Mesotrophic Rivers in Anglian Region Phase 1

June 1994

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Anglian Regional Operational Investigation 564

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National Rivers Authority

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Statement of Use

This document records the results of a preliminary review of the trophic status of rivers within Anglian Region; and recommends firther research and policy objectives for those of low nutrient status.

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EXECUTIVE SUMMARY

1. Mesotrophic rivers are those moderately low in nutrients, in a range where eutrophic are those high in nutrients, and oligotrophic low. In the lowlands of Britain, there are no naturally oligotrophic rivers, because a measurable nutrient load derives from the natural geologies of the catchments.

2. There is far less knowledge available about the trophic status of rivers than there is of lakes, which have been extensively classified by their nutrient, especially phosphorus, input.

3. It is generally recognised however, that in aquatic systems, the limiting nutrient is phosphorus rather than nitrogen.

4. This preliminary review examined the levels of phosphorus in Anglian rivers from routine monitoring data collected in 1992 and classified rivers on a 5 class system from 1 (high) to 5 (low).

5. Phosphorus is primarily derived from sewage effluents rather than land drainage (the major source of nitrogen) so we also examined the location and size (by Dry Weather Flow) of all registered discharges into Anglian rivers, and ranked these on a scale from 1(large) to 5 (small).

6. The major impact of nutrient enrichment is observed upon plant communities, and we examined the available information for selected Anglian rivers from past published records and from the REDS database built up from River Corridor Surveys.

7. We conclude that, at present, the most effective measure of oligotrophic status is low phosphate concentrations measured in the routine water quality monitoring process. Many small streams do not have monitoring stations on them however, so a surrogate for this is low effluent input.

8. The evidence from plant surveys is inconclusive. The trophic ranking and classification system, derived by Holmes and used for national river classification by the NCC (EN), does not adequate separate the rivers on which it was applied in this project. We suspect the reasons for this are this is a combination of data which were not collected for this particular purpose, the REDS database which is not yet complete, and the relatively high trophic state of Anglian rivers compared with the full range of those across the country.

9. We conclude that, at present, the best means of identifying mesotrophic rivers is by phosphorus concentration. We used annual median levels in this analysis, but usually

concentrations are highest in late summer, so a more Accurate classification would use samples taken at this time of the year, although replicates would be required. Small streams without phosphorus measurements should be considered mesotrophic if they contain no major (urban) or accumulation of minor (village) sewage works.

10. Most mesotrophic streams are in the headwaters of catchments which have influences of chalk or limestone, probably because of the chemical precipitation of phosphate which can occur at higher pH levels.

11. We recommend that a more detailed examination of phosphorus concentrations and plant communities in a few selected mesotrophic stream and river systems should be undertaken to find out:

i) the correct phosphorus classification cut offs
ii) the plant communities associated with mesotrophic Anglian rivers
iii) whether there are associated, distinct invertebrate communities
(cf. O.I. on River Nar)
iv) the management strategies necessary to maintain such rivers

Keywords: phosphorus, mesotrophic, Anglian region rivers, effluent dry weather flow, trophic classification

1 INTRODUCTION

Eutrophication is the phenomenon of nutrient enrichment of watercourses and waterbodies. It is widespread in Britain, because the two major plant nutrients, nitrogen and phosphorus, are widely distributed in the environment. Nitrogen is primarily derived from the diffuse sources of agricultural drainage, while phosphorus is derived from the point sources of effluents, chiefly from domestic sewage and food-processing industries.

Phosphorus is considered to be the important nutrient limiting the biological manifestations of eutrophication, which are primarily enhanced plant growth. In lakes, which have been more extensively studied than rivers, the plant growth causing most concern is that of phytoplankton algae. In rivers, phytoplankton are confined to larger, sluggish reaches. In faster and shallower reaches, eutrophication is manifest in denser growths of filamentous algae and littoral macrophyte stands, with accompanying species changes.

This review has made a preliminary examination of the phosphorus status of Anglian rivers and draws conclusions about the distribution of low-phosphorus stretches, termed mesotrophic.

1. 1 Statutorv background

Control of nutrients in rivers was, until recently, only been considered to be important in the UK where rivers flow directly into reservoirs or lakes of conservation importance such as the Broads in Norfolk. Problems with toxic algae in standing waters since 1989 have given the issue much wider importance; recent Directives of the EC, reflect this. Current relevant initiatives are the Nitrates Directive, the Urban Wastewater Directive and the Statutory Water Quality Objectives. Of these three, the first is less important in the present context as this review focuses upon phosphorus, but the other two are of central importance.

The Urban Wastewater Directive will apply to waters receiving discharges from 10,000 population equivalent, which may be declared 'sensitive areas'. There are three categories of 'sensitive' areas; those at risk from eutrophication, those which are potable water supplies, and those where 'more stringent' treatment of discharges may be necessary to meet other EC directives, such as Freshwater Fisheries or Special Protection Areas under the Habitats Directive.

The SWQO scheme under consideration for the U.K. is in many ways complementary to the UWWD, although more wide in its scope. The SWQO provides for a Special Ecosystem Classification for rivers which may require protection for environmental reasons other than water supply or fisheries, chiefly for conservation. Phopshorus standards are likely to be central to Special Ecosystem Classification.

1. 2 Scientific background

In rivers, as in lakes, nutrients directly affect plant growth. Eutrophication in lakes has been reviewed in several books and reports (e.g. Harper 1992) but far less is known about the role or the effects of nutrients in rivers. Lowland reaches are sluggish enough to develop true phytoplankton populations, but these are strongly controlled by hydraulic conditions as well as nutrients and light (Reynolds 1994a, 1994b). Macrophytes (higher plants) and macroalgae are the more prominent primary producers in river ecosysytems, and their growth is influenced by light penetration, flow conditions, and sediment as well as nutrient concentration.

There is evidence for general changes which nutrient enrichment causes to river plant communities, but these are often difficult to distinguish from other effects of pollution (Haslam 1978, 1990) and they come through two routes; water and sediment. The most common effect is a reduction in plant diversity and dominance by one or two species, such as the macroalga *Cladophora* and robust species such as *Potamogeton pectinatus*. Subsequent effects upon invertebrates may also be difficult to interpret clearly, as a major effect of excessive plant growth is an altered oxygen regime, similar to that which occurs as a result of organic pollution.

Nevertheless, several investigators have successfully used macrophytic communities to classify rivers by trophic state across the UK. One of these classification systems (Anon 1987) developed in the North-West region, allocated species a score in a parallel fashion to the invertebrate water quality score system (BMWP) widely used in the NRA. Another (Holmes, 1991) allocated species a trophic rank and derived a site score from the trophic indicator species present. A third (Haslam & Wolseley 1981) uses a colour-coded system to indicate community state. The former two are the more widely used, and most recently, the North-West's system has been provisionally modified to suit Anglian Region rivers with promising initial results (Holmes unpublished).

This preliminary study did not attempt to demonstrate any biological consequence of trophic state for Anglian rivers (such activity is recommended for Phase II); rather its objective was to find out whether existing evidence allowed mesotrophic rivers to be identified within the Anglian Region. Internal NRA investigations in relation to the SWQO scheme have addressed this important issue and concluded after review of the (patchy) literature, that the main biological consequences are indeed excessive plant growth leading to species reduction.

1. 3 Project objectives

The project was initiated with the following objectives:

1: To identify mesotrophic rivers in the Anglian Region

2: To demonstrate the scientific value of mesotrophic catchments and develop protocols for their protection

3. To recommended cost-effective management prescriptions.

This report represents the first phase of the project. It identifies a preliminary list of mesotrophic catchments within Anglian Region from baseline data and suggests guidelines for the development of subsequent phases of the investigation.

2 METHODOLOGY

2.1 Definition of mesotrophic

In the literature of lake eutrophication, which is extensive, definitions of trophic state are numerous. It is almost impossible to classify trophic state by a cut-off level, such as a minimum phosphorus concentration, because of temporal changes in such things as water renewal rate, changes inflow concentration and rate of sedimentation. The most accepted standards of classification, those of OECD, use graphical representation of probabilities for lake classification in a number of categories, such as transparency, phosphorus loading, in-lake phosphorus concentration, chlorophyll a concentration (Figure 1).

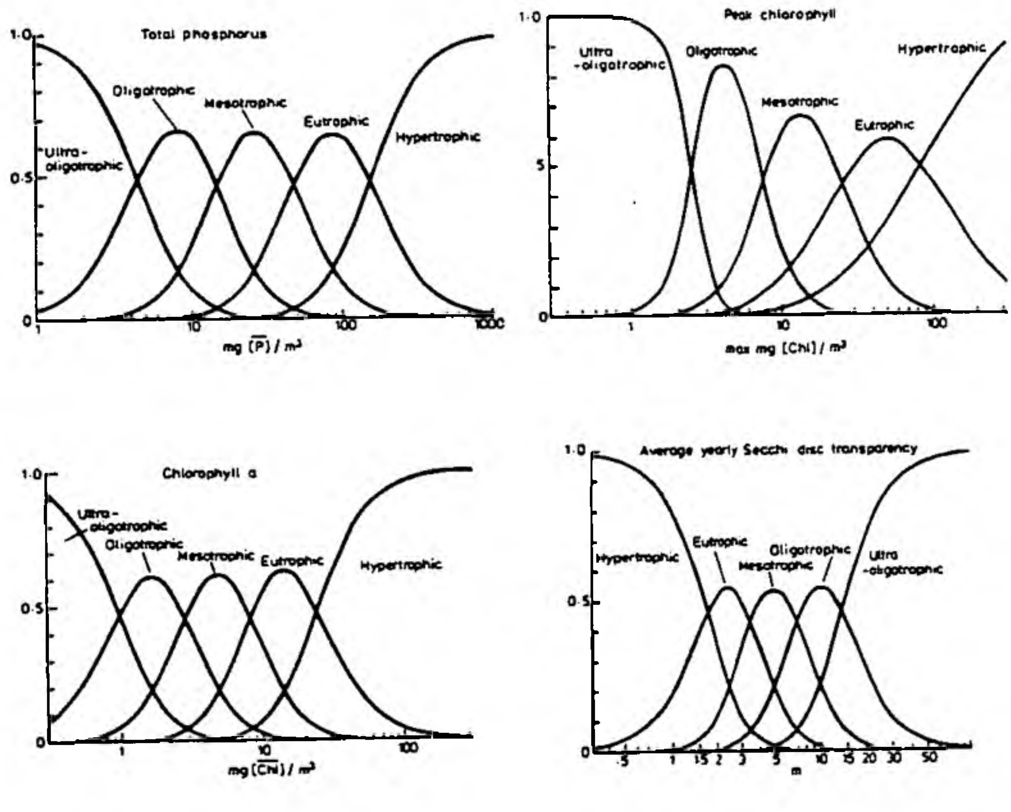

Figure 2.1. Example of the eutrophication classification for lakes, from Harper (1992).

The only parameter common to lakes which can be used in rivers at present is phosphorus concentration. This is beset with difficulties, as it is in lakes, which centre around the nature of the phosphorus analysed and the nature of the summary value used because of rapid temporal change. The former is a problem because there is sometimes considerable difference between concentrations of total phosphorus and the many different types of soluble phosphorus; there is also disagreement about which represents the most biologically useful form. The latter is a problem because a very high fraction of the annual input of phosphorus from a catchment can be transported in single storm events, and there is often considerable variation in concentration with flow. Even then, the impact of such phosphorus is not necessarily related to inflow because an unquantified proportion passes out of the river downstream. There is thus, at present, no clear indicator of the correct phosphorus species, or concentration, or time period, to use as a standard for classification of river trophic state.

This issue has been addressed by bodies such as English Nature (in consideration of the standards which are needed to protect riverine SSSIs), and by the NRA itself, in consideration of the UWWT Directive and the SWQO. The majority of opinion is tending to suggest 100 μg/l phosphorus as P as a threshold value for lakes and 200 μg/l for rivers, above which ecological damage characteristic of eutrophication (excessive plant growth and its consequences) becomes more and more apparent. In lakes this is more often expressed as total P, but in rivers, both ortho-P (approximately equivalent to soluble P) and total P are used). Ortho-P is generally reckoned to account for 80% or more of total P in rivers. Concentrations below 200 μg/l are generally therefore considered to be mesotrophic.

2.2 Data selection

This preliminary assessment only had the time to use immediately accessible data, either publically available or on NRA computer archives. The following information was chosen:

1: River size. This is not connected with trophic status *per se*, but is the simplest and most valuable means of separating rivers into a manageable classification which is likely to be related to the parameters more directly connected with trophic status below.

2: Geology. This is likely to be of importance as the factor controlling the natural background nutrient concentration of catchment runoff.

3: Phosphorus concentrations. This is the most central measure of nutrient status (although there is much debate about the nature of phosphorus measured, see above)

4: Sewage effluent input as dry weather flow. This is the primary source of phosphorus in rivers.

5: Macrophyte communities. Macrophytes are the only biological group which have so far been developed as trophic state indicators (see above).

For all interpretations except macrophytes, river stretches were placed into one of 3-5 classes. This was because the data sets used are either themselves summaries of large data sets (e.g river discharge classes, sewage treatment works dry weather flows) or small 'example' sets (e.g. one year's phosphorus analyses from the CDPS). The number of classes chosen was based upon the accuracy of the initial information. These simple classifications were then compared by rank ordering in tabular form, which was felt to be the most appropriate way of displaying such preliminary data. No statistical tests were applied because it was felt they would confer a spurious accuracy upon the results.

2.3 Stream selection

The rivers and streams of the region were listed as single named tributaries or stretches within a catchment or group of small catchments (such as those watercourses along the Lincolnshire coast). The main channel of each major river within a catchment (e.g. Nene) was subdivided into upper, middle and lower stretches. The rivers and river stretches used in this analysis are shown in Table 2.1.

The river stretches were grouped into the following three size classes using the 1: 250,000 map of river discharges in Anglian Region (DOE 1979):

Class 1	10.00 - > 80.00 m^3s^{-1}
Class 2	1.25 - 10.00 m^3s^{-1}
Class 3	< 0.31 - 1.25 m^3s^{-1}

2. 4 Stream geology

Individual watercourse geology was recorded from Quaternary and Geological maps (Ordnance Survey 1:625,000; Anon 1957. 1977). The predominant rock type present along the length of each watercourse was noted from both maps. Five categories were used:

- limestone (l)
- clay (c)
- alluvium (a)
- sandstone (s)
- mixed (m).

Table 2.1. Rivers and river stretches within the Anglian region, arranged geographically from north to south

Catchment	River	Catchment	River	Catchment	River
Ancholme	Winterton Beck	**Great Ouse**	Little Ouse (middle)	**Yare**	Tud
Ancholme	New Ancholme	**Great Ouse**	Little Ouse (lower)	**Yare**	Tiffey
Ancholme	Rase	**Great Ouse**	Thet	**Yare**	Tas
Ancholme	Black Dyke	**Great Ouse**	Whittle	**Yare**	Hempnall Beck
Ancholme	North Kelsey Beck	**Great Ouse**	Larling Brook	**Yare**	Tat
Ancholme	Kettleby Beck	**Great Ouse**	Melsop Stalland	**Yare**	Chet
Lincolnshire Coast	East Halton Beck	**Great Ouse**	Buckenham Stream	**Waveney**	Waveney
Lincolnshire Coast	Freshney	**Great Ouse**	Sapiston	**Waveney**	Starston Beck
Lincolnshire Coast	Laceby Beck	**Great Ouse**	Stowlangtoft Stream	**Waveney**	Dove
Lincolnshire Coast	Buck Beck	**Great Ouse**	Botesdale Brook	**Waveney**	Finningham w/c
Lincolnshire Coast	Tetney Haven	**Great Ouse**	Lark (upper)	**Waveney**	Chickering Beck
Lincolnshire Coast	Lud	**Great Ouse**	Lark (lower)	**Waveney**	Easton Broad
Lincolnshire Coast	Thoresway Beck	**Great Ouse**	Tuddenham Stream	**Waveney**	Walpole
Lincolnshire Coast	Waithe Beck	**Great Ouse**	Cavenham Stream	**Waveney**	Blyth
Lincolnshire Coast	Long Eau	**Great Ouse**	Linnet	**Waveney**	Wang
Lincolnshire Coast	Great Eau	**Great Ouse**	Culford Stream	**Deben/Gipping**	Alde
Lincolnshire Coast	Steeping	**Great Ouse**	Kennett	**Deben/Gipping**	Ore
Lincolnshire Coast	Lymn	**Great Ouse**	Cam	**Deben/Gipping**	Tang
Witham	Witham (upper)	**Great Ouse**	Soham Lode	**Deben/Gipping**	Butley
Witham	Witham (middle)	**Great Ouse**	New	**Deben/Gipping**	Deben (upper)
Witham	Witham (lower)	**Great Ouse**	Burwell Lode	**Deben/Gipping**	Deben (lower)
Witham	Bain	**Great Ouse**	Reach Lode	**Deben/Gipping**	Earl Soham w/c
Witham	Waring	**Great Ouse**	Swaffham Bulbeck	**Deben/Gipping**	Lark
Witham	Slea	**Great Ouse**	Bottisham Lode	**Deben/Gipping**	Fynn
Witham	Old Slea	**Great Ouse**	Cottenham Lode	**Deben/Gipping**	Shottisham
Witham	Kyme Eau	**Great Ouse**	Bourne Brook	**Deben/Gipping**	Mill
Witham	Brant	**Great Ouse**	Granta	**Deben/Gipping**	Gipping
Witham	Barlings Eau	**Great Ouse**	Rhee	**Deben/Gipping**	Haughley Stream
Witham	Foston Beck	**Great Ouse**	Shep	**Deben/Gipping**	Rattlesden
Witham	Cringle Beck	**Great Ouse**	Melbourn Brook	**Deben/Gipping**	Belstead Brook
Witham	Till	**Great Ouse**	Mel	**Stour/Colne**	Stour
Witham	Reeds Beck	**Great Ouse**	Whaddon Brook	**Stour/Colne**	Stour Brook
Welland	Welland (upper)	**Great Ouse**	Mill	**Stour/Colme**	Barnardiston Brook
Welland	Welland (middle)	**Great Ouse**	Ivel	**Stour/Colne**	Glem
Welland	Welland (lower)	**Great Ouse**	Pix Brook	**Stour/Colne**	Chad Brook
Welland	Glen	**Great Ouse**	Hiz	**Stour/Colne**	Box
Welland	Gwash	**Great Ouse**	Barton Brook	**Stour/Colne**	Brett
Welland	North Brook	**Great Ouse**	Campton Brook	**Stour/Colne**	Bildeston Brook
Welland	Chater	**Great Ouse**	Flit-Ivel Navigation	**Stour/Colne**	Lavenham Brook
Welland	Eye Brook	**Great Ouse**	Elstow Brook	**Stour/Colne**	Ramsey Brook
Nene	Nene (upper)	**Great Ouse**	Kym	**Stour/Colne**	Colne
Nene	Nene (middle)	**Great Ouse**	Brampton Brook	**Stour/Colne**	Stambourne Brook
Nene	Nene (lower)	**Great Ouse**	Ellington Brook	**Stour/Colne**	Toppesfield Brook
Nene	Old Nene	**Great Ouse**	Alconbury Brook	**Stour/Colne**	Bourne Brook
Nene	Ripton Brook	**Great Ouse**	Broughton Brook	**Stour/Colne**	Roman
Nene	Highlode	**Great Ouse**	Clipstone Brook	**Blackwater**	Blackwater
Nene	Willow Brook	**Great Ouse**	Ouzel (upper)	**Blackwater**	Pant
Nene	Willow Br. South	**Great Ouse**	Ouzel (lower)	**Blackwater**	Belchamp Brook
Nene	Willow Br. North	**Great Ouse**	Padbury Brook	**Blackwater**	Rivenhall Brook
Nene	Harpers Brook	**Great Ouse**	Claydon Brook	**Blackwater**	Brain
Nene	Ise	**Great Ouse**	Tove	**Blackwater**	Pods Brook
Nene	Slade Brook	**Bure**	Burn	**Blackwater**	Layer Brook
Nene	Brampton Nene	**Bure**	Binham	**Blackwater**	Higham Brook
Nene	Whilton Nene	**Bure**	Stiffkey	**Chelmer**	Chelmer
Great Ouse	Great Ouse (upper)	**Bure**	Glaven	**Chelmer**	Stebbing Brook
Great Ouse	Great Ouse (middle)	**Bure**	Gunthorpe Stream	**Chelmer**	Wid
Great Ouse	Great Ouse (lower)	**Bure**	Scarrow Beck	**Chelmer**	Ter
Great Ouse	Hundred Foot River	**Bure**	Kings Beck	**Chelmer**	Can
Great Ouse	Bedford River	**Bure**	Bure	**Chelmer**	Thorndon Brook
Great Ouse	Heacham	**Bure**	Ant	**Chelmer**	Stock Brook
Great Ouse	Ingol	**Bure**	East Ruston Stream	**Chelmer**	Sandy Brook
Great Ouse	Babingley C'ment	**Bure**	Mermaid	**Chelmer**	Roxwell Brook
Great Ouse	Gaywood	**Yare**	Yare	**Chelmer**	Sandon Brook
Great Ouse	Nar	**Yare**	Wensum	**Chelmer**	Crouch
Great Ouse	Wissey	**Yare**	Blackwater	**Chelmer**	Rettendon Brook
Great Ouse	Stringside	**Yare**	Whitewater	**Chelmer**	Rayleigh Brook
Great Ouse	Watton Brook			**Chelmer**	Prittle Brook
Great Ouse	Little Ouse (upper)			**Chelmer**	Mar Dyke

A river or stream described as 'mixed' has three or more rock types present along its length. Where the surface or Quaternary geology differed from the underlying older geology, the watercourse was assigned two letters respectively to describe both of these. Conversely, with the exception of alluvium, a single letter indicates that the influencing rock type is predominant throughout the immediate lithosphere. Letters in brackets denote that a rock type might have an influencing effect on the river or stream channel without being the predominant rock within either geological strata. Haslam (1981) compiled a rock type map for the UK. She used a greater number of rock types, for example, the classification of limestone in this study was separately identified as chalk, oolite and hard limestone by Haslam. Small scale rock outcrops are, however, not detailed on her map. The allocation of each river and stream to a geological type in this study has taken account of these minor variations in surface rock.

2. 5 Phosphorus status

Phosphorus data derived from samples taken at bridge sites along most Anglian rivers and streams during 1992 were obtained from CDPS. The mean concentration (mg/l) of soluble reactive phosphorus (SRP) for each site was calculated and placed in a rank class in order to separate sites into five groups. These were:

- Class 1 over 1.00 mg/l
- Class 2 0.50 - 1.00 mg/l
- Class 3 0.25 - 0.50 mg/l
- Class 4 0.10 - 0.25 mg/l
- Class 5 under 0.10 mg/l

The classes and their upper and lower limits were chosen solely to separate the river sites into five groups, as five was considered to be the maximum number of groups which a summary of one year's data could realistically justify. The median value of the ranks within any named tributary or or river stretch was then used to represent the P-status of that.

Rivers in Rank class 5 are those which are clearly mesotrohic, those in class 4 probably so. (The errors inherent in using a summary classification on only one year's data mean that 250 µg/l can in this instance, be consideered as the mesotrophic boundary equivalent to 200 µg/l in more accurate reviews). Class 3 represents eutrophic river water, whilst classes 2 and 1 represent highly eutrophic waters with a mean concentration above 500 µg/l.

2. 6 Sewage effluent discharges

The amount of effluent discharged from sewage treatment works and private and commercial property into each watercourse was calculated from dry weather flow (DWF) data obtained from the Water Quality Section, Kingfisher House. A summed value for each river and river length was derived from the addition of the separate DWF inputs (m^3 per day) for the length of a receiving water. These cumulative values were then given a rank class:

- Class 1 over 25,000 m^3 per day
- Class 2 over 10,000 m^3 per day
- Class 3 over 5,000 m^3 per day
- Class 4 under 5,000 m^3 per day
- Class 5 under 500 m^3 per day

Where DWF data was missing, the watercourse was placed in Class 5.

2.7 Data analysis

These classifications by size, geology, phosphorus, and sewage effluent discharge were compiled within a single spreadsheet. Rank ordering of that spreadsheet for each parameter in turn indicated visual connections between different parameters.

2.8 River macrophytes

Macrophyte data for six rivers of the region were extracted from the REDS database (Kingfisher House). A number of methodologies were then applied to the species lists in order to both assess the trophic status of the rivers chosen and identify the most workable of these methods. The methodologies included those of Haslam (1981), Holmes (1983), Newbold and Palmer (1979) and Harding (1981).

Haslam made surveys of river vegetation between 1969 and 1980 making use of bridges as points from which to record macrophyte species. Those plants within the channel and above normal water level on the bankside were recorded within an identifiable range both upstream and downstream of the bridge. This permitted a uniform overhead assessment of the vegetation at each bridge site. Haslam recorded a total of approximately 80 species of macrophyte and bank species, considering this number of species sufficient for diagnostic purposes. The degree of species abundance was recorded on a 2-point scale: much or little. The allocation of species to a trophic range (dystrophic to eutrophic) was based upon analysis of species assemblages and nutrient data.

Holmes (1983) classified river types by the plant communities present. Data on river flora were collected from 1,055 sites located on over 200 rivers and tributaries between 1978 and 1982. Each site surveyed covered 1km of river with 5-10 km between individual sites. The survey at each site included the river channel and both immediate banksides. Relative abundance was measured on a 3-point scale: 1= rare, 2 = frequent and 3 = co-dominant or dominant. Similarly relative cover of individual species was assessed as: 1 = < 0.1% cover, 2 = 0.1 - 5.0 % cover and 3 = > 5.0 % cover. In addition, information for each site was gathered on a number of physical parameters including range of substrates, water depth, water velocity, river width, slope, shade and adjacent land use. Information on geology, hydrology, altitude and slope was collected from maps.

The channel and bankside data and abundance ratings were analysed using Twinspan. This programme classified the sites with similar plant communities into groups and also listed the species which were indicative of that group. In the first instance, the analysis defined four main categories of plant assemblage and river type; (A) lowland, enriched rivers with eutrophic plant assemblages, (B) sandstone and limestone rivers, with meso-eutrophic plant assemblages, (C) upland or lowland rivers on Tertiary sands or nutrient poor rocks with mesotrophic plant assemblages and (D) highland or lowland acid heathland rivers with oligotrophic plant assemblages. Further analysis divided the plant communities and thus river sites into 56 groups. Group A category has the greatest number of stream type subdivisions. Holmes attempted to assess the trophic status of the 56 community types within the descriptive text for each stream type. This was a subjective evaluation based upon assemblage, species and geological information, given that there were no available data on water or substrate.

Newbold and Palmer also tried to evaluate trophic status by the macrophytes present within a watercourse by assigning a trophic value to each species (Newbold and Palmer 1979, in Holmes and Newbold, 1984) They sequentially listed and ranked 150 plant species from those confined to oligotrophic waters through to those able to tolerate hypertrophic conditions. An assessment of the trophic status of a site could be made by calculating the mean of the rank values of the macrophytes present.

Holmes and Newbold (1984) later evaluated the objectivity of this essentially arbitrary method by ranking the species indicative of Holmes's (1983) stream type classes. They found that their ranking values could be used objectively since the results coincided with Holmes prescribed trophic range for each stream type. Holmes and Newbold also recommended improvements to the system such as omitting the generalist species that occur across the trophic range of waters and altering some of the ranks assigned to certain species.

Harding (1981) similarly proposed a ranking system for macrophytes. A smaller number of macrophytes were scored on a scale from 1-10, the higher rank values indicating a species less tolerant of pollution and enrichment. A score for site trophic status, ASPT (Average Score Per Taxon) could then be calculated from the mean value for the participating macrophyte species.

The trophic ranking system of Newbold and Palmer was used here to analyse the REDS data for six of the region's rivers. Macrophyte species were extracted from five consecutive sample stretches taken from the upper, middle and lower reaches of each river. Each species was ranked according to recommendations made by Holmes and Newbold such that generalist species (those occurring across the whole trophic range) were omitted. These include *Glyceria fluitans, Agrostis stolonifera, Myosotis scorpioides, Mentha aquatica, Potamogeton crispus, Phragmites australis and Lemna minor*. The ranks proposed by Holmes and Newbold have replaced the original values. The mean value was calculated for each of five reaches within three sections (upper, middle, lower) of the six rivers. The mean values obtained and the number of contributing species (in brackets) were tabulated. Table 2.2 lists the macrophyte species extracted from the REDS data with the trophic rank assigned to each.

REDS data are derived from river corridor surveys and as such contain lists of terrestrial as well as aquatic vegetation. A comparison was made, prior to analysis, between the relevant REDS listings and the aquatic macrophyte data collected in some detail from the River Welland in 1987 (Smith, Harper and Barham, 1991) to assess the validity of REDS in terms of the number of recorded macrophyte species. The REDS listings were shown to be sufficiently thorough in their recording of aquatic species.

Table 2.2 Macrophyte species used in the trophic ranking

Species	Trophic Rank
Cardamine amara	30
Carex acuta	40
Iris pseudocorus	41
Juncus effusus	51
Ranunculus fluitans	60
Ranunculus penicillatus	69
Ranunculus aquatilis	70
Elodea canadensis	71
Myosoton aquaticum	74
Veronica beccabunga	76
Phalaris arundinacea	78
Lemna gibba	88
Nasturtium officinale	97
Sparganium emersum	102
Sparganium erectum	103
Veronica catenata	105
Veronica anagallis-aquatica	106
Apium nodiflorum	106
Oenanthe fluviatilis	107
Alisma plantago-aquatica	109
Carex acutiformis	110
Ranunculus sceleratus	111
Rorippa amphibia	112
Carex riparia	114
Glyceria maxima	116
Sagittaria sagittifolia	127
Scirpus martimus	128
Potamogeton perfoliatus	135
Nuphar lutea	138
Polygonum amphibium	141
Scirpus lacustris	142
Ceratophyllum demersum	144
Typha latifolia	146
Potamogeton pectinatus	149
Myriophyllum spicatum	148
Zannichellia palustris	150

3. RESULTS

3.1 Geology

The review of macrophyte classifications above, particularly that developed by Holmes, show clearly how geology influences macrophyte communities across the broad spectrum of rock types found in the United Kingdom. Catchments of Anglian region drain most of the soft rock types of the UK, but few or none of the hard rocks. Moreover, all the catchments are strongly influenced by surface deposits derived from the last glacial retreat, some 20,000 years ago.

The majority of watercourses were alluvial, followed by clay, then limestone. A few were sandstone and a few mixed (Table 2). Alluvial and clay-based streams are likely to contain eutrophic plant communities even without human influence, according to the classifications of Haslam and of Holmes.

There was a slight tendency for the limestone streams be lower in phosphorus concentrations (the average P rank for limestone streams was just over 3 compared with around 2.5 for allubvial and clay streams). Closer examination of the table suggests that the differences are more pronounced for headwater streams although there are noticeable exceptions, such as the Ouzel or Willow Brook (with high effluents discharges) or upper Stour (Ely-Ouse basin transfer).

Table 3.1. Rivers of Anglian region arranged by rock type. a) Alluvial

River System	Stream	Rock type	Flow rank	DWF rank	Median P-rank
Ancholme	New Ancholme	a	2	3	3
Lincolnshire Coast	Tetney Haven	a	2	3	
Lincolnshire Coast	Lud	a	3	5	5
Lincolnshire Coast	Long Eau	a	3	4	3
Lincolnshire Coast	Great Eau	a	3	5	5
Lincolnshire Coast	Steeping	a	2	4	3
Witham	Witham (middle)	a	2	1	2
Witham	Witham (lower)	a	1	4	3
Witham	Bain	a	3	4	3
Witham	Kyme Eau	a	3	5	1
Witham	Barlings Eau	a	3	5	2
Welland	Welland (middle)	a	2	2	2.5
Welland	Welland (lower)	a	2	2	3
Nene	Nene (middle)	a	2	1	1
Nene	Nene (lower)	a	1	4	2
Nene	Old Nene	a	3	4	2
Nene	Highlode	a	3	4	1
Nene	Whilton Nene	a	3	4	
Great Ouse	Great Ouse (middle)	a	2	1	1.5
Great Ouse	Great Ouse (lower)	a	1	1	1
Great Ouse	Hundred Foot River	a	1	4	1.5
Great Ouse	Bedford River	a	1	4	2
Great Ouse	Little Ouse (upper)	a	3	4	5
Great Ouse	Little Ouse (lower)	a	2	4	3
Great Ouse	Lark (lower)	a	2	3	1
Great Ouse	Cam	a	2	1	1
Great Ouse	Granta	a	3	4	1
Great Ouse	Flit-Ivel Navigation	a	3	1	1
Great Ouse	Elstow Brook	a	3	4	2
Great Ouse	Broughton Brook	a	3	5	4
Great Ouse	Ouzel (lower)	a	2	2	1
Great Ouse	Padbury Brook	a	2	4	3
Great Ouse	Claydon Brook	a	3	4	1.5
Great Ouse	Tove	a	2	3	3
Bure	Kings Beck	a	3	5	5
Bure	Bure	a	2	3	5
Bure	Ant	a	3	4	5
Yare	Yare	a	2	4	4
Yare	Wensum	a	2	3	3
Yare	Blackwater	a	3	5	5
Yare	Whitewater	a	3	5	
Yare	Tud	a	3	4	3.5
Yare	Tiffey	a	3	4	2
Yare	Tas	a	3	4	3
Waveney	Waveney	a	2	3	4
Waveney	Easton Broad	a	3	5	3.5
Waveney	Blyth	a	3	4	3
Deben/Gipping	Tang	a	3	5	5
Deben/Gipping	Deben (lower)	a	2	4	3
Deben/Gipping	Lark	a	3	4	
Deben/Gipping	Fynn	a	3	5	3
Deben/Gipping	Gipping	a	2	3	2
Deben/Gipping	Rattlesden	a	3	5	3
Stour/Colne	Stour	a	2	2	2
Stour/Colne	Brett	a	3	4	2.5
Nene	Nene (upper)	a(l)	3	5	3
Great Ouse	Ivel	a(l)	2	2	1
Great Ouse	Burwell Lode	a/l	3	4	2
Great Ouse	Reach Lode	a/l	3	5	3

Table 3.1. Rivers of Anglian region arranged by rock type b) Clay

River System	Stream	Rock type	Flow rank	DWF rank	Median P-rank
Ancholme	Kettleby Beck	c	3	4	
Lincolnshire Coast	East Halton Beck	c	3	5	
Lincolnshire Coast	Freshney	c	3	5	2.5
Lincolnshire Coast	Laceby Beck	c	3	4	
Lincolnshire Coast	Buck Beck	c	3	5	4
Lincolnshire Coast	Waithe Beck	c	3	5	4
Nene	Willow Br. South	c	3	2	2.5
Nene	Willow Br. North	c	3	5	4
Great Ouse	Stringside	c	3	5	3.5
Great Ouse	Watton Brook	c	3	4	2
Great Ouse	Melsop Stalland	c	3	5	1
Great Ouse	Buckenham Stream	c	3	4	4
Great Ouse	Sapiston	c	3	4	1.5
Great Ouse	Stowlangtoft Stream	c	3	4	
Great Ouse	Botesdale Brook	c	3	5	
Great Ouse	Lark (upper)	c	3	2	2.5
Great Ouse	Kym	c	3	4	2
Great Ouse	Alconbury Brook	c	3	4	3.5
Bure	Gunthorpe Stream	c	3	5	5
Bure	Scarrow Beck	c	3	5	5
Yare	Hempnall Beck	c	3	5	3
Waveney	Chickering Beck	c	3	5	1
Deben/Gipping	Belstead Brook	c	3	3	3
Stour/Colne	Chad Brook	c	3	5	4
Stour/Colne	Box	c	3	4	1.5
Stour/Colne	Bourne Brook	c	3	5	1
Stour/Colne	Roman	c	3	4	1
Blackwater	Pant	c	3	4	2
Blackwater	Belchamp Brook	c	3	5	5
Chelmer	Can	c	3	5	1.5
Chelmer	Sandy Brook	c	3	5	
Ancholme	North Kelsey Beck	c(l)	3	5	1
Welland	Eye Brook	c(l)	3	5	5
Great Ouse	Cavenham Stream	c(l)	3	5	1
Great Ouse	Linnet	c(l)	3	5	2
Great Ouse	Bourne Brook	c(l)	3	4	1
Stour/Colne	Colne	c(l)	2	3	2
Chelmer	Chelmer	c(l)	2	4	2
Chelmer	Roxwell Brook	c(l)	3	5	3
Blackwater	Rivenhall Brook	c(s)	3	5	
Welland	Welland (upper)	cl	3	5	4
Bure	Glaven	cl	3	4	5
Stour/Colne	Stour Brook	cl	3	3	1
Stour/Colme	Barnardiston Brook	cl	3	5	1
Stour/Colne	Bildeston Brook	cl	3	5	5
Stour/Colne	Lavenham Brook	cl	3	5	3
Stour/Colne	Stambourne Brook	cl	3	5	3
Stour/Colne	Toppesfield Brook	cl	3	5	3
Deben/Gipping	Haughley Stream	cs	3	5	3.5

Table 3.1. Rivers of Anglian region arranged by rock type c) Limestone and chalk

River System	Stream	Rock type	Flow rank	DWF rank	Median P-rank
Ancholme	Black Dyke	l	3	4	
Lincolnshire Coast	Thoresway Beck	l	3	5	
Witham	Witham (upper)	l	3	4	3
Welland	Glen	l	3	4	5
Welland	Gwash	l	3	4	4.5
Welland	North Brook	l	3	4	
Nene	Willow Brook	l	3	4	1
Nene	Harpers Brook	l	3	5	4
Great Ouse	Great Ouse (upper)	l	3	3	3
Great Ouse	Heacham	l	3	4	5
Great Ouse	Ingol	l	3	4	1
Great Ouse	Larling Brook	l	3	5	
Great Ouse	Kennett	l	3	5	3
Great Ouse	Swaffham Bulbeck	l	3	4	1
Great Ouse	Bottisham Lode	l	3	4	
Great Ouse	Shep	l	3	5	3
Great Ouse	Melbourn Brook	l	3	5	3
Great Ouse	Mel	l	3	5	
Great Ouse	Whaddon Brook	l	3	4	1
Great Ouse	Mill	l	3	4	1.5
Great Ouse	Pix Brook	l	3	3	2.5
Great Ouse	Clipstone Brook	l	3	5	2
Great Ouse	Ouzel (upper)	l	3	2	1
Bure	Burn	l	3	4	2
Bure	Stiffkey	l	3	4	4
Yare	Tat	l	3	5	
Great Ouse	Tuddenham Stream	l(c)	3	5	3
Bure	Binham	l(c)	3	5	3
Great Ouse	Cottenham Lode	l(s)	3	4	2
Ancholme	Winterton Beck	lc	3	5	5
Lincolnshire Coast	Lymn	lc	3	5	
Witham	Waring	lc	3	5	
Witham	Brant	lc	3	4	2
Witham	Foston Beck	lc	3	5	2
Witham	Cringle Beck	lc	3	5	5
Welland	Chater	lc	3	4	4.5
Nene	Ripton Brook	lc	3	5	
Nene	Ise	lc	2	4	4
Nene	Slade Brook	lc	3	5	5
Nene	Brampton Nene	lc	2	4	2.5
Great Ouse	New	lc	3	5	5
Great Ouse	Ellington Brook	lc	3	5	4
Stour/Colne	Ramsey Brook	lc	3	5	2
Blackwater	Layer Brook	lc	3	5	3
Blackwater	Higham Brook	lc	3	5	
Chelmer	Stebbing Brook	lc	3	4	5
Chelmer	Wid	lc	3	2	1
Chelmer	Thorndon Brook	lc	3	5	
Chelmer	Stock Brook	lc	3	5	
Chelmer	Sandon Brook	lc	3	5	3
Chelmer	Crouch	lc	3	4	1
Chelmer	Rettendon Brook	lc	3	5	
Chelmer	Rayleigh Brook	lc	3	5	
Chelmer	Prittle Brook	lc	3	5	4
Great Ouse	Nar	lm	3	4	4
Great Ouse	Babingley C'ment	ls	3	5	5
Great Ouse	Gaywood	ls	3	4	5
Great Ouse	Rhee	ls	3	3	1.5
Great Ouse	Barton Brook	ls	3	4	2
Great Ouse	Campton Brook	ls	3	4	1.5

Table 3.1. Rivers of Anglian region arranged by rock type d) Sandstone and mixed

River System	Stream	Rock type	Flow rank	DWF rank	Median P-rank
Bure	East Ruston Stream	s	3	5	5
Bure	Mermaid	s	3	5	5
Waveney	Starston Beck	s	3	4	1
Waveney	Dove	s	3	4	2.5
Waveney	Walpole	s	3	5	4
Deben/Gipping	Ore	s	3	4	2.5
Deben/Gipping	Butley	s	3	5	5
Deben/Gipping	Mill	s	3	5	
Yare	Chet	s(c)	3	4	
Waveney	Finningham w/c	s(c)	3	5	1
Waveney	Wang	s(c)	3	5	1
Great Ouse	Little Ouse (middle)	s(l)	2	4	3.5
Deben/Gipping	Deben (upper)	s(l)	3	4	3
Deben/Gipping	Earl Soham w/c	s(l)	3	5	2
Witham	Old Slea	sc	3	4	1
Witham	Reeds Beck	sc	3	5	
Great Ouse	Brampton Brook	sc	3	4	1
Deben/Gipping	Shottisham	sc	3	5	5
Blackwater	Blackwater	sc	3	2	1.5
Blackwater	Brain	sc	3	3	1
Blackwater	Pods Brook	sc	3	5	4
Chelmer	Ter	sc	3	4	3
Witham	Slea	sl	3	5	3
Great Ouse	Culford Stream	sl	3	5	5
Stour/Colne	Glem	sl	3	4	2
Ancholme	Rase	mc	3	4	3
Witham	Till	mc	3	4	1.5
Chelmer	Mar Dyke	mc	3	5	1
Great Ouse	Wissey	mc/c	2	4	3
Great Ouse	Thet	ml	2	3	4
Great Ouse	Whittle	ml	3	5	3
Great Ouse	Soham Lode	ml	3	3	1
Great Ouse	Hiz	ml	3	2	2.5
Deben/Gipping	Alde	ms	3	4	5

3.2 Sewage Effluent Input

Rivers sorted in rank order of effluent input (Table 3) show clearly that any watercourse lower than rank 4, i.e receiving appreciable quantities of sewage effluent, contains high concentrations of phosphorus. There are also differences bewteen effluent ranks 4 (whose watercourses have an average phosphorus rank of 2.7) and 5 (whose watercourses have an average phosphorus rank of 3.8). Such differences would probably reach statistical significance if based upon a more comprehensive data set and analysed more thoroughly.

Several low-effluent streams (high DWF rank) are high in phosphorus, and individual reasons for this discrepancy would need to be investigated on a case-by-case basis. If they are larger watercourses, they almost certainly receive phosphorus-rich water from upstream effluents, which have not been counted in this preliminary assessment (effluents have only been allocated to the stretch that they enter). Probably for smaller watercourses there are local circumstances, such as the standard of individual effluents, or the influence of other point sources such as agricultural units, which are missed in an overview. Sixteen stretches out of eighty nine, or 18% of stetches with low effluent input were phosphorus-rich, but the remaining 82% nevertheless, could be considered mesotrophic.

Thus watercourses receiving an effluent discharge which is below 500 m^3/day are likely to be mesotrophic, those receiving more than this eutrophic. The majority of these watercourses are, not unexpectedly, in the lowest discharge class – i.e. headwater streams and tributaries.

Table 3.2. Rivers sorted by sewage effluent dry weather flow. a) DWF rank 5 (lowest)

River System	Stream	DWF rank	DWF m^3/day	Median P-rank	Flow rank	Rock type
Ancholme	Winterton Beck	5		5	3	lc
Ancholme	North Kelsey Beck	5	290	1	3	c(l)
Lincolnshire Coast	East Halton Beck	5	425		3	c
Lincolnshire Coast	Freshney	5		2.5	3	c
Lincolnshire Coast	Buck Beck	5		4	3	c
Lincolnshire Coast	Lud	5		5	3	a
Lincolnshire Coast	Thoresway Beck	5	260		3	l
Lincolnshire Coast	Waithe Beck	5	360	4	3	c
Lincolnshire Coast	Great Eau	5		5	3	a
Lincolnshire Coast	Lymn	5	260		3	lc
Witham	Waring	5			3	lc
Witham	Slea	5	284	3	3	sl
Witham	Kyme Eau	5	143	1	3	a
Witham	Barlings Eau	5	4451	2	3	a
Witham	Foston Beck	5	160	2	3	lc
Witham	Cringle Beck	5	41	5	3	lc
Witham	Reeds Beck	5			3	sc
Welland	Welland (upper)	5	123	4	3	cl
Welland	Eye Brook	5	165	5	3	c(l)
Nene	Nene (upper)	5	75	3	3	a(l)
Nene	Ripton Brook	5			3	lc
Nene	Willow Br. North	5		4	3	c
Nene	Harpers Brook	5	410	4	3	l
Nene	Slade Brook	5	86	5	3	lc
Great Ouse	Babingley C'ment	5	391	5	3	ls
Great Ouse	Stringside	5	100	3.5	3	c
Great Ouse	Whittle	5	492	3	3	ml
Great Ouse	Larling Brook	5	65		3	l
Great Ouse	Melsop Stalland	5		1	3	c
Great Ouse	Botesdale Brook	5	280		3	c
Great Ouse	Tuddenham Stream	5		3	3	l(c)
Great Ouse	Cavenham Stream	5	385	1	3	c(l)
Great Ouse	Linnet	5	400	2	3	c(l)
Great Ouse	Culford Stream	5		5	3	sl
Great Ouse	Kennett	5	370	3	3	l
Great Ouse	New	5		5	3	lc
Great Ouse	Reach Lode	5	232	3	3	a/l
Great Ouse	Shep	5		3	3	l
Great Ouse	Melbourn Brook	5	15	3	3	l
Great Ouse	Mel	5			3	l
Great Ouse	Ellington Brook	5	330	4	3	lc
Great Ouse	Broughton Brook	5		4	3	a
Great Ouse	Clipstone Brook	5	1	2	3	l
Bure	Binham	5		3	3	l(c)
Bure	Gunthorpe Stream	5		5	3	c
Bure	Scarrow Beck	5	345	5	3	c
Bure	Kings Beck	5		5	3	a
Bure	East Ruston Stream	5		5	3	s
Bure	Mermaid	5		5	3	s
Yare	Blackwater	5	430	5	3	a
Yare	Whitewater	5			3	a
Yare	Hempnall Beck	5	340	3	3	c
Yare	Tat	5	500		3	l
Waveney	Finningham w/c	5		1	3	s(c)
Waveney	Chickering Beck	5	15	1	3	c
Waveney	Easton Broad	5	200	3.5	3	a
Waveney	Walpole	5		4	3	s
Waveney	Wang	5	129	1	3	s(c)

Table 3.2a) . Rivers sorted by sewage effluent dry weather flow, DWF rank 5, continued

River System	Stream	DWF rank	DWF m³/day	Median P-rank	Flow rank	Rock type
Deben/Gipping	Tang	5		5	3	a
Deben/Gipping	Butley	5		5	3	s
Deben/Gipping	Earl Soham w/c	5		2	3	s(l)
Deben/Gipping	Fynn	5	363	3	3	a
Deben/Gipping	Shottisham	5		5	3	sc
Deben/Gipping	Mill	5			3	s
Deben/Gipping	Haughley Stream	5	330	3.5	3	cs
Deben/Gipping	Rattlesden	5	493	3	3	a
Stour/Colme	Barnardiston Brook	5		1	3	cl
Stour/Colne	Chad Brook	5	260	4	3	c
Stour/Colne	Bildeston Brook	5	310	5	3	cl
Stour/Colne	Lavenham Brook	5	480	3	3	cl
Stour/Colne	Ramsey Brook	5	160	2	3	lc
Stour/Colne	Stambourne Brook	5		3	3	cl
Stour/Colne	Toppesfield Brook	5	80	3	3	cl
Stour/Colne	Bourne Brook	5	338	1	3	c
Blackwater	Belchamp Brook	5		5	3	c
Blackwater	Rivenhall Brook	5	80		3	c(s)
Blackwater	Pods Brook	5	480	4	3	sc
Blackwater	Layer Brook	5		3	3	lc
Blackwater	Higham Brook	5			3	lc
Chelmer	Can	5	195	1.5	3	c
Chelmer	Thorndon Brook	5			3	lc
Chelmer	Stock Brook	5			3	lc
Chelmer	Sandy Brook	5	45		3	c
Chelmer	Roxwell Brook	5	220	3	3	c(l)
Chelmer	Sandon Brook	5		3	3	lc
Chelmer	Rettendon Brook	5			3	lc
Chelmer	Rayleigh Brook	5			3	lc
Chelmer	Prittle Brook	5		4	3	lc
Chelmer	Mar Dyke	5	18	1	3	mc

Table 3.2. Rivers sorted by sewage effluent dry weather flow b) DWF rank 4

River System	Stream	DWF rank	DWF m^3/day	Median P-rank	Flow rank	Rock type
Ancholme	Rase	4	1883	3	3	mc
Ancholme	Black Dyke	4	2100		3	l
Ancholme	Kettleby Beck	4	662		3	c
Lincolnshire Coast	Laceby Beck	4	600		3	c
Lincolnshire Coast	Long Eau	4	520	3	3	a
Lincolnshire Coast	Steeping	4	1855	3	2	a
Witham	Witham (upper)	4	745	3	3	l
Witham	Witham (lower)	4	2945	3	1	a
Witham	Bain	4	3643	3	3	a
Witham	Old Slea	4	4313	1	3	sc
Witham	Brant	4	900	2	3	lc
Witham	Till	4	1479	1.5	3	mc
Welland	Glen	4	3706	5	3	l
Welland	Gwash	4	1356	4.5	3	l
Welland	North Brook	4	1100		3	l
Welland	Chater	4	1406	4.5	3	lc
Nene	Nene (lower)	4	1385	2	1	a
Nene	Old Nene	4	1440	2	3	a
Nene	Highlode	4	1960	1	3	a
Nene	Willow Brook	4	561	1	3	l
Nene	Ise	4	702	4	2	lc
Nene	Brampton Nene	4	3088	2.5	2	lc
Nene	Whilton Nene	4	1419		3	a
Great Ouse	Hundred Foot River	4	1300	1.5		a
Great Ouse	Bedford River	4	1465	2		a
Great Ouse	Heacham	4	4500	5	3	l
Great Ouse	Ingol	4	1470	1	3	l
Great Ouse	Gaywood	4	721	5	3	ls
Great Ouse	Nar	4	828	4	3	lm
Great Ouse	Wissey	4	3142	3	2	mc/c
Great Ouse	Watton Brook	4	3000	2	3	c
Great Ouse	Little Ouse (upper)	4	533	5	3	a
Great Ouse	Little Ouse (middle)	4	2426	3.5	2	s(l)
Great Ouse	Little Ouse (lower)	4	2960	3	2	a
Great Ouse	Buckenham Stream	4	585	4	3	c
Great Ouse	Sapiston	4	4610	1.5	3	c
Great Ouse	Stowlangtoft Stream	4	540		3	c
Great Ouse	Burwell Lode	4	625	2	3	a/l
Great Ouse	Swaffham Bulbeck	4	820	1	3	l
Great Ouse	Bottisham Lode	4	1911		3	l
Great Ouse	Cottenham Lode	4	1588	2	3	l(s)
Great Ouse	Bourne Brook	4	561	1	3	c(l)
Great Ouse	Granta	4	2248	1	3	a
Great Ouse	Whaddon Brook	4	2616	1	3	l
Great Ouse	Mill	4	1640	1.5	3	l
Great Ouse	Barton Brook	4	955	2	3	ls
Great Ouse	Campton Brook	4	1130	1.5	3	ls
Great Ouse	Elstow Brook	4	2617	2	3	a
Great Ouse	Kym	4	1594	2	3	c
Great Ouse	Brampton Brook	4	1300	1	3	sc
Great Ouse	Alconbury Brook	4	1609	3.5	3	c
Great Ouse	Padbury Brook	4	1077	3	2	a
Great Ouse	Claydon Brook	4	4820	1.5	3	a

Table 3.2. Rivers sorted by sewage effluent dry weather flow. b) DWF rank 4 continued

River System	Stream	DWF rank	DWF m³/day	Median P-rank	Flow rank	Rock type
Bure	Burn	4	780	2	3	l
Bure	Stiffkey	4	705	4	3	l
Bure	Glaven	4	1740	5	3	cl
Bure	Ant	4	3132	5	3	a
Yare	Yare	4	3752	4	2	a
Yare	Tud	4	850	3.5	3	a
Yare	Tiffey	4	3315	2	3	a
Yare	Tas	4	2416	3	3	a
Yare	Chet	4	930		3	s(c)
Waveney	Starston Beck	4	1710	1	3	s
Waveney	Dove	4	3381	2.5	3	s
Waveney	Blyth	4	2118	3	3	a
Deben/Gipping	Alde	4	1659	5	3	ms
Deben/Gipping	Ore	4	2540	2.5	3	s
Deben/Gipping	Deben (upper)	4	1057	3	3	s(l)
Deben/Gipping	Deben (lower)	4	654	3	2	a
Deben/Gipping	Lark	4	719		3	a
Stour/Colne	Glem	4	960	2	3	sl
Stour/Colne	Box	4	890	1.5	3	c
Stour/Colne	Brett	4	2372	2.5	3	a
Stour/Colne	Roman	4	2122	1	3	c
Blackwater	Pant	4	1255	2	3	c
Chelmer	Chelmer	4	1977	2	2	c(l)
Chelmer	Stebbing Brook	4	1630	5	3	lc
Chelmer	Ter	4	1110	3	3	sc
Chelmer	Crouch	4	1300	1	3	lc

Table 3.2. Rivers sorted by sewage effluent dry weather flow. c) DWF ranks 3-1 (highest)

River System	Stream	DWF rank	DWF m³/day	Median P-rank	Flow rank	Rock type
Ancholme	New Ancholme	3	5517	3	2	a
Lincolnshire Coast	Tetney Haven	3	7535		2	a
Great Ouse	Great Ouse (upper)	3	6059	3	3	l
Great Ouse	Thet	3	7965	4	2	ml
Great Ouse	Lark (lower)	3	6834	1	2	a
Great Ouse	Soham Lode	3	8613	1	3	ml
Great Ouse	Rhee	3	7039	1.5	3	ls
Great Ouse	Pix Brook	3	9600	2.5	3	l
Great Ouse	Tove	3	6862	3	2	a
Bure	Bure	3	5060	5	2	a
Yare	Wensum	3	9447	3	2	a
Waveney	Waveney	3	9458	4	2	a
Deben/Gipping	Gipping	3	6890	2	2	a
Deben/Gipping	Belstead Brook	3	5444	3	3	c
Stour/Colne	Stour Brook	3	5782	1	3	cl
Stour/Colne	Colne	3	9719	2	2	c(l)
Blackwater	Brain	3	6160	1	3	sc
Welland	Welland (middle)	2	11190	2.5	2	a
Welland	Welland (lower)	2	12360	3	2	a
Nene	Willow Br. South	2	10760	2.5	3	c
Great Ouse	Lark (upper)	2	11752	2.5	3	c
Great Ouse	Ivel	2	14484	1	2	a(l)
Great Ouse	Hiz	2	11589	2.5	3	ml
Great Ouse	Ouzel (upper)	2	20969	1	3	l
Great Ouse	Ouzel (lower)	2	13299	1	2	a
Stour/Colne	Stour	2	11826	2	2	a
Blackwater	Blackwater	2	13975	1.5	3	sc
Chelmer	Wid	2	16342	1	3	lc
Witham	Witham (middle)	1	58844	2	2	a
Nene	Nene (middle)	1	62046	1	2	a
Great Ouse	Great Ouse (middle)	1	58922	1.5	2	a
Great Ouse	Great Ouse (lower)	1	40035	1	1	a
Great Ouse	Cam	1	44982	1	2	a
Great Ouse	Flit-Ivel Navigation	1	26595	1	3	a

3.3 Phosphorus concentrations

The watercourses ranked by phosphorus concentrations show that almost all low-phosphorus (ranks 4 & 5; < 0.25 mg/l) streams have little or no sewage effluent input (Table 4). Exceptions are often limestone streams where phosphate precipitation may occur (e.g. Gwash, Glen) or larger rivers reflecting the effects of phosphate-stripping (e.g. Ant). Those watercourses without phosphorus data are almost all without effluent input and so most could be reasonably expected to be low in phosphorus.

Almost all the low-phosphorus streams are headwater streams, with the only exceptions being rivers where phosphorus removal occurs (Norfolk) or where sewage diversion (as a result of regional treatment works construction) has occurred (Ise).

There is little geological linkage with low phosphorus; all geological types are represented in the phosphorus rank 5 watercourses in proportion to their frequency within the region.

Forty six watercourses or river stretches fall into the two lowest-phosphorus ranks, i.e. have a mean phosphorus concentration less than 0.25 mg/l. A further 45 fall within rank 3; with phosphorus concentration 0.25 - 0.5 mg/l. Thirty four are within rank 2; mean concentration 0.5-1 mg/l and 45 in rank 1, over 1 mg/l phosphorus. A further 29 watercourses did not have phosphorus data recorded in 1992.

Table 3.3. Rivers ranked by mean 1992 soluble phosphorus concentrations.
a) Ranks 5 & 4 (<0.25 mg/l)

River System	Stream	Median P-rank	DWF rank	Flow rank	Rock type
Ancholme	Winterton Beck	5	5	3	lc
Lincolnshire Coast	Lud	5	5	3	a
Lincolnshire Coast	Great Eau	5	5	3	a
Witham	Cringle Beck	5	5	3	lc
Welland	Glen	5	4	3	l
Welland	Eye Brook	5	5	3	c(l)
Nene	Slade Brook	5	5	3	lc
Great Ouse	Heacham	5	4	3	l
Great Ouse	Babingley C'ment	5	5	3	ls
Great Ouse	Gaywood	5	4	3	ls
Great Ouse	Little Ouse (upper)	5	4	3	a
Great Ouse	Culford Stream	5	5	3	sl
Great Ouse	New	5	5	3	lc
Bure	Glaven	5	4	3	cl
Bure	Gunthorpe Stream	5	5	3	c
Bure	Scarrow Beck	5	5	3	c
Bure	Kings Beck	5	5	3	a
Bure	Bure	5	3	2	a
Bure	Ant	5	4	3	a
Bure	East Ruston Stream	5	5	3	s
Bure	Mermaid	5	5	3	s
Yare	Blackwater	5	5	3	a
Deben/Gipping	Alde	5	4	3	ms
Deben/Gipping	Tang	5	5	3	a
Deben/Gipping	Butley	5	5	3	s
Deben/Gipping	Shottisham	5	5	3	sc
Stour/Colne	Bildeston Brook	5	5	3	cl
Blackwater	Belchamp Brook	5	5	3	c
Chelmer	Stebbing Brook	5	4	3	lc
Welland	Gwash	4.5	4	3	l
Welland	Chater	4.5	4	3	lc
Lincolnshire Coast	Buck Beck	4	5	3	c
Lincolnshire Coast	Waithe Beck	4	5	3	c
Welland	Welland (upper)	4	5	3	cl
Nene	Willow Br. North	4	5	3	c
Nene	Harpers Brook	4	5	3	l
Nene	Ise	4	4	2	lc
Great Ouse	Nar	4	4	3	lm
Great Ouse	Thet	4	3	2	ml
Great Ouse	Buckenham Stream	4	4	3	c
Great Ouse	Ellington Brook	4	5	3	lc
Great Ouse	Broughton Brook	4	5	3	a
Bure	Stiffkey	4	4	3	l
Yare	Yare	4	4	2	a
Waveney	Waveney	4	3	2	a
Waveney	Walpole	4	5	3	s
Stour/Colne	Chad Brook	4	5	3	c
Blackwater	Pods Brook	4	5	3	sc
Chelmer	Prittle Brook	4	5	3	lc

Table 3.3. Rivers ranked by mean 1992 soluble phosphorus concentrations.
b) Ranks 3 & 3.5 (0.5 - 0.25 mg/l)

River System	Stream	Median P-rank	DWF rank	Flow rank	Rock type
Great Ouse	Stringside	3.5	5	3	c
Great Ouse	Little Ouse (middle)	3.5	4	2	s(l)
Great Ouse	Alconbury Brook	3.5	4	3	c
Yare	Tud	3.5	4	3	a
Waveney	Easton Broad	3.5	5	3	a
Deben/Gipping	Haughley Stream	3.5	5	3	cs
Ancholme	New Ancholme	3	3	2	a
Ancholme	Rase	3	4	3	mc
Lincolnshire Coast	Long Eau	3	4	3	a
Lincolnshire Coast	Steeping	3	4	2	a
Witham	Witham (upper)	3	4	3	l
Witham	Witham (lower)	3	4	1	a
Witham	Bain	3	4	3	a
Witham	Slea	3	5	3	sl
Welland	Welland (lower)	3	2	2	a
Nene	Nene (upper)	3	5	3	a(l)
Great Ouse	Great Ouse (upper)	3	3	3	l
Great Ouse	Wissey	3	4	2	mc/c
Great Ouse	Little Ouse (lower)	3	4	2	a
Great Ouse	Whittle	3	5	3	ml
Great Ouse	Tuddenham Stream	3	5	3	l(c)
Great Ouse	Kennett	3	5	3	l
Great Ouse	Reach Lode	3	5	3	a/l
Great Ouse	Shep	3	5	3	l
Great Ouse	Melbourn Brook	3	5	3	l
Great Ouse	Padbury Brook	3	4	2	a
Great Ouse	Tove	3	3	2	a
Bure	Binham	3	5	3	l(c)
Yare	Wensum	3	3	2	a
Yare	Tas	3	4	3	a
Yare	Hempnall Beck	3	5	3	c
Waveney	Blyth	3	4	3	a
Deben/Gipping	Deben (upper)	3	4	3	s(l)
Deben/Gipping	Deben (lower)	3	4	2	a
Deben/Gipping	Fynn	3	5	3	a
Deben/Gipping	Rattlesden	3	5	3	a
Deben/Gipping	Belstead Brook	3	3	3	c
Stour/Colne	Lavenham Brook	3	5	3	cl
Stour/Colne	Stambourne Brook	3	5	3	cl
Stour/Colne	Toppesfield Brook	3	5	3	cl
Blackwater	Layer Brook	3	5	3	lc
Chelmer	Ter	3	4	3	sc
Chelmer	Roxwell Brook	3	5	3	c(l)
Chelmer	Sandon Brook	3	5	3	lc

Table 3.3. Rivers ranked by mean 1992 soluble phosphorus concentrations.
c) Ranks 2 & 2.5 (1.0 - 0.5 mg/l)

River System	Stream	Median P-rank	DWF rank	Flow rank	Rock type
Lincolnshire Coast	Freshney	2.5	5	3	c
Welland	Welland (middle)	2.5	2	2	a
Nene	Willow Br. South	2.5	2	3	c
Nene	Brampton Nene	2.5	4	2	lc
Great Ouse	Lark (upper)	2.5	2	3	c
Great Ouse	Pix Brook	2.5	3	3	l
Great Ouse	Hiz	2.5	2	3	ml
Waveney	Dove	2.5	4	3	s
Deben/Gipping	Ore	2.5	4	3	s
Stour/Colne	Brett	2.5	4	3	a
Witham	Witham (middle)	2	1	2	a
Witham	Brant	2	4	3	lc
Witham	Barlings Eau	2	5	3	a
Witham	Foston Beck	2	5	3	lc
Nene	Nene (lower)	2	4	1	a
Nene	Old Nene	2	4	3	a
Great Ouse	Bedford River	2	4		a
Great Ouse	Watton Brook	2	4	3	c
Great Ouse	Linnet	2	5	3	c(l)
Great Ouse	Burwell Lode	2	4	3	a/l
Great Ouse	Cottenham Lode	2	4	3	l(s)
Great Ouse	Barton Brook	2	4	3	ls
Great Ouse	Elstow Brook	2	4	3	a
Great Ouse	Kym	2	4	3	c
Great Ouse	Clipstone Brook	2	5	3	l
Bure	Burn	2	4	3	l
Yare	Tiffey	2	4	3	a
Deben/Gipping	Earl Soham w/c	2	5	3	s(l)
Deben/Gipping	Gipping	2	3	2	a
Stour/Colne	Stour	2	2	2	a
Stour/Colne	Glem	2	4	3	sl
Stour/Colne	Ramsey Brook	2	5	3	lc
Stour/Colne	Colne	2	3	2	c(l)
Blackwater	Pant	2	4	3	c
Chelmer	Chelmer	2	4	2	c(l)

Table 3.3. Rivers ranked by mean 1992 soluble phosphorus concentrations.
d) Ranks 1 & 1.5 (>1.0 mg/l)

River System	Stream	Median P-rank	DWF rank	Flow rank	Rock type
Witham	Till	1.5	4	3	mc
Great Ouse	Great Ouse (middle)	1.5	1	2	a
Great Ouse	Hundred Foot River	1.5	4		a
Great Ouse	Sapiston	1.5	4	3	c
Great Ouse	Rhee	1.5	3	3	ls
Great Ouse	Mill	1.5	4	3	l
Great Ouse	Campton Brook	1.5	4	3	ls
Great Ouse	Claydon Brook	1.5	4	3	a
Stour/Colne	Box	1.5	4	3	c
Blackwater	Blackwater	1.5	2	3	sc
Chelmer	Can	1.5	5	3	c
Ancholme	North Kelsey Beck	1	5	3	c(l)
Witham	Old Slea	1	4	3	sc
Witham	Kyme Eau	1	5	3	a
Nene	Nene (middle)	1	1	2	a
Nene	Highlode	1	4	3	a
Nene	Willow Brook	1	4	3	l
Great Ouse	Great Ouse (lower)	1	1	1	a
Great Ouse	Ingol	1	4	3	l
Great Ouse	Melsop Stalland	1	5	3	c
Great Ouse	Lark (lower)	1	3	2	a
Great Ouse	Cavenham Stream	1	5	3	c(l)
Great Ouse	Cam	1	1	2	a
Great Ouse	Soham Lode	1	3	3	ml
Great Ouse	Swaffham Bulbeck	1	4	3	l
Great Ouse	Bourne Brook	1	4	3	c(l)
Great Ouse	Granta	1	4	3	a
Great Ouse	Whaddon Brook	1	4	3	l
Great Ouse	Ivel	1	2	2	a(l)
Great Ouse	Flit-Ivel Navigation	1	1	3	a
Great Ouse	Brampton Brook	1	4	3	sc
Great Ouse	Ouzel (upper)	1	2	3	l
Great Ouse	Ouzel (lower)	1	2	2	a
Waveney	Starston Beck	1	4	3	s
Waveney	Finningham w/c	1	5	3	s(c)
Waveney	Chickering Beck	1	5	3	c
Waveney	Wang	1	5	3	s(c)
Stour/Colne	Stour Brook	1	3	3	cl
Stour/Colme	Barnardiston Brook	1	5	3	cl
Stour/Colne	Bourne Brook	1	5	3	c
Stour/Colne	Roman	1	4	3	c
Blackwater	Brain	1	3	3	sc
Chelmer	Wid	1	2	3	lc
Chelmer	Crouch	1	4	3	lc
Chelmer	Mar Dyke	1	5	3	mc

Table 3.3. Rivers ranked by mean 1992 soluble phosphorus concentrations.
e) Rivers without P data in 1992

River System	Stream	Median P-rank	DWF rank	Flow rank	Rock type
Ancholme	Black Dyke		4	3	l
Ancholme	Kettleby Beck		4	3	c
Lincolnshire Coast	East Halton Beck		5	3	c
Lincolnshire Coast	Laceby Beck		4	3	c
Lincolnshire Coast	Tetney Haven		3	2	a
Lincolnshire Coast	Thoresway Beck		5	3	l
Lincolnshire Coast	Lymn		5	3	lc
Witham	Waring		5	3	lc
Witham	Reeds Beck		5	3	sc
Welland	North Brook		4	3	l
Nene	Ripton Brook		5	3	lc
Nene	Whilton Nene		4	3	a
Great Ouse	Larling Brook		5	3	l
Great Ouse	Stowlangtoft Stream		4	3	c
Great Ouse	Botesdale Brook		5	3	c
Great Ouse	Bottisham Lode		4	3	l
Great Ouse	Mel		5	3	l
Yare	Whitewater		5	3	a
Yare	Tat		5	3	l
Yare	Chet		4	3	s(c)
Deben/Gipping	Lark		4	3	a
Deben/Gipping	Mill		5	3	s
Blackwater	Rivenhall Brook		5	3	c(s)
Blackwater	Higham Brook		5	3	lc
Chelmer	Thorndon Brook		5	3	lc
Chelmer	Stock Brook		5	3	lc
Chelmer	Sandy Brook		5	3	c
Chelmer	Rettendon Brook		5	3	lc
Chelmer	Rayleigh Brook		5	3	lc

3.4 Macrophyte analysis

The trophic status of the six rivers classified by macrophytes are shown in Table 5. There is little to distinguish either between the rivers or between their sites. For example, the rivers Colne and Rhee, which are high in phosphorus status, achieved rankings similar to the Nar and Welland, which are low in phosphorus (at least the upper Welland). Macrophyte species richness (of species within the trophic indicator group) gave a stronger indication, with median species richness highest on the Nar (19) and lowest on the Colne and Rhee. The potential disruptive influence of habitat structure is apparent in these comparisons however, because the species richness of the Nar falls to only 9 in its lower reaches, where it is canalised, despite its low phosphorus status.

Table 3.4. Trophic analysis of river sites by macrophytes. Mean trophic rank with number of species in brackets

River name	Survey replicate	Section: Upper	Middle	Lower
Nar	1	86 (10)	101 (23)	95 (12)
	2	101 (17)	90 (10)	99 (14)
	3	100 (15)	110 (19)	104 (9)
	4	115 (8)	106 (17)	110 (9)
	5	98 (14)	104 (24)	99 (4)
Colne	1	92 (2)	111 (7)	107 (12)
	2	91 (2)	101 (5)	99 (12)
	3	84 (4)	115 (4)	103 (8)
	4	97 (3)	91 (2)	92 (6)
	5	102 (5)	107 (9)	98 (4)
Rhee	1	109 (5)	90 (8)	104 (8)
	2	109 (6)	89 (7)	103 (9)
	3	99 (10)	100 (8)	99 (11)
	4	98 (7)	105 (8)	110 (7)
	5	85 (9)	107 (6)	105 (10)
Granta	1	101 (10)	99 (6)	76 (3)
	2	92 (4)	92 (8)	89 (6)
	3	97 (7)	101 (10)	100 (6)
	4	100 (9)	101 (10)	103 (13)
	5	94 (6)	98 (6)	97 (12)
Witham	1	91 (4)	108 (7)	126 (2)
	2	99 (4)	106 (12)	126 (2)
	3	94 (5)	107 (11)	111 (1)
	4	84 (3)	111 (9)	118 (6)
	5	96 (6)	105 (12)	97 (2)
Welland	1	96 (9)	104 (12)	98 (8)
	2	86 (5)	111 (10)	96 (10)
	3	84 (6)	102 (8)	99 (10)
	4	89 (5)	100 (10)	96 (8)
	5	94 (6)	95 (7)	102 (9)

3.5 Conclusion

This preliminary survey suggests that mesotrophic rivers are best identified by their phosphate status. None of the other parameters investigated provides a surrogate as does, e.g. transparency or chlorophyll concentrations in lakes. Low phosphorus concentration is usually found in headwaters without, or with low quantities of, sewage effluent input. Taking a regional view such low phosphorus streams are located in the headwaters of the main river systems in the bands of limestone, chalk and sands sweeping in two broad curves through the region from south west to north east. Good examples are concentrated in the tributaries of the upper Nene and Welland (e.g. Chater, Eye Brook, Ise), the chalk tributaries of the lower Ouse (e.g. Babingly, Nar), the coastal Lincolnshire streams and the sandstone-influenced tributaries of the Ouse and Norfolk rivers (e.g. Thet).

3.6 Limitations

The main limitation on this study was of time, and this imposed restrictions on those data which could be considered. Nitrogen was ignored, but only because the assumption was made that phosphorus is usually the nutrient responsible for trophic staus in north temperate freshwater systems. Macroalgae were ignored, because no data exist for them in the region. This is an important gap, because a number of studies elsewhere have identified *Cladophora* growth to be linked with phosphate concentration more clearly than is the growth of macrophytes. Only one year's phosphate data was used.

The REDS database was at an early stage in its development and the number of rivers with a full macrophyte data set which could be extracted was limited. There have been large numbers of river corridor surveys carried out over the past three years whose data, on paper, was not accessible in the time available.

The systems for macrophyte assessment of trophic status used here were not sensitive enough for Anglian rivers. They were either developed for a full UK perspective, or for an upland region with a full spectrum of trophic states, from ultra-oligotrophic to hyper-eutrophic. At the drafting stage of this report however, but too late to incorporate into the results, a new classification system exclusive to Anglian rivers was commissioned from N.T.H. Holmes. The preliminary report looks promising, and this part of the project should certainly be re-evaluated.

4 DISCUSSION AND RECOMMENDATIONS

4.1 Discussion

4.1.1 Evidence for mesotrophic status

The data set examined show clearly that the Anglian region, despite being the most lowland region in the country with low rainfall and intensive agriculture, does contain rivers of low phosphate concentration which may be classified as mesotrophic. At the present stage of the investigation, there is no clear evidence that this nutrient status is accompanied by biological distinctivness; nevertheless this is almost certainly the case. Recent developments since this report was commissioned, notably connected with the Urban Wastewaters Directive and associated macrophyte surveys, and with the development of the REDS database for River Corridor Survey information, make it highly likely that the information now exists within NRA to demonstrate this link.

4.1.2 The importance of mesotrophy

Mesotrophic watercourses are importance for two main reasons, water quality and ecological. For water quality reasons they are likely to be the most pristine, particularly in respect of their oxygen regime; eutrophic streams suffering from enhanced plant growth will experience dramatic diurnal fluctuations of oxygen. The evidence here is that mesotrophic streams are almost free of sewage effluent discharge and, if also free of agricultural point sources, are likely to be the cleanest watercourses in the region (even though some of them may be insignificant in terms of discharge).

Their conservation value is likely to stem from their pristine nature. Animals most sensitive to oxygen concentrations are likely to find refuge in such streams and they might therefore be expected to be species-rich in insect groups such as Plecoptera and Ephemeroptera. The indirect influence of low phosphorus upon invertebrates is far from clear, but several mesotrophic rivers in this classification are also of importance for their invertebrate assemblages. The Nar (see Leicester OI Report, March 1993), the Ise (an SSSI for invertebrates) and the Eye Brook (containing the nationally rare *Hydropsyche saxonica*) are all examples.

4.1.3 Associated factors

There are several associated factors which may influence biological communities in streams which are mesotrophic. Many may for example, coincidentally, be the least physically disturbed because some of them will not even be classified as 'main river'. The Eye Brook has probably never been canalised or even 'pioneered' and is rich in debris dams and accumulated in-stream detritus. On the other hand, the Nar is most rich in invertebrates in its most physically disturbed lower reaches.

4.2 Recommendations

4.2.1 Overview

- This study has shown that there are mesotrophic watercourses in the Anglian region, recognisable by mean annual phosphorus concentrations. Therefore a more detailed survey to identify them and characterise them, using all available phosphorus data, would be successful.

- It is probable also that many of these watercourses could also be identified by their macrophyte assemblages using the most recent data and techniques. This avenue would also produce a successful conclusion.

- It is intuitively likely that mesotrophic rivers will have high water quality because of high oxygen concentrations. This should be explored further in simple field testing.

- If the above statement is correct, then it is also highly likely that mesotrophic rivers will have a more diverse invertebrate community. This should be investigated, initially by comparative analysis of routine biological score data, supplemented by liaison with appropriate R&D (e.g. headwater streams). Subsequently it should be investigated to species level.

4.2.2 Site focusing

The work required is a combination of further scientific justification for the status of mesotrophic rivers together with clearer identification of such rivers before any management effort is targetted upon them. The evidence presented here suggests that clusters of watercourses should be identified, most of them in headwater catchments, and that pairs of watercourses should be chosen so that mesotrophic is compared with eutrophic. The headwaters where suitable streams exist are the upper Welland, the eastern headwaters of the lower Great Ouse, the Lincolnshire coast (limestone) streams. One pair of streams in each location would be a suitable start. Some of the larger discharge watercourses which are experiencing reduced phosphorus concentrations as a consequence of P-stripping in sewage works might also be considered, although those in Norfolk are physically degraded due to navigation and so inappropriate.

4.2.3 Further work

- A full evaluation of NRA phosphorus data would involve around three years' data from most sites and longer runs of data for intensively monitored sites such as Harmonised Monitoring ones. I envisage that examining these data would take 6 weeks. It could most usefully be incorporated with a review of a) the nature and frequency of phosphorus measurements and b) a review of the value of cut-off levels for phosphorus in mesotrophic and eutrophic river categories, which would also take about 6 weeks.

- A comparative evaluation of plant assemblages (including macroalgae) should be made in watercourses of different trophic range (but physical similarity) using the new trophic evaluation system of Holmes. Use should also be made of historical data and the full development of REDS, as well as current fieldwork. This would take about 2 months for the evaluation of historical data, and 3 months for the fieldwork (in summer period). For six watercourses, each would need five sites, thirty sites in all.

- A comparative evaluation, together with a literature review, should be undertaken to ascertain the differences in invertebrate assemblages of watercourses in different trophic states (but similar physical state. Initially this should evaluate existing routine biological data, taking about 1 month. It should then develop into fieldwork with species-level identification, taking at least three months. As with the plant species investigation, five sites on each of six watercourses would be needed, thirty sites in all. This would take around 3 months if done thoroughly with up to 5 replicate samples of all habitats (to take into account inevitable physical differences) per site. The literature review would take about 1 month.

- The frequency and nature of analysis for phosphorus should be examined by ideally at least one year's study on the six watercourses, with analysis of at least soluble and total P as frequently as each fortnight in all sites and at hourly intervals over 1-2 storm events at a few sites. This is an intensive workload thirty sites per week, with 3 replicates per site, for two parameters – approximately 100 samples per week.

- The possible contribution of any other parameters (e.g. N) to trophic status in rivers should be evaluated by literature review, taking about 1 month.

- The contribution of any other factors or policies to river trophic state classification (e.g. retention period in watercourses, lengthened by debris dams, which influences sequestration of phosphorus; buffer strips and wetlands which alter inflows; the effect of land use on P-runoff) should be evaluated by literature review and liaison within the NRA. The timescale for this review would be about two months.

- The total work involved in all these recommendations is approximately two qualified persons over one year; they would ideally work concurrently, one on water chemistry and one biology.

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