NRA Project 574

R&D Project 574

Switch mechanisms between alternative stable states in freshwater communities:

October 1993 - March 1994

March 1993
R&D Interim Report 01/574/1/A

Switch mechanisms between alternative stable states in freshwater communities

First 6 months of PhD investigation: October 1993 - March 1994
CASE Studentship

D Stephen

Research Contractor:
University of Liverpool
University supervisor: Brian Moss

National Rivers Authority
Kingfisher House Goldhay
Peterborough
PE2 OZR

R&D Interim Report 01/574/1/A

Commisioning Organisation
National Rivers Authority
Kingfisher House
Goldhay Way
Orton Goldhay
Peterborough
PE2 OZR

Tel: 0733 371811
Fax: 0733 231840

Research Contractor
This document was produced under R&D Project 574 by:

D. Stephen
D.E.E.B
University of Liverpool
P.O. Box 147
Liverpool
L69 3BX

Tel: 051 794 4940
Fax: 051 794 5094

NRA Project Leader

Geoff Phillips- NRA Ipswich Office

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1. INTRODUCTION

Recent field studies have shed light on some aspects of shallow (<3m) freshwater lake ecology (for example: Balls et al 1989, Irvine et al 1989, Leah et al 1980, Timms and Moss 1984). Prior to these studies it was predicted that a eutrophicated, phytoplankton dominated system could be restored to one dominated by macrophytes simply by reducing the nutrient loading (Moss 1991).

The contemporary view is that the switch between the two states (phytoplankton dominated and macrophyte dominated) is more complex than this, as at intermediate nutrient loadings (TP 50-150ug/l) either state may exist (Moss 1993). These two alternative stable states in shallow lakes have been postulated (Scheffer et al 1993). It is thought that each state has a number of mechanisms which act as stabilisers or buffers (Moss 1991).

Mechanisms stabilising the phytoplankton dominated state are thought to include early spring growth (which can hamper plant growth by shading and/or reducing CO_2 availability), shorter diffusion pathways for CO_2 and HCO_3, and absence of grazing pressure from Cladocera through lack of refuges (Moss 1990). Stimulation of internal release of phosphate from the sediments (Moss 1993) and a shift in the age structure of predatory fish towards younger zooplanktivorous fish (Moss 1991) may also buffer the phytoplankton state.

Buffers of the plant dominated state are thought to include the harbouring of Cladoceran grazers within plant beds which can control algal crop size, a shift in community composition from low-growing plant species to tall species, and the shedding of leaves burdened by epiphytes (Moss 1990). In addition plants may release alleopathic substances which inhibit phytoplankton (Van Vierssen and Prins 1985), and reduced oxygen levels within plant beds may discourage entry of zooplanktivorous and perhaps herbivorous fish (Moss 1991). Further buffers may include luxury consumption of nutrients by plants and denitrification (Ozimek et al 1990, Van Donk et al 1989).

At present experimental tests of a number of these proposed buffers are lacking, and this project will investigate the nutrient dynamics of the macrophyte and phytoplankton dominated states. A greater understanding of nutrient mechanisms, in particular internal loading, is important because many lake restoration strategies assume costly removal of sediment is necessary (Moss 1993).

In addition an investigation of resource allocation strategies of freshwater aquatic plants under different nutrient conditions will be undertaken. Both the nutrient dynamics and resource allocation investigations will be carried out in some of the Norfolk Broads and West Midland Meres. Such a comparative study is important as it will allow a greater understanding of these phenomena.

The Broads, a series of shallow freshwater and brakish lakes, which formed in the fourteenth century AD when Danish peat workings in the area flooded(Moss 1987), have been the subject of many ecological studies (for example: Balls et al 1989, Irvine et al 1993, Irvine et al 1989, Phillips et al 1978, Stansfield et al 1989). These studies were prompted by the observed change from lakes rich in aquatic macrophytes to ones dominated by phytoplankton. It is thought that increases in nutrient inputs and bank erosion which have occured in recent decades are the cause of this switch. Conversion from septic tank systems to mains sewerage and an intensification of agriculture have caused the greatly increased nutrient loadings, and a booming boat industry together with increases in private boating have resulted in severe bank erosion (Moss 1987).

At present work is being carried out in the Broads aimed at improving ecological understanding, thereby facilitating appropriate management and restoration of this area. This research project will be integrated with studies of switch mechanisms underway at the NRAs' Haddiscoe laboratory. The following sites will be inclided in this investigation: Hickling, Bumtfen and Upton (see table 3.6.1 for details of the plants).

As well as the fore-mentioned investigations a continuation of the monitoring of three of the West Midland Meres (Mere Mere, Little Mere, and Rostherne Mere) which began in 1990 will be undertaken.These Meres are situated in the north of the Cheshire Plain and are connected by a brook. Water flows from Mere Mere (15.5ha, mean depth 2.8m) over a sluice into Little Mere (2.8ha, mean depth 0.7m), and onto Rostherne Mere (48.7ha, mean depth 13.6m) which is about 2km away. Little Mere and Rostherne Mere received sewage effluent until mid-1991 when the sewage was diverted (Carvalho 1993). Monitoring of these Meres therefore provides an excellent opportunity to observe how these systems respond to a reduction in external nutrient loading.

Mere Mere did not receive sewage effluent and therefore acts as a control for Little Mere. It appears to have undergone only minor eutrophication in recent years and has a diverse and abundant aquatic plant community (Moss et al 1992).

The nutrient concentrations in Little Mere were very high (on average a Total P of over 2000 ug/l) prior to diversion, despite this emergent aquatic plants flourished and algal crops were not large (Beklioglu, M. personal communication). It is thought phytoplankton crops were controlled by grazers which developed huge populations as a result of summer fish-kills (Carvalho 1993). The picture for Little Mere since the diversion has been one of falling, but still relatively high, nutrient concentrations in the water (about a 10 fold decrease to an average Total P of 200 ug/l), coupled with an increase in mid-day dissolved oxygen concentrations, which has led to a fish population recovery. Chlorophyll-a concentrations and pH have not significantly changed, and the Mere is still rich in aquatic plants. It is surprising that algal populations have remained low despite the combination of high nutrients and increasing fish numbers. It is thought that this is because the aquatic plants provide refuge for zooplankton which graze on algae (Beklioglu, M. personal communication).

Carvalho's (1993) work provides the background to Rostherne Mere which, due to its deep nature, supports few aquatic plants (<5 % of the lake area). Prior to diversion nutrient concentrations were high (growing season SRP of 100-200 ug/l), although DIN (Dissolved Inorganic Nitrogen) dropped to low levels during the summer. Large phytoplankton crops were found in summer, dominated by cyanobacteria, and grazing appeared to have no significant effect on algal crop size. There has been no detectable change in the ecology of Rostherne Mere since the diversion, and nutrient levels have remained constant over this period, probably as a result of internal phosphorus release from the sediments. He has predicted that the phytoplankton crop-size may become phosphorus limited as a result of the sewage diversion, although this is dependent upon the extent of internal phosphorus release. Nitrogen limitation in the future is also a possibility.

2. HYPOTHESES

2.1 Phosphorus

Theory: The release rate of phosphorus from sediment is influenced by the following factors:

i : Plant community: composition, species abundance, and species biomass.

ii : Chemical and physical variables: temp, light, oxygen, pH, and sediment organic content.

H_1: Phosphorus release rates from the sediment are increased by: the presence of aquatic plant communities, increasing the plant abundance, increasing the plant biomass, increasing the temperature, and increasing the light.

H_1:: Anoxic conditions promote phosphorus release.

H_1: Increases in release rates of phosphorus vary between species in the same habitat.

H_1: Elevating pH increases the release of phosphorus.

H_1: Above a critical sediment organic content level the rate of phosphorus release increases as the organic content increases.

2.2 Nitrogen uptake

Theory: The rate of nitrogen uptake from the water is influenced by the following factors:

i : Plant community: composition, species abundance and biomass.

ii : Light

H_1 The rate of nitrogen uptake from water is increased by: the presence of aquatic plant communities, increasing the plant density, increasing the plant biomass, and increasing the light..

H_1: Increases in nitrogen uptake varies between areas dominated by different plant species in the same habitat.

2.3 Denitrification

Theory: The rate of denitrification in the sediment is influenced by the following factors:

i : Plant community: composition, species abundance and biomass.

ii : Chemical and physical variables: light, oxygen, and sediment organic content.

H_1 The rate of denitrification in sediments is increased by: the presence of aquatic plant communities, increasing the plant density, increasing the plant biomass, increasing the light, and increasing the sediment organic content.

H_1: Increases in denitrification rates vary between areas dominated by different plant species in the same habitat.

H_1: Anoxic or very low oxygen conditions are necessary for denitrification.

2.4 Resource Allocation Strategies

Theory 1: Habitat fertility is a determinant of the resource allocation strategy of a particular species.

i : The root:shoot ratio is determined by fertility.

ii : The sexual:asexual allocation ratio is determined by fertility.

H_1 The root:shoot biomass ratio decreasesas as the fertility increases.

H_1: The sexual:asexual allocation ratio decreases as the fertility increases.

Theory 2: Resource allocation strategies vary amongst species within the same habitat.

H_1: The root:shoot ratio varies between species in the same habitat.

H_1: The sexual:asexual allocation ratio varies between species in the same habitat

Theory 3: Habitat fertility is a determinant of the turnover rate of a particular species.

H_1: The turnover rate of a particular species increases as the fertility increases.

3. APPROACHES

3.1 Phosphorus

Within plant beds and bare sediment control areas identify the plant species determine plant abundance, and measure pH, oxygen, and temperature. Collect intact cores (approx. 30cm sediment & 30cm water) and measure the following in the laboratory: phosphorus release rate, pH, oxygen, sediment organic content, and temperature.

In the laboratory establish dense growths of Elodea canadensis and Myriophyllum spicatum and place them in controlled flow systems, using artificial sediment and water, then drip in ^{32}P and budget fate.

3.2 Nitrogen Uptake

Set up enclosures in the field (some containing plant communities and some plant-free as controls) treated with graded additions of nitrogen and monitor nitrogen levels within the containers.

In the laboratory establish dense growths of Elodea canadensis and Myriophyllum spicatum and place them in controlled flow systems, using artificial sediment and water, then drip in ^{15}N and budget fate.

3.3 Denitrification

In the laboratory develop an appropriate method for measuring denitrification in sediments, possibilities include the ^{15}N tracer method, and the acetylene inhibition technique.

3.4 Resource Allocation Strategies

Collect plant shoots and roots from the field using a quantitative sampler, and mark leaves of nymphaeids to determine leaf turnover rates.

In the laboratory identify, separate and dry the samples. Then measure the dry weights of the various fractions.

3.5 Monitoring of Rostherne Mere, Little Mere, and Mere Mere

Collect water, zooplankton, and phytoplankton samples from each Mere. Monitor Rostherne Mere's inflow and outflow for flow and water depth, and collect water samples from these sources.

Analyse water samples for chlorophyll-a, carotenoids, total phosphorus, soluble reactive phosphorus, nitrate, and ammonia.

3.6 Sampling sites and plant species

Table 3.5.1 gives details of the plants and locations which have been selected. Plant species were chosen so as to give examples from as many contrasting growth strategies as possible. The choice of sampling sites was then dictated by where the chosen plants could be found in sufficient numbers.

Table 3.6.1: Sampling sites and plant species

Plant Species	Norfolk Broads	West Midland Meres
Elodea canadensis	N/A	Little, Mere, Tatton.
Potamogeton berchtoldii	N/A	Little, Mere, Tabley.
Myriophyllum spicatum	Hickling	Mere, Tatton.
Nuphar lutea	Burntfen	Little, Mere, Tabley.
Littorella uniflora	N/A	Mere
Najas marina	Hickling, Upton.	N/A

3.7 Work Schedule

Table 3.7.1, overleaf, shows the work schedule for the project, and how the work will be divided between The Broads and The Meres until October 1996.

Table 3.7.1: Work Schedule

	JAN 94 … DEC 94	JAN 95 … DEC 95	JAN 96 … DEC 96
Resource-allocation Broads & Meres	MAR		MAR
Phosphorus release Broads & Meres	MAY OCT		
Radioactive labelling Liverpool		JAN DEC	
Enclosures in Little Mere		MAY OCT	
Monitoring of the Meres	APR		MAR
Write-up			MAR OCT

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