun being absorbed by built surfaces during the day and then released at night. Heat generated by human energy use in high density areas of the city also adds to this effect. London's current urban heat island is illustrated by **Figure 3.3** with the scale showing the number of occasions that temperatures exceeded 19°C for 48 consecutive hours. It can be seen that the heat island effect is most intense in the most densely developed central part of the city with lower temperatures found in outer London and over large green spaces.

Figure 3.3: London's urban heat island



Source: Mayor of London (2008) The London Climate Change Adaptation Strategy: Draft report

3.20. The difference between city and rural temperatures (the 'urban heat island intensity') peaks in London between 2am and 4am when central London temperatures are typically 3-4°C warmer than the surrounding countryside. During the summer heatwave of 2003, the centre of London was up to 10°C warmer that the surrounding greenbelt.

3.21. Research for the GLA cited in the draft Adaptation Strategy shows that London's summers are already getting warmer. The temperatures of the hottest days and night time temperatures are increasing at a faster rate than average daytime temperatures. The urban heat island intensity is set to increase in London due to increasing development density. Against this background, climate change will increase the risk of overheating in London due to:

- Higher summer temperatures and more cloudless days.
- Increasing anthropogenic heat inputs to densely developed areas from energy use for cooling.
- Reduced cooling by evapo-transpiration from vegetation due to reduced summer rainfall and associated drought periods (unless sustainable approaches to irrigation can be identified). When vegetation is water-stressed it will close its stomata to conserve water. This means that there is less cooling from green areas through the process of evapotranspiration. Hence the cooling effect of vegetation in urban areas is reduced during these periods when it is most needed. Irrigation will be needed to ensure it continues to provide 'evaporative cooling'. The challenge is to find ways of sourcing this sustainably (so that it is not viewed as anti-social behaviour), potentially through capturing and storing excessive rainfall at other times and using it for irrigation during droughts.

Potential threats, opportunities and drivers for change for biodiversity

Threats

Increased pressures on biodiversity from people using open spaces for recreation in hot weather.

Increased tree planting (for shade and cooling) is a potential threat to open habitats such as grassland and heathland.

Opportunities

Green cover (trees, green roofs, parks etc) provides cooling through evaporative cooling, shading and allowing air flow into urban areas. In terms of evaporative cooling, the type of 'greenery' does not affect its cooling properties, so there is considerable flexibility to delivery biodiverse 'greenery'.

Sustainable sources of irrigation for greenspaces will provide evaporative cooling for Londoners as well as helping to support biodiversity.

Water surfaces are effective at evaporative cooling (even at higher temperatures when evapotranspiration by vegetation is reduced), and offer a range of opportunities for biodiversity.

If more green spaces and water features are created to deliver urban cooling, there will be associated opportunities for creating biodiversity rich spaces.

Tree planting to provide shade for people could enhance biodiversity e.g. through improved connectivity of habitats.

Strategic green corridors, which may aid air flow, can enhance ecological connectivity.

Drivers for change

Potential change in species composition due to higher temperatures.

4. HOW WILL LONDON'S BIODIVERSITY BE DIRECTLY AFFECTED BY CLIMATE CHANGE?

INTRODUCTION

4.1. This Section provides a review of available literature to identify potential direct effects of climate change on London's habitats and species.

4.2. A large volume of information has been published on the effects of climate change on the UK's biodiversity. At the national scale, possible effects of climate change on UK Biodiversity Action Plan (BAP) priority habitats have recently been reviewed by Mitchell *et al*[37]. Literature reviews by Wilby and Perry[38] and the London Climate Change Partnership[39] provide detail on potential impacts of climate on biodiversity focusing specifically on London. However, relatively little published information is available relating to potential climate change effects on specific habitats (the above sources cover broad habitat groups in London) and their characteristic species. A summary of findings of the review of available literature is presented below in two sections. These areas follows:

1. Overarching mechanisms by which climate change may affect London's species and habitats;
2. Information on possible specific effects of climate change on key habitats and species in London.

4.3. The full detailed review of literature is presented in **Appendix 2. Appendix 2** also contains baseline information for London's habitats, identifying characteristic species associated with these.

OVERARCHING IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

4.4. **Section 3** of this report provides an overview of likely changes to London's climate, all of which may impact upon biodiversity. In order to frame discussion of specific impacts of climate change on habitats and species in London it is helpful to identify the broad mechanisms by which species and habitats may be affected by a changing climate. In addition, it is useful to identifiy other factors (those not directly related to climate change) leading to biodiversity change in London.

Other factors causing biodiversity change in London

4.5. Other factors causing biodiversity change have been extensively reported elsewhere[40]. However, it is useful to frame the relative effect of climate change on biodiversity against key existing threats, therefore, they are briefly listed below:

- **Habitat destruction and fragmentation:** the primary causes of habitat destruction and fragmentation in London are residential, commercial and infrastructure development, changes in land use and water abstraction.

- **Changes in management practices:** such as discontinuation of traditional management techniques such as hay cutting in grasslands or coppicing in woodlands.

- **Non-native species:** the majority of non-native species are not invasive, however, in a number of instances non-native species do become invasive leading to a range of negative effects on London's biodiversity.

- **Pollution:** pollutants may have toxic effects, such as poisoning of plants and animals or non-toxic effects such as changes in species communities resulting from nutrient enrichment.

- **Population growth:** London's population is set to continue to increase. Population growth does not inherently lead to loss of biodiversity, however, high population density can put pressure on species and habitats in London.

Mechanisms underpinning the effect of climate change on biodiversity

4.6. The climate change projections detailed in **Section 3** of this report provide a basis for considering how environmental processes in London may change under climate change. However, two important caveats moderate the utility of these projections:

- There is a great deal of academic uncertainty as regards 'downscaling' the projections of climatic models designed for the national and regional scale (e.g. south-east England) to Greater London[41, 42, 43].

- Urban ecosystems are relatively poorly understood[44]. Many studies of the ecological effects of climate change are focused on non-urban 'natural' or 'semi-natural' ecosystems[45]. The findings of these studies may not always be entirely transferable to urban ecosystems where for example, factors such as anthropogenic disturbance and the influence of alien species are of greater prevalence than in the surrounding countryside[46].

4.7. Hopkins[47] provides a useful categorisation of five types of change which might be expected to occur to British wildlife as a result of climate change. These include changes to:

- Phenology (the seasonal timing of life history stages in plants and animals).
- Species' distributions.
- Species' habitat preferences.
- Composition of plant and animal communities.
- Ecosystem processes (e.g. growth and decay).

4.8. The following account draws on the review carried out by Hopkins[48].

Phenology

4.9. Many ecological events are strongly correlated with the seasonality of the British climate. Numerous research papers have reported an advance in spring and summer events correlated with climate warming. For example advances have been reported in the date of first flowering in plants[49]; date of first leafing in trees[50]; flight times in butterflies and moths[51]; dates of egg laying by birds[52]; and spawning of amphibians[53]. Whilst this general trend appears to hold for a number of taxa, working out the implications of phenological change with respect to London's habitats and species raises a number of issues:

- Whilst spring and summer events appear to be commencing earlier, it is not simply the case that autumnal and winter events are occurring later. For example, winter tree fall may occur earlier if summer drought conditions prevail[54].

- London experiences a 'heat island' effect. It might be expected that ecological events will occur even earlier in central areas of London than studies based on national or regional data sets predict.

- There is evidence to suggest that different species are responding differently to a warming climate. For example, based on a review of 385 flowering plant species, Fitter and Fitter[55] report an average advance in flowering time of 4.5 days. This conceals the fact that 3% of species studied actually appeared to have a delayed flowering.

- Species at different levels in the food chain may respond differently to climate change. For example, whilst certain invertebrates may be emerging earlier in the season due to climatic warming, there is evidence to suggest that other species which prey upon those invertebrates (e.g. summer migrant birds) have not yet adjusted to this by advancing the timing of breeding to exploit food resources.

Species distribution

4.10. Climate is acknowledged to be one of the main factors governing species distributions [56]. The climatic variables which determine the absolute northerly and southerly distribution of a species are referred to as its 'climate space' or 'bioclimatic envelope'. In broad terms, in the face of climate warming, species requiring warmer conditions might be expected to expand their ranges northwards and those species adapted to cooler conditions may experience a retraction in their range to the north. In relation to the implications for London's biodiversity, this raises a number of issues:

- In a UK context, it is unlikely to be the case that species adapted to cooler conditions reach the southern limit of their distribution in London. However, with climate warming added to by the urban heat island effect, some of London's habitats may become too hot and dry for certain species. London may experience a loss of certain species which might otherwise be encountered in the surrounding countryside (e.g. Surrey, Sussex, Kent, Essex, Hertfordshire, and Buckinghamshire).

- London may become host to a number of new colonists from southern England and continental Europe. For example, species with high dispersal abilities such as lesser emperor dragonfly *Anax parthenope,* the small red-eyed damselfly *Erythromma viridulum*, Roesel's bush cricket *Metrioptera roeselii* and the little egret

Egretta garzetta are all recent colonists or species shown to be expanding their ranges northwards. Other colonists newly recorded in London during the last 15 years include the long-winged cone-head *Conocephalus discolour* and the wasp spider *Argiope bruennichi.*

- Research indicates that for a number of species restricted to the south by cooler conditions, range expansion to the north in response to climate warming is not occurring as might be anticipated[57, 58]. This it is theorised, may relate to the overriding influences of biotic interactions, evolutionary change and the limited dispersal ability of species[59]. London's habitats are highly fragmented; it may be the case that otherwise suitable habitats cannot be colonised by new species owing to the inability of species to disperse to or through London.

Species habitat preferences

4.11. It has been shown that with climate change, species restricted to a particular habitat niche may experience an expansion in the range of ecological resources they are able to exploit. For example, egg-laying in the silver-spotted skipper *Hesperia comma* (a butterfly which favours south facing slopes on chalk grasslands in south east England) is related to temperature. With climate warming this species is now able to exploit taller/ranker vegetation types which formerly had insufficient thermal properties to act as breeding habitat[60]. In effect, climatic warming has increased the amount of breeding habitat available to this species.

Composition of plant and animal communities

4.12. Climate change may bring about colonisation by new species and accelerate the extinction of existing species (operating through phenological change, change to species' distribution and changes to species' habitat preferences). A corollary of this is that new communities of plants and animals might be expected to emerge in response to climate change. This may lead to negative effects on current communities brought about by the colonisation of invasive aliens[e]. For example, longer growing seasons, reduced incidence of night frosts and higher maximum temperatures in summer may favour introduced plants such as New Zealand pygmyweed *Crassula helmsii,* parrot's-feather *Myriophyllum aquaticum*, and floating pennywort *Hydrocotyle ranunculoides* which can become over dominant at the expense of other species in London's ponds and watercourses.

4.13. Conversely, it is already the case in London that plant and invertebrate communities which have colonised former industrial brownfield sites in the last 50 years constitute an ecotype of high biodiversity value not distributed widely outside of the urban area[61, 62]. Fitter[63] identifies a number of possible colonists which might move into London as a result of climate change by the end of the 21st century. These include the queen-of-Spain fritillary *Issoria lathonia* (currently a rare migrant) and painted lady *Vanessa cardui* (currently a late summer migrant from southern Europe) butterflies. Similarly, Swindells[64] reflects on London's 'urban flora' as an ecological community composed of non-native plants which exploit a distinct niche (*"pavements,*

[e] An invasive alien species is a non-indigenous species that brings about adverse ecological effects on habitats it colonises. The term invasive refers to the possession of ecological traits such as a high reproductive rate or high dispersal abilities and/or the ability to be a habitat generalist. Therefore, the potential for 'invasive' species to bring about negative ecosystem effects is extensive.

walls, waste places") on account of inner London's urban climate. For example, these include tree-of-heaven *Ailanthus altissima* (originally from China and an escape from Chelsea Physic Garden), red valerian *Centranthus ruber* (originally a resident of south west Europe) and *Senecio inaquidens* (originally from South Africa).

Ecosystem processes

4.14. Fundamental ecosystem processes such as the cycling of carbon and nitrogen which is facilitated by the growth and decay of organisms might be strongly affected by a changing climate[65]. For example, Mitchell *et al.*[66] report effects on below-ground processes and soil microbial communities. They also note that the implications of these changes in below-ground processes on the wider ecosystem are largely unknown.

POTENTIAL IMPACTS ON LONDON'S HABITATS

4.15. The proceeding section considers how seven key habitat types in London could specifically be affected by climate change. The seven habitat types are as follows:

- Acid grassland.
- Heathland.
- Chalk Grassland.
- Neutral Grassland.
- Rivers and Streams and associated habitats.
- Standing Water and associated habitats.
- Woodland.

4.16. The full rationale for the selection of habitats types is detailed in **Appendix 2**. However broadly, selection of the seven habitat types, by the project steering group, was for the following reasons:

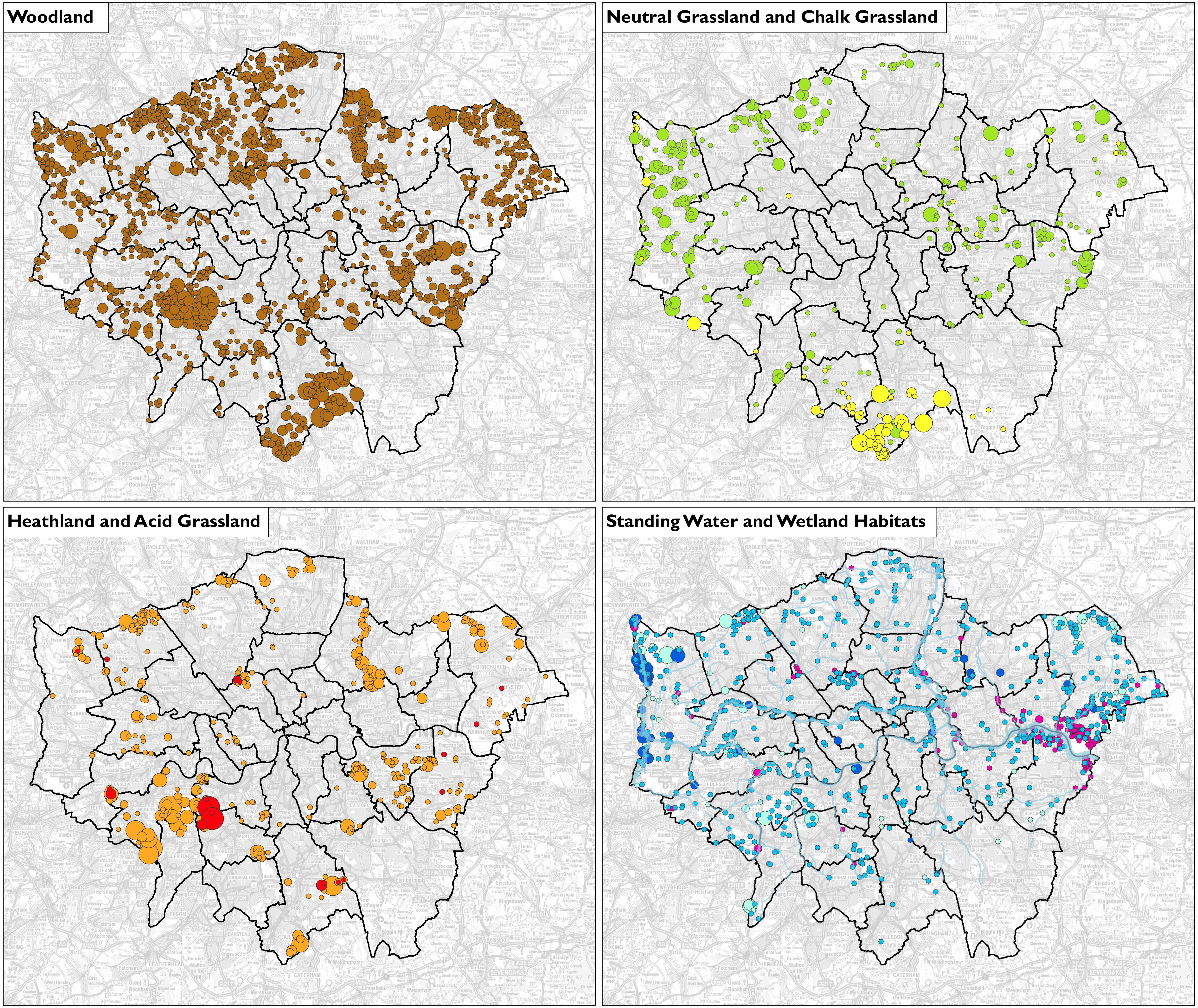
- Together these habitats account for a significant proportion of London's biodiversity.
- These habitats, via related Biodiversity Action Plans, are subject to challenging management targets, which could be affected by climate change.
- Notable omissions include private gardens and brownfield sites, both of which are considered to be of high biodiversity value[67, 68.] However, it was felt that insufficient literature was available concerning climate change impacts on these habitats specifically, given the high incidence of novel and exotic plant and animal communities comprising these habitats. The generic mechanisms underlying climate change effects on biodiversity (detailed above) are applicable to these habitat types.

4.17. **Figure 4.1** illustrates the distribution of the seven habitat types across London[f]. It can be seen that the distribution of different habitats and species across London is uneven. For example, the majority of chalk grassland habitats are located in south and south-east London and the majority of heathlands are situated in west London.

4.18. **Appendix 2** (**Tables A2.1 – A2.7**) provides summary information relating to each of the key the habitat types including:

- Key sites and the broad distribution of each habitat.
- Characteristic species associated with each habitat.
- Relevant BAP targets relating to each habitat from the London BAP.
- Environmental processes responsible for maintenance of the ecological value of each habitat.

[f] The distribution patterns presented in Figure 4.1 should be treated as indicative as they are based on point data allocated to a central point of those sites which have been surveyed for the London Habitat Survey (GiGL, 2008) and does not include the actual boundaries of different habitat patches. The data is also limited to those sites which have been included in the London Habitat Survey.



Climate Change and Biodiversity in London

Figure 4.1 Distribution of London's semi-natural habitats

Habitat type

- Acid grassland
- Heathland
- Chalk grassland
- Neutral grassland
- Woodland
- Ponds
- Eutrophic standing water
- Reed bed
- Wet woodland

Area of habitat parcel (ha)

- 0.110 - 2.00
- 2.01 - 5.00
- 5.01 - 10.0
- 10.1 - 25.0
- 25.1 - 50.0
- 50.1 - 200
- 201 - 416

NOTE:

Maps produced before L.B. Bromley data available

N W E S

0 5 10 Km

Source: London Biodiversity Partnership/ GLA

Date: 18/05/2009

Revision: A

File: S:\4500\4510 Climate Change and Biodiversity in London\GIS\Themes\ArcGIS9\4564_01_007_habitats_combined_map2.mxd

4.19. **Table 4.1** summarises potential positive and negative changes to London's habitats which may result from climate change (this is based on the detailed literature review included in **Appendix 2**). Also included in **Table 4.1** is an assessment of the feasibility of achieving London BAP targets, taking into account the possible effects of climate change. The third column includes an assessment of the risk to different habitats in London of direct impacts from climate change, based on work by Mitchell *et al.*[69]. However, Mitchell *et al*'s risk assessment is not directly applicable to London, since it is based on the potential for climate change to affect the UK's national stock of different BAP Priority habitat types, and specifically BAP habitats which occur in the wider countryside and not those occurring in urban areas. Mitchell *et al.* note that in urban areas the degree of habitat fragmentation is considered to be 'extreme', and that threats to biodiversity associated with a dense human population (e.g. pollution, disturbance to plants and animals) are likely to be more prevalent. As such, the 'risk category' should be treated as an optimistic assessment of potential climate change impacts on London's habitats. The last column rates the strength of evidence on which the conclusions are based, from poor to good this is also based on the assessment by Mitchell *et al*.

Table 4.1: Summary of potential positive and negative changes to habitats

Potential response to climate change (based on literature review presented in Appendix 2)	Feasibility of London BAP targets	Risk of direct impacts from climate change on UK BAP Priority Habitat[g]	Strength of evidence[h]
Acid grassland			
• Many acid grassland species are already adapted to conditions of drought stress. Suitable climatic conditions are likely to be available for this habitat type in south east England up to at least the middle of this century. This may allow for maintenance of this habitat at its current distribution in London. • There is evidence that certain common plant species may disappear as a result of increased incidence of drought (e.g. common stork's-bill *Erodium cicutarium*). These may be replaced by European species which are better adapted to drought conditions (e.g. Spanish catchfly *Silene otites*) (see **Appendix 2**). • Little is known about possible climate change effects on a range of acid grassland fauna including invertebrate communities of conservation importance.	Based on the review of available literature the BAP target to restore and increase the amount of acid grassland in London may indeed be feasible in view of anticipated climatic change. However, the success of restoration/recreation of the current suite of species will depend on the ability of existing acid grassland species to colonise new habitat and existing barriers to species dispersal in London.	Low (lowland dry acid grassland BAP habitat)	Poor
Heathland			
• Suitable climate space may be available in the short to		Medium (lowland	Good

[g] after Mitchell et al. 2007
[h] after Mitchell et al. 2007

Potential response to climate change (based on literature review presented in Appendix 2)	Feasibility of London BAP targets	Risk of direct impacts from climate change on UK BAP Priority Habitat[g]	Strength of evidence[h]
medium term for maintenance of heathland habitat in London. However, conditions may become unsuitable towards the end of this century. Predictions based on the highest rate of climate change indicate climate space for Ericoid species (which are a core constituent of heathland habitats, for example, heather) will diminish significantly towards the end of this century. • The competitive balance between heath and acid grassland communities may shift in favour of grassland if warmer conditions result in higher soil nitrogen through increased decomposition. • Anecdotal evidence and informal plant recording indicate that certain species which are currently restricted to southern English heathlands may not possess the dispersal powers to exploit new climate space in London.	Computer modelling carried out as part of the BRANCH programme suggests that the objective of heathland restoration/expansion may be viable in the short to medium term. However, under the highest scenarios for climate change, maintenance of the current heathland plant communities may be questionable as a long-term objective.	heathland and upland heathland BAP habitat)	
Chalk grassland			
• In general, this habitat may be resilient to direct impacts from climate change towards the middle of this century. For example, many plants of chalk grassland are typically hardy and include species tolerant of dry, exposed conditions. • It is possible that chalk grassland species currently restricted to southern England may find suitable climate space in	Based on the review of available literature it would appear that objectives to restore and increase the amount of chalk grassland in London may indeed be feasible in view of anticipated climatic change. Though certain species currently restricted to southern counties may be able to exploit new habitat on account of warmer summers/milder winters (e.g. butterflies), the exact composition of new chalk	Low (lowland and upland calcareous grassland BAP habitat)	Moderate

Potential response to climate change (based on literature review presented in Appendix 2)	Feasibility of London BAP targets	Risk of direct impacts from climate change on UK BAP Priority Habitat[g]	Strength of evidence[h]
London. • There may be a shift in community composition to greater abundance of deep rooted herbs if droughts are more prevalent. • Predictions based on the highest rate of climate change indicate that suitable climate space may not exist for certain species. For example, chalk grassland species in Hampshire such as the silver-spotted skipper butterfly *Hesparia comma* and crested hair-grass *Koeleria macarantha* by 2080 and 2020 respectively (see **Appendix 2**). The effect of climate change on chalk grassland would also be compounded if vulnerable species perform a 'keystone' ecological function (for example certain grass species).	grassland plant and animal communities will be a function of differing dispersal abilities. Under the highest predictions certain common and characteristic species may decline in the long-term (e.g. certain grasses).		
Neutral grassland			
• In general, maintenance of this habitat may be resilient to a climate change impacts up to the middle of this century. • There may be a transition to plant communities better adapted to drought conditions such as deeper rooted plants. • The productivity of grasses may be reduced with knock-on impacts higher up the food chain for species which	No targets relating specifically to neutral grassland were identified in the London BAP. In general, effective conservation management (grazing/hay cutting/ water-level management) may lessen/mask the impact of climate change for characteristic species.	Medium (lowland meadow BAP habitat)	Poor

Potential response to climate change (based on literature review presented in Appendix 2)	Feasibility of London BAP targets	Risk of direct impacts from climate change on UK BAP Priority Habitat[g]	Strength of evidence[h]
feed/shelter/nest in grasslands. • Little evidence was found relating to species specific effects of climate change.			
Rivers streams and associated habitats			
• Extensive changes to in-stream habitats due to altered magnitude and frequency of flooding. • Increased urban run-off may increase instances of flash flooding, scouring of river channels and increased mobilisation of pollutants and organic matter. • Low river flows may lead to concentration of pollutants and reduced oxygen. • Increased water temperatures would lead to reduced oxygen levels. • Characteristic riverine species such as Atlantic salmon may become extinct if excessive low flows lead to a reduction in the availability and/or degradation of upstream spawning gravels. • If soft-engineering solutions are adopted to address the increased risk of flooding, species and habitats associated with riparian habitats (woodlands, reedbeds, flood-	The London BAP specifies targets for the restoration of 100 km riparian habitat by 2020 and 15 km of river and steam habitat by 2015. In addition, there is an objective to create five new areas of habitat associated with the Tidal Thames by 2008. A focus on providing additional high quality functional habitats (rather than specifying target species) is perhaps more realistic given uncertainty regarding the responses of river and wetland species to climate change.	Medium (rivers UK BAP habitat)	Moderate

Potential response to climate change (based on literature review presented in Appendix 2)	Feasibility of London BAP targets	Risk of direct impacts from climate change on UK BAP Priority Habitat[g]	Strength of evidence[h]
meadows) could benefit.			
Standing water and associated habitats			
• Extensive changes to hydrology of many wetlands due to the reduced availability of water, both in terms of precipitation and human resource requirements. • Elevated temperatures in combination with the high nutrient loads found in urban areas may lead to proliferation of certain invasive aquatic species and/or increased abundance of cyanobacteria within lake and pond phytoplankton communities. Elevated temperatures may also lead to reduced oxygen levels in standing water bodies. • If soft-engineering solutions (for example, SUDS) are adopted to address the increased risk of flooding and drought, species and habitats associated with standing water habitats (ponds, reedbeds, lakes) could benefit.	The restoration/creation of new habitats must be guided by the future availability of water resources. This would likely include a prioritisation exercise to identify the most sustainable projects. Water bodies for which water supplies can be made available in the long-term are likely to be preferable to those which would require significant resource inputs to sustain a given hydrological regime.	High (Standing Water BAP Habitat) Medium (Fen, Marsh and Swamp BAP Habitat).	Moderate
Woodlands			
• Considered to be one of the more resilient habitat types based on predicted climate change to the middle of this century. • In general, species adapted to summer droughts in both the canopy and field layer may fare better. Changes in	Achievement of conservation targets will be dependent on the planting of appropriate tree species with long term projected climate changes in mind. Management to address other threats to woodland biodiversity such as lack of conservation management may lead to greater resilience of this	Medium (lowland beech and yew woodland BAP habitat)	Good

Potential response to climate change (based on literature review presented in Appendix 2)	Feasibility of London BAP targets	Risk of direct impacts from climate change on UK BAP Priority Habitat[g]	Strength of evidence[h]
woodland species composition may reflect this. • If trees are placed under increased physiological stress through summer drought or increased exposure to storms they may experience greater susceptibility to pests and pathogens.	habitat to climate change.		
• It is likely that certain canopy species such as beech *Fagus sylvatica*, which is relatively shallow rooted, may undergo a decline in response to relatively poor adaptation to drought and/or lower tolerance of increased climatic storminess. It is noted that the susceptability of beech to climate change may be more prevalent where this species has been planted on unsuitable soils (**Appendix 2**). • New scrub communities may emerge based on drought adapted garden escapes and colonists from southern Europe in the long term future.		Low (lowland wood pasture and parkland BAP habitat)	Poor

SUMMARY OF POTENTIAL IMPACTS ON LONDON'S SPECIES

4.20. A sample of key species and species groups was selected to further investigate possible effects of climate change on biodiversity in London. Key species were identified taking into account the following criteria:

- those with particular public resonance, for example species regularly encountered by Londoners or with particular cultural links to London.
- those of particular conservation importance within the London context, including those for which London holds significant populations at the national scale. These have been identified by the London Biodiversity Partnership[70].
- species which range widely across areas of London and would typically be expected to make use of one or more habitats.

4.21. Based on available literature, **Table 4.2** presents an assessment of potential climate change effects on eleven key species or groups of species within London. **Table 4.2** indicates affinities of key species with habitats identified within the London BAP and also lists relevant targets from the London BAP. As is the case for London's habitats it is evident from **Table 4.2** that there is a high level of uncertainty, with climate change offering simultaneous opportunities and threats to many species.

4.22. Included in **Table 4.2** is an assessment the risk to different species/groups of species in London of direct impacts from climate change. For the majority of the species no literature was identified specifically reviewing possible climate change impacts. Therefore, this column represents professional judgement by the authors and in all cases should be regarded as tentative until such time as more detailed research is published.

Table 4.2: Examples of key London species and potential effects of climate change

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
Sand martin *Riparia riparia*	Conservation importance (London BAP species)	• Rivers and streams and associated habitats • Standing water and associated habitats	Create 15 sand martin banks in London by 2006	Sand martin has undergone a decline in recent years. This is associated with loss of summer breeding grounds in London as well as droughts in sub-Saharan Africa, where they spend their winters[73]. Milder winters and warmer summers could promote an increase in insect populations. However, increased summer drought conditions could degrade wetland habitats favoured by sand martins. The availability/condition of sand martin nest sites may diminish if increased incidence of flooding damages nesting sites.	Medium
Grey heron *Ardea cinerea*	Public resonance Conservation importance (London BAP species)	• Coastal and floodplain grazing marsh • Eutrophic standing waters • Ponds • Reedbeds • Rivers and streams • Standing open water and canals	Maintain between 15 and 20 heronries at the end of 2011	Previous studies suggest that grey heron is experiencing an increase in numbers linked to the absence of severe winters and greater numbers of freshwater fish resulting from improving water quality[74]. This species might be expected to continue to increase with milder winters. However, this will depend on the availability of suitable prey species (for example, freshwater fish and amphibians).	Low

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
House sparrow *Passer domesticus*	Public resonance Conservation importance (London BAP species)	• Built environment • Parks and gardens • Brownfield sites	Halt the decline in house sparrow populations in London	Urban populations of house sparrow have undergone a 60% decline between 1979 and 1995[75]. Reasons for decline are not fully understood but may include: a reduction in the availability of favoured food (including insects when young are being reared), increased levels of pollution in urban and suburban habitats, loss of suitable nesting sites, increased prevalence of disease, changes in the use and type of loft insulation and increased levels of predation. No research has been identified on potential direct effects of climate change on house sparrow. Certainly the global distribution of this species includes a broad range of climatic zones both to the north and south of the UK. It would seem that the species is tolerant of a range of climatic conditions and would probably be adaptable to any variation brought about through climate change. However, given that populations are currently declining and fragmented across London, if climatic change acts to exacerbate any of the existing threats (noted above) there may be potential for further local extinction of this species in areas of London.	Medium
Peregrine falcon *Falco peregrinus*	Public resonance Conservation importance (London BAP species)	• Roosts in built structures, trees and hedgerows • Feeds over all habitats.	Encourage the establishment of breeding pairs of peregrines within the City	Currently considered to be increasing in numbers in London[76]. The effect of climate change on this species may be mediated though its effect on the availability of prey items and breeding success. The global distribution of peregrine falcon includes a broad range of climatic	Low

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
	Wide-ranging species		of London	zones occurring both to the north and south of the UK. Therefore, it would seem the species is tolerant of a range of climatic conditions and suitable climate space is likely to continue to exist in London.	

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
Bats	Conservation importance (London BAP species; and national biodiversity indicator[77]) Wide ranging species	• All semi-natural habitats (particularly London's wetlands[78]) • Linear features are important for commuting and built structures and mature trees provide roosting opportunities.	Establish 40 new roosting opportunities by 2006	Species such as noctule *Nytalus noctula* and serotine *Eptesicus serotinus* have undergone significant declines since the 1980s[79]. Reasons for decline include loss of invertebrate-rich feeding sites, loss of commuting routes and loss of roosts within residential houses. At least seven species of bat breed in the London area, all of which have differing ecological requirements. Responses to climate change in this group could be varied. Milder winters may benefit overwinter survival of hibernating bats. However, if weather patterns become less predictable and more sporadic this may lead to 'energy expensive' wakening from torpor at times during the winter when insect prey are not available. Warmer summers may promote more insect generations per season and higher insect numbers which may benefit bats. However, if summer droughts become more frequent this may suppress insect prey for example if this leads to a deterioration of insect rich wetland feeding sites. In the longer term, given sufficient climatic warming, it is possible that southern restricted species such as the greater mouse-eared bat *Myotis myotis* may find suitable climate space in the London area. However, barriers to dispersal from breeding locations in mainland Europe may prevent this.	Medium

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
Reptiles (adder *Vipera berus*, common lizard *Zootoca vivpara,* slow worm *Anguis fragillis, and* grass snake *Natrix natrix*)	Public resonance Conservation importance (London BAP species)	• Potentially present in all the seven key habitat types but optimal habitats in London comprise acid grassland, heathland, and neutral grasslands. Wetlands are also important for grass snake.	Ensure management is in place to maintain viable adder populations by 2007. Increase the population of reptiles within the Greater London region.	The adder underwent a marked decline in London in the 20th century[80]. This species currently exists in approximately five highly fragmented populations. With regard to adder populations, given a high restricted distribution and that they are not able to disperse across the urban landscape, if climate change brings about any decline in habitat quality this could lead to localised extinction[81]. Milder winters and warmer summers could stand to benefit species such as common lizard and slow worm by promoting overwinter survival and increased breeding success. However, the propensity of these species to colonise new habitats will depend on their ability to disperse between habitat fragments in London as environmental conditions become more/less suitable. If the quality/area of wetland habitats are reduced through summer droughts, this may lead to negative effects on grass snake. If climate changes leads to certain habitats becoming highly desiccated and dry increased incidence of fire may cause local population extinction of reptiles. Suitable climate space may arise for new reptilian colonists such as European wall lizard *Podarcis muralis* which is currently naturalised on the south Dorset coast.	Medium

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
Amphibians (common toad *Bufo bufo*, common frog *Rana temporaria*, smooth newt *Lissotriton vulgaris*, palmate newt *Lissotriton helveticus*, great crested newt *Triturus cristatus*).	Public resonance Conservation importance (London holds populations of internationally protected great crested newt; common toad has recently been listed as a national BAP priority).	• Standing open water and canals Ponds • Reedbeds • Rivers and streams	Great crested newt is the only amphibian listed on the London BAP, targets include: Monitor and maintain all known populations through sympathetic habitat management Review and attempt habitat restoration & re-introduction where appropriate Co-ordinate and distribute management guidance to private sector managing agencies Protect and	As a result of their dependence on freshwater, amphibians could be markedly affected by climate change if, for example, breeding ponds become dry for successive seasons, water pollutants are mobilised by rising water temperatures, or terrestrial habitat surrounding breeding ponds is subjected to water stress. It is important to note that if ponds dry only occasionally, this may actually benefit amphibians as the loss of one year's larvae would be offset against extinction of any predatory fish thus benefiting amphibian numbers in subsequent years. The ability of amphibians to disperse from breeding ponds and wetlands which become unfavourable as a result of climate change will be important in determining their susceptibility. Failure to disperse through highly urban parts of London may lead to localised extinctions. The date of arrival of amphibians at breeding ponds in spring has been shown to be positively correlated with average winter temperatures[82]. It has also been shown that the length of the tadpole stage in common toad is negatively correlated with the date of appearance of first spawn[83]. Both these factors could cause ecological changes to amphibian populations, for example, higher exposure to predation in earlier spawning years and/or greater vulnerability of eggs which are laid earlier to occasional spring frosts.	High

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
			maintain any new populations emerging from further surveys	Climate change could also exacerbate the effects of fatal pathogens thought to be leading to global amphibian declines such as chytridiomycosis fungus. Warmer summers and milder winters may also favour proliferation of introduced species that could become invasive and compete/predate upon native amphibian species. For example, the red-eared terrapin *Trechemys scripta elegans*and marsh frog *Rana ridibunda*[84].	
Stag beetle *Lucanus cervus*	Public resonance Conservation importance (London BAP species)	• Gardens and allotments • Veteran and street trees	Increase the provision of habitats within its known current range by 2005	Stag beetle has undergone a national decline in the last 50 years but a nationally important population remains in London's woods, parks and gardens. This species has broad habitat affinities provided that tree-associated food (for example, the larvae feed on dead wood) is available. Climate is thought to be a primary determinant of stag beetle distribution[85]. For example, in East and West Sussex the beetle is almost exclusively found in low-lying areas where rainfall does not consistently exceed 900 millimetres per annum and where soils are free draining[86]. Future suitable climate space for this species in London may be dictated by the availability of such conditions at the micro-scale and may have a marked positive or negative effect. Other climate change effects may include milder winters increasing the over-winter survival of beetle larvae. However, stag beetles require decaying wood and summer droughts may affect wood decay	Medium

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
				processes. If climate change increases incidence of disease in trees, stag beetles could benefit in the short term from the increase in available dead wood habitat.	
Burrowing bees and wasps (e.g. Five-banded tailed digger wasp *Cerceris quinquefasciat* and shrill carder bee *Bombus sylvarum*)	Conservation importance (London holds significant populations in a national context)	• Brownfield sites with suitable substrates for burrowing and suitable flower-rich vegetation for foraging	*Examples include:* Monitor population size and distribution at known site Maintain and extend population through sympathetic habitat creation and management	This group of species has undergone a decline in recent years caused by urban development on brownfield sites and decline of flower-rich arable habitats. A number of species which occurred historically are thought to be extinct in London at present[87]. Many of these species are parasites of other insect species. For example, the Five-banded tailed digger wasp provisions its nest with weevils. The effect of climate change on this species may depend on its effects on host species numbers. The effect of climate change on burrowing bees and wasps may also be mediated indirectly through the availability of habitat. Conceivably, hot, dry summer conditions resulting from climate change, may favour the installation of drought tolerant ruderal plant communities resembling brownfield sites in parks and gardens.	Low
Smelt *Osmerus eperlanus*	Conservation importance (London holds significant populations of	• River Thames, River Lea, Bow Creek and River Wandle	Targeted river channel habitat-creation schemes,	The smelt has been in steady decline since the 19th century and is now comparatively rare. Decline is associated with increasing pollution, over-exploitation and destructive river engineering schemes which effect both up-river migration as well	High

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
	smelt in a national context)		including deployment of spawning and refuge cages	as the spawning grounds. Greater London has a nationally significant population of this species[88]. At present, populations of smelt in London may be increasing in response to improving water quality. Possible climate change effects on this species include increased exposure to pollutants which may be mobilised by higher water temperatures. Higher water temperatures may also lead to a reduction in in-stream oxygen levels. Given rapid run-off rates in urban areas, higher incidence of storms may lead to increased scouring of in-stream habitats which may be used for sheltering and feeding by smelt, for example, erosion of sediment and vegetation. Furthermore, if invasive exotic species enter smelt habitat, this could lead to a range of effects on its habitat, for example, clogging of water courses by vegetation growth. Each of these factors might increase the risk of extinction of smelt given existing low population numbers. Hard engineering solutions to climate change induced, heightened flood risk, could further remove available habitat for these species. However, smelt may benefit from other approaches to managing flood risk. For example, wetland creation has potential to provide spawning and sheltering habitat.	
Rare plants of chalk grassland (for example,	Public resonance (attractive constituents of	• Chalk grassland	Ensure continued favourable management of	At present, several populations of these species exist on south London chalk grassland sites. Longer term survival is thought to be dependent on the presence	Medium

Species	Rationale for inclusion in study	Habitat affinities[71]	Relevant BAP targets[72]	Trend/ predicted impact of climate change	Risk of direct impacts from climate change
Chalk eyebright *Euphrasia pseudokerneri*, Man orchid *Aceras anthropophorum*)	London's flora) Conservation importance (London holds significant populations in a national context)		sites	of appropriate grazing and scrub control. It is uncertain whether suitable climate space will exist for this group of species given the range of changes in climatic variables under different scenarios and individualistic responses of different species (see **Appendix 2**). Few (if any) of London's chalk grassland species are at the northern edge of their range. In addition, certain chalk grassland plants have high dispersal powers (e.g. many orchids). Chalk grassland plant diversity could stand to increase as species from southern counties colonise London. Conversely, for species with poor dispersal powers, if climate change causes these to become extinct in London there may not be any opportunity for re-colonisation.	

SPATIAL VARIATION IN CLIMATE CHANGE IMPACTS ON BIODIVERSITY

4.23. The nature and magnitude of climate change impacts will also vary spatially across London, potentially affecting habitats in some areas more than in others. Section 3 of this report describes how climatic warming, flooding and drought could vary across London. For example, the urban heat island phenomena will result in London experiencing higher temperatures compared to surrounding areas, with temperatures particularly elevated in central London. Flood risk also varies spatially in London, by virtue of the characteristics of different water courses and the location and type of flood defences. These factors are explored in turn below.

4.24. However, in seeking to assess the differing spatial effects of climate change at the city scale, it should be noted that the majority of in-depth studies exploring possible impacts of climate change focus on the regional or national scale and do not consider detailed spatial considerations such as these. Therefore there is little evidence on which to base conclusions at the city scale.

Urban heat island

4.25. Habitats in London stand to experience hotter/drier conditions than those beyond London, with particularly elevated changes in central London (**Figure 4.2**). This may exacerbate effects on those habitats which are more vulnerable to higher temperatures (for example, rivers and standing waters). In certain circumstances the operation of the urban heat island effect may benefit the emergence of new drought adapted communities, for example, those composed of exotic species such as those of southern European origin which are currently present but have a restricted distribution in London.

Flood risk

4.26. As indicated by **Figure 4.3**, increased risk of fluvial flooding could affect a wide area in London and potentially all of the seven habitats types. However, in reality extensive flood management is in place much of which will be enhanced in the face of increased flood risk (for example the Thames Estuary 2100 project is advising on tidal flood management requirements), and flood management itself could greatly affect habitats. Flood management could be via a range of techniques, from restoration of flood plains to engineered solutions. Beyond the Thames Barrier, in particular, flood management objectives could lead to a more naturalistic approach to flooding, with the restoration of functional flood plain and concomitant changes to habitats (often from low quality to higher quality habitats).

4.27. Spatially, rivers, streams, standing water and wetlands habitats are likely to be particularly affected by flooding and/or strengthened flood management measures by virtue of their location. Flood risk and flood management could affect habitats located in the valleys of the rivers Lee, Ingrebourne and Roding (north-east), Colne, Crane and Brent (west), Ravensbourne (south-east) and Wandle (south-west). For example, increased occurrence of flash flooding could lead to extreme flows scouring the stream bed and banks. Dependent on flood management objectives and the exact specification of flood alleviation schemes, green spaces located on floodplains across London could be managed to incorporate a range of additional plant and animal communities suited to wetter conditions, e.g. wet grassland/woodland or ephemerally wet fen communities.

4.28. In addition to fluvial flooding, surface water flooding (affected by drainage capacity, topography, soil type and permeability) could have some adverse effect on habitats, for example on street trees and gardens (although it is unlikely to have a significant effect on the seven habitat types covered in this research).

4.29. Coastal habitats in the Thames Estuary, including mudflats, salt marshes and grazing marshes, could also be affected by flood risk in a range of ways. Changes will largely depend on the flood responses put in place. For example, hard flood defences, combined with rising sea levels, will contribute to a process of 'coastal squeeze' whereby the extent of coastal habitats is reduced. In areas where 'managed retreat' is the favoured response (where areas of (typically) farmland are allowed to flood) a change in habitat types will occur.

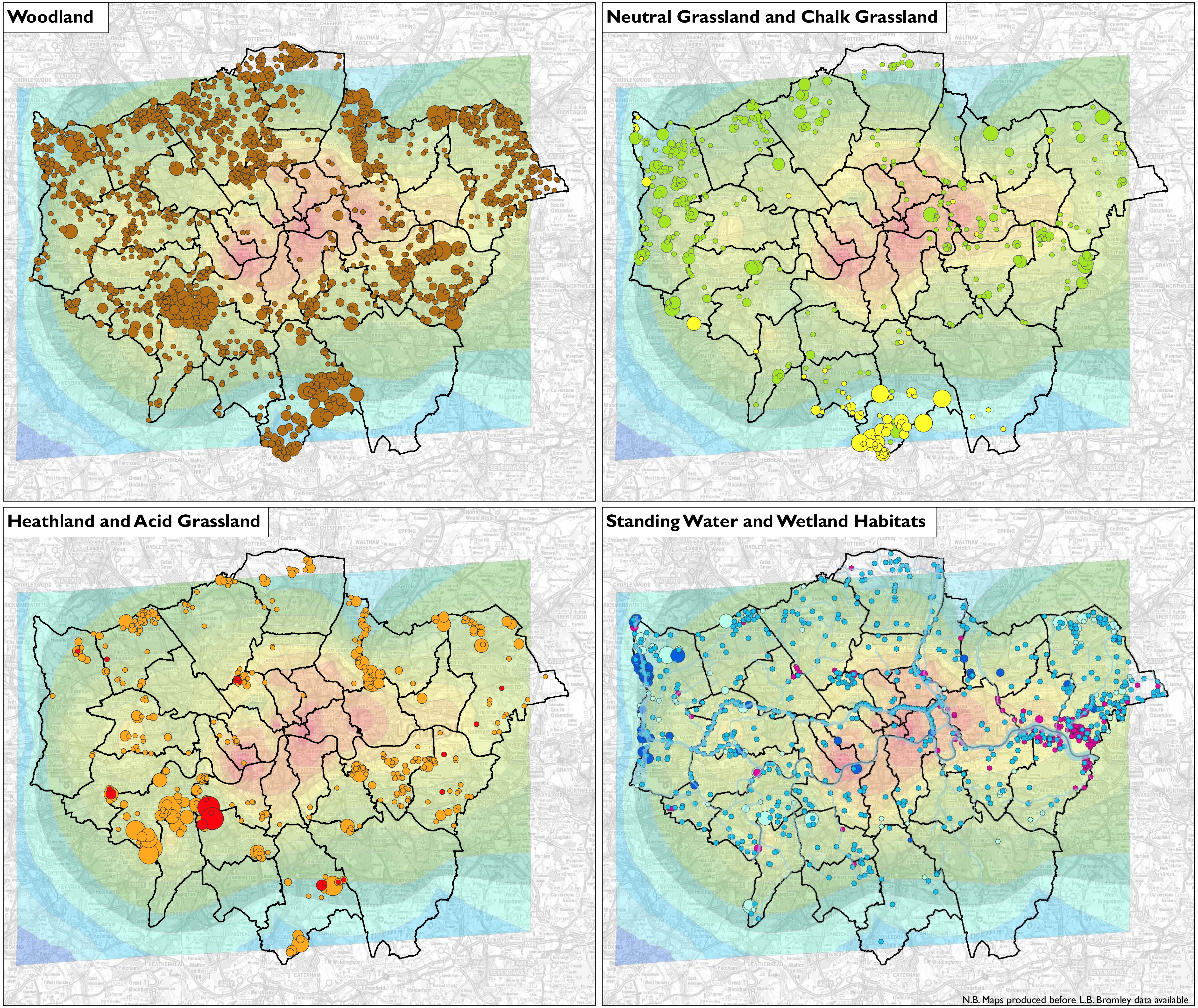
4.30. In many cases responses to flood risk involving restoration of natural processes (functioning flood plains and tidal inundation) will benefit habitats, particularly where habitats of little ecological value are restored to higher value habitats.

Density of the urban fabric and permeability

4.31. The concept of 'permeability' describes how easy it is for species to move through the cityscape. It might be expected that in areas of London where species can disperse more freely, plants and animals will be able to respond to climate change by avoiding specific areas of high impact (which, for example, may result from reduced availability of water or higher temperatures). In areas of high permeability, plants and animals may also be able to recolonise formerly occupied habitats more readily if climate change impacts (e.g. fire, flooding) cause any temporary local extinctions. By contrast, in areas of London where species dispersal is highly constrained, climate change may result in a greater incidence of local species extinction.

4.32. Generally, densely urbanised areas (i.e. those with relatively little green space) provide fewer opportunities for species to move, shelter, feed or grow than areas containing abundant parks, gardens and areas of waste land. In densely urbanised areas roads and railways may also act as barriers to species movement, particularly for invertebrates, mammals, reptiles and amphibians that disperse overland.

4.33. However, it is beyond the scope of this study to investigate the dispersal capabilities of London's species, so no more detailed conclusions may be drawn on this point.



Climate Change and Biodiversity in London

Figure 4.2: London's habitats in relation to urban heat island intensity

The number of occasions that temperatures exceeded 19°C for 48 consecutive hours.

21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 09, 08, 07, 06

Habitat type

- Acid grassland
- Heathland
- Chalk grassland
- Neutral grassland
- Woodland
- Ponds
- Eutrophic standing water
- Reed bed
- Wet woodland

NOTES:

This Canopy Layer Map was developed using air temperature measurements gathered in 1999 - 2000.

The canopy layer heat island is the urban heat island we are most familiar with. It refers to the increased air temperature between ground level and roof height.

N, W, E, S

0 5 10 Km

Source: London Biodiversity Partnership/ GLA/ Watkins et. al. (2002). The London Heat Island: results from summertime monitoring. Building Services Engineering Research and Technology, Vol. 23, No. 2, 97-106

Date: 18/05/2009

Revision: A

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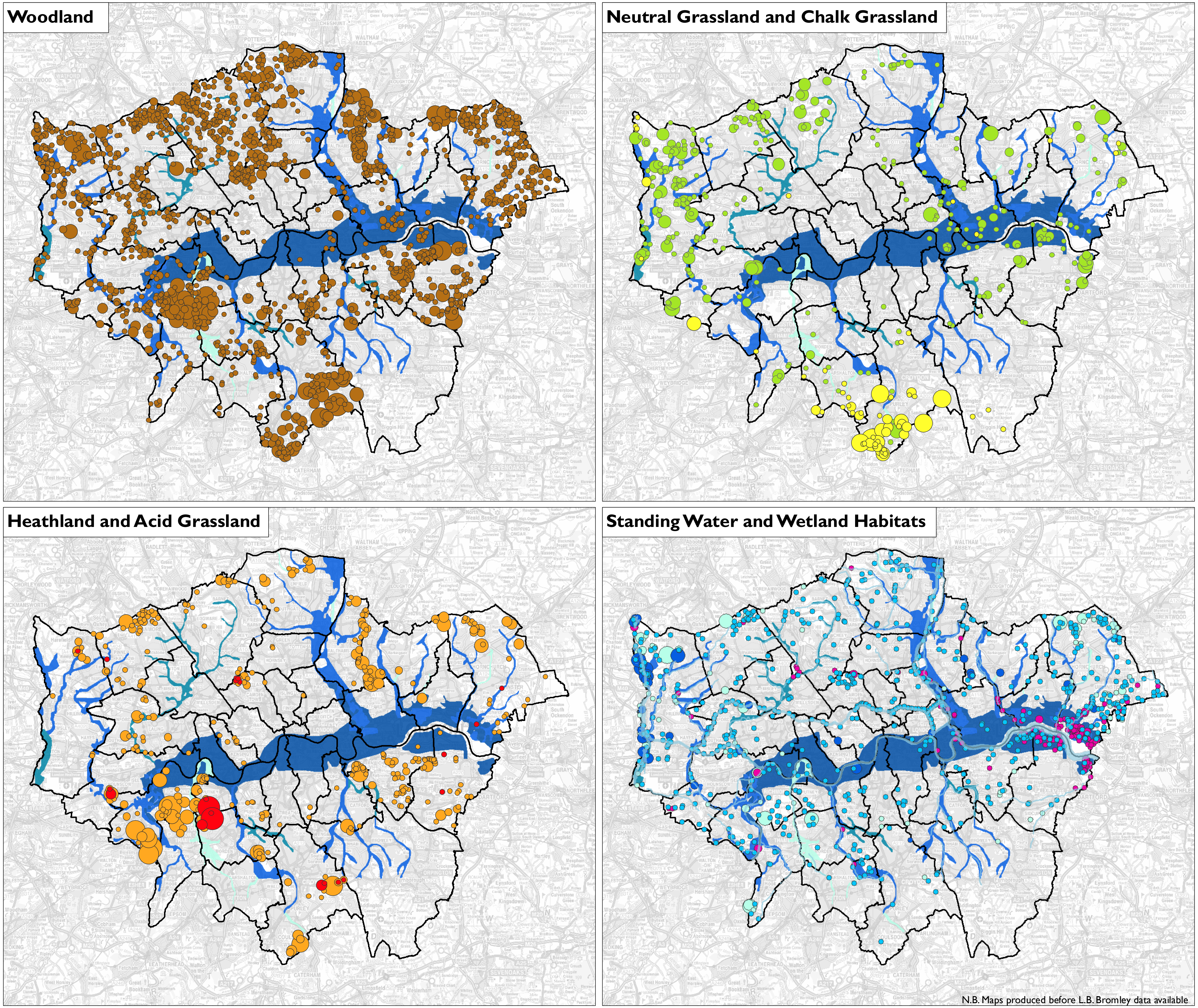

Climate Change and Biodiversity in London

Figure 4.3: London's habitats in relation to the probability of flooding

Area of London protected by flood defences (with probability of flooding expressed as a return period)

- 1:1000 year
- 1:20 - 1:50 year
- 1:75- 1:100 year
- <1:20 year

Habitat type

- Acid grassland
- Heathland
- Chalk grassland
- Neutral grassland
- Woodland
- Ponds
- Eutrophic standing water
- Reed bed
- Wet woodland

NOTES:

The standard of protection provided by London's flood defences, and hence the likelihood of being flooded can be mapped for tidal and fluvial flooding.

This probability is usually expressed as a 'return period'. The 'return period' is how often a flood of a given magnitude would be expected to occur over a long period of time. For example, '1 in 100' means that a flood of that severity would occur only once, on average, every hundred years.

N W E S 0 5 10 Km

Source: London Biodiversity Partnership/ GLA/ LCCP

Date: 18/05/2009

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CONCLUSIONS

4.34. Based on the preceding summary of available literature and the more detailed literature review presented in **Appendix 2** the following conclusions may be drawn:

- Many of London's most valued habitats have a very limited distribution and are surrounded by areas of dense urban development and roads which may act as barriers to species dispersal. This is particularly the case for acid grassland and heathland. Compared to equivalent habitats patches in the wider countryside, if species are lost from urban habitats as a result of climate change, there is likely to be a limited opportunity for new colonists from Europe and southern England to replace them.

- The urban heat island phenomenon could affect habitats throughout London (as temperatures will be elevated compared to the surrounding countryside). This may exacerbate the effects on those habitats which are highly vulnerable to elevated temperatures (for example, rivers and standing waters). In certain circumstances the operation of the urban heat island effect may benefit the emergence of new drought adapted communities, for example, those composed of exotic species such as those of southern European origin which are currently present but have a restricted distribution in London.

- London may have to accept that some habitat changes will occur. Moreover, conservation targets may have to be revised to account for the emergence of new ecological communities which are better adapted to climate change.

- Studies indicate that species' responses to climate change are very individualistic. The difficulties of predicting the responses of ecological communities based on species specific studies is compounded by possible interactions between species and colonisation of habitats by new species. Given uncertainty, in many instances it may be more appropriate to seek to conserve functional habitat processes, for example, flooding cycles in a wetland or grazing regimes on a grassland, which support biodiversity, rather than target management actions at the conservation of particular species. Enhancing the permeability of the cityscape is another potential response, as this can increase resilience to unpredictable events such as fires or floods through enabling species to move from one site to another and re-colonise areas where they may have become locally extinct.

4.35. In relation to the seven habitat types considered in the literature review the following is concluded:

- Direct effects from climate change are considered to be of medium to high risk for **standing water** and **river and stream and associated habitats**. Both habitats stand to experience significantly altered hydrological regimes. For example, higher summer temperatures could particularly affect aquatic habitats through oxygen depletion. In addition, increased incidence of storms in combination with high urban run-off rates could lead to scouring of in-stream habitats such as those used by certain freshwater fish species. In relation standing water habitats, if summer drying occurs for successive seasons this could lead to loss of certain amphibians. Some species of freshwater fish and amphibian may be lost from these habitats. In addition, both habitat types currently suffer from a number of invasive species. This may exacerbate any direct effects of climate change;

- Given the operation of the urban heat island effect, maintenance of areas of **amenity grassland** in areas of inner London may become less feasible as this vegetation type is highly susceptible to dessication. This may present opportunities for ecological enhancement utilising drought tolerant plant species.

- Direct impacts from climate change are generally considered to be of medium risk for habitats such as **neutral grassland** (lowland hay meadows), **woodland** and **heathland.** For all three habitats, shifts in the relative abundance of characteristic species may occur. For example, the balance between grasses and heather on heathlands may be altered, whilst climatic warming may create a selective pressure for deeper-rooted herbs on neutral grasslands. In woodlands, increased severity and regularity of summer drought may disadvantage shallower rooting tree species; exposure to a greater frequency of storms may increase wind-blow of canopy trees; and milder winters may foster greater survival of insect pests. Although the overall structure of these habitats may be maintained, this does not preclude possible declines of species which are characteristic in the UK, for example, beech in woodlands and heather on heathlands (under high emissions scenarios).

- **Acid grassland** is likely to be moderately resilient to potential direct effects from climate change, particularly summer droughting. Many lowland acid grassland species are already adapted to conditions of drought stress, although research indicates that certain acid grassland species may decline. Where acid grassland occurs as a mosaic with other habitats such as wet heathland, the former may be more resilient to drought and in certain areas replace the latter. If acid grassland is not to diminish in overall species richness, **efforts will be needed to ensure micro-climatic variation is present within sites to provide a range of climatic 'niches'. Barriers to species dispersal should also be reduced as far as possible, but some loss of those species which have poor dispersal abilities is likely to be inevitable, given limited potential for increasing habitat connectivity of this fragmented habitat type.**

- **Chalk grassland** is likely to be relatively resilient to potential direct effects from climate change based on the fact that many species characteristic of this habitat are adapted to conditions of moderate drought and exposure. In addition, several chalk grassland plants and invertebrates occur in southern England at the northern edge of their distribution. Climatic warming could increase the range of niches available to these species.

- For all habitats **effective conservation action to address other threats to biodiversity may considerably offset future impacts of climate change by increasing overall resilience**.

4.36. In terms of impacts on species which are characteristic of London or of particular conservation importance to London, the following key messages are identified:

- **Species which rely on the maintenance of water based habitats** could be particularly adversely affected as summer rainfall is reduced. For example, amphibians could lose out to climate change if, for example, breeding ponds become dry for successive seasons, or terrestrial habitats surrounding ponds become subject to water stress. Rising water temperatures could also lead to the mobilisation of pollutants leading to increased concentrations of environmental toxins encountered by aquatic species. Another example of a water-reliant species which is potentially very vulnerable to climate change is smelt (of which London holds a significant population in the national context). Decline in habitat quality through scouring of in-stream vegetation and sediments linked to increased storminess and high urban runoff rates could affect this species. It could also be vulnerable to loss of habitat to hard flood defences which commoly remove 'natural' geomorphological features of stream channels (e.g. gravel bars/ back-water pools) in an attempt to channel flood water away more efficiently.

- Milder winders and warmer summers could stand to benefit **reptile species**, such as common lizard. However, if the quality or area of wetland habitats are reduced through summer droughts species such as grass snake could be negatively affected. In addition, any increase in incidence of fires caused by drought conditions may lead to local extinction of reptile populations. Urban landscapes are frequently impermeable to reptile dispersal, therefore once extinct locally there may be little prospect of re-colonisation of formerly occupied habitats. Suitable climate space may arise for new colonists such as European wall lizard which is currently present on the south Dorset coast.,however, given the distance of pionner populations in the UK from London, it is unlikely that such species would establish in London naturally.

- Some species are likely to be **relatively well equipped to respond to climate change**, for example **grey heron** are likely to fare well with milder winters. However, this will depend on the availability of suitable prey species (for example, freshwater fish and amphibians). Similarly, **peregrine falcon** is likely to respond neutrally to warmer temperatures, provided prey items are not adversely affected by climate change.

- The **responses of many species to changed climate conditions are more uncertain**. For example, **house** sparrow is already declining; a key factor is thought to be the lack of food at critical times of year, such as when young are being raised.Whilst this species should be tolerant of a range of climatic conditions, if climate change exacerbates any of the existing threats, further local extinctions could occur.

- **Bat species and stag beetle could also have mixed responses to climate change**, dependent on how the habitats these species rely on are affected by climate change, and the availability of prey species in the case of bats.

- **The response of floral species is also uncertain**. For example, the response of rare chalk grassland plants, which are of high conservation importance and appreciated by the public, is uncertain. Climate change may permit the northwards colonisation of species currently only found in Surrey and

Kent. However, this will only be possible if these species are able to dispersal to suitable habitat patches in London.

4.37. A number of limitations and further research requirements are identified as follows:

- The majority of studies reviewed predict the impact of climate change on biodiversity based on computer modelling at the regional scale. This has attendant limitations when seeking to extrapolate findings to London. In addition, many modelling studies do not consider the additional climate warming London may experience as a result of the urban heat island effect.

- A need is identified for further 'species specific' research, for example, there is little information available on the effects of climate change on invertebrates and fungi despite the fact many of London's rare species are invertebrates, and fungi play a critical role in nutrient recycling.

- Future research should incorporate the fragmentation of London's existing habitats and the quality and quantity of habitat resources in London and the surrounding landscape. Simply investigating shifts in the theoretical suitable climate space of species overlooks the propensity of species to colonise newly available habitat and to escape unfavourable conditions.

- There are too many species for primary research to address climate change impacts on individual species in any substantive way. There will be a continuing need for species experts to review emerging information on species behaviour and emerging climate science to consider how London's species may be affected by changes in climatic conditions and to review conservation targets accordingly.

PART B: THE WAY FORWARD

5. PRINCIPLES FOR ADAPTING LONDON'S BIODIVERSITY TO THE EFFECTS OF CLIMATE CHANGE

5.1. Decisive action to conserve and enhance the capital's biodiversity, including helping it to adapt to climate change, is important for safeguarding the delivery of ecosystem services and maintaining and improving quality of life for Londoners. This section presents contextual information on the actions required to conserve and enhance London's biodiversity in response to climate change.

5.2. There is a high degree of uncertainty in seeking to identify how plant and animal communities will change in the face of a changing climate. This is particularly the case when seeking to extrapolate the findings of regional and national studies to the city scale. For species, the identification of clear 'winners' and 'losers' depends on a range of complex interactions between individual species' responses to changing weather patterns, dispersal abilities and interactions with other species.

5.3. Recent guidance from Defra (Hopkins *et al.* 2007) strongly indicates that climate change and uncertainty should not confound conservation actions and outlines eight principles for enhancing the ability of biodiversity to adapt to climate change:

- 1a. Conserve Protected Areas and other high quality habitats.
- 1b. Conserve range and ecological variability of habitats and species.
- 2. Reduce sources of harm not linked to climate.
- 3a. Conserve and enhance local variation within sites and habitats.
- 3b. Make space for the natural development of rivers and coasts.
- 4. Establish ecological networks through habitat protection, restoration and creation.
- 5. Make sound decisions based on analysis
- 6. Integrate adaptation and mitigation measures into conservation management, planning and practice

5.4. An outline of these principles is provided below, where possible drawing parallels to London species and habitats (arguments presented in this account draw on Hopkins et al. 2007; Hopkins, 2007b) and identifying the likely applicability or feasibility for London.

1a. Conserve Protected Areas and other high quality habitats

5.5. Although suitable climate space will change for a number of species this should not invalidate the role of protected areas. SSSIs, SINCs and LNRs[i] generally encompass a large number of rare and threatened species in London[89]. These sites also tend to be

[i] SSSI = Site of special scientific interest; SINC = Site of importance for nature conservation; LNR = Local Nature reserve.

occupied by species which have more demanding habitat requirements and are sites where the largest populations of rare and threatened species exist (e.g. London's chalk and acid grasslands). Hence they represent the best opportunity for conserving wildlife. Further, the biodiversity associated with these sites will very likely result from a range of environmental properties that make them favourable to a diversity of species (e.g. varied water regimes, non-nutrient enriched soils). In this respect they will remain attractive habitat for a diversity of new colonists even if native London species may be lost.

Conserve Protected Areas and other high quality habitats: Applicability of principle to London

High.

It will be essential to continue to protect high quality wildlife habitats throughout London, whilst accepting that the species mix may change as climate changes. Such habitats will remain attractive habitat for wildlife, albeit that the species mix may be of a different composition. In London particular pressures, aside from climate change, which must be addressed, include development pressures, pressures from people visiting habitats for recreation, and pollution.

Where possible create buffers around sites or where this is not feasible work to 'soften' the landscape around sites e.g. through tree planting and urban greening initiatives.

1b. Conserve range and ecological variability of habitats and species

5.6. Species and habitats are unlikely to face the same risks in all locations. A pragmatic approach to coping with the uncertainty of effects of climate change is to ensure the range of conditions inhabited by different species is preserved:

"Embracing range and ecological variation of a species in our conservation work is a strategy for reducing the risk of extinction... [by spreading]...out conservation investment" (Hopkins, 2007: 383)

Conserve range and ecological variability of habitats and species: Applicability of principle to London

High.

It will be important to conserve a wide range of habitats in a range of states or conditions e.g. successional stages to provide as many habitat niches as possible. This principle should be applied throughout London through LBAPs and the preparation of management plans.

2. Reduce sources of harm not linked to climate

5.7. The effects of climate change may further exacerbate existing threats faced by biodiversity in London. Research suggests that species populations which are already depleted by other factors will be even less resilient to climate change. Broadly these existing threats comprise:

- Abandonment of management, leading to scrub encroachment (e.g. London's grassland habitats).
- Nutrient enrichment and pollution (e.g. decline in otter Lutra lutra populations nationally is strongly linked to pollution by polychlorinated biphenyls and organochlorine pesticides).
- Over-abstraction of water (e.g. this problem commonly occurs on streams fed by chalk aquifers).
- Aerial pollutants (e.g. the inner London lichen flora is thought to be impoverished, compared with outer London areas, as a result of susceptibility to aerial pollution (Purvis 2004)).
- Existing fragmentation of habitat meaning that many populations are now too small and isolated to be viable in the long term (e.g. in 2005 the black redstart was confined to just three confirmed breeding sites in the London area (Self, 2005)).
- London's population is set to increase in the next fifty years - this may bring with it competition for natural resources shared by wildlife e.g. water, soils etc. Additional human visitor pressure could lead to disturbance of sensitive species.

Reduce sources of harm not linked to climate: Applicability of principle to London

High.

It is important that efforts to minimise or manage other sources of harm are continued throughout London.

In London particular pressures, aside from climate change, which must be addressed, include development pressures, pressures from people visiting habitats for recreation (balancing this with targets which have been set for ensuring all Londoners have access to nature), and pollution.

Review HAPs, SAPs, LBAPs and other conservation management plans and projects to ensure that all non-climate causes of adverse change have been identified and measures put in place to address them.

Establish surveillance and early responses to tackle threats of invasion.

3a. Conserve and enhance local variation within sites and habitats

5.8. Maintaining diversity with respect to features such as vegetation structure, slope, aspect and water regime will increase the chances that species whose current habitat becomes unfavourable due to climate change will be able to spread locally into newly favourable habitat. Many species respond, even at the scale of individual sites, to variations in micro-climate and ground temperature. Whilst general trends predict an overall warming in London's climate, there will be variations at the very localised scale. Research described in Section 4 of this report noted how butterfly communities in chalk grassland habitats use the north and south facing slopes differently, which illustrates this principle (e.g. Davies *et al.* 2006). Options for species to avoid unfavourable climatic conditions could be maximised by seeking to promote variations across London's habitats. For example by retaining soils which warm and retain water to differing degrees and by encouraging the development of a varied micro-topography within sites. Areas in London offering potential development of such topographic variation may include previously developed sites and gravel workings which are inherently varied due to past land uses. These spaces are often attractive to rare invertebrates, reptiles and birds on account of the varied microclimatic conditions. This could apply equally to encouraging a more flexible approach to management of many of London's parks and green spaces which are typified by homogenous amenity grassland and heavily pruned trees.

Conserve and enhance local variation within sites and habitats: Applicability of principle to London

High.

It is important that management of existing, and creation of new, sites throughout London encourages micro-topographic and hence micro-climatic variation. This may be particularly appropriate when new sites are being developed e.g. in the Thames Gateway or when considering how to enhance the value of existing open spaces which currently have very little biodiversity interest.

3b. Make space for the natural development of rivers and coasts

5.9. Predictions for heavier winter rainfall at the regional scale and increased flooding may particularly affect London's river and wetland habitats. For example, heavy rainfall in the summer storms of 2004 overwhelmed London's sewers leading to a discharge of sewage into the Thames and a mass 'fish kill' event. There are therefore social and economic as well as environmental arguments for developing better means of managing flood waters.

5.10. Open spaces may present options for restoration of flood meadows and wetlands. Restoration of ecological processes offers opportunities for furthering ecosystem resilience in the face of uncertainty with respect to climate change impacts on specific constituent species. Functioning ecological processes, such as sedimentation and erosion, will better enable communities of plants and animals to 'naturally' colonise such habitats. This approach has been successfully demonstrated by the creation of a series of wetland habitats (including reedbeds, ponds, shallow lagoons and shingle islands) at the London Wetland Centre at Barnes in south west London.

This site was designated as a SSSI only six years after creation and continues to attract unexpected species of plant and animal which are otherwise very rarely encountered in London.

Make space for the natural development of rivers and coasts: Applicability of principle to London

Medium - High.

Making space for rivers is a key response for ensuring riverine and wetland habitats are resilient to the increased pressures of climate change. It also has an important role to play in managing flood risk to society. The London Rivers Action Plan[90] recognises the climate change adaptation potential of river restoration as well as the opportunity such projects provide to improve habitats and corridors for river wildlife. Whilst the built up nature of London limits opportunities to 'naturalise' rivers on a large scale, the Action Plan and associated website[91] show that many smaller scale opportunities exist within the capital.

The most likely opportunities for restoring natural floodplains on a larger scale are likely to arise in the outer areas of London, for example, within a green belt, and to the east of the Thames Barrier (the latter particularly because it coincides with the aims of the Thames Estuary 2100 project in terms of flood management – see below). Other areas of potential for restoring natural flood plains to enhance biodiversity may arise where rivers run through open spaces/disused land. However, allowing open spaces to function as flood plains may compromise other objectives, such as provision of space for recreation.

The Thames Estuary 2100 project is ongoing, and is seeking to identify the next generation of strategic flood risk management options for the tidal Thames and the Thames Estuary. On the back of this study, the Draft London Climate Change Adaptation Strategy identifies that, amongst other actions, there will be a need to identify a number of riverside sites (open space and industrial land) downstream of the Thames Barrier that could provide space for future flood storage and so reduce flood risk.

The Draft Adaptation Strategy also notes that on the non-tidal Thames (west of Teddington) the open nature of many of the river banks in west London provides the potential to use areas such as the Old Deer Park in Richmond for flood storage. Residents in this part of the river are often already aware of local flood risk and are more likely to be able to adopt local community-based schemes.

The London Wildlife Trust's Living Landscape approach has identified the River Crane, Lee Valley, Colne Valley and Wandle Valley as key projects for river restoration in London. It has also identified landscape management of Erith, Crayford and Dartford Marshes as a key mechanism for flood alleviation and biodiversity enhancement.

Where possible, measures to 'make space for rivers' should be incorporated into River Basin Management Plans, LBAPs and other local management frameworks.

4. Establish ecological networks through habitat protection, restoration and creation

5.11. All species run the risk of chance local extinction but where they are subject to fragmentation and isolation, it is less likely that suitable populations will exist in the vicinity to enable recolonisation. In London this could apply to species such as stag beetle which has very specific habitat requirements. The principle behind creating ecological networks is to permit species which occur in highly fragmented habitats an opportunity to move through isolated habitat patches within the cityscape as environmental conditions change (often referred to as 'ecological connectivity'). For certain species the provision of dark corridors is also important to facilitate movement, for example bat species[92] .

5.12. It may be intuitive to assume that linear habitats fulfil a corridor function assisting species dispersal. However, evidence is mixed as to whether linear habitats such as roads verges and hedgerows fulfil this function for all species (e.g. Beier and Noss, 1998). In addition, physical continuity of habitats may not be a requirement for dispersal, Hopkins (2007) notes that:

"...most species do not need this continuity of habitat in order to spread. For virtually all species, the world consists of patches of habitat separated by varying amounts of inhospitable habitat through which they have evolved to disperse..." (Hopkins, 2007: 386).

5.13. In London the most extensive type of 'greenspace', accounting for approximately 20% of London's land cover, is the private garden (GLA, 2002). Intuitively, gardens are therefore likely to play a critical role in allowing species inhabiting isolated habitats to relocate to other suitable habitat patches either within or outside of London as environmental conditions change. River corridors also provide good opportunities for creating or enhancing connectivity.

Establish ecological networks through habitat protection, restoration and creation: Applicability of principle to London

Medium - High.

Whilst the value of ecological networks is not fully understood, there is a wide body of thought that such networks can help species to disperse as climate space changes, and to recolonise habitats where localised extinctions have occurred. However, it may be the case that species would typically move around London utilising the green belt and surrounding countryside, rather than seeking to filter through the urban centre.

Nevertheless, given that green networks can provide many other benefits for humans as well as wildlife it is considered that creating ecological networks should be given a high level of priority. However, it is recognised that as one moves into the dense urban centre of the city, opportunities for creating such networks diminish.

The London Wildlife Trust's Living Landscape approach is an example of work which is underway to develop ecological networks. For example, the LWT has identified the role that London's gardens and various river corridors and wetlands (the Crane, Lee Valley, Colne Valle, Wandle Valley and Erith Crayford and Dartford Marshes) can play in improving connectivity and permeability of landscapes for wildlife. The East London Green Grid[93] is another example of an approach to enhancing connectivity.

5. Make sound decisions based on analysis

5.14. There is a need to establish monitoring programmes to understand the responses of London's species and habitats to the range of adaptation measures outlined above. As identified in Section 4 of this report, a range of conservation targets exist for habitats and species in London. It will be necessary to continue to review conservation targets and to adopt appropriate and feasible targets as our understanding of species' responses to climate change improves. Monitoring the northward movement of species currently restricted to bordering southern counties (e.g. Surrey, Hampshire and Sussex) is necessary to understand if and how species are colonising more northerly climate spaces (within and around London). Such an understanding will allow us to better develop management responses in future, to both encourage dispersal and to manage new species which may colonise sites within London.

Make sound decisions based on analysis: Applicability of principle to London

High.

There is a need to establish a robust system of species and habitat monitoring in London which covers potential changes due to climate change and the success of climate change adaptation measures for biodiversity. Such a system should include provision of data to GIGL. It is also important that conservation targets established through the London BAP are kept under review (Section 4 of this report identifies the extent to which BAP targets are likely to be achievable as climate change progresses).

Examples of current monitoring which could form the basis of analysis include:

- Bird monitoring such as the Wetland Bird Survey, looking at changes in wintering populations of waterbirds, or monitoring of breeding bird populations and identification of new breeding species such as Little Egret or Cetti's Warbler.
- Invertebrate monitoring such as moth trapping to monitor spread of species such as Toadflax Brocade or Jersey Tiger (Rothamstead light traps feed data into the national monitoring scheme); butterfly monitoring in London e.g. data collated by Butterfly Conservation and London Natural History Society (butterfly data is fed into a UK database which could highlight trends).

6. Integrate adaptation and mitigation measures into conservation management, planning and practice

5.15. Current approaches to managing sites for wildlife may not be appropriate in the face of changing environmental conditions. For example, a longer growing season may mean that grazing of hay meadows needs to be extended to maintain a floristically rich species composition. In addition, drier summers may mean that incidence of fire is an increased threat to wildlife and that hardier breeds of grazing animal may need to be utilised.

Integrate adaptation and mitigation measures into conservation management, planning and practice: Applicability of principle to London

High.

It will be important that managers of London's open spaces and sites of importance for biodiversity are aware of the likely impacts of climate change, and adjust their management techniques as appropriate. Such management changes should be identified in site management plans.

6. OPPORTUNITIES FOR, AND THREATS TO, BIODIVERSITY OF PROPOSED ANTHROPOGENIC CLIMATE CHANGE ADAPTATION MEASURES

6.1. This section considers the potential opportunities for, and threats to, biodiversity conservation and enhancement in London that are presented by emerging 'anthropogenic' climate change adaptation proposals designed to respond to the three main threats to London from a changing climate:

i. Flooding

ii. Overheating

iii. Drought.

6.2. The adaptation proposals are principally drawn from the draft London Climate Change Adaptation Strategy (LCCAS).

6.3. **Table 6.1** looks at each adaptation proposal in turn, identifying opportunities and threats to biodiversity and relating the opportunities to the Defra principles for making biodiversity more resilient to climate change (see **Section 5** for description of the principles). Each proposal is scored on a scale from ++ (major opportunity for biodiversity) to **- -** (major threat to biodiversity) to summarise the significance of the opportunity and/or threat. This analysis draws on discussions that took place at a stakeholder workshop in London in March 2009, augmented by professional judgement and research.

Table 6.1: Biodiversity opportunities and threats of climate change adaptation measures

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principles[j]								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
1. ADAPTING TO OVERHEATING												
1.1 Define an 'urban heat island action area' within the central London boroughs where major new developments will be required to incorporate measures such as 1.9, 1.11 and 1.12 below.	Green roofs and green walls present opportunities for biodiversity.		Tree planting could potentially damage existing open habitats.	See individual measures below (1.9, 1.11 and 1.12).								
1.2 Initiate a pan-London Urban Greening Programme to identify, prioritise and implement opportunities for urban greening.	Increased area of habitat and improved connectivity. May help to relieve pressure of public use on existing areas of biodiversity value. Opportunities to engage volunteers (for site management etc) and to	Green space to mitigate the urban heat island will not necessarily be good for biodiversity, unless biodiversity objectives are specifically incorporated. Access management issues in ecologically sensitive new habitat	Disturbance of newly created habitat through public use. Tree planting on areas of existing valuable grassland and other open habitats.	■	■	■	■	■	■		■	++/-

[j] The Defra guiding principles on building capacity for biodiversity to adapt to climate change are described fully in Section 5. In brief they are 1a: Conserve high quality habitats; 1b: Conserve variability of habitats and species; 2: Reduce other sources of harm; 3a: Conserve and enhance site-scale habitat variation; 3b: Make space for natural development of rivers and coasts; 4: Establish ecological networks; 5: Make decisions based on analysis; 6: Recognise climate change in site management.

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
	raise the profile of biodiversity issues through community involvement and educational opportunities.	areas. Careful design is required to mitigate perceived risks to public safety from dense planting etc. Challenge of securing resources and establishing delivery mechanisms for the on-going management for biodiversity.										
1.3 Require all London boroughs to use their Open Space Strategies to manage the urban heat island by protecting local green spaces and identifying opportunities for urban greening.	Increased area of habitat and improved connectivity. May help to relieve pressure of public use on existing areas of biodiversity value.	As for 1.2 above. Potential exists for disjointed actions across borough boundaries and with neighbouring regions. A strong vision and guidance at London-wide level and a joined-up approach with adjacent regions is needed to address this risk.	Disturbance of newly created habitat through public use. Tree planting on areas of existing valuable grassland and other open habitats.	■	■	■	■	■	■		■	++

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
1.4 Create breeze pathways that enhance natural ventilation.	Incorporation of street trees and other vegetation in breeze pathways. Design guidance could specify this.	None identified.	None identified.						■			+
1.5 Orientate developments/ streets to optimise solar gain.	None identified.	None identified.	None identified									0
1.6 Punctuate new development with green spaces.	Increased area of habitat and improved connectivity. May help to relieve pressure of public use on existing areas of biodiversity value. Opportunities to engage volunteers (for site management etc) and to raise the profile of biodiversity issues through community involvement and educational opportunities.	Lack of management control over private gardens and developer-owned green spaces may make it difficult to ensure that it is managed for biodiversity.	None identified.						■			+

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
	The climate change agenda provides an additional hook for funding provision and maintenance of green space which is managed, in part, for biodiversity.											
1.7 Optimise the street width to allow for appropriate scale deciduous street trees.	Increased habitat area and connectivity from more street trees or other vegetation.	Potential/ perceived subsidence issues may limit public support for street tree planting.	Increasing the width of streets to make room for trees may leave less space in new developments for other habitats. Potential to impact on existing habitats adjacent to streets.						■			+/-
1.8 Use low-albedo (pale and reflective) materials, e.g. permeable paving, road surface, car parks etc.	None identified.	None identified.	None identified.									0
1.9 Incorporate green roofs and green walls.	Significant opportunities to increase habitat area and improve connectivity. Green	Lack of knowledge amongst developers/lack of policy requirement	None identified.						■			++

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
	roofs represent one of the few opportunities for creating habitats in central London. Green roofs can be designed to deliver specific biodiversity benefits e.g. habitat for invertebrates.	from local authorities.										
1.10 Avoid high glare facades and finishes.	None identified.	None identified.	None identified									0
1.11 Plant and manage deciduous trees in streets, public spaces and private gardens to provide dense summer shade.	Increased habitat area and connectivity. Opportunity to educate the public on the biodiversity importance of private gardens.	Need to ensure local habitat and species conditions and priorities are reflected in planting plans.	Potential damage to existing open habitats. Potential increase in planting of invasive, non-native species e.g. false acacia.						■			+/-
1.12 Ensure that mechanical ventilation or cooling systems vent waste heat above the roof level, that cooling systems draw cool air (i.e. from the north side or shaded side of the	Anecdotal evidence that reduced heat build-up around building may help to avoid magnifying the effects of a warming climate on local habitats.	None identified.	Anecdotal evidence of potential thermal pollution of aquatic habitats from heat exchangers.									0

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principles								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
building, or from over a green roof) and examine other heat exchange opportunities e.g. with ground or water.												
1.13 Ensure that where cooling is still required, low carbon, energy efficient methods are used.	None identified.	None identified.	None identified.									-
1.14 Help Londoners adapt their behaviour and lifestyles to higher temperatures e.g. measures to avoid excessive exposure to the sun and dehydration and measures to adapt people's homes, gardens and workplaces to hotter summer temperatures.	Likely greater public use of open space provides opportunity to engage the public in the importance of biodiversity. Opportunity to educate people about the biodiversity potential of private gardens and the most appropriate vegetation in the light of climate change.	None identified.	Likely greater public use of existing open spaces creates a risk of greater disturbance impacts on habitats and species present in those spaces.									+/-
1.15 Ensure that a tried and tested heat-wave emergency plan exists to manage extreme	None identified.	None identified.	None identified.									0

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
events - principally measures to be taken by Primary Care Trusts.												
2. ADAPTING TO FLOODING												
2.1 Flood defence walls and gates: On the tidal Thames this would include raising the height of defences downstream of the Thames barrier and making adjustments to the barrier itself. For non-tidal sections of the Thames this may involve increasing upstream defence heights and increasing flood storage capacity.	Some (limited) potential for biodiversity enhancement to flood defence structures themselves (during any replacement/refurbishment of defences).	None identified.	None identified.				■					0
2.2 Set back defences (give rivers room): For example, identifying a number of riverside sites (open space and industrial land) downstream of the Thames Barrier that could provide space for future flood storage and so reduced flood risk.	Increase biodiversity value along stretches of river which currently have little biodiversity value. Potential wetland and saltmarsh habitat creation opportunities. Where alteration to	None identified.	None identified.			■		■				++

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principles[j]								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
	defences occurs in areas with high value habitats, this could lead to a change in habitat types e.g. grazing marsh to saltmarsh. Flood storage in suitable locations reduces the risk of adverse impacts on riverside habitats which are vulnerable to flooding.											
2.3 Improve/ restore storm drains: This includes both physical measures such as restoring and/or enhancing the capacity of existing drains and strategic planning measures such as collating data on drainage ownership, capacity and management to assess the capability of the drainage system in London under a	Opportunity to deal with urban diffuse pollution and its adverse effects on ecosystems.	Concrete rather than naturalistic channels provide few habitat opportunities.	A greater number of more effective storm drains is likely to Increase rate at which rainfall is transmitted to freshwater systems and hence peak flows (which may damage aquatic habitat). It may also result in a higher number of sudden nutrient inputs			■						+/--

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principles[j]								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
changing climate.			into freshwater systems during intense rainfall.									
2.4 New and improved secondary flood defences: Construction of temporary defences or additional structures beyond the main defences.	Secondary flood defences could take the form of vegetated bunds, overflow basins etc. which could be designed to provide additional habitats.	None identified.	Raised flood defences may prevent people from observing waterways and their wildlife.				■	■				+/-
2.5 Construction of flood conveyance channels: These are artificially constructed river channels which are designed to attenuate river water upstream of flood prone areas or allow water to bypass flood prone areas.	Opportunity for naturalistic artificial channels which provide new habitat.	Concrete rather than naturalistic channels would provide few habitat opportunities.	Potential for scouring or habitat damage at channel outflow.					■	■			+/-
2.6 Flood-resilient design at the development scale (landscaping): This may include construction of drainage channels/ditches within new developments and raising land	Increased habitat area within drainage channels and ditches. Increased access to nature.	Limited space in urban areas to incorporate natural features.	None identified.						■			+

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
levels in flood prone areas.												
2.7 Flood resilient design at the development scale (buildings): Options include (i) raising buildings above the flood level; (ii) constructing buildings to prevent flood water entering and to promote fast drying and easy cleaning; and (iii) constructing buildings in such a way that although flood water enters the building damage by flood water can be easily repaired.	None identified.	None identified.	None identified.									0
2.8 Urban greening - Creating new and enhancing existing green spaces.	Increased area of habitat and improved connectivity. May help to relieve pressure of public use on existing areas of biodiversity value. Opportunities to engage volunteers (for site management etc) and to	Access management issues in ecologically sensitive new habitat areas. Careful design is required to mitigate perceived risks to public safety from dense planting etc. Challenge of securing	Disturbance of newly created habitat through public use. Tree planting on areas of existing valuable grassland and other open habitats.	■	■	■	■	■	■		■	++/-

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
	raise the profile of biodiversity issues through community involvement and educational opportunities.	resources and establishing delivery mechanisms for the on-going management for biodiversity.										
2.9 Urban greening - Reducing 'garden grabbing' e.g. Government's water strategy proposes removal of permitted development right to paving over of front gardens if impermeable surfaces are used and this aspiration is reiterated within the LCCAS.	Protection of existing habitat. Opportunity to educate public on the biodiversity value of gardens and to encourage more wildlife-friendly gardening.	None identified.	May increase pressure for development on brownfield land with biodiversity value and possible greenfield sites elsewhere.						■			+
2.10 Urban greening - Increasing street tree cover. N.B. should extend to other trees e.g. in parks.	Habitat creation.	None identified.	Tree planting on areas of existing valuable grassland and other open habitats.						■			+/-

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principles[j]								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
2.11 Urban greening - Requiring the installation of sustainable urban drainage systems (SUDS) and permeable materials in new developments. N.B. Should extend to retro-fitting to existing developments.	Habitat creation e.g. wetlands, reedbeds.	SUDS do not necessarily provide good habitat. Guidance and incentives to design for biodiversity need to be put in place. Need to ensure resources are in place to ensure ongoing management to maintain biodiversity value.	None identified.						■			+
2.12 Urban greening - Flood resilient design at the neighbourhood scale e.g. the potential for utilising greenspace for temporary floodwater attenuation and/or storage.	Significant opportunities for creation of natural habitats e.g. wetland and wet woodland.	Ensure resources are in place to ensure ongoing management to maintain biodiversity value.	None identified.					■	■			+
2.13 Not locating flood-vulnerable development and infrastructure in high flood risk areas.	May help to facilitate natural functioning of flood plains.	None identified.	May increase development pressures elsewhere.									0
2.14 'Risk Trading': This involves long-term (second half of the century) spatial planning	Less vulnerable uses could include green spaces managed for	None identified.	Potentially could require development on existing habitat in					■	■			+/-

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
approaches which review opportunities to swap vulnerable land uses in flood risk areas with less vulnerable uses elsewhere.	biodiversity.		exchange for creation of new habitat with different characteristics in another location.									
2.15 Institutional measures e.g. public awareness raising; develop flood warning systems; put in place business continuity measures.	Awareness raising campaigns that focus on climate risks could also provide education on opportunities for biodiversity benefits to be incorporated into adaptation measures.	None identified.	None identified.									+
2.16 Restoration of non-tidal components of Thames to provide increased floodwater storage.	Restoration of natural habitats e.g. wetland creation and enhancement. Reduced risk of flood damage to sites of existing value.	Areas of opportunity may be limited in densely populated areas.	None identified.			■		■	■			+
3. ADAPTING TO DROUGHT												
3.1 Desalination: The practice of removing the salt from	Potential to build in biodiversity	None identified.	Development of new plant could impact on									+/-

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
seawater, for example the tidal Thames, to produce drinking water.	opportunities through appropriate design. Desalinisation could reduce the need to abstract from rivers in times of extreme drought.		existing biodiversity due to location close to intertidal habitats. Although less impact than some measures since the volume of water taken is likely to be small and plant would not be regularly used. Desalination is energy intensive and the generation of that energy could have indirect impacts on biodiversity e.g. if large scale planting of bio-fuel crops was undertaken. Potential impact on aquatic species within water intake. This risk could be mitigated by an appropriately designed screening and return									

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principles[j]								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
			system. May make it more difficult to persuade water consumers of the need to be water efficient.									
3.2 Increase in reservoir capacity: Increase both the size and/or the number of reservoirs. N.B. there is very little opportunity in London itself – the main proposal is in South Oxfordshire which would be used to top up Surrey reservoirs and serve London.	Opportunities to secure a net biodiversity gain e.g. grassland on embankments; wetland creation; wet meadows; hedgerow enhancements. Reservoirs provide refuges for birds displaced by activities elsewhere e.g. water sports.	None identified.	Local loss of arable land and farm birds. Species in the River Thames at reservoir abstraction point(s) could be harmed. Potential change in river water quality when water is returned during dry periods. May need more abstractions from rivers to levels below those allowed today in order to fill reservoirs, with consequent threat to						■			+/-

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principles[j]								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
			river ecology, particularly in a warmer climate where dissolved oxygen.									
3.3 Artificial groundwater recharge: e.g. the North London Aquifer Recharge Scheme [NLARS] operated by Thames Water where water is abstracted from the River Lea in winter, treated and injected into the aquifer to be abstracted during dry periods. There is also a South London scheme.	Minor opportunities to build biodiversity friendly features into the buildings involved e.g. bat boxes. S106 funds could be used for these local biodiversity benefits. This measure is primarily about moving excess water within limits set by the Environment Agency, so it is unlikely to affect river ecology positively or negatively.	None identified.	Artificial recharge is energy intensive and the generation of that energy could have indirect impacts on biodiversity e.g. if large scale planting of bio-fuel crops was undertaken.									0
3.4 Demand management: - Compulsory water metering of all properties in London.	Demand management will mean less stress on the environment as more water available in	None identified.	None identified.			■						+

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
- Improving water efficiency standards in new development - Retrofitting improved water efficiency in existing homes. - Changing consumer behaviour to conserve water.	the environment.											
3.5 Use reclaimed water for non-potable uses: For example, use of rainwater or grey water from showers, baths or basins for toilet flushing and outdoor water uses. N.B. Opportunities for large scale storage through collectivised schemes.	Potential to create wetlands/reedbeds by incorporating grey water collection storage into SuDS schemes. Opportunity to use grey water to water plants, maintaining their health during dry periods. Opportunity to use rainwater butts and water from roofs to top up ponds and drainage ditches incorporating wetland habitat.	None identified.	Water quality may not be adequate to avoid harm to some habitats.			■						+

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
	Less frequent sewer flooding would reduce contamination from sewer flooding. Water efficiency will have indirect biodiversity benefits. People will think about where water comes from and conserve it better.											
3.6 Reduce the loss of water through better leakage management.	Less stress on the environment as more water available in the environment.	None identified.	Potential threats (anecdotal evidence): • Damage to root systems. • Less water for street trees. • Possibly more subsidence. Whilst the presence of clay soils in London is the key issue,			■						+/-

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
			trees can accentuate subsidence risk as they may draw water out of soils if leakage water is not available. • Choice of tree species is important to reduce the risk. • Rail companies may clear vegetation due to fears of subsidence.									
3.7 Respond to drought by increasing water transfers between catchments.	Less stress on the environment as more water available in the environment in catchments where demand exceeds river needs.	None identified.	Differences between the quality of transferred water and 'native' water may adversely affect river ecology. Potential to increase spread of disease or			■						+/-

Proposed CC adaptation measure	Potential opportunities for biodiversity	Barriers to realising opportunities	Potential threats to biodiversity	Contribution to Defra guiding principlesj								Opportunity/ threat
				1a	1b	2	3a	3b	4	5	6	(++ to --; 0 = neutral)
			non-native species.									
3.8 Rising groundwater in London – potential to use? EA to review.	If feasible then potentially less stress on the environment as more water available in the environment.	None identified.	None identified.			■						+

SUMMARY OF KEY OPPORTUNITIES FOR BIODIVERSITY

6.4. **Table 6.1** shows that many of the climate change adaptation measures under consideration in the draft LCCAS present opportunities for biodiversity conservation and enhancement. This is borne out by the ability of those opportunities to deliver on one or more of the Defra guiding principles for *'building capacity for biodiversity to adapt in a changing climate'* (see **Section 5** for a description of these principles). The table shows that there is significant potential for adaptation measures to deliver benefits for London's biodiversity under the following Defra principles:

- Establishing ecological networks (Defra principle 4);
- Making space for the natural development of rivers (Defra principle 3b)
- Measures to protect and appropriately manage sites/spaces to maximise climate change adaptation capacity for biodiversity (Defra principles 1b, 3a, 6)
- Reducing sources of harm not linked to climate change (Defra principle 2).

6.5. Each area of opportunity is explored further below.

Establishing ecological networks and making space for the natural development of rivers

6.6. Many climate change adaptation measures have the potential to create new areas of habitat or to enhance existing ones through management with a biodiversity focus. Example measures drawn from **Table 6.1** (adaptation reference in brackets) include:

- Requiring borough Open Space Strategies to identify opportunities for green space which could address the urban heat island effect and provide wildlife habitat (measure 1.3).
- Increasing planting of street trees to provide shading and enhance connectivity between habitats (measures 1.11, 2.10).
- Incorporating green roofs and walls into new and existing developments (measure 1.9).
- Planning measures to discourage paving over or development of gardens (measure 2.9).
- Setting back flood defences and restoring river channels to a more natural state to increase flood storage and provide riverine and wetland habitats (measures 2.2, 2.16).

Measures to protect and appropriately manage sites/spaces to maximise climate change adaptation capacity for biodiversity

6.7. **Table 6.1** shows that proposed adaptation measures can also deliver against other Defra principles relating to the conservation and management of habitats, for example:

- Conserve protected areas and other high quality habitats – urban greening measures which are aimed at managing the urban heat island may also help to conserve existing high quality habitat by, for example, providing buffer areas around them or providing alternative natural green spaces which reduce recreation pressure on them.

- Conserve range and ecological variability of habitats and species – similarly to the point above, conserving the range of existing London habitats also helps to conserve the variety of habitats occupied by particular species and hence increases the chances that some of those habitats will provide suitable conditions for the species to thrive under a changing climate.

- Conserve and enhance local variation within sites and habitats - re-examination of how public and private green spaces can best be managed to, for example, provide more shade for people or create flood storage areas also offers the opportunity to ensure that a wide range habitat niches are created with different conditions of temperature, humidity and so on.

Reduce sources of harm not linked to climate

6.8. In addition, many of the identified opportunities will also help to reduce **other sources of harm to biodiversity (Principle 2),** which are caused by factors other than climate change (or which are already a problem, and will be further exacerbated by the effects of climate change). In particular this category includes:

- Many habitats are already water stressed due to over abstraction. Measures to respond to drought (3.3, 3.4, 3.5, 3.6) will help to reduce the existing stress/harm caused by summer droughts;

- London's habitats are currently negatively affected by storm overflow. Therefore measures to improve storm drains will help to reduce this source of harm (2.3);

- Visitor pressures are a further source of harm. Increased provision of green space will help to alleviate existing pressures of visitors to habitats in London (1.2, 1.3, 2.8).

6.9. **Section 7** of this report develops these ideas further through a series of recommendations on how to maximise the biodiversity benefits of measures in the draft LCCAS. The recommendations are aimed at a range of organisations from the GLA, to local authorities and site managers.

7. CONCLUSIONS AND RECOMMENDATIONS

POTENTIAL DIRECT IMPACTS OF CLIMATE CHANGE ON LONDON'S HABITATS AND SPECIES

Changing 'climate space' for London's habitats and species

7.1. Climate space is the area a species can live in because the climate is suitable. As climate changes, so too will the climate space suitable for different species. For example, wasp spiders, which are found on the south coast of England, are extending their distribution northwards as winters get milder.

7.2. London is subject to an urban heat island effect, whereby temperatures are higher compared to the surrounding countryside, due to the thermal mass of buildings and thermally absorbent surfaces. Rising temperatures could particularly threaten habitats such as rivers and standing waters.

7.3. Some London species are likely to decline as conditions become unfavourable (for example, too hot or too dry), but others may become more common. New species are likely to colonise London's habitats as their climate space shifts northwards from Europe and southern England.

7.4. However, species decline may be hastened and colonisation by new species limited due to a lack of habitat connectivity or dispersal capabilities. Many of London's most valued habitats occur in isolated pockets, surrounded by areas of dense urban development and infrastructure. This lack of connectivity acts as a barrier to species dispersal. This is particularly the case for acid grassland and heathland.

Habitats: impacts will be mixed

7.5. Key findings:

- **Standing water habitats** could experience a loss of some species of amphibians and fish due to reduced water availability.
- **Rivers and streams** will be affected by higher summer temperatures due to reduced oxygen levels. Increased flash flooding could lead to scouring of in-stream habitats and increased pollution.
- **Amenity grassland may be more difficult to maintain due to increasing temperatures,** as this vegetation type is highly susceptible to drying out. This may present opportunities for ecological enhancement utilising drought tolerant native plant species.
- **Neutral grassland and heathland are likely to be at medium risk from the direct impacts of climate change**. Changes in the relative abundance of characteristic species may occur. For example, grasses may become more prevalent than heather on heathlands, and deeper-rooted herbs on neutral grasslands.

- **Woodlands are also likely to see a change in species mix**. Increased severity and regularity of summer drought may disadvantage shallower rooting tree species and characteristic species such as beech may decline. Woodlands will also be affected by storms leading to increased wind-blow of canopy trees and milder winters may foster greater survival of insect pests.

- **Acid grassland is likely to be moderately resilient** to the direct effects of climate change, particularly summer drought. If acid grassland is not to diminish in overall species richness, efforts will be needed to vary site topography and reduce barriers to species dispersal. Some loss of species with poor dispersal abilities is likely to be inevitable.

- **Chalk grassland is likely to be relatively resilient** to the direct effects of climate change because many species characteristic of this habitat are adapted to conditions of moderate drought and exposure. Climatic warming could increase the climate space available to several chalk grassland species in southern England which are currently at the northern edge of their distribution.

Species: some will be more resilient than others

7.6. In terms of impacts on species which are characteristic of London or of particular conservation importance to London, the following key messages are identified:

- **Species dependent upon water based habitats** could be particularly adversely affected by drought.

- Milder winters and warmer summers could stand to benefit **reptile species** such as the common lizard.

- Some species such as the **grey heron and peregrine falcon** are likely to be relatively well equipped to respond to climate change.

- The **responses of many species to climate change are uncertain**. Some are already declining for reasons unconnected to climate change. Climate change could exacerbate these existing problems, increasing the likelihood of further local extinctions. Other species may benefit from the availability of an expanded climate space, enabling their northwards colonisation, but only if they are able to disperse to suitable habitat patches in London.

A pragmatic response to climate change

7.7. Suitable climate space is likely to be lost for some species and gained for others, and decision makers and site managers must accept that changes in habitats and species will occur.

7.8. Focus should be placed upon conserving functional habitat processes which support biodiversity, for example, flooding cycles in a wetland or grazing regimes on a grassland, rather than trying to target management actions at the conservation of particular species.

Table 7.1: Principles for enhancing the ability of biodiversity to adapt to climate change[k]

Principle for enhancing the ability of biodiversity to adapt to climate change	Applicability to London
1a. Conserve Protected Areas and other high quality habitats.	High
1b. Conserve range and ecological variability of habitats and species.	High
2. Reduce sources of harm not linked to climate change.	High
3a. Conserve and enhance local variation within sites and habitats.	High
3b. Make space for the natural development of rivers and coasts.	Medium-high
4. Establish ecological networks through habitat protection, restoration and creation.	Medium-high
5. Make sound decisions based on analysis	High
6. Integrate adaptation and mitigation measures into conservation management, planning and practice	High

OPPORTUNITIES FOR BIODIVERSITY FROM ANTHROPOGENIC CLIMATE CHANGE ADAPTATION MEASURES

7.9. Many of the climate change adaptation measures identified in the Draft LCCAS (which are seeking to address flooding, overheating and drought) present opportunities for biodiversity conservation and enhancement, including increasing adaptive capacity of biodiversity to climate change, provided that they are planned, delivered and managed in a way which is sensitive to biodiversity opportunities (see **Table 6.1**).

7.10. Measures which pose particular opportunities for biodiversity (as identified by the range of Defra's *'guiding principles for building capacity for biodiversity in a changing climate*' to which they could contribute (see **Table 6.1**)) include measures to adapt to overheating, including:

- Initiating a pan-London Urban Greening Programme to identify, prioritise and implement opportunities for urban greening (1.2).
- Requiring all London boroughs to use their Open Space Strategies to manage the urban heat island through protecting local green spaces and identifying opportunities for urban greening (1.3).
- Helping Londoners adapt their behaviour and lifestyles to higher temperatures, in particular adapting parks and gardens to hotter summer temperatures (1.14).

[k] Defra (2007) Conserving biodiversity in a changing climate: guidance on building capacity to adapt.

7.11. Measures to adapt to flooding also offer particular opportunities, including the following:

- Urban greening – creating new and enhancing existing urban green spaces (2.8) and requiring the installation of SuDS (2.11).
- Restoration of non-tidal components of the Thames catchment to provide increased floodwater storage (2.16).

7.12. In addition to the above measures which could provide multi-benefits for biodiversity (contributing to several guiding principles for building capacity for biodiversity to adapt in a changing climate), several other measures, relating to the planting of street trees, provision of green roofs, SUDS and other forms of green space and river channel habitats, offer opportunities to create ecological networks.

7.13. Measures in the Draft LCCAS have particular scope to contribute to the following Defra *guiding principles for building capacity for biodiversity to adapt in a changing climate* (recommendations as to how to deliver these opportunities are detailed at the end of this chapter):

- ***Opportunity 1: Urban greening and development of ecological networks (Defra Principle 4)*** (via a strategic approach to the delivery of key LCCAS measures e.g. green spaces delivered through an Urban Greening Programme). This could increase biodiversity in London generally, and the climate change adaptive capacity of biodiversity across a range of habitats and species, provided green spaces are planned and managed in line with local biodiversity objectives. Species with poor dispersal abilities, such as reptiles, could particularly benefit from enhanced connectivity.

Summary of relevant measures for urban greening and development of ecological networks identified in the Draft LCCAS

- *Increased provision of green space at a range of scales*
- *Green roofs*
- *Street trees*
- *Landscaping to include SuDs and drainage channels in developments*
- *Measures to increase trees and habitats in private gardens, and reduce paved surfaces.*

Issues to be addressed

- *How to create space in a constrained urban area, which will require innovative solutions e.g. use of canals, rail corridors, green bridges, etc.*
- *Managing intensity of use of green space as London's population grows and as demand increases in hotter weather*
- *Ensuring sufficient resources are available for management*
- *Ensuring local authorities fully recognise the value of ecosystem functions played by*

green spaces

- *Ensuring appropriate habitats are created and species used in planting.*

- ***Opportunity 2: River restoration and flood storage (Defra Principle 3b)*** (via a strategic approach to the delivery of key LCCAS measures to respond to flood risk). Careful design and management of river restoration and flood storage schemes could provide significant benefits for rivers and streams and associated habitats, and species which depend upon them. For example, amphibians and fish, which are particularly vulnerable to reduced water levels.

Summary of relevant measures for river restoration and flood storage identified in the Draft LCCAS

- *River restoration to create a more naturalistic form*
- *Naturalised flood conveyance channels*
- *Set back of flood defences to 'give rivers room'*
- *Creation of areas for temporary flood water storage.*

Issues to be addressed

- *Finding space for naturalisation of river channels in a heavily urbanised area*
- *Public resistance to flood water storage areas due to temporary/permanent loss of recreation/play space to flood water storage*
- *Potential safety issues of flood water storage*
- *Need to maximise biodiversity benefits in 'hard' engineering solutions also e.g. concrete river channels through incorporating 'niches' which may be used by different species e.g. gravel for fish.*

- ***Opportunity 3: Appropriate wildlife habitat management to maximise the ability of biodiversity to adapt to climate change*** (Defra Principles 3a and 6) (this relates to how ecological networks and rivers are managed to enhance biodiversity via careful design, delivery and management of green spaces delivered through an Urban Greening Programme)

THREATS TO BIODIVERSITY FROM ANTHROPOGENIC CLIMATE CHANGE ADAPTATION MEASURES

7.14. A number of threats to biodiversity from measures in the Draft LCCAS have been identified which will need to be managed if climate change adaptation measures are not to threaten London's biodiversity.

7.15. Threats to biodiversity from measures in the Draft LCCAS (identified through the stakeholder workshop, literature review and Steering Group input) could include:

- Tree planting on existing high quality grassland and other open habitats.

- Potential harm to biodiversity if open spaces are used more intensively by people during hotter weather.

- Measures which maximise biodiversity benefits may not be the least-cost way to achieve desired climate change adaptation outcomes e.g. reflective surfaces to reduce overheating may be cheaper than green walls and roofs. Multi-benefits must be recognised in decision making.

- Heat exchange technology where water is used to cool buildings and then returned could lead to thermal pollution of aquatic habitats.

- Potential impacts of major water resource infrastructure development on biodiversity (e.g. impact on local biodiversity and aquatic habitats of desalinisation/reservoirs).

- Water quality issues for biodiversity from water transfers between catchments and from use of grey water.

- Anecdotal evidence that leakage management can lead to less water for street trees and damage to root systems. Trees could also contribute to subsidence if 'leakage' water is no longer available.

7.16. Responses to address such threats to biodiversity could include:

- Cohesive green infrastructure planning to maximise multi-functional benefits.

- Management of spaces to manage visitor pressures.

- Careful planning and decision making to assess trade-offs and maximise win-win scenarios.

THE EXISTING POLICY APPROACH TO CLIMATE CHANGE AND BIODIVERSITY

7.17. From the policy review, presented in **Appendix 1**, it is concluded that national and London wide policies and initiatives are aimed at either adapting to the effects of climate change or conserving and enhancing biodiversity. There are few examples of policies or initiatives which identify the need for, and scope of, anthropogenic climate change adaptation measures to provide biodiversity benefits. There is also little emphasis on the need to ensure adaptive capacity is built up for biodiversity to respond to climate change.

7.18. The complexity of the issues and the relatively recent elevation of climate change in public perceptions and policy priorities could explain this situation. In response to this there is a need to raise the profile of biodiversity opportunities afforded by climate change adaptation through policy and practice, for example green infrastructure planning.

7.19. In terms of green infrastructure planning and management in London, there is an array of policy and initiatives seeking to improve and augment green infrastructure and open space networks. Policy includes London Plan policy requiring boroughs to prepare open space strategies in line with GLA guidance, and the East London Green Grid SPG to the London Plan. In addition, there are other initiatives involving a range of partners, with a non-statutory remit, such as the 'Green Arc' around outer London. It is arguable that the existing approach to green space planning and management could be further coordinated to ensure a full range of environmental, economic and societal benefits are delivered in a fully coordinated manner across London.

RECOMMENDATIONS FOR MAXIMISING OPPORTUNITIES FOR BIODIVERSITY THROUGH CLIMATE CHANGE ADAPTATION

7.20. The three key responses needed to maximise biodiversity opportunities in the light of climate change are:

1) Urban greening and development of ecological networks:

- Incorporate biodiversity aims into planning/delivery of urban greening (parks, green roofs, etc)
- Increase connectivity between habitats
- Utilise drought tolerant species
- Create topographic/climatic niches
- Create a mix of habitat types.

2) River restoration and flood storage:

- Incorporate biodiversity aims into river restoration and flood storage schemes.

3) Appropriate wildlife habitat management to maximise the ability of biodiversity to adapt to climate change:

- Create micro-climatic variation through varied topography to help species respond to changes in temperature
- Use appropriate management practices e.g. to control invasive species
- Use drought tolerant species/cultivars
- Monitor species change.

7.21. A series of recommendations for decision makers and managers of biodiversity in London are detailed below, which aim to ensure London's biodiversity is conserved in a changing climate. The recommendations also seek to ensure that opportunities for biodiversity benefits are maximised through delivery of measures within the LCCAS.

Table 7.2: Recommended actions for key players

1) Urban greening & development of ecological networks	
Recommendations to Mayor	
Mayor to define objectives and scope of a London wide Urban Greening Programme to provide improvements in terms of flood and overheating risk management and biodiversity, and to consider the need for an overarching vision and strategy document.	GLA Group (with Natural England and Environment Agency)
Mayor to establish Urban Greening taskforce as recommended by draft Climate Change Adaptation Strategy	GLA
Mayor to review/implement fiscal measures to encourage climate change adaptation with biodiversity benefits e.g. through funding criteria as part of Priority Parks bids.	GLA
Recommendations to London biodiversity and climate change partners	
Establish a working group to support the work of the Urban Greening Taskforce to ensure the climate change adaptation and biodiversity opportunities of urban greening are realised. The working group should: • Identify spatially specific strategic priorities where urban greening measures could have particular climate change adaptation and biodiversity benefits e.g. areas of opportunity to enhance connectivity/permeability or to develop buffers around existing sites. • Promote the specific recommendations (below), to key delivery organisations. • Collect and share case study information on climate change adaptation and biodiversity benefits of measures. • Work with delivery partners to promote one or more demonstration projects[1] that show how urban greening measure can deliver climate change adaptation and biodiversity benefits.	Range of partners (Natural England and London Biodiversity Partnership)

[1] Demonstration projects could include:

- An exemplar public building incorporating green roofs with a mix of appropriate habitats e.g. for invertebrates, wetland creation through SuDS and functional habitats around buildings.
- Incorporation of urban greening within a project to be funded/delivered by a partner e.g. (i) urban greening (at a range of scales) within a regeneration project with LDA involvement (ii) Borough level delivery of urban greening through an Open Spaces Strategy.
- The Mayesbrook Park enhancement scheme in Barking & Dagenham.

Recommendations to local level delivery partners	
Boroughs to develop policy and strategy to deliver biodiversity friendly urban greening (in line with Borough BAPs) through Climate Change Action Plans, LDFs and supplementary planning documents e.g. Open Space Strategies /Design Guides.	London Boroughs
Raise awareness of the role and value of green spaces (public spaces and private gardens) in delivering climate change adaptation and biodiversity benefits.	London Boroughs, London Wildlife Trust, Groundwork
2) River restoration & flood storage	
Recommendations to London biodiversity and climate change partners	
Establish a London Rivers Restoration Group to ensure biodiversity opportunities of river restoration and flood storage are realised as part of a wider approach to flood risk management/climate change adaptation in London. The partnership should: • Identify opportunities and priorities for river restoration and flood storage and communicate clear messages to all partners involved in delivery. • Review the need to develop guidance or sign-post to existing guidance on design of restoration and flood storage schemes to ensure project level delivery maximises climate change adaptation and biodiversity benefits. • Work with partners to promote one or more demonstration projects[m] that show how making space for rivers can enhance flood storage capacity and deliver biodiversity benefits.	Natural England and Environment Agency
Recommendations to local level delivery partners	
Undertake community engagement to consult communities on river restoration and flood storage options, and to raise awareness of the need for such measures (for biodiversity and to respond to flood risk).	Environment Agency, London Boroughs
3) Appropriate wildlife habitat management to maximise the ability of biodiversity to adapt to climate change	
Maintain a London wide system of species and habitat monitoring: • Identify indicators to monitor e.g. species potentially under stress, northward migration of species, phenological changes.	Partners including Natural England, GIGL, LBP, LWT, London Boroughs

[m] The Mayesbrook Park scheme is under development as a demonstration project. See http://www.trrt.org.uk/index.aspx?articleid=15960

• Monitor the success of any measures introduced to adapt biodiversity to climate change (e.g. micro-climatic variation within sites).	
When planning/managing sites: • Create micro-topographic and hence micro-climatic variation e.g. through development of a range of grassland heights. • Review management practices to ensure they are appropriate in the face of climatic change e.g. grazing periods, mowing regimes, control of invasive species etc (based on the findings of monitoring and site observations).	Natural England, LBP, LWT, London Boroughs, and all other partners involved in the planning and management of wildlife habitats

CASE STUDIES

7.22. A series of case studies, which illustrate climate change adaptation measures responding to drought, overheating and flooding and which deliver biodiversity benefits, are included in **Appendix 3** as follows:

- Sunshine Garden, London Zoo (biodiversity benefits through a scheme designed to respond to drought).
- Dagenham Washlands (biodiversity benefits through a scheme designed to manage flooding).
- Living roof at Ethelred Estate, Lambeth (biodiversity benefits through a scheme which will help to manage overheating and flood risk).
- Restoration of River Ravensbourne at Cornmill Gardens, Lewisham (biodiversity benefits through a scheme to manage flooding).

Land Use Consultants

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APPENDIX 1

Review of climate change adaptation and biodiversity policy

APPENDIX 1: REVIEW OF CLIMATE CHANGE ADAPTATION AND BIODIVERSITY POLICY

This appendix reviews key policies and initiatives relating to biodiversity conservation and enhancement, climate change adaptation and open space in order to determine whether the biodiversity implications of climate change adaptation are adequately considered within these plans and policies.

REVIEW OF EXISTING POLICY

National policy

One of the objectives of **Planning Policy Statement: Planning and Climate Change Supplement to PPS1** is that planning authorities should prepare spatial strategies which '*conserve and enhance biodiversity, recognising that the distribution of habitats and species will be affected by climate change*'. In selecting which areas should be developed, they should consider any effect on the capacity of biodiversity to adapt to climate change and the contribution that existing or new green infrastructure could make to urban cooling, sustainable drainage systems, and conserving and enhancing biodiversity. The PPS Supplement also states that in considering the environmental performance of proposed developments planning authorities should expect them to provide open space which offers a choice of shade and shelter whilst recognising opportunities for wildlife (amongst other functions).

Planning Policy Statement 9: Biodiversity and Geological Conservation (PPS9) recognises that habitat and species distributions will be affected by climate change and requires regional spatial strategies to take this into account. **Planning Policy Statement 25: Development and Flood Risk** does not explicitly link climate change adaptation and biodiversity. It nevertheless recognises that climate change will increase flood risk for some developments and in the context of flood resilience states that '*those proposing development should seek opportunities to use multi-purpose open space for amenity, wildlife habitat and flood storage uses*'.

London wide policy/strategy

Since its adoption in 2004, substantial revisions have been made to the **London Plan** to address climate change. Policies recognise that various things that are good for biodiversity are also good for climate change, and vice versa, e.g. green roofs and open space. The only place where biodiversity and climate change are directly discussed together, however, is in the supporting text to Policy 3D.14 Biodiversity and Nature Conservation. This states that priority should be given to connecting fragmented habitat and increasing the size of habitat areas with a view to increasing species' resilience to climate change.

The **Mayor's draft Open Space Strategies Best Practice Guidance** lists amongst the benefits of preparing an open space strategy both protecting and enhancing biodiversity and measures which may help to adapt to the effects of climate change, such improving flood control or moderating extremes of temperature. Similarly, National Indicators cited as potentially relevant to open space include NI188 - planning to adapt to climate change and NI197 - improved local biodiversity. The two themes are not linked however.

The **Mayor's Biodiversity Strategy** highlights the opportunity for re-creation of riverside habitats as a secondary benefit of managing the increased flood risk that will come with climate change by allowing rivers to flood where they will do least harm rather than through hard engineering solutions. In considering links to energy and climate change issues, the strategy highlights that greening features installed on or adjacent to buildings to improve thermal efficiency or micro-climate (e.g. green roofs, climbing plants, shade trees) can also benefit biodiversity. Recognition of such policy links is evident in two of the strategy's proposals:

- Proposal 60: The Mayor will keep links between biodiversity and other aspects of the environment under review (flood control strategies required by rising sea levels are cited as an example).
- Proposal 61: The Mayor will consider biodiversity effects as part of an overall appraisal of the impacts of climate change in London.

Key London initiatives

The **East London Green Grid SPG**[94] promotes the creation of a network of multi-functional open space in East London. Development or regeneration proposals in East London are expected to incorporate elements that contribute to the Green Grid by, amongst other things, '*providing new and/or enhancing existing wildlife sites, reducing areas of deficiency*' and '*mitigating and adapting to the impacts of climate change*'. SPG Implementation Point 7: Climate Change and Flood Risk states that Green Grid design elements to be included in development proposals include green roofs designed for biodiversity and green open space and deciduous street trees to help reduce the Urban Heat Island effect. Implementation Point 10: Biodiversity states that in addition to enhancing habitats and access to nature, development proposals should also contribute to providing ecosystem services such as flood management. The fact that such ecosystem services can help to adapt to the effects of climate change impacts is made elsewhere in the SPG.

The **London Rivers Action Plan**[95] sets out the benefits of and potential opportunities for restoring London's rivers to a more natural condition. River restoration is presented as a tool for adapting both human society (for example by better flood management) and the wildlife dependent on river habitats (for example by reducing extreme variations in flow) to the effects of climate change.

The **London Tree and Woodland Framework**[96] explains that the right trees in the right places can help to adapt to the effects of a changing climate. Like other vegetation they can intercept rainfall and this together with the absorbent nature of leaf litter can help to reduce the rate and scale of surface run-off, thus reducing the risk of flash flooding. Trees can also help to adapt to warmer conditions by shading buildings, open spaces and soils. Both of these effects are of potential benefit to wildlife as well as to human society and trees can also, of course, provide habitat for wildlife in their own right.

The **draft London Climate Change Adaptation Strategy**[97] recognises that provision or enhancement of open spaces and street trees have the potential to deliver both climate change adaptation for Londoners and biodiversity opportunities. One of the proposals in the document is development of an Urban Greening Programme, one goal of which would be to identify strategic opportunities to implement environmental enhancement projects that provide maximum benefits in terms of ecosystem services. This research report is intended to help inform the final version of the Adaptation Strategy as well as an Urban Greening Programme. Detailed exploration of the opportunities for and threats to biodiversity associated with proposed adaptation measures is therefore provided in **Section 6**.

APPENDIX 2

The effects of climate change on London's biodiversity

– Detailed literature review

APPENDIX 2: THE EFFECTS OF CLIMATE CHANGE ON LONDON'S BIODIVERSITY – DETAILED LITERATURE REVIEW

BASELINE INFORMATION: LONDON'S HABITATS AND SPECIES

The following Tables (**A2.1-A2.7**) provide summary information on each of the habitat types covered in the research and identifies characteristic species associated with these.

Table A2.1: Baseline information for acid grassland

Habitat type	• Acid grassland
Corresponding Biodiversity Action Plan(s)	London BAP habitat action plan[n] (Acid Grassland) UK BAP Priority Habitat (Lowland Dry Acid Grassland)
Key sites & broad spatial distribution	Key concentrations of acid grassland are located to the west and south of London in the boroughs of Richmond and Croydon with smaller concentrations in Harrow, Barnet, Ealing, Waltham Forest and Redbridge. Key sites include: Hounslow Heath, Hounslow Richmond Park, Richmond upon Thames Bushy Park, Richmond upon Thames Wimbledon Common, Wandsworth Mitcham Common, Merton Chislehurst Common, Bromley Wanstead Flats, Redbridge Hadley Green, Barnet Ruislip Woods NNR, Hillingdon
Key environmental processes which maintain habitat integrity	• Plants and animals associated with lowland acid grassland typically require free-draining acidic soil. • Maintenance of species characteristic of this habitat also depends to an extent on active management. If neglected, the sward becomes dominated by tall, vigorous grasses or bracken which, together with an associated build-up of dead plant matter, suppresses less vigorous species and reduces the botanical richness. Eventually the sward reverts to scrub and even woodland. • Traditionally, management has consisted of stock grazing and this remains an effective management tool. Grazing helps to maintain an open sward of small tussocky grasses and, through disturbance and trampling, creates areas of open ground suitable for colonization by the lichens, ephemeral plants and a varied micro-topography required by invertebrates and reptiles that are often characteristic of this type of grassland.
Indicative species which typify habitat	Acid grassland has relatively few but characteristic plant species, comprising fine-leaved grasses and wildflowers as well as a distinctive group of invertebrates. Red Banded Sand Wasp *Ammophila sabulosa* Harebell *Campanula rotundifolia* Heath Bedstraw *Galium saxatile*

[n] BAP = Biodiversity Action Plan. The London BAP comprises specific action plans for 14 habitats and 12 species.

	Pink Waxcap *Hygrocybe calyptriformis* var. *calyptriformis* Small Copper *Lycaena phlaeas* Green Woodpecker *Picus viridis* (Source: London Biodiversity Action Plan on Biodiversity Action and Reporting System [BARS], 2008)
Key targets contained within the London BAP	i. All major existing acid grassland sites to be in improving condition and to have restored, or in some cases created, an additional 20 hectares of acid grassland by 2015; ii. Produce a strategic conservation plan for invertebrate fauna (in particular Thames Terrace Invertebrates) found on acid grassland in London by 2010; iii. To promote appreciation of Acid Grassland and its wildlife, using a strong invertebrate theme by 2015.

Table A2.2: Baseline information for heathland

Habitat type	• Heathland
Corresponding Biodiversity Action Plan(s)	London BAP habitat action plan (Heathland) UK BAP Priority Habitat (Lowland Heathland)
Key sites & broad spatial distribution	The majority of heathland habitat in London is concentrated in the south west in the boroughs of Richmond, Wandsworth, Merton and Hounslow. Key sites include: Stanmore Common (Harrow) Poor's Field (Hillingdon) Hounslow Heath (Hounslow) Wimbledon Common and Putney Heath (Kingston upon Thames / Merton / Wandsworth) Mitcham Common (Merton / Sutton / Croydon) Croham Hurst, Addington Hills, Shirley Hills (Croydon) West Wickham, Hayes and Keston Commons (Bromley) Bostall Heath (Greenwich) Lesnes Abbey Wood (Bexley) Chislehurst and St Paul's Cray Commons (Bromley) Two heathland and bog SSSIs are designated in London.
Key environmental processes which maintain habitat integrity	• Heathland supports the greatest diversity of plants and animals (including a diverse invertebrate fauna and a number of characteristic bird species) where management maintains the open nature of the heath and promotes a varied structure of uneven-aged stands of native heathers and other characteristic plants. • It is generally beneficial if all stages of the heather life cycle are present. Without such management, heathland becomes progressively dominated by bracken, gorse and, on wet ground, purple moor grass tussocks. Eventually scrub and trees will invade.
Indicative species which typify habitat	Lowland heath is a historic, open landscape created by traditional land management practices and characterised by low-growing shrubs such as heather and dwarf gorse, with boggy acid pools in damper areas. Common Heather *Calluna vulgaris* Linnet *Carduelis cannabina* subsp. *autochthona/cannabina* Green Tiger Beetle *Cicindela campestris* Bell Heather *Erica cinerea* Cross-leaved Heath *Erica tetralix* Gorse *Ulex europaeus* (Source: London Biodiversity Action Plan on Biodiversity Action and Reporting System [BARS], 2008) Viviparous lizard *Zootoca vivipara*

	(Source: London Biodiversity Partnership, 2006)
Key targets contained within the London BAP	i. Maintain current extent and Improve condition of all heathland sites by 2015. Promote and publicise heathland sites to members of the public ii. Increase extent of heathland habitat by 20ha by 2015

Table A2.3: Baseline information for chalk grassland

Habitat type	• Chalk Grassland
Corresponding Biodiversity Action Plan(s)	London BAP habitat action plan (Chalk grassland) UK BAP Priority Habitat (Lowland calcareous grassland)
Key sites & broad spatial distribution	The majority of this habitat is located in boroughs with areas of underlying calcareous geology including Croydon, Bromley and Sutton. Key sites include: Farthing Downs, Devilsden Wood and Happy Valley, Croydon Saltbox Hill and Jewels Wood, Bromley West Kent Golf Course and Down House, Bromley Only 300 ha of this habitat remain in London. Much of the habitat is protected as Sites of Special Scientific Interest (SSSIs).
Key environmental processes which maintain habitat integrity	• The species-rich plant communities which characterise calcareous grassland and its associated insects and other invertebrates, require active management / grazing / disturbance to prevent over-dominance of rank grass species and succession of grassland to scrub / woodland. • Greater biodiversity within calcareous grassland habitats is promoted by maintaining heterogeneity in the structure of vegetation including areas of taller / tussocky grass (these are important for certain invertebrates); areas of scrub (in particular for breeding birds) and small areas of bare earth (important for reptiles, invertebrates and seed germination).
Indicative species which typify habitat	Pyramidial Orchid *Anacamptis pyramidalis* Quaking-grass *Briza media* Small Blue *Cupido minimus* Yellow Meadow Ant *Lasius flavus* Marbled White *Melanargia galathea* (Source: London Biodiversity Action Plan on Biodiversity Action and Reporting System [BARS], 2008)
Key targets contained within the London BAP	i. Establish and maintain up-to-date records of the extent and status of existing and potential chalk grassland resource in Greater London ii. Maintain and enhance existing, high quality ('key') chalk grassland sites iii. Implement habitat creation or reversion to increase extent of quality chalk grassland in the region

Table A2.4: Baseline information for neutral grassland

Habitat type	• Neutral Grassland
Corresponding Biodiversity Action Plan(s)	Potentially corresponds with London BAP habitat action plan for: - Parks and urban green spaces - Churchyards and cemeteries - Private gardens - a grazing marsh HAP is to be formed in 2009 (P*ersonal Communication*, Richard Bullock[o]). UK BAP Priority Habitat types: - Lowland Meadows - Coastal and floodplain grazing marsh
Key sites & broad spatial distribution	The distribution of unimproved neutral grassland in London is distinctly skewed towards the outer London boroughs with north west London accounting for the majority of this habitat type. Key sites include: Wennington Avely and Rainham marshes, Havering Erith Marshes, Bexley Fray's Farm Meadows, Hillingdon Yeading brook fields, Hillingdon / Ealing Horsenden Hill, Ealing Fryent Country Park, Brent Bentley Priory open space, Harrow Totteridge Fields, Barnet The Royal Parks
Key environmental processes which maintain habitat integrity	• Many of London's semi-natural neutral grasslands were historically managed as hay meadows. The greatest diversity of plants and animals in this habitat type is usually maintained by allowing grasslands to develop through the spring and summer with an annual cut to in late summer to remove a hay crop. This should be after ground-nesting birds have fledged their young and any short-lived, characteristic plants have set seed. • Aftermath grazing (post the summer hay cut) is another technique which is practiced in late summer/autumn. Grazing is important for maintaining a species-rich sward, both through controlling competitive grasses and through hoof-prints providing suitable sites for seedlings to establish.
Indicative species which typify habitat	• Skylark *Alauda arvensis* • Black knapweed *Centaurea nigra*

[o] *Personal Communication* (January, 2009). Richard Bullock. Senior Biodiversity Officer. Wildfowl and Wetlands Trust, London Wetlands Centre

	• Oxeye daisy *Leucanthemum vulgare* • Meadow brown *Maniola jurtina*
Key targets contained within the London BAP	No specific habitat action plan exists for neutral grassland within the London BAP.

Table A2.5: Baseline information for river and streams and associated habitats

Habitat type	• River and Streams and associated habitats
Corresponding Biodiversity Action Plan(s)	Potentially corresponds with London BAP habitat action plan for: - Rivers and Streams - Tidal Thames - Canals - Reedbeds UK BAP Priority Habitat types: - Rivers - Reedbeds
Key sites & broad spatial distribution	Key river systems in London include: Ingrebourne Valley (outer east London) Lea Valley (east London) Lower Colne (outer west London) The River Thames and Tidal Tributaries (west, central, east London) River Cray (south east London) The River Wandle (south London)
Key environmental processes which maintain habitat integrity	• High levels of riverine /riparian biodiversity are associated with high levels of habitat heterogeneity in respect of a river's physical structure and function. High quality nature conservation sites usually therefore exhibit 'natural' flow regimes and a diversity of erosion and sedimentation processes. For example, bars, pools, riffles and associated backwaters all provide habitats for different species. • Physical connectivity is a key feature of riverine ecosystems in promoting high biodiversity. This incorporates the ability of species to move upstream/downstream, physical connections between a rivers and its floodplains and connectivity between different river catchments; • Riparian areas and the wider catchment need to be managed sensitively to avoid excessive run-off of soil particles and nutrients into the river and streams. • Representative areas of semi-natural riparian vegetation showing a gradation from fully aquatic to swamp / wet woodland should be maintained at the catchment scale. • Increased growth of epiphytic algae and planktonic algae can lead to excessive shading of plants, reduced seed germination, enhanced capture of silt.
Indicative species which typify habitat	Species listed under the Rivers and Streams habitat action plan (London BAP): Kingfisher *Alcedo atthis* Eel *Anguilla anguilla*

	Water Vole *Arvicola terrestris* Otter *Lutra lutra* Banded Demoiselle *Calopteryx splendens* Grey Wagtail *Motacilla cinerea* Daubenton's bat *Myotis daubentonii* Stream Water-crowfoot *Ranunculus penicillatus* Species listed under the Tidal Thames habitat action plan (London BAP): Teal *Anas crecca* Grey Heron *Ardea cinerea* Sea Aster *Aster tripolium* Smelt *Osmerus eperlanus* Atlantic Salmon *Salmo salar* Common Tern *Sterna hirundo* (Source: London Biodiversity Action Plan on Biodiversity Action and Reporting System [BARS], 2008) *See also species listed under standing water and associated habitats.*
Key targets contained within the London BAP	*Rivers and streams HAP:* i. To increase and enhance quality of riparian habitats through the prevention of any further loss of existing riparian habitats and the improvement of 100km of riparian habitats by 2020 ii. Restore 15km of river and stream habitat in London by 2015 *Tidal Thames HAP* iii. Create five new areas of habitat in London by 2008 iv. Investigate and implement measures to improve the water quality on the River Lee Navigation and Bow Back rivers by 2010. *Canals HAP:* v. Create 500 meters of emergent and marginal planting (this can include softening piles) by 2009. vi. Develop a strategic and targeted mink control regime along the Grand Union Main Line Canal and the River Lee Navigation by 2008. vii. Carry out five projects to facilitate the movement of otters along the River Lee Navigation and the Bow Back River System in 2007 and 2008. viii. Incorporate two new in channel features to promote fish populations every year. ix. Carry out in partnership at least one large scale project on the Bow Back Rivers, Bow Creek and Abbey Creek by 2010.

Table A2.6: Baseline information for Standing Water and associated habitats

Habitat type	• Standing Water and associated habitats
Corresponding Biodiversity Action Plan(s)	Potentially corresponds with London BAP habitat action plan for: - Standing water - Canals - Reedbeds Potentially corresponds with UK BAP Priority Habitats: - Eutrophic Standing Waters - Ponds - Reedbeds - Wet woodland
Key sites & broad spatial distribution	Numerous ponds are located across London. Other larger standing water sites include: South West London Waterbodies, Ramsar site Brent Reservoir, Brent / Barnet London Wetlands Centre, Richmond upon Thames Walthamstow reservoirs The Grand Union Canal The Hertford Union Canal The Regents Canal
Key environmental processes which maintain habitat integrity	*General* • A mosaic of open water, emergent and fen vegetation, and shallowly sloping banks provides suitable conditions waterfowl, amphibians and aquatic invertebrate. Scattered willow and alder provide additional habitat diversity but excessive scrub and trees can shade out aquatic and emergent vegetation and contribute to the silting up and drying out of lakes / ponds / canals. • Sympathetic management of water levels is necessary for the maintenance of optimal water depths throughout the year (according to the requirements of the plant and animal species present). *Ponds/lakes* • Some ponds/lakes may only contain water during certain periods of the year, or have marked seasonal fluctuations in water level. These seasonally wet habitats are important for a specialised group of plants and animals. • Ponds/lakes often require periodic management to prevent a build up of plants and silt which will reduce water depth and cause a build up of nutrients. However, on a site containing many ponds it may be desirable to maintain a range of ponds in various stages of succession. • The relatively small area and water volume of some ponds/lakes means they are particularly vulnerable to pollution events.

Indicative species which typify habitat	Kingfisher *Alcedo atthis* Water Vole *Arvicola terrestris* Banded Demoiselle *Calopteryx splendens* Grey wagtail *Motacilla cinerea* Daubenton's bat *Myotis daubentonii* Pipistrelle bat *Pipistrellus pipistrellus* Sand Martin *Riparia riparia* Common toad *Bufo bufo* Smooth newt *Triturus vulgaris* (Source: London Biodiversity Action Plan on Biodiversity Action and Reporting System [BARS], 2008)
Key targets contained within the London BAP	*Standing Water HAP* i. To create new standing water habitats in London by 2015 ii. To restore areas of Standing Water habitat across London by 2015 *Canals HAP* iii. Establish and map on GIS the distribution of water vole and otter on the London canals by 2008. iv. Create one habitat feature for reptiles every year. v. Ensure bat roosting opportunities are retained when work is carried out to trees and built structures and two new roosting sites created every year. vi. Promote a variety of bird nesting opportunities creating two new pieces of habitat or installing bird boxes every year (e.g. duck ramps, kingfisher holes (in piles), sand martin boxes and barn owl posts/boxes along the river corridors). vii. Conduct two positive hedgerow management, restoration or creation schemes each year.

Table A2.7: Baseline information for woodland

Habitat type	• Woodland
Corresponding Biodiversity Action Plan(s)	• London BAP habitat action plan (Woodland) • Potentially corresponds UK BAP Priority Habitats: - Lowland Beech and Yew Woodland - Lowland Mixed Deciduous Woodland - Wood-Pasture & Parkland
Key sites & broad spatial distribution	• Woodland habitats are recorded fairly evenly across London. Key concentrations are found at the following sites: • Dulwich and Sydenham Hill Woods, Southwark • Epping Forest, Redbridge / Waltham Forest • Ruislip Woods, Hillingdon • Lesnes Abbey Woods and Bostall Woods Bexley / Greenwich • Highgate Woods, Camden • Trent Park, Ealing • Hainault Forest, Redbridge
Key environmental processes which maintain habitat integrity	• A diverse woodland structure, with open space, a dense shrub layer, and a more mature canopy layer provides habitat heterogeneity for a range of species to exist. • A range of ages and species within and between stands is desirable. For example, dead and decaying wood, such as fallen logs, can provide habitats for fungi and invertebrates. • Both temporary and permanent open spaces benefit groups of invertebrates such as butterflies. • Non-native trees and shrubs (e.g. Rhododendron) may reduce the biodiversity value of woodlands by over-shading the woodland understory.
Indicative species which typify habitat	• Hornbeam Carpinus betulus • Bluebell Hyacinthoides non-scripta • Stag Beetle *Lucanus cervus* • Badger Meles meles • Wild Service-tree *Sorbus torminalis* Nuthatch *Sitta europaea*

	Great spotted woodpecker *Dendrocopos major* • (Source: London Biodiversity Action Plan on Biodiversity Action and Reporting System [BARS], 2008)
Key targets contained within the London BAP	i. To increase extent of woodland habitat in London by 20 hectares by 2015 ii. Increase production, use and markets for sustainable timber and woodland products in London by 2007 iii. Promote knowledge of best practice in woodland management and increase the area of woodland which is managed appropriately by the end of 2007 iv. To protect and conserve London's veteran trees

LITERATURE REVIEW: IMPACTS ON KEY HABITAT TYPES

Rationale for including habitats in the literature review

The following habitat types to be addressed through the research were identified by the project steering group:

- Acid grassland
- Heathland
- Chalk Grassland
- Neutral Grassland
- Rivers and Streams and associated habitats
- Standing Water and associated habitats
- Woodland

The reason for this selection was as follows:

- together these habitats account for a significant proportion of London's biodiversity;
- these habitats, via related Biodiversity Action Plans, are subject to challenging management targets, which could be affected by climate change.
- for each of the seven habitats, examples of key ecological processes and characteristic species are presented in Tables **A2.1** and **A2.7** above. On pragmatic grounds it was not possible to investigate the effects of climate change on all characteristic species within the seven habitats, given the lack of existing studies relating to impacts upon individual species, the complexity in understanding how individual species may respond, and the sheer diversity species present within London. Instead characteristic species were used to guide the selection of appropriate literature to inform how London's habitats may be affected by climate change.

It was decided to exclude 'brownfield' habitats and private gardens from this section of the report. This was based on the following factors:

- threats to 'brownfield' biodiversity are likely be more a function of the urban redevelopment process than climate change. Equally the condition of private garden wildlife relates more to prevailing gardening practices and people's attitudes towards wildlife gardening;
- both private gardens and brownfield habitats are characterised by a high incidence of non-native species and atypical ecological communities which are not commonplace in the wider countryside. Therefore, little published information exists on climate change impacts for these habitats or 'typical' species of gardens.
- private gardens represent a collective term for a variety of different land uses. Accordingly it is difficult to provide a representative commentary on climate change impacts based on any particular habitat type.

However, the high biodiversity value of 'brownfield' habitats is recognised as illustrated by their recent listing on the UK BAP Priority Habitat list ('Open Mosaic Habitats on Previously Developed Land'[98]). Additionally, the biodiversity conservation value of private gardens is often considered to be potentially greater than many habitats occurring in the wider countryside, such as intensive farmed land[99]. Both habitats are also included on the London BAP (wasteland habitats and private gardens). Lastly, these land uses may also function as 'stepping stones' for species movement between other 'semi-natural' habitats (e.g. acid grassland, chalk grassland), something that will be highly significant if species are to be able to adapt to the effects of climate change.

Selection of literature sources

Literature sources to inform the research were identified through consultation with the project Steering Group, by following up citation lists within publicly available literature sources and using internet search engines. The recently published '*England Biodiversity Strategy - Towards adaptation to climate change*'[100] carried out an extensive literature review of potential climate change effects on species and habitats at the UK scale. This document formed a core information source for identification of possible climate change effects on biodiversity at the London scale. All literature sources used to inform this section are referenced at the end of this Appendix.

For each of the seven habitats identified above, literature pertaining to generic impacts (including key environmental processes) and impacts on species characteristic of that habitat in a London context is reviewed. Based on the literature review an assessment of the suitability/feasibility London BAP targets relating to each habitat is provided.

Acid grassland

Climate change impacts on habitat

London's acid grasslands occur on low-nutrient, acidic soils overlying acidic rocks or on free draining, gravelly and sandy soils[101]. Potentially, increased incidence of high intensity rainfall could lead to greater leaching of soil nutrients making these less available to plants. Many acid grassland species are already adapted to conditions of drought stress. It is possible that warmer drier summers may benefit certain species. For example, species such as harebell *Campanula rotundiflora* and heath bestraw *Gallium saxatile* are adapted to conditions of water stress[102]. The MONARCH (Modelling Natural Resource Responses to Climate Change[103]) programme predicted an increase in acid grassland in south-east England often in replacement for wet heathland habitats. English Nature[104] indicate that if warmer/dryer summer conditions prevail this could favour incidence of heather species colonising acid grassland. However, this would depend upon which management regime the habitat was subjected to. Experimental work on the impact of climate change on this habitat is lacking[105].

At the national scale, Berry et al.[106] present results of a modelling study undertaken to explore the effect of climate change (under the UKCIP98 climate change scenarios: UKCIP, 1998) for 54 species representing 15 habitats. A very generalised conclusion of this study was that for *"...lowland heath, wet heath, cereal field margins, coastal grazing marsh, drought-prone acid grassland and calcareous grassland, the species either showed little change or an increase in suitable climate space"*[107]. Whilst the underlying principle behind this research: that drought prone species may benefit from climate change provides some indication of how London's acid grasslands may fare, several factors limit further inferences for London.

There is no current method for downscaling national climate predictions to London[108]. In addition, "little change" of a habitat resource at the national scale (i.e. net change) may conceal dramatic change at the local (i.e. London) scale. It should also be noted that the UKCIP98 scenarios on which the study was based were updated in 2002 and are soon to be further updated. Therefore, the findings may no longer be valid.

Climate change impacts on species characteristic of habitat type

Modelling undertaken by MONARCH at the national scale predicted that some common species such as the common storksbill *Erodium cicutarium* will disappear from acid grasslands as a result of drought, while the Spanish catchfly *Silene otites*, common in Europe but confined to the dry grasslands of in the East of England may spread first to Essex and then to the Midlands by 2050[109]. However, *Mitchell et al.*[110] note that though Spanish catchfly has the potential to expand in England, little is known about its dispersal ability.

As part of the BRANCH project (www.branchproject.org.uk), van Rooij et al.[111], again employing a computer model, simulated the impact of UKCIP02 climate change scenarios[112] on a number of English and Dutch species. This study is perhaps of greater relevance to London as it was partly based on species and habitats found within Kent. As a proxy for the impact of climate change on 'acid grassland / heathland' habitats four Kentish bird species were selected. The status of these species in London is indicated in parenthesis[113]:

- Dartford Warbler *Sylvia undata* (very rare London breeding species, typically found in heathland Sites in the UK);
- Woodlark *Lullula arborea* (this species is typically found in heathland sites in the UK, whilst it has not been recorded within London in recent years it does occur at sites within 20 miles of St. Paul's[p]);
- European Stonechat *Saxicola torquata* (a localised breeding species in London; for example, it is present in Richmond and Bushy parks);
- Nightjar *Caprimulgus europaeus* (not a breeding species in Greater London, however, recorded as a rare breeding summer visitor within a 20 mile radius of St Paul's).

Clearly, the species used in the study bear little correspondence to species typifying acid grassland in London (see **Table A1.1**). Further, they are all species of bird which might be very poor indicators of the habitat requirements of acid grassland plants, invertebrates and reptiles. In addition, modelling of climate space within the model pays very little attention to the availability of suitable habitat across Kent (i.e. climatic requirements are the sole consideration). With these marked caveats in mind, the findings van Rooij et al.[114] reveal an increase in available climate space for all four species between 2007 and 2050. However, for both Nightjar and Woodlark, owing to the fragmentation of existing Kentish populations, the prospect of these species expanding their ranges is highly limited (i*bid.*).

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[p] A 20 mile radius from St. Paul's Cathedral is used as the recording area of the London Natural History Society (Self, 2005).

Acid grassland: evaluation of London BAP targets in view of potential climate change effects

Based on the review of available literature it would appear that the objective to restore and increase the amount of acid grassland in London may indeed be feasible in view of anticipated climatic change. However, the success of habitat restoration/recreation will depend on the ability of existing acid grassland species to colonise new habitat and existing barriers to species dispersal in London. As indicated above, despite the prediction that greater areas of Kent will become suitable for two species of bird through climate change[115] it is considered unlikely these species will benefit from an increase in suitable climate space owing to their inability to disperse to new habitat sites. Similarly, though climate space may appear for certain European plant species as climate changes (e.g. MONARCH), little is known of dispersal in these species thus limiting the predictability of whether new additions to London's acid grassland flora will appear.

There are numerous invertebrates of conservation importance linked with acid grassland habitats in London. No information regarding climate change impacts on these species was identified in the literature review. Further information will be required if a more holistic assessment of changes to this habitat in London is to be completed.

Heathland

Climate change impacts on habitat

In general, as with acid grassland, heathland commonly occurs on free draining sandy soils in London. Indeed the two habitats are often found in close association[116]. Based on the UKCIP02 climate change scenarios projected for 2080, English Nature[117] (now Natural England) suggested that in London *"Suitable climate space should exist for dominant lowland heath species such as heather, gorse and cross-leaved heath."* However, they highlight an increased risk of fire in summer drought conditions (*ibid*). It is suggested that the balance between the three dominant heathland communities of acid grassland, heather *Calluna vulgaris* and bracken *Pteridium aquilinum* will shift as changes in climate affect the relative competitive ability of these species through effects on biomass production and nutrient availability[118]. The competitive balance between heath and acid grassland habitats may also shift as increased decomposition rates in warmer conditions result in increased soil nitrogen levels favouring grass growth[119]. Importantly, Mitchell *et al.*[120] anticipate that the effects of climate change on the dominance of key heathland species is likely to be secondary to the effects of grazing, burning and nutrient enrichment. Finally, referring to the scope for changing heathland plant communities in London, Fitter[121] cites anecdotal evidence of the absence of wild gladiolus *Gladiolus illyricus*, which is localised in the New Forest, but has not spread north to the Hampshire/Surrey border (*ibid*). His inference is that the loss of habitat species from London's heathland sites may not be replaced readily by suitable colonists from the south.

Climate change impacts on species characteristic of habitat

A study carried out by Berry *et al.*[122] as part of the BRANCH project focused on impacts of future climate change scenarios on heathland habitats in Hampshire. The SPECIES[q]

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[q] SPECIES = Spatial Estimator of Climate Impacts on the Envelope of Species

computer model was employed to identify potential impacts on a suite of heathland species which were used as proxies for heathland habitat itself. The model was calculated for five different climate scenarios, again based on UKCIP02 climate data[123]. This included predictions for species distribution for 2020, 2050 and 2080, both nationally and for Hampshire. The study is potentially analogous to the London area for three reasons. Firstly, it is based in south east England. Secondly, a comparison of the species used by Berry *et al.*[124] with important heathland species in London (see **Table A1.8**) reveals some correspondence. Thirdly, heathland habitats in Hampshire are highly fragmented as they are in London (*ibid.*), although much larger habitat patches would be expected in Hampshire. Similar limitations apply with extrapolating the findings of computer modelling studies carried out at the regional scale to London as was identified above for acid grassland. However, accepting these limitations, key finding of Berry *et al.* are that:

- for certain species potential suitable climate space and habitat is maintained into the future. These include wavy hair grass *Deschampsia flexuosa*, sheep's sorrel *Rumex acetosella* and Dartford warbler *Sylvia undata.*

- Silver-studded blue *Plebejus argus* could actually show an increase in the amount of suitable habitat available as this species is able to colonise habitats (e.g. non-south facing slopes) which were formerly too cold for it to breed.

- certain species lose all potential suitable climate space (e.g. bog orchid *Hammarbya paludosa*).

- the study suggests that habitat re-creation could expand the potential range of cross-leaved heath *Erica tetralix*, bell heather *Erica cinerea* and common heather *Calluna vulgaris* given that suitable climate space will exist for these species up to 2050.

- under the '2080 High' projection, climate space becomes unsuitable for the majority of plant species including all Ericaceous (heath) species.

As indicated by **Table A1.8** the effects of climate change differ markedly between species. Certain species are predicted to expand their potential climate space and others to experience a retraction.

Heathland: evaluation of London BAP targets in view of potential climate change effects

If the projections offered by Berry *et al.* can be relied upon as indicative of changes in biodiversity in London, it would appear that the objective of heathland restoration/expansion is indeed viable in the short to longer term (up to 2050). Given highly fragmented nature of heathland in London, the success of recreation schemes will depend on the dispersal powers of different species (e.g. invertebrates, and heathland plants). However, under the '2080 High' scenario (*Ibid.*) it would appear that many species (including species of heath (*Erica* sp. and *Calluna vulgaris*) which are critical to the integrity of the heathland ecosystem) begin to lose climate space. Whilst the 2080 projection represents an extreme climate warming compared with the present, given temperature increases caused by the operation of the urban heat island effect, which is additional to background climate change, it may be valid in a London context. The viability of heathland recreation targets may be questionable in the long term. It is key to note that the effects of climate change on the dominance of key heathland species is likely to be secondary to the effects of appropriate management including grazing burning and nutrient enrichment[125].

Table A2.8: Comparison of the species used by Berry et al. (2007) with species indicative of heathland habitat in London

Species	Taxa	Status in London	Possible impact as a resulting from climate change after Berry et al.[126]
Cross-leaved heath *Erica tetralix*	Plant	This is a species of conservation importance in London.	Hampshire – very minor loss of climate space up to 2050 but potential complete loss by 2080
Bell heather *Erica cinerea*	Plant	This is a species of conservation importance in London.	Hampshire – very minor loss of climate space up to 2050 but potential complete loss by 2080
Western gorse *Ulex gallii*	Plant	*Ulex minor* is of conservation importance in London	Hampshire – loss of potential climate space by 2050 (but very restricted distribution anyway)
Heather *Calluna vulgaris*	Plant	Very important constituent of heathland	Hampshire – very minor loss of climate space up to 2050 but potential complete loss by 2080
Wavy hair grass *Deschampsia flexuosa*	Plant	Important constituent of heathland	Nationally - little or no loss of potential climate space by 2050 and large loss to southern areas by 2080 Hampshire – very minor loss

Species	Taxa	Status in London	Possible impact as a resulting from climate change after Berry et al.[126]
			of climate space up to 2080
Bristle bent *Agrostis curtisii*	Plant	Unknown	Hampshire – very minor loss of climate space up to 2050 but potential complete loss by 2080
Purple moor-grass *Molinia caerulea*	Plant	Important constituent of heathland	Nationally - little or no loss of potential climate space by 2050 and large loss to southern areas by 2080 Hampshire – very minor loss of climate space up to 2050 but potential complete loss by 2080
Common cotton grass *Eriophorum angustifolium*	Plant	This is a species of conservation importance in London.	Hampshire –loss of potential climate space by 2050
Marsh clubmoss *Lycopodella inundata*	Lower plant	Unknown	Hampshire – very minor loss of climate space up to 2050 but potential complete loss by 2080
Green-ribbed sedge *Carex binervis*	Plant	Unknown	Hampshire – very minor loss of climate space up to 2080
Sheep's sorrel *Rumex acetosella*	Plant	Characteristic species of heathland/ acid grassland	Nationally - little or no loss of potential climate space by 2050 and some loss to southern areas by 2080 Hampshire – very minor loss of climate space up to 2080
Bog asphodel *Narthecium ossifragum*	Plant	This is a species of conservation importance in London.	Hampshire – very minor loss of climate space up to 2050 but potential complete loss by 2080
Bog orchid *Hammarbya paludosa*	Plant	Unknown	Hampshire – loss of all potential climate space by 2020
Dartford warbler *Sylvia undata*	Bird	This is a species of conservation importance in London.	Hampshire – climate suitable for this species under all scenarios
Silver-studded blue *Plebejus argus*	Butterfly	Grayling *Hipparchia semele* and Small heath *Coenonympha pamphilus*	Hampshire – slight gains in suitable climate space for this

Species	Taxa	Status in London	Possible impact as a resulting from climate change after Berry et al.[126]
		have different ecological requirements to *P. argus* but are species of conservation importance associated with heathland in London.	species under all scenarios

Chalk Grassland

Climate change impacts on habitat

Plants on chalk grassland are typically short and hardy, and include species tolerant of dry, exposed conditions such as Quaking grass *Briza media*[127]. Broadly, studies investigating the effect of climate change on chalk grassland predict an increase in available climate space for this habitat at the national scale[128], however, the spread of this habitat is obviously limited by the availability of suitable substrates (e.g. underlying chalk geology). Studies on chalk grassland plant community composition indicate a shift to plants adapted to warmer conditions[129]. At the micro scale, an increase in the amount of habitat available to species currently restricted to southern facing slopes has also been documented[130]. Duckworth *et al.*[131] caution that attempts to predict the change in distribution of chalk grassland habitat may overestimate the effect of climate change if they do not take account of interactions between different species and interactions between a species and environmental factors (e.g. soil type and grassland management practices).

The response of calcareous grassland plant communities to climate change appears to be related to the history of the grassland. Fertile or early successional calcareous grasslands composed of fast-growing or short-lived species are more likely to be affected by climate change than older calcareous grasslands[132]. In addition, deep-rooted herbs and short-lived ruderal species will increase on calcareous grasslands under drought, while grasses will only increase if rainfall increases which is unlikely[133]. It might be expected that as the climate changes, the plant community composition of calcareous grasslands will change with an increase in herbs and ruderal species. Referring to chalk grassland plant communities, Fitter[134] is doubtful of the potential for habitat specialist species from southern England to colonise further north, perhaps replacing those that may be lose suitable climate space as the climate warms in London. He cites anecdotal evidence of round-headed rampion *Phyteuma orbiculare*, which is frequently found on the South Downs yet absent from the North Downs (*ibid*).

Climate change impacts on species characteristic of habitat

No studies specifically focusing on the impacts of climate change on chalk grassland in Greater London area were identified. As for heathland, the study by Berry *et al.*[135] provides a useful analogue. A comparison of the species used by Berry *et al.* with chalk grassland species which typify chalk grassland habitat in London reveals good correspondence (**Table A1.9**).

The findings of Berry *et al.* reveal differential effects between the species which were considered. Several broad finding are of relevance:

- For a number of species e.g. kidney vetch *Anthyllis vulneria*, upright brome *Bromopsis erecta*, common rock-rose *Helianthemum nummularium*, dwarf sedge *Carex humilis* and horseshoe vetch *Hippocrepis comosa* little change in suitable climate space was recorded up to 2050. The possibility of restoring habitats for these species was highlighted.

- A number of species are projected to experience loss of all potential suitable climate space in Hampshire by 2020 (e.g. crested hair-grass *Koeleria macrantha*; a London species) and by 2050 (e.g. musk orchid *Herminium monorchis*). In the case of crested hair-grass, this species may form an important constituent of habitat structure within a grasslands or a food plant for invertebrates (e.g. for micro moths). Loss of this single species resulting directly from climate change may have knock-on indirect effects for a range of other species which may have otherwise remained unaffected.

- Lastly, for species such as wild thyme *Thymus polytrichus* and silver-spotted skipper *Hesperia comma* complete loss of suitable habitat space was predicted under the most extreme scenario for 2080.

Chalk grassland: evaluation of London BAP targets in view of potential climate change effects

There are numerous limitations associated with extrapolating results of modelling studies undertaken at the regional scale to London. However, two important points arise from the study by Berry *et al.* in relation to the London BAP. It may be important to identify chalk grassland species which stand to gain suitable climate space. For these species, future potential distribution may be limited more by the availability of suitable chalk substrate and appropriate management than by climate change. Restoration/recreation of chalk grassland habitat may be successful for such species. Conversely, with only moderate temperature increases under the 2020 scenario and further increases under the 2050 and 2080 scenarios[136] increasing numbers of chalk grassland species indicate a decline in all available climate space. If climate change is added to by the urban heat island effect in London, the 2080 scenario may present a plausible indication of likely environmental change.

Further research beyond the scope of this study is required to identify which London species might be destined for inevitable decline in the longer term. This is particularly the case if any of these species perform a 'keystone' function for this habitat (e.g. species of grass). Habitat restoration targets must review the viability of conservation targets for such species in the long-term.

There are several invertebrates of conservation importance linked with chalk grassland habitats in London. Information is required relating to climate change impacts on these species if a more holistic assessment of changes in this habitat in London is to be completed.

Table A2.9 Comparison of the species used by Berry et al. (2007) with species indicative of chalk grassland habitat in London

Species	Taxa	Species occurring in London or possible analogues to species in London	Possible impact as a resulting from climate change after Berry et al. (2007)
Kidney vetch *Anthyllis vulneria*	Plant	Yes	Hampshire – little change in suitable climate space up to 2050
Upright brome *Bromopsis erecta*	Plant	Yes	Hampshire – little change in suitable climate space up to 2080
Dwarf sedge *Carex humilis*	Plant	Spring sedge *Carex caryophyllea*	Hampshire - gains in suitable climate space by 2050 east to the south

Species	Taxa	Species occurring in London or possible analogues to species in London	Possible impact as a resulting from climate change after Berry et al. (2007)
			downs
Common rock rose *Helianthemum nummularium*	Plant	Yes	Hampshire – sever or total loss of climate suitable climate space by 2080
Meadow oat grass *Helictotrichon pratense*	Plant	Yes	Hampshire - loss of potential climate space by 2020
Musk orchid *Herminium monorchis*	Plant	No	Hampshire – potential loss of climate space by 2050
Silver-spotted skipper *Hesperia comma*	Butterfly	No	Hampshire - considerable gains in climate space across to the South Downs by 2050 but potential complete habitat loss by 2080
Horseshoe vetch *Hippocrepis comosa*	Plant	Yes	Hampshire – little change in suitable climate space up to 2050
Crested hair-grass *Koeleria macrantha*	Plant	Yes	Hampshire - loss of potential climate space by 2020
Chalk milkwort *Polygala calcarea*	Plant	Yes and also Dwarf milkwort *Polygala amarella*	Hampshire - gains in suitable climate space by 2050 east to the south downs but potential sever or total loss of climate suitable climate space by 2080
Chalkhill blue *Polyommatus coridon*	Butterfly	Yes and also potentially Dingy skipper *Erynnis tages*, Grizzled skipper *Pyrgus malvae*, Small blue *Cupido minimus*	Hampshire - considerable gains in climate space across to the South Downs potentially up to 2050 but potential sever or total loss of climate suitable climate space by 2080
Wild thyme *Thymus polytrichus*	Plant	Yes	Hampshire – little change in suitable climate space up to 2050 but potential sever or total loss of climate suitable climate space by 2080

Neutral Grassland

Climate change impacts on habitat

English Nature[137] indicate that dominant grasses of neutral grassland including common bent *Agrostis capillaris*, sheep's fescue *Festuca ovina* and sweet vernal grass *Anoxatham odoratum*, should continue to find suitable climate space up to 2080 (based on UKCIP02 climate scenarios). However, they also indicate that other herbaceous species associated with neutral grassland could become stressed by drier summers (*ibid.*). For example, Buckland[138] links the summer drought of 1995 to the development of communities favouring deeper rooted plants. Whilst certain species of grass may prove to be resilient to hotter/drier summer conditions, grass productivity may be substantially reduced[139]. A reduction in the productivity of dominant grassland species might be expected to have knock-on effects for the energy available to herbivorous invertebrates, birds and mammals associated with neutral grassland. Thornley and Cannell [140] used a computer model to experimentally manipulate inputs of carbon, nitrogen and water (as proxies for climate change) into a typical lowland grassland ecosystem. One of their key conclusions was that *"grazing can drastically alter the magnitude and sign of the response of grasslands to climate change, especially rising temperatures*" (p.1). This highlights the prospect that London's neutral grasslands may well respond differently and be affected to different extents by climate change dependent on the prevailing management regime (e.g. mowing, grazing, non-intervention).

Climate impacts on species characteristic of habitat

No sources of literature were identified.

Neutral grassland: evaluation of London BAP targets in view of potential climate change effects

No London BAP targets specifically relating to this habitat were identified.

Rivers and Streams and associated habitats

Climate change impacts on habitat

River corridors and wetlands are of high importance to numerous species of nature conservation importance across London. This is evidenced by the number of riverine/wetland Sites of Special Scientific Interest (SSSIs) in the London/Thames region[141]. Difficulties in elucidating impacts on London's rivers, streams and associated habitats are compounded by the large diversity of species and habitats which potentially fall within the category (e.g. riparian woodlands, reed beds, tidal rivers, streams fed by ground water). In seeking to identify impacts of climate change, it is useful to consider the 'hydrological signature' of a water course/wetland to which species are adapted. The hydrological signature of a water course can be defined as *"the balance between inflows and outflows of water, soil contours and subsurface conditions"*[142]. For example, the development of plant communities is strongly correlated with the individual hydrological signature of each water course/wetland[143]. Mitchell *et al.*[144] identify the following parameters of river systems that may be affected by climate change, these are:

- carbon fluxes;

- alteration of biogeochemical cycles including mobilisation of heavy metals and pesticides[145], nitrogen mineralisation and de-nitrification;
- precipitation patterns (e.g. the amount and spatial distribution);
- river flows – including quantity, timing, duration, frequency. For example, changes in river discharge will lead to changes in the physical habitat available[146]. In addition, the occurrence of summer low flows[147] and flashy high flows resulting from storms may increase.
- river flows – water quality. For example, both physical quality (for example, temperature[148]) and chemical quality (e.g. pH, suspended sediment load);
- the balance of water being stored and released from wetlands. For example, the balance of inflow and outflow from water courses and ground water sources, the balance of precipitation and evapotranspiration;
- biological patterns of activity (e.g. floral/faunal composition);
- sea level rise in tidal rivers. In London this may lead to squeezing of saltmarsh and reedbeds habitats between rising sea levels and immovable coastal/river flood defences;
- altered demand by human populations (e.g. for abstraction or drainage).

Climate impacts on species characteristic of habitat

Changes in river flow regimes, water temperature and water quality can affect the survival, spawning times, reproductive success and growth of invertebrates, freshwater fish, amphibians[149, 150]. Extreme events (drought and flood) may cause physical disruption of habitat and communities through erosion, deposition of sediment and riparian vegetation. With reference to computer modelling carried out on the River Kennet (a chalk tributary of the Thames), Wade[151] predicted the effects of different flow regimes on riverine plant communities. The study highlighted the possibility for a proliferation of epiphytic algae growth in extended periods of summer low flow which could greatly reduce river macrophyte biomass. A high profile impact of climate change may be the potential for a large reduction and eventual demise in numbers of salmon *Salmo salar* as a species associated with the river Thames. Wilby and Perry[152] report a trend for declining numbers of salmon migrating upstream in association with low river flows in hot summers and associated loss of available in stream habitat. In general it is difficult to draw broad conclusion as to changes which may result to freshwater biodiversity through climate change. Wilby and Perry[153] caution against extrapolating the results of regional modelling to local impacts: *"the site-specific response of London's 273 ha of fragmented wetland will ultimately be governed by the water level requirements of individual species"*. A key variable governing how resilient different river systems are to climate change effects is likely to be the degree to which riverine and riparian habitats are fragmented by stretches of highly modified flood plains (e.g. highly urbanised sections) and culverted, channelised river stretches (*Personal Communication*, David Webb)[r].

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[r] *Personal Communication*. January 2009. David Webb. Nature Conservation Technical Specialist. Environment Agency South East, Thames Region.

Although not directly linked with climate change, species richness within areas of several London rivers and streams is already threatened by the presence of invasive alien species. Climate change could further exacerbate these problems by increasing the productivity of some of these invasive species. Key examples include:

- Chinese mitten crab *Eriocheir sinensis* which is associated with undermining of river banks and predation of native white-clawed crayfish *Austropotamobius pallipes*;
- the North American signal crayfish *Pacifastacus leniusculus* which is attributed with the spread of crayfish plague to native white-clawed crayfish;
- floating pennywort *Hydrocotyle ranunculoides* which out-competes many native plants and is attributed with de-oxygenation of water courses;
- feral mink *Mustela vison* which is associated with declines in water fowl species and the water vole *Arvicola terrestris* through predation.

Rivers and streams and associated habitats: evaluation of London BAP targets in view of potential climate change effects

The London BAP specifies targets for the restoration of 100 km riparian habitat by 2020 and 15 km of river and steam habitat by 2015. In addition, there is an objective to create five new areas of habitat associated with the Tidal Thames by 2008. A focus on providing additional high quality functional habitats (rather than specifying target species) is perhaps more realistic given uncertainty regarding the responses of river and wetland species to climate change.

Standing Water and associated habitats

Climate change impacts on habitat

As was noted for London's 'Rivers and Streams' the effects of climate change on associated species of plants and animals will be mediated through the changes to the specific hydrological signature of standing water bodies. For example, cycles of wetting/drying and seasonal water levels. Given the potentially large number of ponds, lakes and canals in London this gives rise to a large number of possible effects. Mitchell *et al.*[154] indicate that water supply mechanisms may affect the vulnerability of wetlands to drying following climate change, with rain-fed (ombrotrophic) wetlands more susceptible to change than groundwater-fed systems. Given that many urban ponds and lakes are man-made the availability of water in periods of drought may be another key determinant of the susceptibility of biodiversity associated with standing water habitats to climate change. The availability of water will be controlled directly by changing climatic variables such as rainfall but also indirectly by competing human requirements for water resources. For example, it may be possible to control water levels in London's network of canals through inputs from reservoirs but this will depend on the demand for drinking water. Mitchell *et al.*[155] cite several studies which infer that climate change may favour the dominance of cyanobacteria in lake and pool phytoplankton communities. This effect was modelled to be at its most pronounce where elevated water temperatures were combined with high nutrient loads such as in urban areas[156].

Impacts on species characteristic of habitat

Mitchell *et al.* report the conclusions of a recent Dutch review[157]: Climate change may lead to the following outcomes for London's standing water habitats:

- Reductions in the numbers of several target species of birds.
- Favour and stabilise cyanobacterial dominance in phytoplankton communities.
- Cause more serious incidents of botulism among waterfowl and enhance the spreading of mosquito borne diseases.
- Benefit invasive species originating from the Ponto-Caspian region.
- Stabilise turbid, phytoplankton-dominated systems, thus counteracting restoration measures.
- Destabilise macrophyte-dominated clear-water lakes.
- Increase the carrying capacity of primary producers, especially phytoplankton, thus mimicking eutrophication.
- Affect higher trophic levels as a result of enhanced primary production.
- Have a negative impact on biodiversity which is linked to the clear water state.
- Affect biodiversity by changing the disturbance regime.

Standing water and associated habitats: evaluation of London BAP targets in view of potential climate change effects

There are numerous London BAP targets associated with this habitat type (see **Table A2.6**). These include:

- creation of new standing water habitats and restoration of areas of standing water in London by 2015;
- restoration of otter populations on the River Lea and the Bow Back River System;
- incorporating two new channel features in London's canals to promote fish populations;
- to carry out one large scale project on the Bow Back Rivers, Bow Creek and Abbey Creek by 2010.

The restoration/creation of new habitats must be guided by the likely future availability of water resources. This would likely include a prioritisation exercise to identify the most sustainable projects. Water bodies for which water supplies can be made available in the long-term are likely to be preferable to those which would require significant resource inputs to sustain a given hydrological regime. An assessment could also be undertaken of which standing water habitats are of highest quality in terms of nature conservation and/or those which support species which are of greatest sensitivity to water level fluctuations to prioritise use of limited water supplies. There is a great deal of uncertainty attached to projecting both future human water resource requirements, future water availability and the specific requirements of individual wetland species. This may complicate actions to plan strategically for habitat restoration/creation. One approach may be to focus on maximising the variety of different types of standing water habitat and the heterogeneity of wetland environments in view of the fact that different communities may adapt better than others but at present we cannot say which these will be[158].

Woodland

Climate change impacts on habitat

A number of potential effects on woodlands resulting from climate change have been identified in the literature, these are:

- Change in rates of photosynthesis: research indicates that young trees typically exhibit a 30-50% increase in biomass production when CO_2 concentration is doubled[159]. This may have a corresponding effect on leaf area, timber quality and the nutritional quality of foliage to insects[160].
- Phenological change: the average leaf opening dates of oak *Quercus robur* and ash *Fraxinus excelsior* have been documented as occurring earlier over a 40 year period in Cambridgeshire[161]. In contrast, beech shows a less marked advance in leafing date (*ibid*.). All three species are key components of London's woodlands. If canopy tree species flower earlier in the year it might be anticipated that less light will be available to woodland ground floras early in the year when these species flower and set seed.

- Temperature change: nationally it is suggested that climatic warming alone may not have a radical effect on British trees as no tree species has its southern distributional limit in Britain[162]. However, negative effects of hot/dry summers on beech *Fagus sylvatica* have been reported in areas where beech is planted on unsuitable substrates, for example, chalk (*ibid.*), which is prone to reduced water availability in times of drought. Temperature change may induce a range of other responses in British tree species. These include: the delay failure of trees to complete winter hardening; the failure of winter temperatures to meet chilling requirements for seed germination; and effects on seed moisture content[163].

- Exposure to weather extremes: increased incidence of storms and increases in mean winter wind speeds may lead to increased incidence of tree fall within woodlands[164]. If winter rainfall increases this may lead to increased waterlogging[165] and reduced soil stability in these areas.

- Incidence of tree pests and pathogens: it is suggested that the responses of tree pathogens and pests to climate change will likely be complex on account of the variety of life strategies these organisms employ. Broadly, plants experiencing stress induced by other means (e.g. drought stress) are more susceptible to pest and pathogen attack. In addition, with reference to insect pests, warmer summers and milder winters may benefit their population numbers[166].

- Change in species composition: Fitter[167] hypothesizes that if global warming, supplemented by the urban heat island effect, induces the northward shift of non-drought tolerant species from Greater London, new scrub communities may emerge in London. It is speculated that novel drought tolerant scrub communities may be based on hawthorn *Crategus monogyna*, however, owing to the slow dispersal abilities of certain native and north European scrub species and their inability to colonise; drought tolerant garden escapes such as Lavender *Lavendula* sp. and bladda senna *Colutea arborescens* may add to London's scrub communities (*ibid.*).

Climate change impacts on species characteristic of habitat

In respect of herbaceous, woodland plants, based on long-term studies undertaken in Buff Wood (near to Cambridge), Rackham[168] suggests that primrose *Primula vulgaris* undergoes a marked decline following 'hot summers'. In the same study, the closely related oxlip *Primula elatior* appears to have declined over the same period, principally, it is suggested through deer browsing and not drought. In contrast to primrose, oxlip being more drought tolerant is able to regenerate more successfully and maintain a more extensive distribution. Rackham[169] recorded no evidence of overall decline in bluebell *Hyacinthoides non-scripta* despite changes in distribution and anecdotal evidence to suggest this species would be affected by climatic warming.

Although not carried out specifically for London, modelling carried out as part of the MONARCH programme Berry, et al.[170] suggests the following birds, all of which have affinities with London woodlands, may experience reductions in their available climate space in future years:

- nightingale *Luscinia megarhynchos* (potentially a species of cultural resonance and one of conservation concern in London restricted to the outer boroughs[171];

- willow tit *Parus montanus* (a probable former London breeding resident[172]);

- nuthatch *Sitta europea* (a common breeding resident[173]).

In relation to trees, Fitter[174] speculates as to the future species composition of London's woodlands in one hundred years time (from 2001) in view of climate change. He suggests that:

- Norway maple *Acer platanoides* - which is already increasing in London may respond further to a warming climate;

- Holm oak *Quercus ilex* - which currently forms woodlands on the Isle of Wight and Exmore coast may colonise as far north as the north downs and south London.

Woodland: evaluation of London BAP targets in view of potential climate change effects

London BAP targets for woodland include:

- to increase the area of woodland by 20ha by 2015;

- increase production and markets for sustainable timber and woodland products.

Based on the literature review, it would appear that the selection of appropriate species of tree may be critical to the success of woodland creation schemes/woodland management. In addition, species able to cope with the future climate in 2015 may be substantially different from those able to cope with climatic conditions in, for example, 2100. Given the long-lived nature of trees the selection of appropriate woodland species for the future needs to consider longer term projected trends.

APPENDIX 3

Case studies illustrating biodiversity benefits of climate change adaptation

Sunshine Garden, London Zoo

Adaptation to:

Flooding	Reduced rainfall	Overheating

Partners:

Thames Water, Environment Agency, Royal Horticultural Society, London Zoo, Mayor of London

Relevant Defra climate change and biodiversity principles:

Integrate adaptation and mitigation measures into conservation management, planning and practice.

Description:

The Sunshine Garden aims to show Londoners how a typical London back garden can be transformed into a drought resistant haven for wildlife. The garden uses recycled materials and features plants which require little water, as well as showcasing water efficient gardening techniques. The Sunshine Garden was displayed at the Hampton Court Palace Flower show in 2006, designed by top garden designer Paul Stone, and was then moved to London Zoo.

Benefits to biodiversity:

The sunshine garden mixes native species and new varieties from the Mediterranean to create a diverse and biodiversity centred garden. To draw wildlife to the garden sea holly, verbascum, hebe, rock rose and buddleia were planted. To attract bees, butterflies and moths, a lavender hedge and chamomile lawn were planted. All of these plants have the added benefit of being efficient water users.

Climate change adaptation benefits (in addition to biodiversity):

The garden demonstrates adaptation to reduced rainfall by showcasing:

- Drought tolerant plants.
- Water efficient technologies to maximise water use – from traditional mulches to rainwater harvesting and water recycling systems.
- Design – the introduction of shady spots, including a pergola with a ‘green’ roof.
- Practise – a change in approach to gardening focusing on simple solutions to the changing climate.

Source(s) and further information:

http://www.london.gov.uk/sunshinegarden/2006.jsp

Dagenham Washlands at East Dagenham

Adaptation to:

Flooding	Reduced rainfall	Overheating

Partners:

The Land Restoration Trust; Environment Agency; London Borough Barking and Dagenham; London Borough Havering.

Relevant Defra climate change and biodiversity principles:

Create ecological networks; Make space for rivers; Integrate adaptation and mitigation measures into conservation management, planning and practice.

Description:

Dagenham Washlands will create c. 53 ha of high quality, multi-functional open space providing an enhanced landscape for local communities, wildlife and businesses within south Dagenham in line with the Thames Gateway Parklands and Greening the Gateway strategies.

The proposed project forms a key part of Environment Agency flood alleviation works, designed to protect £1.5 billion worth of public and private assets and infrastructure from flooding from the River Beam and Gores Brook. It will restore and naturalise sections of the Rivers Beam and Wantz and provide high quality parkland and improved access linking fragmented communities and employment zones to Barking Town Centre. Together with associated streetscape enhancements for existing and potential new communities across south Dagenham, it will create a safe and secure site for local people.

Benefits to biodiversity:

A single management regime, secured through an endowment, will ensure continued access and biodiversity conservation in perpetuity.

Habitat creation or enhancement outputs will include:

- Restoration/naturalisation of 2,500 m of stream channel, including realigning and reprofiling existing channels of Rivers Wantz and Beam.
- Restoration of acid grassland/woodland creation.
- Creation of:
    - 6 ha of wet fen and reedbed.
    - 22 new groundwater ponds.
    - 0.6 ha of dry woodland/ scrub screen planting on boundaries to provide attractive edge and increasing habitat.
    - 0.25 ha of restored acid grassland.
    - 1.5 ha of wet grassland and shrub.
    - 3 surface water ponds.
    - 1 ha of dry woodland.
    - 200 m of hedgerow.
    - 400 m of reedbed.

Climate change adaptation benefits (in addition to biodiversity):
The scheme provides adaptation to flood risk through: • Provision of 30,000 m^3 of flood storage within the Beam flood storage area. • Parkland habitats and infrastructure designed to withstand flooding and climate change. • A more natural stream profile which transmits floodwater downstream more slowly than a concrete channel.
Source(s) and further information:
http://barking-dagenham.limehouse.co.uk/portal/adult_and_community_services/beam_parklands_consultation/beam http://www.landrestorationtrust.org.uk/

Living roof at Ethelred Estate, Lambeth

Sedum roof at Ethelred Estate, Lambeth

Photo credit: © London Borough of Lambeth

Adaptation to:

Flooding	Reduced rainfall	Overheating

Partners:

Ethelred Tenant Management Organisation (TMO), Lambeth Housing, Government Office for London, Apollo London Ltd (contractor)

Relevant Defra climate change and biodiversity principles:

Delivery of ecological networks through urban greening measures.

Description:

Living roofs have been developed on several medium rise blocks on the estate. Sedum plants cover over 4,000 m^2 of roofs, which is the largest area of green roof created through a refurbishment project in the UK. Funding was provided by the Government Office for London, Lambeth Housing and leaseholders as part of a programme of major repairs.

Benefits to biodiversity:

The scheme has created a new habitat for small garden birds and invertebrates.

It also has wider benefits, for example, through slowing rainwater runoff from roofs it helps to reduce the risk of combined sewer overflows which can harm freshwater species in rivers by reducing dissolved oxygen.

Climate change adaptation benefits (in addition to biodiversity):

The scheme provides adaptation to flooding and overheating by:

- Slowing the rate of rainwater runoff from roof surfaces, helping to reduce flooding.
- Reducing the contribution of the buildings to London's urban heat island.
- Increasing thermal insulation of the building, so reducing the risk of overheating to building occupants during summer months.

Source(s) and further information:

http://www.lambeth.gov.uk/Services/HousingPlanning/Planning/EnvironmentalIssues_EXTRA.htm

http://www.london.gov.uk/mayor/auu/docs/living_roof_casestudies.pdf
http://livingroofs.org/livingpages/caseethelredgreenroof.html

Restoration of River Ravensbourne at Cornmill Gardens, Lewisham

Provision of gravel/rock riffles within the channel

Photo credit: The River Restoration Centre

Adaptation to:

Flooding	Reduced rainfall	Overheating

Partners:

The River Restoration Centre, Building Design Partnership (BDP), Lewisham Borough Council, Environment Agency

Relevant Defra climate change and biodiversity principles:

Conserve and enhance local variation within sites and habitats; Make space for the natural development of rivers and coasts; Establish ecological networks through habitat protection, restoration and creation

Description:

Prior to restoration this stretch of urban river flowed through a narrow concrete channel designed to manage flooding. The primary purpose of the restoration scheme was to create an attractive public open space as part of Lewisham's 'Urban Renaissance' programme. The scheme involved removing approximately 100m of concrete banks. Following a process of masterplanning and public consultation, the concrete walls, high steel railings and overgrown vegetation were removed and a naturalistic landscape and river channel design implemented. A series of wooden platforms and steps facilitate river bank access.

Benefits to biodiversity:

Vertical concrete walls were replaced with more naturally graded banks sown with a wildflower mix, whilst marginal areas were planted with native species such as rush and iris. The river bed was lined with puddle-clay to help restore flows. Stream-bed habitat diversity has been increased through the addition of rock and gravels. These will also encourage formation of features such as riffles through natural channel processes. The presence of mallards and moorhens has already been reported at the site.

Climate change adaptation benefits (in addition to biodiversity):

The scheme provides adaptation to flood risk by:

- Creating a more natural stream profile which transmits floodwater downstream more slowly than a concrete channel.
- Lowering open space alongside the river to create additional storage on the floodplain.

Source(s) and further information:

http://www.therrc.co.uk/case_studies/cornmill%20gardens.pdf

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Project partners

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