Reservoir water management

UKCEH

Introduction

UKCEH scientists' novel monitoring techniques and innovative capabilities provide data and solutions to drive effective reservoir water management practice.

Reservoir management challenges

Reservoirs are essential assets for water companies, offering a means to stabilise water availability, manage water supply and prevent flooding. Over time, their use has significantly evolved beyond their original function to encompass energy production and irrigation.

Managing reservoirs is complex in nature, requiring close monitoring of water flows and pollution levels. As climate change and population growth impact water availability, water companies are facing ever more formidable challenges.

UKCEH scientists' novel monitoring techniques and innovative capabilities provide data and solutions to drive effective reservoir water management practice.

Picture credit: Stephen Maberly

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Modelling future scenarios to prevent reservoir failure

UKCEH has pioneered a scenario modelling approach to inform water companies' mitigation plans and alleviate the risks of reservoir failure.

CAPABILITY:

Modelling future scenarios to prevent reservoir failure

Effective reservoir management involves building in flexibility to overcome both established and emerging challenges.

How resilient are current filtering systems against longer lasting issues caused by different types of algal blooms?

How adaptable are they to consequences of climate change?

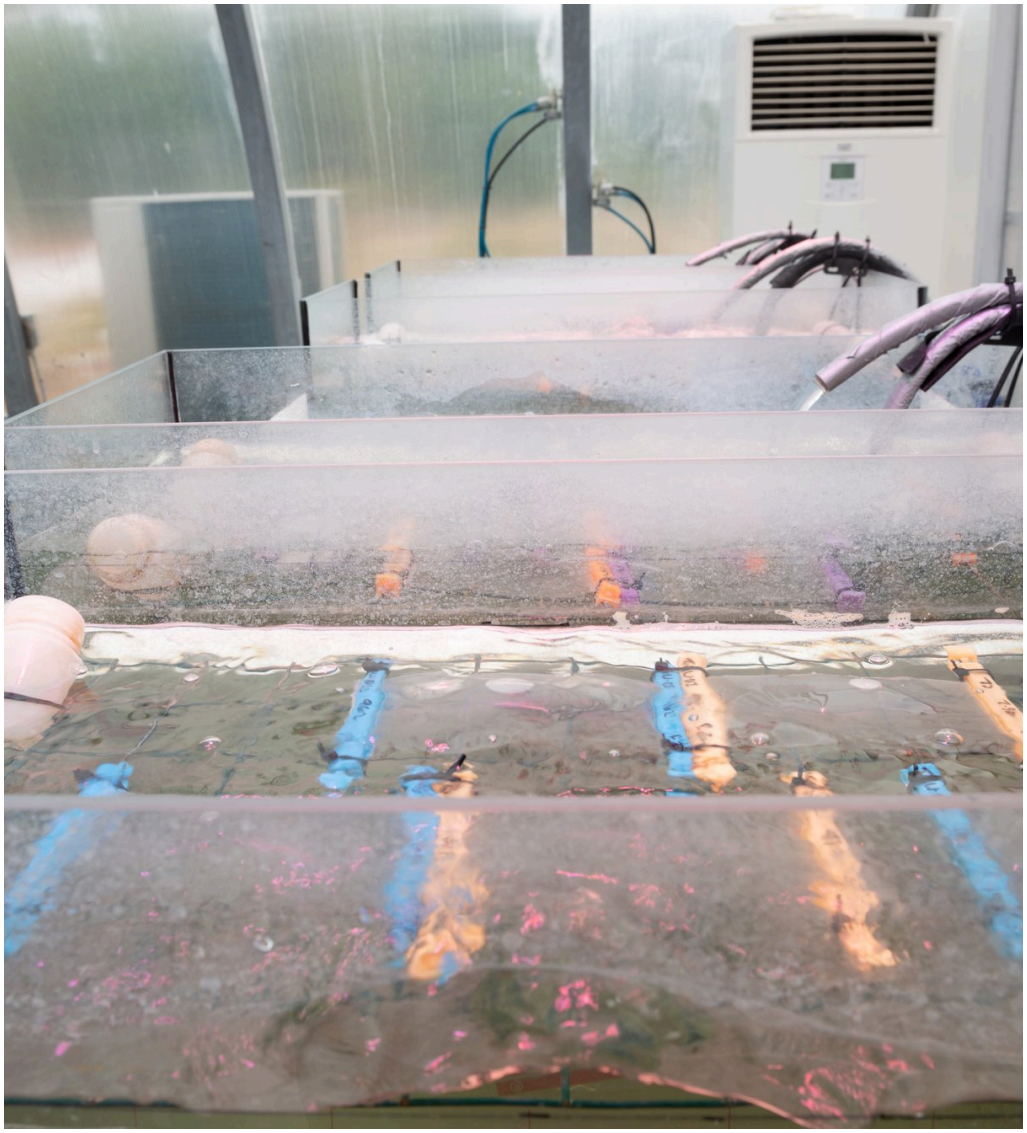
UKCEH has pioneered a scenario modelling approach to inform water companies' mitigation plans and alleviate the risks of reservoir failure. By simulating various environmental stressors and operational scenarios, water companies can also optimise and test reservoir design before finances are committed and construction commences.

TOOL:

PROTECH model

Our PROTECH model (Phytoplankton Responses to Environmental Change) simulates the dynamics of phytoplankton in lakes and reservoirs, and can be used to predict the daily growth patterns of mixed phytoplankton communities, including filamentous algae and cyanobacteria (commonly known as blue-green algae). The model generates comprehensive data, which can be broken down into different groups of interest e.g. taxonomic distinctions (diatoms, cyanobacteria) or size related categories (filter blockers/penetrators), allowing for targeted analysis and insight.

PROTECH has been used to research climate change impacts, including drought occurrences and temperature increases, as well as to assess changes in catchment nutrient inputs for UK water companies, including Thames Water, Welsh Water, Scottish Water and Yorkshire Water.



CASE STUDY:

Testing extreme drawdown in drought

Drought conditions can place extreme demands upon reservoirs, leading water supplies to be depleted to very low levels not encountered during in typical operating conditions. UKCEH scientists conducted research to investigate the impact of such low water levels on the algal communities of five Thames Water reservoirs. Employing the PROTECH model, they simulated the effects of extreme drawdown conditions, generating data to refine the size classification of filter blockers and penetrators and highlighting key issues.

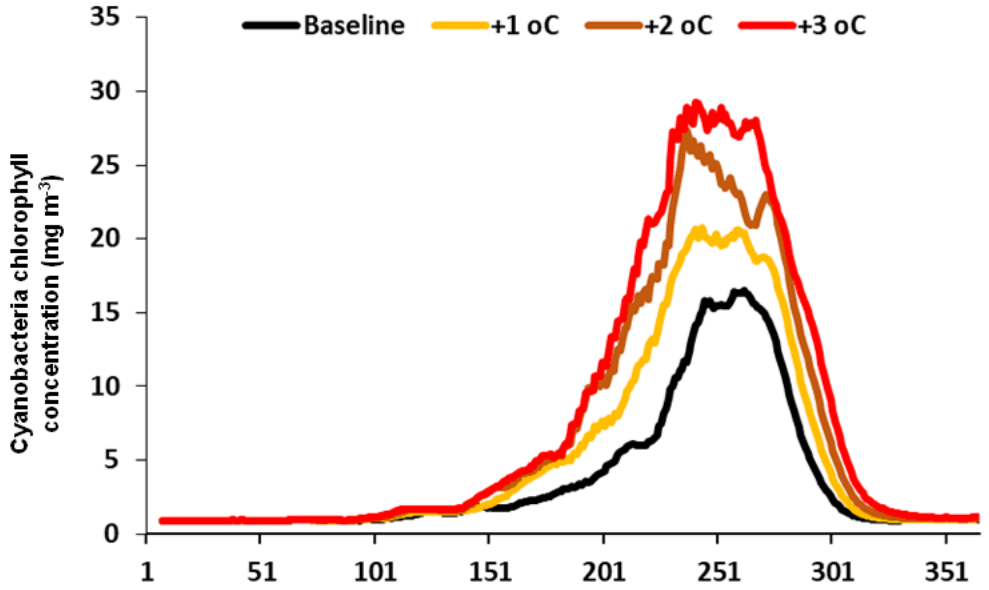
The analysis revealed critical insights such as: blockers cause the Rapid Gravity Filter (RGF) mechanism used in the treatment works to malfunction, whereas penetrators are small enough to pass through the filter and enter the works. Modelling scenarios showed that penetrators can thrive in conditions of extreme drawdown, exacerbating the likelihood of operational issues within the treatment works . Reservoir managers can use these insights to be vigilant for this effect and respond accordingly.

CASE STUDY:

Testing impact of alternative water sources and climate change

Algal-related water quality problems in reservoirs are often caused by nutrients entering the reservoirs, triggering harmful causing blooms. To address this challenge, one possible solution is to use alternative water sources with lower nutrient concentrations.

Our team of scientists used the PROTECH model to test this proposed strategy and extended it to evaluate its sustainability as air temperatures rise. Our analysis confirmed that using the low-nutrient water sources improved the reservoir water quality, but raising temperatures generated a marked increase in the duration and magnitude of cyanobacteria blooms, (see figure).

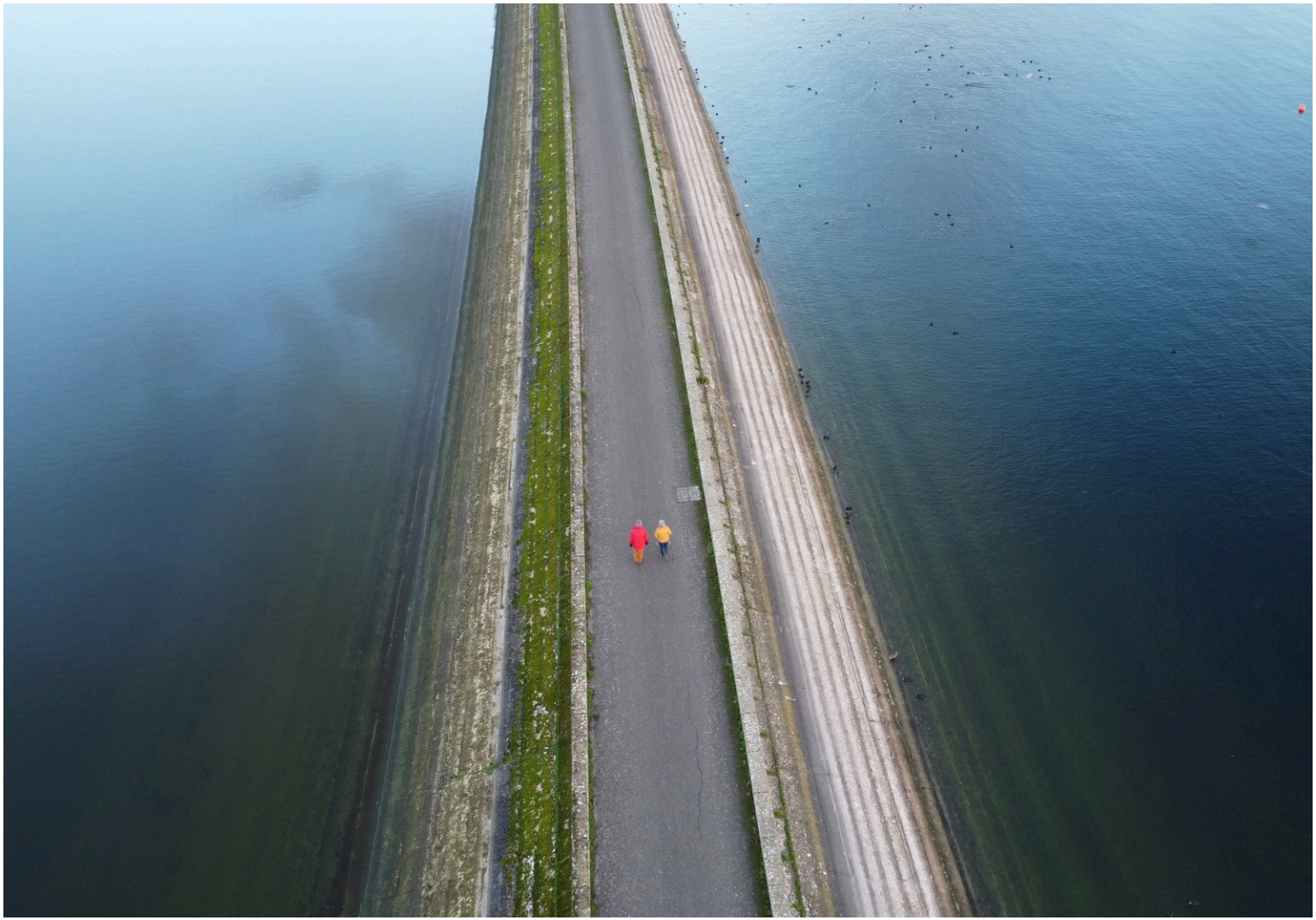


Effect of increasing air temperature on cyanobacteria biomass

CASE STUDY:

Testing new reservoir designs

Our scientists provided Thames Water with relevant data to test the design of a new reservoir prior to construction. Their goal was to optimise both the structural design and operational procedures in order to minimise potential problems. They were primarily interested in the impact of the design on algal bloom formation, but were also able to use the PROTECH tool to extend the research to assess the effects of various water pumping strategies.



UKCEH

Monitoring reservoir water quantity

Our scientists have developed models to monitor and predict water availability at the basin scale.

CAPABILITY:

Monitoring reservoir water quantity

Reservoirs are crucial in preventing water shortages. The regular and accurate management of the water they store is becoming even more critical as climate change amplifies evaporating water loss and alters rainfall patterns.

Our scientists have developed models to monitor and predict water availability at the basin scale. These models take account of the relative impact of reservoirs, water usage across different sectors and the effects of environmental change.

CASE STUDY:

Stars4Water project

UKCEH scientists are leading the improved representation of reservoir operations as part of the Horizon Europe Stars4Water project. We are combining data-driven approaches with process-based modelling to better quantify the impact of reservoir behaviour on water resources management.

We are working with multiple international partners to develop an innovative data-driven methodology which will explore future changes in reservoir storage. This methodology has the potential to incorporate trends in associated sectoral demands, offering valuable insights to inform future reservoir management planning.

Visit the Stars4Water project website

DATA:

Reservoir and lake water level and storage catalogue

As part of the Copernicus In Situ (COINS) project, UKCEH scientists have collated a metadata catalogue showcasing freely available in situ water level and water storage data for reservoirs and lakes worldwide.

Such data are essential for accurately modelling hydrological systems, simulating current operations, and forecasting future water demand and use. There is also a growing requirement for water body data to validate earth observation (EO) products, such as water level products from the Copernicus Global Land Management Service.

The catalogue represents a significant step towards increasing knowledge about the status of water bodies globally, as well as promoting awareness of data products which have the potential to further inform planning around water resources management at the basin scale.

Monitoring reservoir water quality

Our scientists collaborate closely with water companies to monitor and understand changes in reservoir water quality, providing future projections to inform planning and suggesting solutions for effective treatment.

CAPABILITY:

Monitoring reservoir water quality

Maintaining good water quality in reservoirs presents numerous challenges, including sediment accumulation, inputs of organic matter, nutrients and pollutants, as well as taste and odour issues and algal blooms. These challenges can lead to increased water treatment costs and regulatory compliance issues for water companies.

Our scientists collaborate closely with water companies to monitor and understand changes in reservoir water quality, providing future projections to inform planning and suggesting solutions for effective treatment.

CASE STUDY:

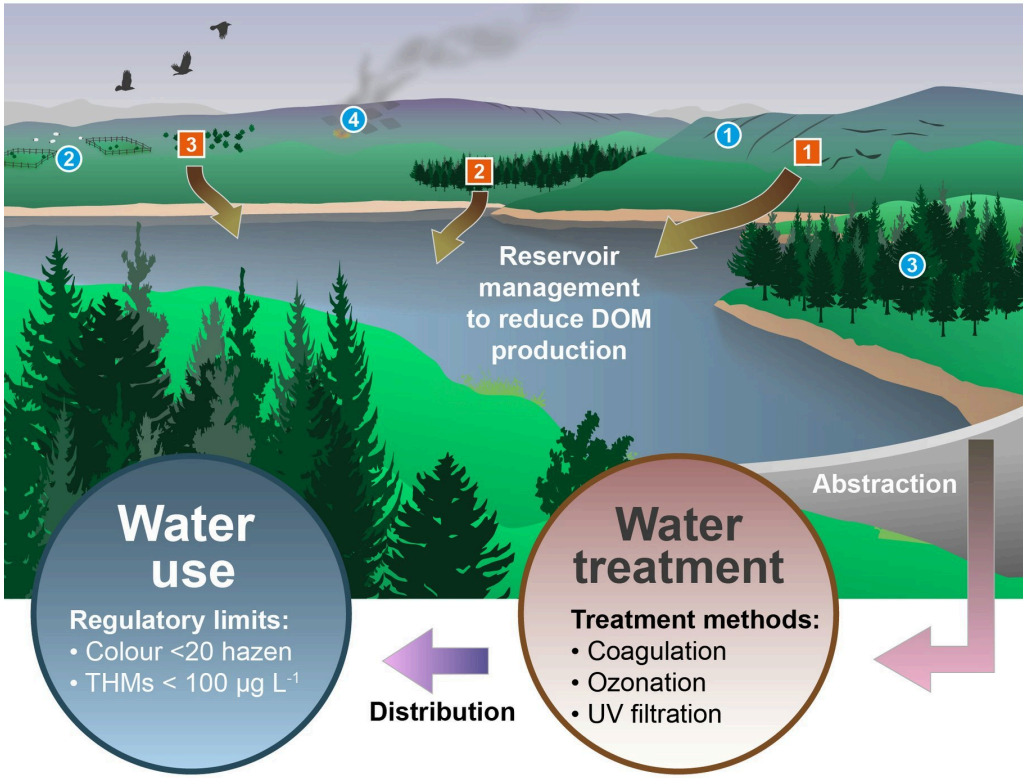
Reservoir management to reduce DOM production

UKCEH scientists led the FREEDOM project and its follow-on project FREEDOM-BCCR, supported by NERC and Scottish Water, which explored the impact of increasing concentrations of Dissolved Organic Matter (DOM) in catchments and strategies to mitigate them. Reservoirs draining peatlands and coniferous forests, and those subject to excessive algal production, can exhibit anomalously high concentrations of DOM.

Our scientists worked with Scottish Water to understand the underlying causes of recent widespread increases in DOM in their reservoirs. They also explored the potential for interventions such as peatland restoration within catchments and reservoirs to relieve stress on water treatment system, guiding decisions about potential investment in treatment plants.

Research highlighted the complexity of controlling DOM concentrations in reservoirs. Some treatments targeting DOM but not nutrients had the potential to exacerbate in-reservoir DOM production. Conversely, alternative measures may prove more effective in nutrient-rich systems. This kind of research informs water companies' decisions about water treatment systems, processes and costs.

Anthropogenic land use pressures affecting dissolved organic matter (DOM) export from peat



DOM inputs:
1. Exposed and degraded peat
2. Forest litter
3. Differential release from vegetation types

Catchment management to reduce DOM inputs:
1. Peat restoration by blocking drainage ditches
2. Create conditions that allow *Sphagnum* growth
3. Restore conifer plantation to bog
4. Reduce moorland burning and risk of wildfires

TOOL:

Bloomin’ Algae app

The Bloomin’ Algae mobile app was created to enable users to report the presence of harmful algal blooms of blue-green algae (Cyanobacteria). The user-friendly app also educates users about how to recognise the risks to humans, children and animals.

Users report suspected blooms via the app. These reports are then checked by a team of verifiers to confirm or reject the presence of blooms and recommend actions, if appropriate.

Recorded blooms can be viewed on an interactive map accessible through the project webpage. Data collected through the app can be used to inform our knowledge of the occurrence of blooms.

More about the app and how to help >

Assessing the ecological impact of reservoirs

Our scientists monitor, analyse and quantify flow regimes in rivers and assess the ecological impacts of reservoir operations.

CAPABILITY:

Assessing the ecological impact of reservoirs

Reservoirs may impact river ecosystems in varied ways.

- When associated with in-river structures like dams, reservoirs can affect a river's longitudinal connectivity and fragment its catchment.
- The operating rules for storing and releasing water can disrupt a river's natural hydrological regime and environmental flows.
- Releasing reservoir water can modify river water quality and ecology, for instance by altering a river's thermal regime or enabling the spread of diatoms throughout its network.

At UKCEH, our scientists monitor, analyse and quantify flow regimes in rivers and assess the ecological impacts of reservoir operations. We also develop ecological and hydrological models to help water companies understand how reservoirs modify river regimes and ecosystems, and find solutions.

Image credit: Roger Bradshaw

CASE STUDY:

Modelling changes in river flow regimes

UKCEH scientists modelled the response of macro-invertebrate indices to changes in river flow regimes resulting from planned reservoir schemes in the Fens and South Lincolnshire. This project was led by Mott Macdonald on behalf of Anglian Water.

Different operating scenarios were run through an eco-hydrological model to assess their potential impact on biological indices commonly used as proxies for river ecology.

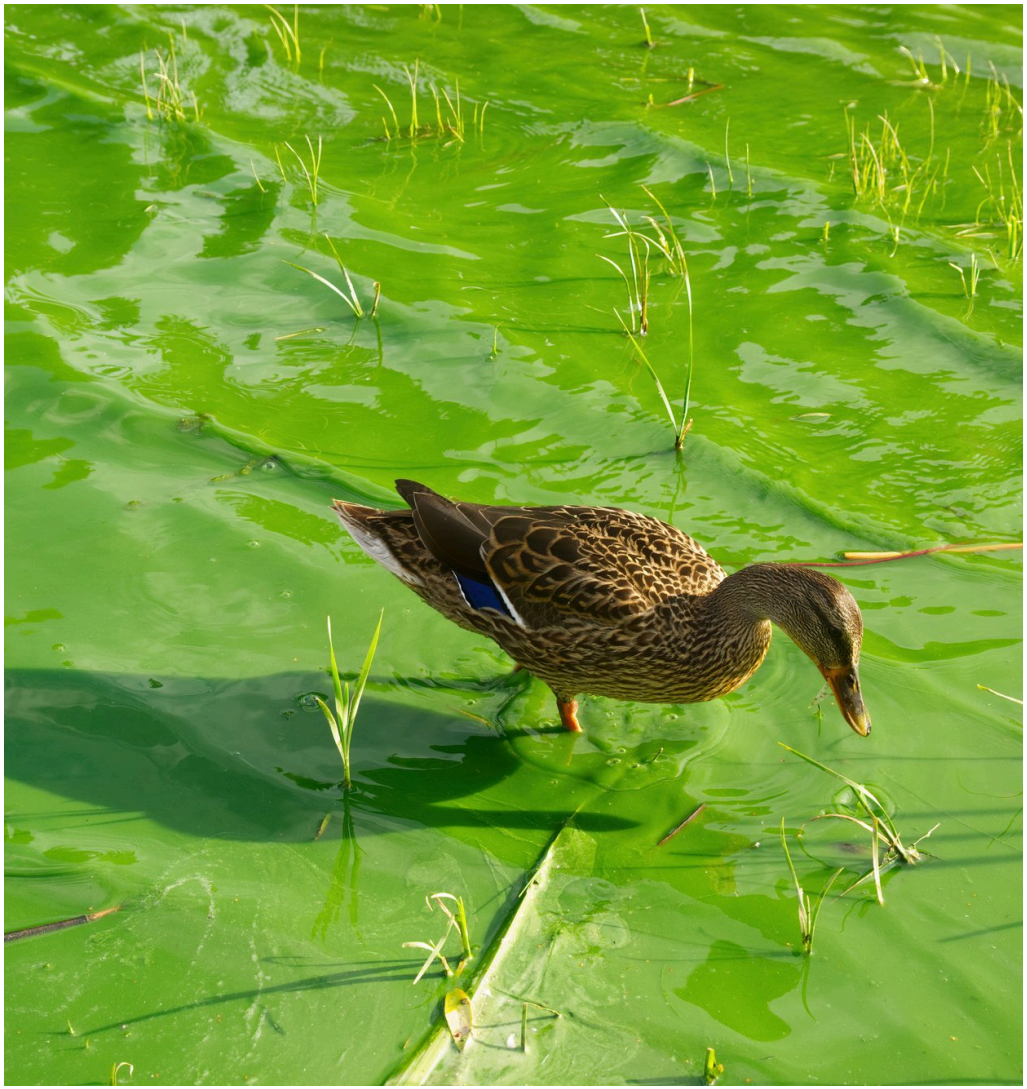
CASE STUDY:

Reservoir impacts on Thames algal bloom risk

UKCEH is conducting research for Thames Water to investigate the impact of reservoir inputs on the algal community and on algal blooms in the River Thames.

As part of this work, water and associated algae from Farmoor and Wraysbury Reservoirs have been mixed with Thames water and incubated within the AQUA-REP facility at Wallingford. This allows us to assess the growth rates of diatoms, green algae and cyanobacteria resulting from reservoir inputs.

We have also been working with Atkins to monitor the water quality and algal communities of these reservoirs at weekly intervals since March 2020.



Researching reservoir-based renewable energy solutions

UKCEH scientists bring expertise in water quality, ecosystem understanding, the development and implementation of monitoring techniques, and data analysis to assess the potential impacts and unintended consequences of renewable energy solutions for water quantity and quality, and biodiversity.

CAPABILITY:

Researching reservoir-based renewable energy solutions

Partnerships between the research community and water and energy companies have generated innovative uses of reservoirs to generate renewable energy. These initiatives leverage the large surface areas provided by reservoirs to harness solar or geothermal energy, contributing to decarbonisation while sparing land for other uses.

As part of these projects, UKCEH scientists bring expertise in water quality, ecosystem understanding, the development and implementation of monitoring techniques, and data analysis to assess the potential impacts and unintended consequences of these renewable energy solutions for water quantity and quality, and biodiversity.

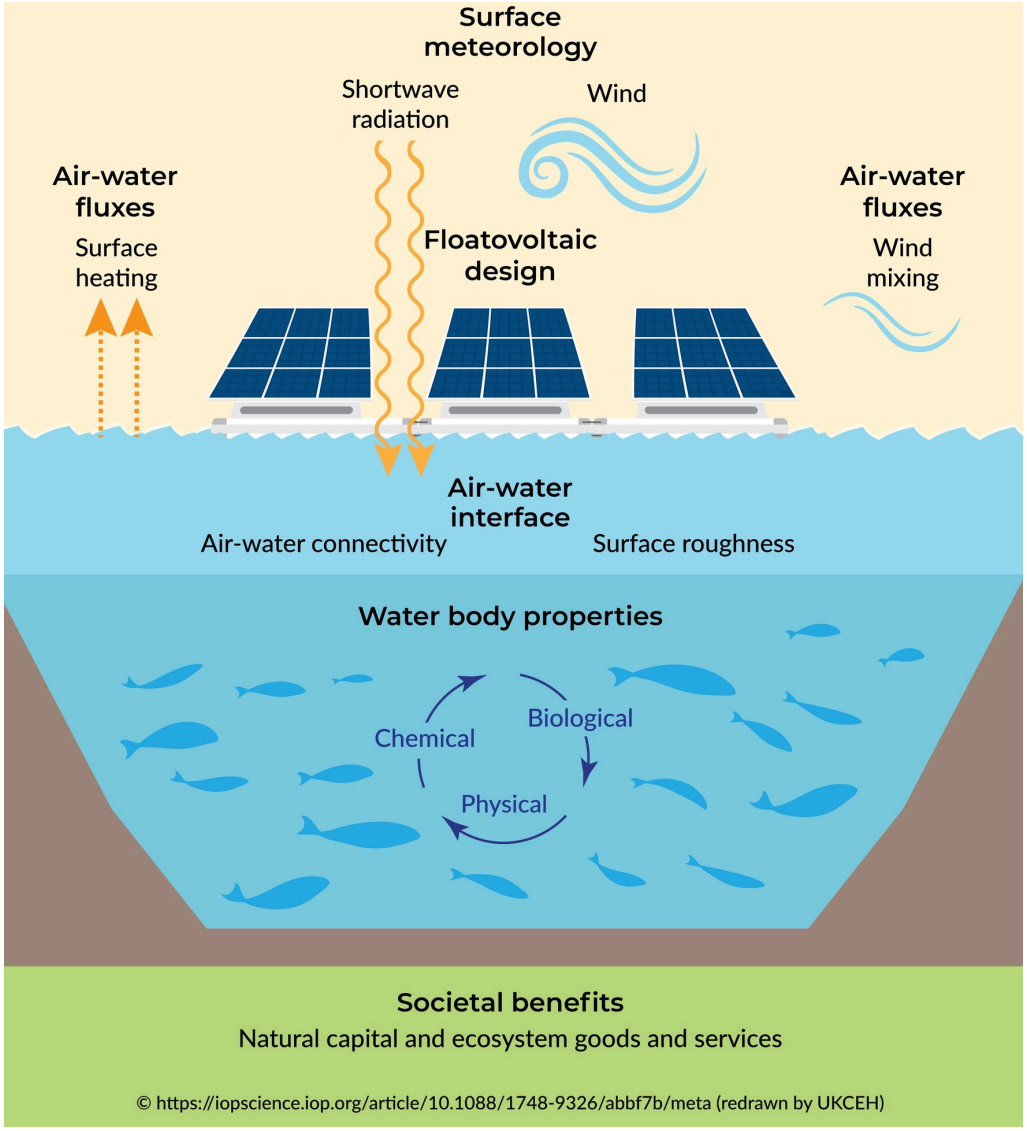
CASE STUDY:

Impact of floatovoltaics on reservoir water

In recent years, some UK water companies have been installing floating solar panels, also called 'floatovoltaics', on selected reservoirs. UKCEH scientists, in partnership with researchers from Lancaster University, are working with the water industry to assess the impact of such installations on reservoir water.

Our scientists have designed and implemented in situ monitoring strategies, using sensors, manual sampling, and cutting-edge laboratory analysis to gather the data necessary to understand how reservoir physical, chemical, and biological conditions change with the installation of floating solar panels.

Research outcomes will provide essential evidence to enable water and energy companies to assess the impact on water bodies and make informed decisions. By avoiding detrimental water quality impacts and delivering water quality benefits, these findings can contribute to tackling climate change mitigation and achieving net zero targets.



CASE STUDY:

Informing the planning and installation of water source heat pumps

While heat pumps are acknowledged as an efficient renewable energy solution, the potential offered by water source heat pumps (WSHP), designed to use heat stored in standing waters like lakes and reservoirs, is under appreciated in the UK. Other countries like Switzerland, Norway and Canada, which have embraced this technology, have gathered more data to support decision making.

Building on these countries' approaches, UKCEH scientists have enhanced the data available in the UK Lakes database with lake temperature data provided by SEPA and the Environment Agency, and gridded population data from the Environmental Information Data Centre. This aggregated UK data can be used to estimate the amount of heat generated in reservoirs and predict potential ecological impacts from alterations in water temperature.

Stakeholders can use our data model to inform decisions about the planning of water source heat pumps in the UK. Our scientists can also monitor relevant data when considering the installation of a WSHP system into a reservoir to ensure ecological impacts remain low.

DATA:

The UK Lakes database

The UK Lakes database is a comprehensive repository containing data for over 40,000 lakes and ponds across the UK. It includes information on lake size, volume, depth, water chemistry, typology, geology, habitats, land cover and hydrological catchments, amongst other characteristics.

Initially compiled in 2004, the database has continued to accumulate data over the years, evolving into the primary resource for lake-related information in the UK. The database is accompanied by spatial data of lake outlines (originally sourced from OS PANORAMA) and catchments for all lakes over 1 hectare in size (delineated from a 50m flow grid).

Data have been compiled from a number of different sources, ranging from individuals to universities and research institutions, reflecting a collaborative effort to compile and maintain a comprehensive dataset of UK lakes and ponds.

Access the database >

About the UK Centre for Ecology & Hydrology

The UK Centre for Ecology & Hydrology (UKCEH) is an independent, not for-profit research centre carrying out excellent environmental science with impact.

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