Watendlath Tarn, Cumbria

11. Standing open water

Climate Change Sensitivity: **High**

Introduction

Climate change is predicted to bring about a range of changes to environmental conditions in lakes and ponds, including shifts in temperature and hydrological regimes. This will bring about changes in the sediment and nutrients delivered to and retained by lakes and ponds. In turn, biological processes will respond to these changes. Some of these changes are already happening and are likely to intensify. The patterns and behaviours of the wildlife associated with our lakes and ponds will change as a result. A range of measures are required to help our lakes and ponds adapt to these changes.

Warmer temperatures will threaten the persistence of some species on the southern edge of their range such as vendace *Coregonus albula*, shelly *Coregonus lavaretus* and arctic charr *Salvelinus alpinus*, and allow other species to spread northwards to new locations within the UK where they can disperse between water bodies, for example dragonflies and damselflies.

Increased temperatures and longer growing seasons may intensify the symptoms of eutrophication, with a greater frequency and duration of algal blooms where nutrient loads are sufficient to support them. This is likely to reduce macrophyte abundance, which will affect the higher trophic levels. There is the potential for mismatches between phytoplankton and zooplankton due to changes in phenology, which may result in zooplankton grazers being unable to control phytoplankton levels. Increased phytoplankton levels will create increased demand for oxygen as the phytoplankton decomposes. This will reduce the oxygen concentration at the sediment-water interface, potentially leading to an increased phosphorus release from the sediment. It has been suggested that climate change may act as a forward switch to a turbid algal dominated state within shallow standing waters.

Even without the increased productivity, higher water temperatures will lead to a reduction in dissolved oxygen concentration, making phosphorus release from the sediment more likely and consequently increasing the nutrient load to the lake from internal sources. Species reliant on well oxygenated water will potentially have their habitat reduced by increased temperatures reducing oxygen concentrations.

Wetter winters and an increase in the frequency of storm events could increase the run-off of silt and nutrients to water bodies, resulting in the increased potential for eutrophication and the potential physical impacts of sediment covering substrates and/or macrophytes. However, wetter conditions can also reduce the water residence time within lakes and increase flushing, which may reduce the concentration of nutrients within a lake, if the water entering the lake has a lower nutrient concentration than the lake water.

Drier summers can have the opposite effect, reducing run-off and thereby reducing nutrient and silt delivery during the summer. Drier summers can also increase retention times and therefore reduce the flushing of nutrients from lakes. Some sites may completely dry out in summer, resulting in the temporary loss of freshwater habitat. However, temporary water bodies still support a range of distinctive flora and fauna.

Drier summers, increased frequency of storms and wetter winters will all result in greater fluctuations in water levels. This will potentially create a wider littoral zone, subject to greater variation in water availability and consequent wave impacts. Whether species can survive the increased stress of these greater water level fluctuations will depend on the extent, speed, timing and frequency of these fluctuations. Fluctuating water levels may also result in increased erosion of both the lake sediments and the shoreline. The magnitude of wave action will depend on lake size, orientation and the extent to which the site is exposed to the wind. As water levels across the wider environment fluctuate, sites previously unconnected may become connected via flood events, and sites which were previously connected may become unconnected during summer droughts. The loss of connectivity will be of particular importance for sites suffering permanent or temporary freshwater habitat loss or change as species will need to migrate to other standing freshwater sites.

Saline intrusion at the coast resulting from rising sea levels will result in affected freshwaters becoming increasingly brackish. This change will result in some water bodies becoming uninhabitable for many of the species they currently support, but they may become more suitable for others. Saline intrusion may also trigger a switch to an algal dominated state.

Standing water systems are under threat from a wide range of non-native species, some of which may be better adapted and spread more quickly in a changing climate. Many of the species whose spread may be facilitated by higher temperatures originate from the Ponto-Caspian region of eastern Europe. These species have already spread into western mainland Europe via a number of routes, most recently the Rhine-Danube canal, and some such as the killer shrimp *Dikerogammarus villosus* have already made their way to the UK.

Climate change also has the potential to affect the pH of standing waters, but this will depend on the hydrological and geological conditions of the site.

Habitat Description

This section provides a short summary of how lake and pond habitats are shaped and how they function. A fuller description is provided in Mainstone *et al* (2016).

Five BAP categories can be considered within the standing waters habitat type. These are: aquifer fed naturally fluctuating water bodies, ponds, oligotrophic and dystrophic lakes, mesotrophic lakes, and eutrophic lakes. Aquifer fed naturally fluctuating water bodies occur over chalk in the Norfolk Breckland and consist of natural water bodies which have an intrinsic regime of extreme fluctuation in water level, with periods of complete or almost complete drying out as part of the natural cycle. They have no inflow or outflow streams at the surface, except at times of very high water level, when temporary out-flows may develop. Instead, they are directly connected to the underlying groundwater system and periodically empty and are recharged via swallow holes or smaller openings in their beds.

Ponds, for the purpose of UK BAP priority habitat classification, are defined as permanent and seasonal standing water bodies up to 2 ha in area. Ponds are widespread throughout the UK, but high-quality examples are now highly localised, especially in the lowlands. In certain areas, high quality ponds form particularly significant elements of the landscape, for example, the marl pits in Cheshire and Norfolk, the New Forest ponds, and the pingos of East Anglia.

The remaining three lake categories contain water bodies greater than 2 ha in size and represent a continuous gradient of productivity. Oligotrophic lakes are the least productive. Their catchments usually occur on hard, acid rocks, most often in the uplands. Dystrophic lakes have peat-stained water and are most often oligotrophic and are therefore included in the oligotrophic lake BAP category, but they can have different trophic statuses. Oligotrophic and dystrophic lakes occur throughout the UK, but mostly in upland parts of the north and west. They encompass a wide range of sizes and depths, and include the largest and deepest water bodies in the UK.

Eutrophic lakes are the most productive and have the highest nutrient concentrations, although naturally these nutrient concentrations would not have been excessive, enabling a range of submerged plants to grow. Eutrophic lakes are most typical of hard water areas in the lowlands of southern and eastern Britain, but they also occur in the north and west, especially near the coast. Mesotrophic lakes lie in the middle of the trophic range and as a consequence have a high botanical diversity. Mesotrophic lakes are relatively infrequent in the UK and are largely confined to the margins of upland areas in the north and west.

The total area of still inland water is estimated at 675 km^2 in England.

Potential climate change impacts

Cause	Consequence	Potential impacts
Sea Level Rise	Saline intrusion	■ Loss of freshwater flora and fauna. ■ Forward switch to a turbid algal dominated state. ■ Increased frequency of flips between saline, brackish and freshwater states.
Increased frequency of storms	Higher intensity rainfall, leading to increased run-off	■ Increased run-off of sediment and nutrients, leading to eutrophication and sedimentation. Sedimentation can reduce recruitment in some fish species such as vendace *Coregonus albula*, which require clean gravels for spawning. Eutrophication has the potential to impact upon the entire food web. ■ Fluctuation in water levels causing erosion by waves over a wider area.
Increased annual average temperatures	Longer growing season	■ Increased likelihood of eutrophic symptoms where nutrient loads are high, with earlier and longer lasting phytoplankton blooms. ■ Possible increased abundance of Cyanobacteria ('blue-green algae') within the phytoplankton community, although this has not always been supported by experimental work, especially in shallow water systems containing macrophytes. ■ Raised phytoplankton productivity causes a reduction in light penetration, competition for carbon dioxide, and a decrease in oxygen concentration as phytoplankton decomposes. This can cause a loss of macrophytes and a loss of those fish which are reliant on high oxygen levels. Benthic organisms may also decline due to inhospitable conditions in the benthos, and eventually zooplankton will decline as there is no refuge from zooplanktivorous fish as the macrophytes have been lost. This will result in an algal dominated turbid lake with reduced biodiversity. ■ Phenology within the plankton community is likely to change with the potential for mismatches between different components of the plankton community, leading to changes in the relative abundance of species. ■ Possible replacement of submerged macrophyte species by evergreen and/or floating macrophyte species. Successful evergreen species may be non-native, such as New Zealand pygmy weed *Crassula helmsii*. ■ Non-native species, especially those which currently have a more southern and/or eastern distribution, are increasingly likely to colonise and expand their range. ■ The reproductive success of introduced and problematic fish species such as the common carp *Cyprinus carpio* may increase as temperatures increase. Some aquatic and riparian non-native plant species may become invasive due to improved winter survival rates. ■ Loss of habitat for cold water species and northward spread of some southern species. Potential for changes in pH due to increased weathering.
	Lower dissolved Oxygen levels	■ Increased likelihood of deoxygenated conditions at the sediment-water interface, leading to the release of phosphorous from the sediment into the water and a risk of eutrophication. As a result, some invertebrate and fish species may find it difficult to survive low oxygen levels.

Cause	Consequence	Potential impacts
Drier summers	Drought	■ Greater water level fluctuations leading to increased exposure of the littoral zone (causing stress for some aquatic plant species) and leading to increased erosion lower down the littoral zone. Encroachment of marginal emergent vegetation into the water body. ■ Drying of the marginal vegetation at the outer edge. ■ Longer and more frequent drying out of shallow/small water bodies. While drying out is detrimental to some species, other species such as the tadpole shrimp *Triops cancriformis* thrives in such conditions. ■ Loss of physical connection with other freshwater and wetland habitats. ■ Potential for changes in pH due to changes in hydrological conditions.
	Decreased summer flushing/longer retention times in summer	■ Increased nutrient concentrations within water bodies, potentially making it harder to recover from eutrophication.
Wetter winters	Flooding	■ Flooding higher up the shoreline, resulting in increased erosion of the shoreline as water levels rise and displace the usual drawdown zone. ■ Increased run-off, sediment and nutrient delivery, leading to sedimentation and eutrophication. ■ Increased winter flushing and shorter retention times in winter, potentially reducing nutrient concentrations lakes in winter if the water entering the lake has a lower nutrient concentration than the lake water.

Adaptation responses

Action to promote adaptation within standing waters needs to take place at a range of scales both within the water bodies themselves and within their catchments. Reducing non-climatic sources of harm can help to increase resilience. This should include reducing nutrient and sediment loads, reducing water management pressures (e.g. abstraction, water diversion/transfer) and controlling non-native species.

Establishing ecological networks and ensuring hydrological connectivity is maintained between naturally connected sites is important to allow species to migrate between sites in response to climate change. However, many standing waters are naturally isolated and artificially connecting such sites may have detrimental effects. These include the easier movement of non-native species and the movement of pollutants into previously unpolluted water bodies. The standing water ecological network can be enhanced by the creation of additional ponds, as they act as stepping stones between standing water sites. In contrast, it is much harder to create new lakes, although there may be some opportunities where minerals have been extracted.

Habitat heterogeneity is important to allow species to respond successfully to some of the difficulties associated with climate change. Examples of heterogeneity in standing waters include ponds at varying stages of succession and with varying depths and permanence of water, and lake shorelines with natural process of succession and patterns of species zonation.

While all standing water sites will be subject to the influences of climate change, those away from the coast may provide refugia for species which would otherwise be subject to saline intrusion. Coastal Habitat Management Plans (CHaMPs) will help identify where saline intrusion at freshwater sites is inevitable. In these situations, additional habitat creation inland should be considered. This is most practical for coastal ponds. If species of conservation concern with poor dispersal ability inhabit the at-risk sites, assisted migration will need to be considered. However, this needs to be incorporated into long term planning before saline intrusion occurs.

Some of the potential adaptation options for this habitat are outlined below:

In the catchment

- Improve natural infiltration of catchment soils and percolation to groundwater, by restoring soil organic matter levels and avoiding soil compaction and capping.
- Create semi-natural vegetation such as woodland and grassland along critical run-off pathways to slow surface water run-off and aid infiltration of water into the soil.
- Make sure that any crops grown are appropriate to the erosion sensitivity of the land in order to minimise erosion and siltation of water courses.
- Restrict nutrient (nitrogen and phosphorus) applications to crops to the minimum necessary for healthy growth, based on methods with high uptake efficiencies.
- Use low-nutrient livestock feeds with high efficiencies of nutrient uptake.
- Use Coastal Habitat Management Plans (CHaMPs) to assess which sites are at risk from saline intrusion and whether habitat creation or assisted migration is required.
- Replace lost habitat and provide stepping stones to allow species to move through the environment where appropriate via the maintenance of the existing ponds and the creation of new ponds. The Wetland Vision (Hume, 2008) includes the aspiration to double the number of ponds in the next fifty years, and includes maps identifying areas suitable for pond creation.
- Lakes are a relatively fixed resource in England; their distribution being fixed by past glacial activity and other topographical features, but there may be some opportunity to create new lakes where minerals have been extracted.

The standing water body

- Manage pollutant loads from effluents to minimise impacts on the natural nutrient status and to minimise concentrations of toxins.
- Maintain or restore lake marginal habitat and emergent structure to provide areas protected from wave action.
- Maintain or restore the natural hydrological regime including action that reduces drainage of surrounding wetlands and allows natural water level fluctuations and flushing rates.
- Optimise shoreline tree cover to provide some areas of shade. While shading reduces plant growth in standing waters, an ample supply of woody debris and leaf litter is beneficial to some species, and buffers against rising water temperatures, and therefore a limited amount of shade is beneficial.
- Manage access and leisure activities to minimise impacts and increase resilience.
- Promote good biosecurity to slow the spread of invasive non-native species and minimise their chances of colonising the water body and control damaging species already present.

Relevant Countryside Stewardship options

Many of the actions outlined above can be supported by Countryside Stewardship. The most relevant Countryside Stewardship options relating to catchments are the soil and water options. Their main aim is to reduce soil erosion and nutrient inputs, but they often work by reducing surface run-off, thereby improving infiltration rates. Further incentives for agricultural erosion and nutrient control are provided by the **Catchment Sensitive Farming** scheme. More direct water body management can be supported by the capital item WN7 for restoring large water bodies, the pond management options WT4 & 5 and capital items WN5 & 6 which can be used for pond restoration or to create new ponds. These options can also be used for controlling damaging species. In addition, fen creation and management options (WT8 and 9) may also be used to help establish a natural hydrosere[4] and reduce drainage of transitional land. A range of options for restoring semi-natural habitats in the catchment can be used to support adaptation measures involving reducing impacts from the catchment.

Others actions may be supported by water-related funding streams, particularly Water Framework Directive implementation, Flood Risk Management budgets, and the water industry's Asset Management Plan (AMP) process.

Relevant case study examples

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4 A hydrosere is a plant succession which occurs in an area of fresh water. In time, an area of open freshwater will naturally dry out, ultimately becoming woodland

Aqualate Mere NNR, Staffordshire. ©Natural England/Mel Brown

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