Lakes, water levels and climate change

Climate change will impact on lakes and their associated wetlands. While much research is being undertaken on the potential effects on temperature and nutrient cycling in lakes, the major issue of water levels is being ignored.

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Climate change and lakes

Global climate change is here, increasing and already affecting ecosystems throughout the UK. Considerable research effort is being put into predicting the impacts it will have on regional weather systems, including rainfall patterns, temperature regimes and extreme events. Based upon these studies, the potential impacts on species distributions are being modelled and the likely effects on biodiversity and nature conservation are being gauged.

Much of the research on wildlife has been focussed on those species and habitats that are perceived to be particularly at risk from the effects of climate change or those already recognised as being of higher conservation value in the UK Biodiversity Action Plan. These include such features as montane communities, chalk rivers, groundwater wetlands and butterflies. Much effort is being put into these and rightly so. However, are there also species or habitats that are simply overlooked, and are there insufficient data and tools available to address them? This article suggests that lakes are currently being neglected, especially in respect of the potential changes to their hydrology that will result as a consequence of climate change.

The following three points provide important context to a consideration of lakes, water levels and climate change:

First, climate change will alter rainfall patterns in most areas of the UK. In many areas, this will result in increased winter rain, less summer rain and greater evapotranspiration rates. In effect, there will be more water available in winter and less in summer[1].

Second, hydrology and the hydroperiod of lakes and other wetlands, is the most critical factor in determining the ecology of these systems and their nature conservation value, according to Weller[2] and other authors. In addition, a Ramsar Convention report[3], states that "it appears that climate change will have its most pronounced effect on wetlands through alterations in hydrological regimes: specifically, the nature and variability of the hydroperiod and the number and severity of extreme events".

Third, very few studies have investigated the seemingly obvious changes that will result to water levels in water bodies and the impacts this may have on

biodiversity, although a great deal of research is being conducted into low-flows in rivers and the potential for groundwater reductions in fens.[4]

The water levels conspiracy

What research has been produced on lake impacts and reported at conferences, in technical documents and in journals, covers changes to water temperatures, nutrient availability, ice cover, oxygen levels and the resulting effects on open-water plankton and fish communities. However, a review of the main publications relating to climate change impacts shows that water levels are very rarely mentioned. Nothing considers the hydroperiod and the potential effects of this on the highly important marginal communities of plants and animals present at the shoreline interface between water and land. For a country with a well-established history in limnology, this apparent lack of interest from the UK scientific community does seem strange. For those who enjoy conspiracy theories, the following evidence, relating to the findings of the climate change research programme (UKCIP), the Environment Agency and others, might start to raise questions.

In the proceedings of a recent Institute for Ecology and Environmental Management conference on the practicalities of climate change[5], lakes are only mentioned twice - in relation to stratification regimes and ice cover. Rivers in contrast get 18 mentions. Even at the recent final conference of the Euro-Limpacs programme – a programme of research to investigate the impact of climate change on European freshwater ecosystems – the presentations were on the effects of temperature increases on eutrophication and similar problems, with water levels not being raised at all as an issue. This lack of attention has been prevalent for some time. The 1998 International Conference on Climate and Water[6] had *"relatively few papers related to lakes, either their hydrological or ecological aspects"*. Considering that the meeting was held in Finland, a country with thousands of lakes, this finding was rightly thought to be *"surprising and somewhat alarming"*.

One of the main programmes of research that would be expected to shed some light on the impacts of climate change on wetlands is the MONARCH project.[4] This states that *"many wetland habitats and species are of national and international significance for conservation. It is therefore important to understand how they might be affected not just by climate change... but also by changes in water levels"*. It pledges that its research will provide *"information on the potential impacts of climate change on the seasonal variability of pond levels, and associated effects on those species whose breeding and life-cycle patterns depend upon it"*.

The MONARCH authors identify that increased water balance in winter and decreases in summer could increase winter flooding and summer drying of wetland habitats, potentially leading to changes in species and habitat composition. The freshwater section of the report concludes, reasonably enough, that these seasonal changes could be significant to raised bogs, wet heaths and coastal dune slacks. It also goes on to say that acid grassland, beech woodland and some chalk grassland species could be affected, but makes no mention of any

swamp or lake habitats. The key case-study in the freshwater chapter of the report is of Upwood Meadows National Nature Reserve, investigating groundwater levels of this wet meadow site (NVC MG5 and MG9, ridge and furrow on boulder clay) and the potential effects on greater burnet, adder's-tongue fern and celery-leaved buttercup, which the study classes as "wetland species". The choice of these species in the context of a study on freshwater impacts is unusual. Greater burnet and adder's-tongue fern are identified as preferring water levels at least 20cm below ground and would be considered by most to be grassland, rather than wetland species. In addition, celery-leaved buttercup is an annual plant, typically colonising bare-mud areas. As a result, increased water level fluctuation is likely to be of benefit to the species, rather than a detriment. Finally, only one of the five dipwells on the site ever records water levels above ground level. Despite these potential drawbacks, the authors are able to make the groundbreaking revelation that it is important to take hydrological changes into account (not just climate space for individual species) when considering the potential impacts of climate change on wetlands!

Bearing in mind the overriding importance of hydrology for the ecology of lakes and other wetlands, we can move on to the Environment Agency. As part of the characterisation process required to deliver the Water Framework Directive, the EA carried out a risk assessment to identify those waterbodies that were at risk of failing to achieve good status as a result of pressures including 'abstraction and flow regulation'.[7] For rivers, every identified waterbody in England and Wales (a total of 5,868 stretches) was assessed for abstraction pressure, with 11% at risk from failure. In stark contrast, for lakes, where there are 432 waterbodies identified, only 114 (26%) were assessed for this pressure. Of those assessed, 8% were considered to be at risk. Given the potential synergy between climate change and demands for water, the fact that 74% of lakes have not been assessed for abstraction pressure is astounding, especially when set against assessments for the other pressures of alien species, diffuse and point source pollution, and morphological impacts, which show that between 9.3 and 59% of lakes are at risk. The method by which lakes were assessed in this risk assessment also expressly concentrated on impacts of abstraction on residence time, excluding consideration of the potential consequences for water levels as apparently "residence time is considered to be the most important factor influencing the ecology of lakes in England and Wales". This may be true in some respects, but for lake littorals and marginal wetlands (where much of the ecological interest lies in these systems), wind/wave action and water level fluctuations are far more important.[8]

A review of the literature will show up many more examples of where climate change impacts on lakes are considered, but water levels never get a mention. Is this simply due to researchers continuing their previous interests and slotting these into a climate change framework? Is the lack of existing research on the impacts of water levels on ecology in the UK holding back new work in this area? For example, the MONARCH report states that "concerning the seasonality of water level changes, little is known about its effect upon wetland plants". This statement is unfortunately indicative both of the lack of research on the subject in the UK and the level of

A reservoir shore indicating the parched conditions.
Photo: Carlos Abrahams

ignorance of the available published information from abroad on the interaction between water levels and ecology – a point highlighted by various authors.[9]

A light in the dark

Despite the general lack of research in this area, there are exceptions that prove the rule. The aforementioned Euro-limpacs project did also produce some material relevant to the subject. One of the research projects[10] provided evidence that water level changes would have significant impacts on the vegetation communities of lakes and reservoirs, perhaps with the replacement of existing perennial vegetation communities with annual species and with the loss of important isoetid (quillworts) communities.

A handful of other studies (none from the UK) also indicate water level fluctuations resulting from climate change would be likely to impact on phytoplankton[11], amphibian populations[12], aquatic invertebrates[13] and other aspects of biodiversity.[14] Although these few European and US studies are available, we don't really need fancy statistics and computer modelling to tell us that hotter, drier summers will produce drought conditions and large drawdowns in waterbodies around the country. We only have to think back to the dry reservoirs and water shortages in 1995 and 1996 to understand that. If we could look back to our biological records for those years and the following seasons, perhaps they might give us some idea of future changes?

Implications for nature conservation

Common sense, together with the available evidence, tells us that water level fluctuations will alter as a result of climate change and will affect the ecology of waterbodies and their marginal wetlands. But does this really matter in terms of nature conservation and biodiversity? Of course it does. The dynamics displayed by water level fluctuations over time, dictate the chemical and physical character of wetland water, the resulting vegetation, and the use of wetlands by birds and other aquatic or semi-aquatic life.[2] Birdwatchers will know that drawdown zones created by seasonal fluctuations in water level are of great importance for waders on autumn migration and botanists will be familiar with the mudwort and shoreweed communities present in these locations. Plantlife has recently highlighted the importance of reservoir shores for rare bryophytes such as *Weissia rostellata*.[15] Invertebrate surveys have also identified that a rare and specialised suite of beetles make use of these habitats. Lastly, close to 200 reservoirs are designated as SSSIs (and SAC/SPAs) for their nature conservation interest, along with many more designated at local levels. These will all be affected by altered hydrology as a result of climate change.

Research and adaptation

To state the obvious, if there is no research on the impacts of climate change on water levels, how can we possibly develop suitable adaptation measures for our lakes and reservoirs? The most pressing requirement, therefore, is for a decent level of study that will identify the ecological and biodiversity consequences of changes to water level regimes. Climate models are not sufficient to determine impacts on wetlands. There needs to be development of hydrologic models and testing of these against historical and new empirical data to allow prediction of ecosystem effects. In particular, the interactions between terrestrial and aquatic phases in fluctuating waterbodies need to be taken into account. One of the stated reasons for lack of research in this area is the lack of water level data for lakes. This needs to be remedied quickly. Long-standing records exist for many reservoirs around the UK. These need to be accessed, together with related biological data. In addition, year-round monitoring programmes need to be implemented across a number of new sites to allow the detection of future trends. The series of lake SSSIs that are not managed for water supply would be a good place to start.

Adaptation measures will follow from the research, and are likely to cover two main areas. Firstly, catchment-scale approaches will be needed to address issues such as water conservation, abstraction management and land-use practices. Interlinking of waterbodies might be needed, with 'sacrificial' reservoirs being used to maintain a high water level in sites where that is needed. An increase in overall wetland area would also help to ameliorate impacts at individual locations. Secondly, adaptation measures can be implemented at a site level, to protect high value biodiversity sites. These may focus on issues such as hydrological management, protection of shoreline substrates, reforming shoreline topography and the potential need for vegetation establishment[16], alongside pollution control and altered fisheries management.

All these measures will require coordination and integration, through processes such as the River Basin Management Plans required under the Water Framework Directive. They would also need to be undertaken together with measures to maintain water supply, flood control and navigation, competing against the varied requirements of these other interests. To be able to do this, we need first to understand, and then to plan for action. At present, we can do neither.

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