

Adaptive strategies to Mitigate the Impacts of Climate Change on European Freshwater Ecosystems

Climate models indicate that even if greenhouse gases were stabilised at present values, future climate change is inevitable. Research has shown that this climate change will have increasing effects on freshwater ecosystems, in many cases exacerbating the impacts already felt from other stresses such as eutrophication and land use change. It is therefore important to know what practical adaptation and mitigation measures can be taken to minimise the adverse effects of climate change on freshwater ecosystems over the next 50 years. Generating the scientific understanding that enables such measures to be implemented successfully is the principal focus of the **REFRESH** project. This is an issue of major practical relevance for the development of policies and implementation strategies needed to protect aquatic and riparian wetland ecosystems, especially with respect to the implementation of the EU Water Framework Directive, the EU Habitats Directive, the RAMSAR Convention, the Convention on Biological Diversity and other national and international conventions and protocols.

REFRESH is concerned with the development of a system that will enable water managers to design cost-effective restoration programmes for freshwater ecosystems at the local and catchment scales that account for the expected future impacts of climate and land-use change in the context of the Water Framework and Habitats Directives. At its centre is a process-based evaluation of the specific adaptive measures that might be taken at these different scales to minimise the expected adverse consequences of climate change on freshwater quantity, quality and biodiversity.



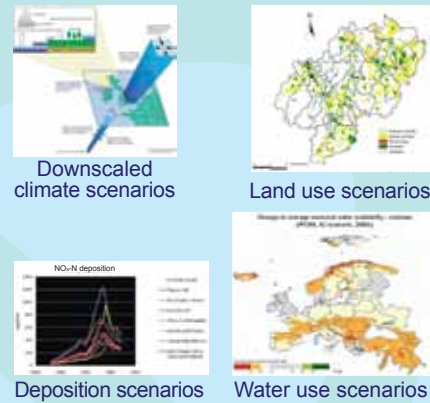
REFRESH will:

- increase understanding how the **functioning** of fresh-water ecosystems is affected by climate change;
- develop a **new set of ecological indicators sensitive to the functional response** of rivers, lakes and wetlands to changes in temperature, flow/water-level and nutrient/organic matter loading;
- develop **new tools for assessing vulnerability** to climate change which take into account both site-specific threats and threats at the landscape scale;
- examine how reference conditions for lakes, rivers and riparian wetlands might change following climate change and how the concept of a **dynamic reference state** can be built into WFD and HD methodologies;
- test a suite of different lake and stream models and take the existing models to a new level by including simple and complex **modules for structure (including food web) and function (metabolism) of stream and lake ecosystems**;
- extend integrated modelling beyond the current state-of-the-art by:
 - (i) developing **chained river-lake-wetland models**;
 - (ii) simulating the interactions and feedbacks between **ecological response and the chemical and physical environment**; and
 - (iii) providing assessments of management options for improving water quality and freshwater ecology at the European scale;
- take into account the **adaptive responses of different water stakeholders** and explore the cost-effectiveness of alternative strategies. By integrating cost-effectiveness analysis into our catchment models, we will develop **cost-effective and ecologically effective compliance strategies at different scales**.



Scenarios of Change

In any assessment of the impact of climate change on freshwater ecosystems, scenarios are needed not only for climate but also for associated changes in land-use, nitrogen deposition and water resource demand. In REFRESH we will use a **co-ordinated approach to develop a scenario framework** based on the IPCC Special Report on Emissions Scenarios (SRES), which outlines different pathways for future socio-economic development and on the exploratory scenarios used by the Millennium Ecosystem Assessment. The scenario framework will be used to **develop a series of coherent storylines** which will be further explored with stakeholders in terms of their consistency and relevance for the demonstration catchments.



Understanding Ecological Response



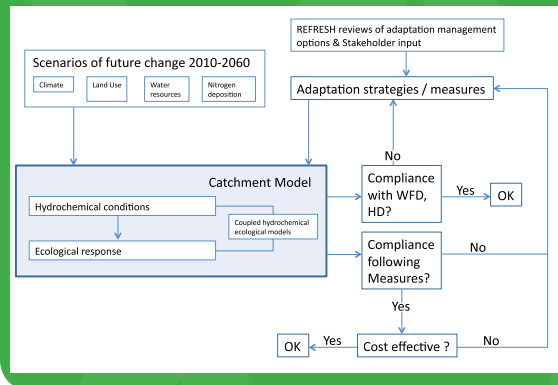
We will undertake a series of field experiments in which **river, lake and wetland** sites have been selected to represent a gradient of climate conditions across Europe. For rivers, the emphasis will be on the impact of changing temperatures and low and variable flows under different nutrient conditions. For **riparian wetlands** the experiments are designed to study the processes involved in changing temperatures, changing flooding regimes and reducing nutrient loading. For **lakes** the focus will be on lake-level fluctuations and on ecosystem functioning especially with respect to carbon, nitrogen, phosphorus, oxygen and salinity dynamics. These harmonised experiments are central to increasing our fundamental understanding of the mechanisms through which the key climate-related drivers will affect freshwaters.



The field experiments will be supported by laboratory and mesocosm experiments, analysis of major databases that enable time-space modelling, further analysis of long-term time-series assembled during the Euro-limpacs project and by evidence from palaeoecological studies where extreme events and abrupt transitions in the past have been recorded. All these approaches will be combined to help develop the process-based models needed to run scenarios for adaptive strategies. They are also required for upscaling from the local to the river basin scale.



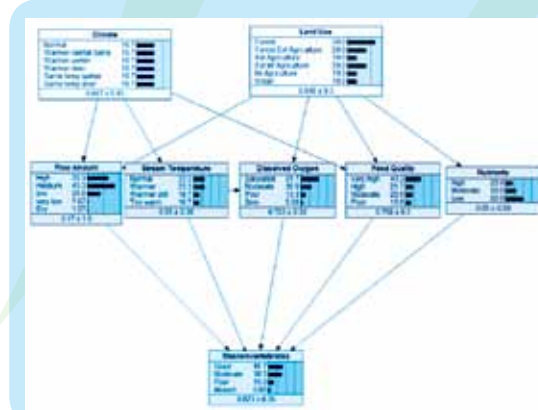
Modelling at Case Study Sites



Modelling Ecological Response

LINKING PROCESS-BASED MODELS WITH ECOLOGICAL MODELS

In REFRESH we develop an empirical approach to **summarise the relationships between changes in the physical environment (climate and land use) to the ecological response** via other measures of habitat suitability (e.g. min oxygen, flow, shading, food availability and morphology).



Adaptation Strategies

REVIEWS OF ADAPTATION STRATEGIES BEING PRACTICISED.

We focus on problems of increasing water temperature, changing hydrology (and salinity) and interactions between climate change and the behaviour of nutrients and organic matter as the principal climate-related threats to freshwater ecosystems. We will review adaptation strategies at various scales and will incorporate these into our models at case study sites. Key strategies include;

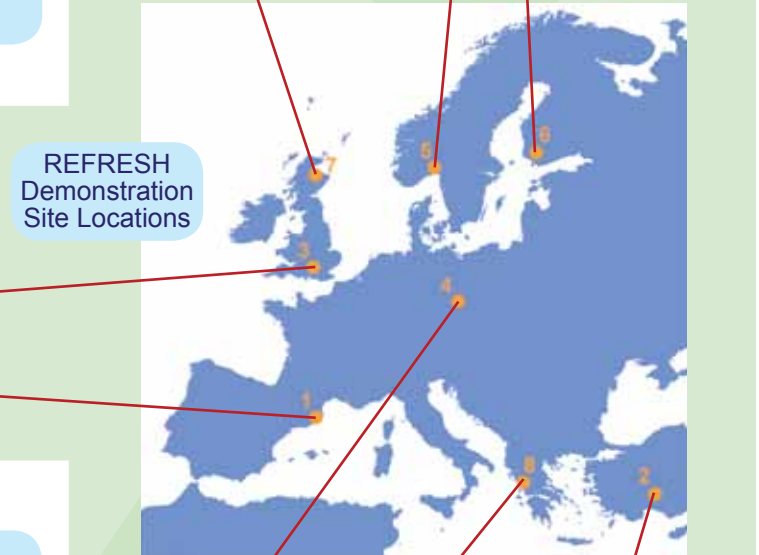
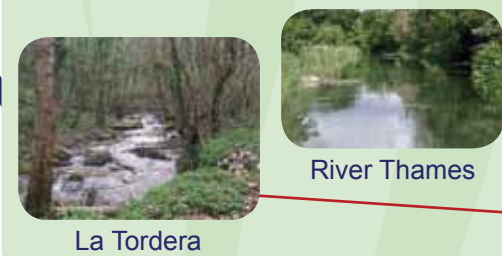
- (i) the management of riparian areas to control water temperature by the establishment of woody riparian vegetation along streams and rivers;
- (ii) the management of catchment hydrology to maintain flow in streams, water-level in lakes and regular flooding in wetlands;
- (iii) the re-creation of riparian floodplains to buffer against extreme precipitation events and changes in hydrodynamics, and to reduce nutrient flows and humic substances to water bodies;
- (iv) the management of catchment land-use to reduce diffuse nutrient loading and soil erosion; and
- (v) the management of water abstraction from, and effluent discharge to, surface waters.



Stakeholder Engagement

We will engage national and local stakeholders in the generation of storylines to develop a consensus view on the relevance and applicability of the various storylines when applied to the demonstration catchments. Workshops with stakeholders will be held to engage users and scientists together in the research process and to elicit stakeholder views that are needed to inform later stages of the project. Further workshops will be held to discuss outcomes of the research and to encourage stakeholders to disseminate the findings.

Case Study Catchments



Costs of Compliance

COST EFFECTIVENESS ANALYSIS
We will identify the most cost-effective ways of mitigating the adverse impacts of climate change and the impacts of these on achieving good ecological status under the WFD or the favourable status of HD sites. This will be achieved by coupling ecological outcomes with the economic outcomes to identify, through in-depth stakeholder dialogue and farm and sub-catchment modelling, the optimum combination of measures that need to be implemented at aggregate catchment scales to achieve WFD and HD compliance in the face of climate change.





Project Partners

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The University of Reading, UK

Finnish Environment Institute, FI

Universitaet Duisburg-Essen, DE

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