



**NATURAL
ENVIRONMENT
RESEARCH COUNCIL**



MACRONUTRIENT CYCLES PROGRAMME

SCIENTIFIC INTEGRATION AND MODELLING STRATEGY

Summary

The scientific integration and modelling strategy for the MC programme has been evolving since the first community workshop in April 2010. Two workshops in 2011 have continued that process and the outputs from these workshops are available at <http://macronutrient-cycles.ouce.ox.ac.uk/downloads/>. The project will integrate across many aspects, including science of N, P and C, different media (atmosphere, soils and water), catchments from the point of view of the translation of fluxes from the atmosphere to the sea, health, pathogens and stakeholders' needs for policy information.

INTRODUCTION

The **overall goal of the MC Programme** is to quantify the scales (magnitude and spatial/temporal variation) of N and P fluxes and the nature of transformations through the catchment under a changing climate and a perturbed C cycle. 'The catchment' is defined as covering exchanges between the atmospheric, terrestrial and aqueous environments, with the limit of the aqueous environment being marked by the seaward estuarine margin.

An understanding of the interactions between N, P and C cycles is at the core of the MC Programme. Interpreting the interaction between cycles is a very difficult procedure because of the numerous processes operating and the highly non-linear nature of many of these processes. In addition the MC programme seeks to assess the linkages between air- sheds, soils, freshwaters and estuarine systems. It also seeks to address the collective impact of changes in the linked cycles on the various ecosystems and ecosystem services.

INTEGRATION OPTIONS PROCESS

There will be many ways to achieve integration in the programme ranging from coupled observations to modelling. The key is to ensure that single nutrients are not considered in isolation, whether the integration is through system processes, media (air, soil, water, etc) interfaces, catchment observations or impacts on biodiversity. There has been considerable discussion of the issues around integration and useful insights are available from the MC Programme community workshop held in April 2010 and in the documents from the May9th workshop. Details of these meeting are available at <http://macronutrient-cycles.ouce.ox.ac.uk/downloads/>

This document describes integration under a number of different headings, but is only meant as a starting point for discussion. It cannot be overemphasised that integration of the science across the nutrient cycles, as described in the Theme Action Plan (see <http://www.nerc.ac.uk/research/themes/tap/documents/tap-natural-resources-2009.pdf>) is the aim of the programme and the reason why NERC Council has set aside strategic funding. However, the TAP document also includes practical considerations for maximising the impact of the research funded by the Programme. For example, there are many issues that are of interest to policy makers, planners, managers, stakeholders and the wider public (see ANNEX 1 and the extended stakeholder policy document available at <http://macronutrient-cycles.ouce.ox.ac.uk/downloads/>)

MC PROGRAMME INTEGRATION

Integration in the Programme will be required across a range of areas including:

- scientific integration (N, P and C)
- integration of different media (atmosphere, soils and water)
- integration from a catchments point of view (i.e. translation of fluxes from the atmosphere to the sea)
- health, pathogens and integration with macronutrient science

- integration from a stakeholders point of view (e.g. how will MC science and deliverables contribute to LWEC¹ partners' interests)

Scientific Integration

Although N, P and C have been studied on an individual level, rarely have studies considered the importance of all three nutrients. The MC programme aims to integrate these three aspects into a single science, establishing the importance of N, P and C coupling. Key considerations include:

- the importance of N, P and C in different settings;
- nitrogen processes and phosphate weathering;
- controls on N, C and P fluxes in terrestrial, aquatic and atmospheric systems;
- controls on bioavailability and the interaction of N, P and C with terrestrial and aquatic ecosystems.

It has not yet been established at what scale to measure C, N and P fluxes, in order to best understand the effects of management on ecosystem processes and services. Therefore an additional key aspect of the MC programme will be to take the “whole systems approach”, by integrating the catchment components with smaller scale measurements, experiments and modelling.

Media Integration

The MC programme aims to drive new research integration in order to establish improved understanding of macronutrient behaviour within atmospheric, terrestrial systems and soils, freshwaters and saline water environments. Links between macronutrient behaviour in the natural and built environment, and other non-nutrient contaminants are also poorly understood. Areas of consideration might include:

- the impacts of disruption of the macronutrient cycle on the function and biodiversity of soil, freshwater and estuarine ecosystems;
- links between processes (physical, chemical, biological) in different habitats (atmospheric, terrestrial, soils and aquatic);
- non-linear feedback mechanisms that control system dynamics;
- the role of urban/industrial versus agricultural sources in macronutrient cycles;
- integration of additional environmental factors required to understand major physico-chemical drivers.

In order to quantify and predict exchange and transport processes at interfaces (of air-land-water) there is an inherent need to better understand these direct and indirect controlling factors.

Catchment Integration

The translation of fluxes of nutrients from the atmosphere to the sea or from the land and water back up into the atmosphere are two key areas of integration. For example there is a

¹ Living with Environmental Change programme – see <http://www.nerc.ac.uk/research/programmes/lwec/>

need to look at the transformation of nutrients from terrestrial systems into waters and their transport along rivers systems into estuaries. At the same time, nutrients can be recycled up into the atmosphere via dust, gaseous emissions or evaporative processes, and these have effects on atmospheric composition.

Human Health Aspects of Integration with MC science

With changing climate and altered fluxes of macronutrients, there are likely to be increased incidents of pollution and disease that could threaten human health. Key issues include:

- whether pathogen survival rates in sediments and waters are affected by disruption of the nutrient cycle;
- if disrupted nutrient cycles influence the mobilisation and delivery of non-nutrient contaminants;
- whether the capacity of aquatic ecosystems to attenuate non-nutrient contaminants is compromised by nutrient enrichment.

For example, increased surface runoff after extreme precipitation events can flush pathogenic bacteria, other contaminants and nutrients into surface waters and thus degrade water quality in rivers or bathing waters. Heavy precipitation has been linked to a number of drinking-water outbreaks of *Cryptosporidium* (a pathogen causing a diarrhoeal illness) in the UK and across Europe. This is due to spores infiltrating springs and lakes and entering drinking water reservoirs. Such pathogens will increase the need for more thorough purification of raw water in drinking water supply systems based on surface waters.

Higher temperatures can result in ecological problems for aquatic flora and fauna, but can also cause prolonged blooms of potentially toxic algae. Higher nutrient concentrations, together with increased temperatures, could lead to the dominance of toxic cyanobacteria in some aquatic systems. The measures being taken to reduce eutrophication (reducing nutrient loading; improved water treatment) are beginning to be at least partly successful in many UK river basins. However, there is a risk that climate change will counteract this success and that the public health risk from waterborne diseases will be increased.

Stakeholder Integration

There are many stakeholders who have interests in the Macronutrient Cycles Programme, including DEFRA, the EA, the Scottish Government and the Welsh Government, Natural England and many more. The MC programme is an accredited LWEC programme and thus there is a need to integrate the findings from the programme to maximise the benefits and knowledge transfer to LWEC partners. Key stakeholder issues include:

- farming practices and food security;
- land and water management;
- increasing demand for natural resources and degradation of ecosystem resources;
- the impact of nutrient enrichment on the capacity of aquatic ecosystems to attenuate non-nutrient contaminants;
- the influence of disruption of the nutrient cycle upon pathogen survival rates in sediments and waters;
- how disrupted nutrient cycles influence the mobilisation and delivery of non-nutrient contaminants

Whilst it may not be possible for all projects to incorporate stakeholders, it is important that proposers should integrate user issues within their research agendas / activities. Clear guidance will be given on stakeholder/enduser requirements, for example through webinar contact between stakeholders and the research community. Workshops will be held between stakeholders and researchers to continue to meet the needs of both the stakeholders and MC research community.

MODELLING STRATEGY

One set of deliverables that should arise from the MC Programme will be new modelling approaches that address MC programme integration issues. It is likely that models developed within the programme will cover three broad areas of interest, these being:

1. *models that can describe the complex process interactions occurring between N, P and C*—such models can assist with the interpretation of field or experimental data to help unravel the feedback mechanisms and chemical and ecological processes operating;
2. *models that can represent the catchment scale and can deliver flux information to coasts and the sea shelf*—this is to meet the requirements of the science community studying the sea shelf and to provide information to LWEC partners;
3. *models that can be aggregated or scaled up to represent the dominant modes of behaviour* and such that they could be integrated to improve earth system models, especially in relation to nutrient exchange with the atmosphere;

These three modelling components, together with others, should be complementary but will clearly operate at different scales and at different levels of complexity to suit the nature of the role they need to play. Of course, in addition to these modelling activities there could well be additional serendipitous research, evaluating such phenomena as the fractal nature of high frequency data and how can such statistical descriptions assist with the physical interpretation of catchment hydrochemical and ecological systems. The modelling strategy will be integrated with empirical science through:

- 1) directing field and lab work using modelling studies;
- 2) conducting field/laboratory work of relevance to the modelling

For this integration there has to be clear consideration by field- and laboratory-based scientists of the data that are required by the modellers and, in turn, the output from the models must help inform further experimental design. For these reasons the start of the modelling should not be delayed. The hypotheses that are to be tested by the models should be clearly postulated. The modelling should start at the beginning of the programme to help define (future) research questions and can be based on existing data. A series of activities are required to address this integration and knowledge exchange. These activities will include, but not be limited to, workshops, conferences, data integration and core modelling. The workshops will range in scope from one-day meetings to build links between scientists, stakeholders and end users and longer meetings where the focus will be the production of integrative papers. **It should be noted that DEFRA and the EA have requirements for models to meet their policy needs and these are summarised in the stakeholder policy document which is available at <http://macronutrient-cycles.ouce.ox.ac.uk/downloads/>**

ANNEX 1 RESEARCH AIMS AND USER ISSUES

Research Aims

The overall goal is to quantify the scales (magnitude and spatial/temporal variation) of N and P fluxes and nature of transformations through the catchment under a changing climate and perturbed C cycle. 'The catchment' is defined as covering exchange between the airshed and land surface through to the estuaries.

Delivery of the overall goal is through three secondary goals linking different science areas and a fourth goal concerned with impacts. All science goals have technology science challenges embedded in them. These goals must interface with one another to deliver the overall science goal:

1. to evaluate the nature and scale of macronutrient (N, C) exchange between the airshed and terrestrial system and consequences for fluxes (N, P, C) to soil, freshwater and atmosphere systems (atmosphere-terrestrial-freshwater feedback system);
2. to determine the role and spatial and temporal variation of macronutrients (N, P, C) on key limiting processes and ecosystem functions (i.e. decomposition, productivity, carbon sequestration) and consequent export at the catchment scale (terrestrial-freshwater systems);
3. to advance understanding of the co-limitation of N/P for eutrophication control in terrestrial systems and along the entire freshwater system to the estuarine boundary (freshwater system);
4. to determine the implications of nutrient enrichment on the fate and effects of other non-nutrient contaminants, including impacts on human health (i.e. pathogens, ozone) and biodiversity.

User issues:

1. Interaction and fate of N, P, and C within the terrestrial and the aquatic environment
2. Relevance of the N,P, and C cycles to social and economic development: agriculture, industry, urban development, amenity resource
3. How changing N and P affects carbon footprint and food security
4. Impacts of social, economic and climatic drivers of change on N,P,C functioning and the consequences to soils and aquatic health
5. Production of a reliable ecosystem functioning model to predict physical, chemical and climate based changes

National Issues:

1. Climate change
2. Agricultural change in relation to the WFD and CAP reforms
3. Urban development and population growth
4. Improving our carbon footprint
5. Improving the aquatic ecosystem
6. Restoration of rivers to a better functioning ecosystem
7. A European dimension to legislation and environmental policy
8. Economic climate – reduced resources and the need for focus on critical issues

9. The user community is critical in linking 1, 2, 3, 4, 5, 6 within the context of 7