Working Papers

No 1

THE INFLUENCE OF SANITARY AND OTHER SOCIAL CHANGES
ON THE EUTROPHICATION OF LOUGH ERNE SINCE 1850:
PROJECT INTRODUCTION AND A CONSIDERATION OF THE
POTENTIAL ROLE OF METABOLIC WASTES

SIMON PATRICK AND RICHARD BATTARBEE

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Palaeoecology Laboratory
Department of Geography
University College London
England

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FOREWORD

Recent limnological studies of Lough Erne have suggested that the lake is highly productive (F.B.I.U. 1975, Gibson et al. 1980) and that the present level of productivity is a result of increasing nutrient inputs to the lake over the past 100 years or so (Battarbee 1977).

It is the purpose of this project, funded by S.S.R.C. grant HR 7437, to document the demographic, dietary and sanitary changes in the catchment since 1850 and to evaluate the relative importance of domestic metabolic waste as a source of nutrient supply.

This report provides an introduction to the project and considers the methods involved in estimating the minimum phosphorus output from households in the catchment for the period 1851 - 1971.

ABSTRACT

Examination of historical dietary data reveals that the minmum recommended adult intake of 800mg. P. Person^{-1} day $^{-1}$ was met 1850 - 1970. Calculated intakes compare closely with published measured values of P from metabolic sources in domestic sewage.

Consideration of the role of metabolic wastes in one river catchment points to the relative insignificance of age structure compared to that of population numbers in determining minimum potential P contributions from this source.

Analysis of census data reveals a marked decrease in the total population of the catchment, suggesting that changes in the quanitity of metabolic wastes are not a relevant factor in the increased P output from such catchments. Of importance however, may be the increasing concentration of population in towns where water borne sanitation may exist.

I. INTRODUCTION

I.1 THE LOUGH ERNE CATCHMENT

The Lough Erne catchment extends over some 4,300 km^2 of north west Ireland (Fig. 1), representing 5.2% of the total land area of Ireland. The central lake system comprises Upper and Lower Lough Erne and Loughs Oughter and Gowna, the catchment being approximately bisected by the border between Northern Ireland and Eire. This study focuses on Upper and Lower Lough Erne and their catchments.

The two Loughs differ in their physical characteristics. The Upper Lough is a drowned drumlin landscape containing numerous islands and is generally quite shallow (mean depth, 2.3m). The Lower Lough is deeper and consists of two main areas. To the south east is an area of islands not unlike that of the Upper Lough, while to the north west the lake opens into a wide, deep central basin known as the Broad Lough (mean depth, 11.9m).

The catchment is drained by seven major rivers (Arney, Ballinamallard, Colebrooke, Erne, Finn, Swanlinbar and Woodford), which include several secondary lake systems(Gowna, Oughter, Garadice and Macnean) and a large number of small lakes. In addition there are a series of minor streams to the north, and a number of areas of low relief around the lake, which drain directly to the lake.

The catchment is characterised by a dispersed low density population. Enniskillen - population 6,608 (1971) - being the largest settlement. Agriculture and forestry dominate the local economy and form the basis of the few manufacturing industries in the region such as creameries and food processing.

A boost to the economy in recent years has come from the development of tourism in the area. Centring on Lough Erne tourism takes advantage of the extensive natural facilities for fishing, sailing, pleasure cruising and other water based recreations. Recently this potential has been recognised by the E.E.C. who in conjunction with the United Kingdom and Irish governments have included the area as part of a scheme to develop tourism and recreation along the Irish border (E.E.C. 1980). These proposals follow the publication of a number of plans advocating extensive development for the region (eg. Ulster Lakeland Plan 1963, Erne Catchment Study, 1980).

I.2 STUDY AREA

In view of the extensive nature of the Lough Erne catchment it was necessary at the outset to restrict the study area. This area is defined in Figure 2. The major secondary lake systems of Loughs Gowna, Oughter, Garadice and Macnean have been excluded and the area remaining represents some 50% of the full catchment.

Care was taken to include all major population centres where sewage schemes can be expected to play a prominant role in the influx of phosphorus (P) to the central lake. Thus sub-catchments of the Rivers Woodford and Erne are included to take account of potential contributions from Ballyconnell and Belturbet respectively.

Within the study the areal framework for data analysis and subsequent presentation of results will ultimately be the river catchment, an area more conducive to the subject under consideration - input of P via watercourses to the lake - than administrative areas; an added advantage being that unlike the latter, river catchment boundaries remain constant through time.

Owing to the paucity of hydrological mapping in the region, river catchments have been defined from the topographic Ordnance Survey.

In order to encompass the period of enrichment inferred from an examination of the sediments (Fig. 3), the study period extends from 1850 - 1971. With the eventual publication of 1981 census data it will hopefully be possible to bring the study up to the present day.

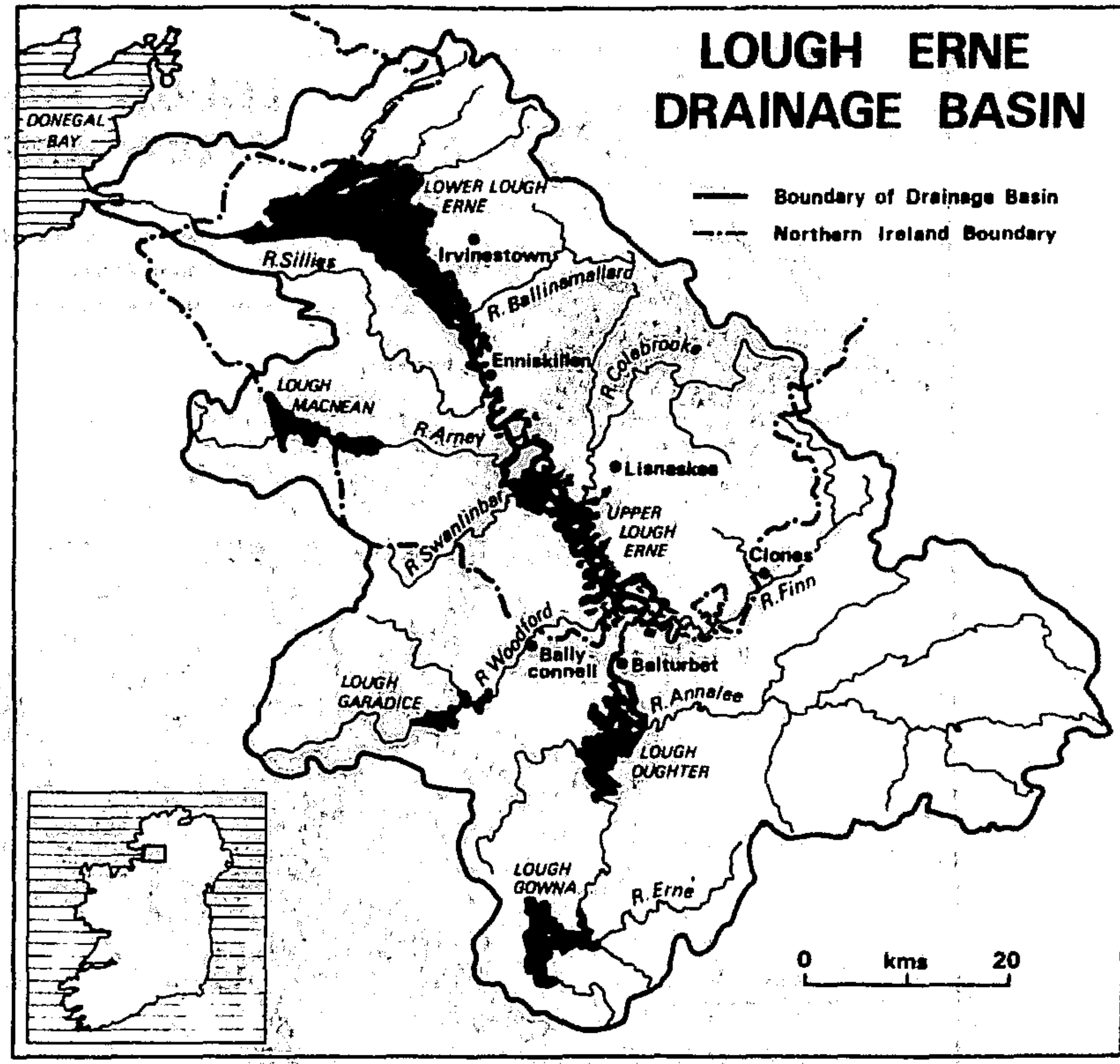
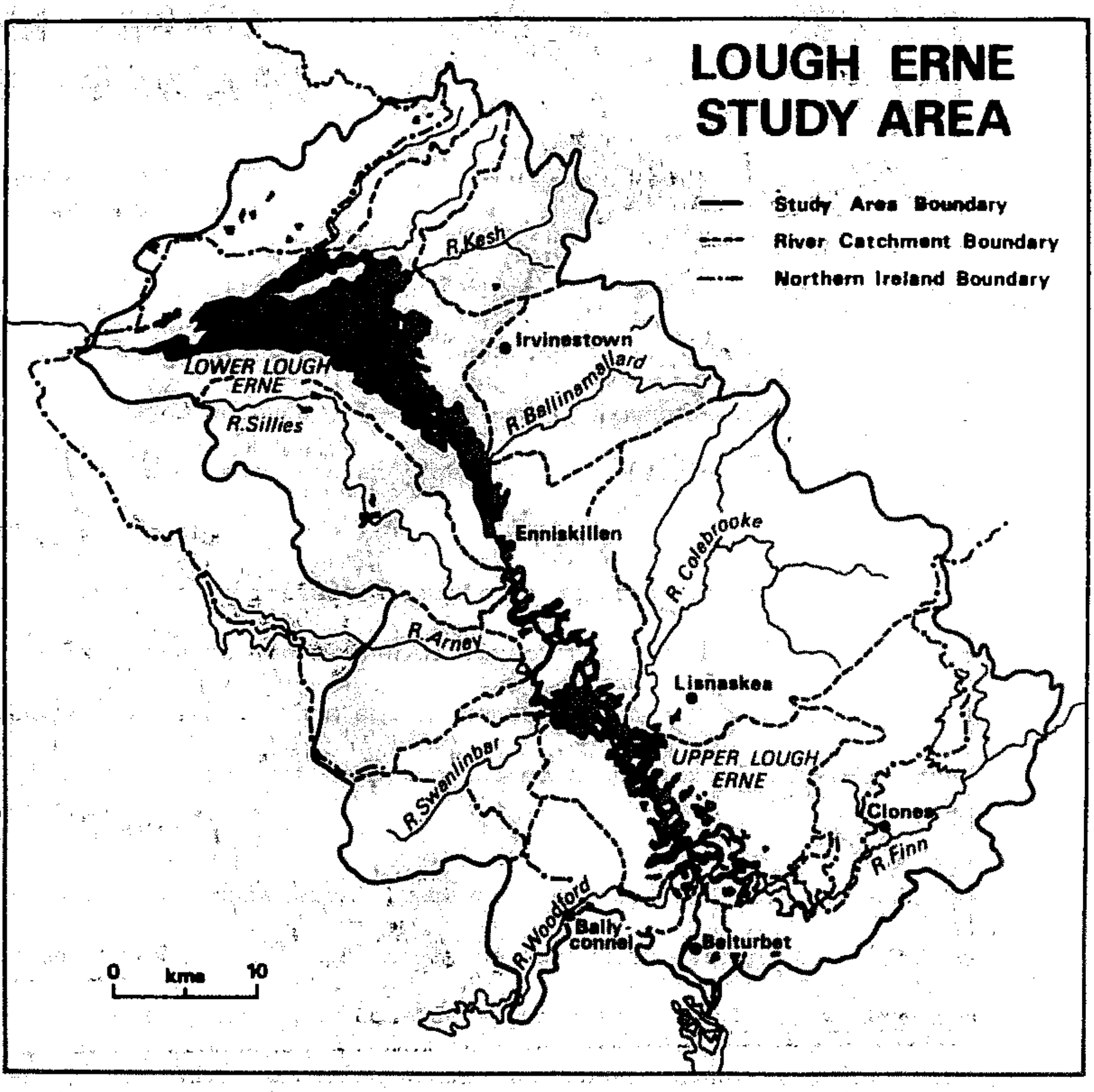

LOUGH ERNE DRAINAGE BASIN
Boundary of Drainage Basin
Northern Ireland Boundary
DONEGAL BAY
LOWER LOUGH ERNE
Irvinestown
R.Sillies
R. Ballinamallard
Enniskillen
R.Colebrooke
LOUGH MACNEAN
R.Arney
Lisnaskea
R.Swanlinbar
UPPER LOUGH ERNE
Clones
R.Finn
R.Woodford
Bally-connell
Belturbet
LOUGH GARADICE
R.Annalee
LOUGH OUGHTER
LOUGH GOWNA
R.Erne
0 kms 20

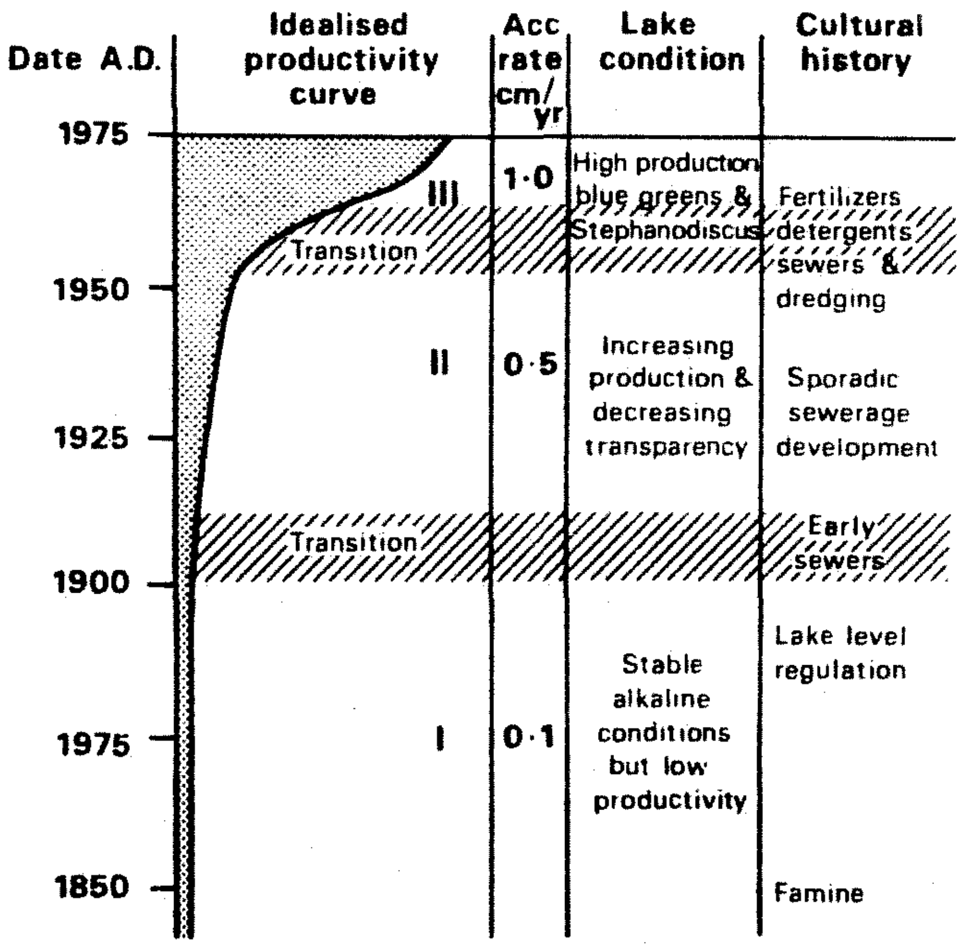
FIGURE 1



LOUGH ERNE
STUDY AREA
Study Area Boundary
River Catchment Boundary
Northern Ireland Boundary
R.Kesh
Irvinestown
R.Ballinamallard
LOWER LOUGH
ERNE
R.Sillies
Enniskillen
R.Colebrooke
R.Arney
Lisnaskea
R.Swanlinbar
UPPER LOUGH
ERNE
Clones
R.Finn
R.Woodford
Bally-
connel
Belturbet
0 kms 10

FIGURE 2

FIGURE 3 **LOUGH ERNE : SUMMARY DIAGRAM**



1.3 EUTROPHICATION

The nature of the water quality problem in Lough Erne is one of eutrophication or nutrient enrichment. An increase in the supply of nutrients previously responsible for limiting primary production in the lake has resulted in the increased production of algal matter to the extent that Lough Erne has become a highly eutrophic water body (Gibson et al, 1980).

Blue green algal blooms occur frequently and are becoming an environmental problem. They are of particular concern for an area seeking to develop water based recreation as:

a) they look unsightly, produce bad smells on decomposition and discourage the use and diminish the recreational value of the water;

b) they are bad publicity for a tourist area often to an extent in excess of their ecological seriousness;

c) they may be concentrated into sheltered bays by local breezes, and on death may exert a strong oxygen demand on the water body, which in extreme circumstances may lead to fish death (Battarbee 1977).

Plans have been mooted to extract water from the Upper Lough. Should such a move be implemented in the future, dense concentrations of algae may pose problems by blocking filters and distorting the taste, colour and smell of the extracted water (eg. Edmondson 1969).

Some lakes are naturally eutrophic, but increasingly common is the phenomenon of 'cultural eutrophication' where, as in the case of Lough Erne, increase in productivity occurs as a result of human activity in the catchment.

Nitrogen (N) and phosphorus (P) are the main nutrients involved in the process of eutrophication, but of the two P is usually in shortest supply in unpolluted waters. It is thus the addition of this element which commonly leads to cultural eutrophication (eg. Thomas 1969; Lund 1972; Smith 1976; Cluis et al. 1979, Vollenweider 1980).

Wood and Gibson (1973) considered this true for Lough Neagh, Northern Ireland. Although compared to Lough Neagh the measured annual P loading of

Lough Erne is low, expressed as loadings per unit area or per unit volume of lake water, it is greater, considerably so in the case of the Upper Lough (Table 1).

TABLE 1 P LOADINGS ON LOUGH NEAGH AND LOUGH ERNE, PER UNIT VOLUME AND PER UNIT AREA (FROM F.B.I.U. 1975).

	Tonnes P yr^{-1}	g P $m^{-3} yr^{-1}$	g P $m^{-2} yr^{-1}$
Upper Lough Erne	173	2.16	5.0
Lower Lough Erne	221	0.17	2.0
Lough Neagh	450	0.14	1.2

1.4 CULTURAL SOURCES OF P IN THE LOUGH ERNE CATCHMENT

In addition to 'natural' inputs from atmospheric and geologic sources, a catchment such as that of Lough Erne may be subject to inputs of P from a variety of anthropogenic sources. Household sewage wastes, domestic industrial and agricultural detergents , phosphate rich fertiliser used in agriculture and forestry,and animal manures and farmyard slurries are all rich in P.

Aside from the quantity reaching a water course, the relative importance of P from different sources depends largely on its chemical form. A large proportion of P other than soluble ortho-P is not immediately available for algal growth, soluble ortho-P however, is completely available to support such growth (Sonzogni and Lee, 1972; Fogg, 1973).

In examining the relative importance of different sources contributing to the P loading of a lake, a distinction can be drawn between 'diffuse' and 'point' sources.

Nutrients derived from diffuse sources are transported by groundwater flow, land runoff and precipitation. Point source nutrients enter a water body via sewer outfall or drainage pipe. Thus if point sources play a dominant role in the nutrient loading of a catchment, management plans for reducing nutrient supply to a lake can be carried out more readily.

Prominant in the output of P from point sources is the discharge of effluent from sewers and sewage works. Consisting primarily of human metabolic and household wastes, but often with important contributions from industry and urban drainage, sewage effluent is P rich, and particularly in a form readily available for algal growth.

Smith (1976) found that treated effluent from sewage works in the River Main catchment, an inflow stream to Lough Neagh, contained 75% of P in the form of soluble ortho-P. An examination of the nutrient budget for the River Main revealed that some 49% of total P and 62% of soluble ortho-P in the river derived from sewered effluent. Hypothesising that complete degradation of non soluble ortho-P forms from effluent occurs in the river, the contribution of soluble ortho-P from sewage would represent some 82% of the P loading of the river.

Similarly a study of the nutrient budget for Lough Neagh as a whole led Wood and Gibson (1973) to conclude that some 80% of P entering the lake originated from point sources, essentially from sewer outfalls. Consequently Smith (1977) found a very significant correlation between the human population density and soluble ortho-P loading in the Lough Neagh catchment.

No such correlation existed between animal population density and P loading. Animal wastes in the form of manures spread on fields, together with phosphate based artificial fertiliser, comprise the major cultural contributions to potential diffuse P sources, particularly in a rural area. However, despite the widespread application of such P rich compounds to agricultural land, the general immobility of P in all but the coarsest sandy soils (eg Cooke and Williams, 1973), means that unless applied on frozen soil, or in times of overland flow, such P will be bound in the soil and released only slowly to lake or river by groundwater flow. Thus Smith (1976) found no relationship between fertiliser use and P concentrations in the River Main.

Hence, even when manures form the single largest potential P input source to a rural catchment, greatly exceeding the sum of all other potential sources (eg Phillips-Howard 1981), their low rate of transfer to the drainage network may render their significance below that of dispersed point sources. In general Vollenweider (1980) estimates the transfer of diffuse sources to the drainage net to be in the order of 1-5% for P, figures supported by the experimental work of Cluis et al (1979). In addition P fractions eroded from agricultural land may be expected to occur in a predominantly particulate form and thus not readily available for algal growth.

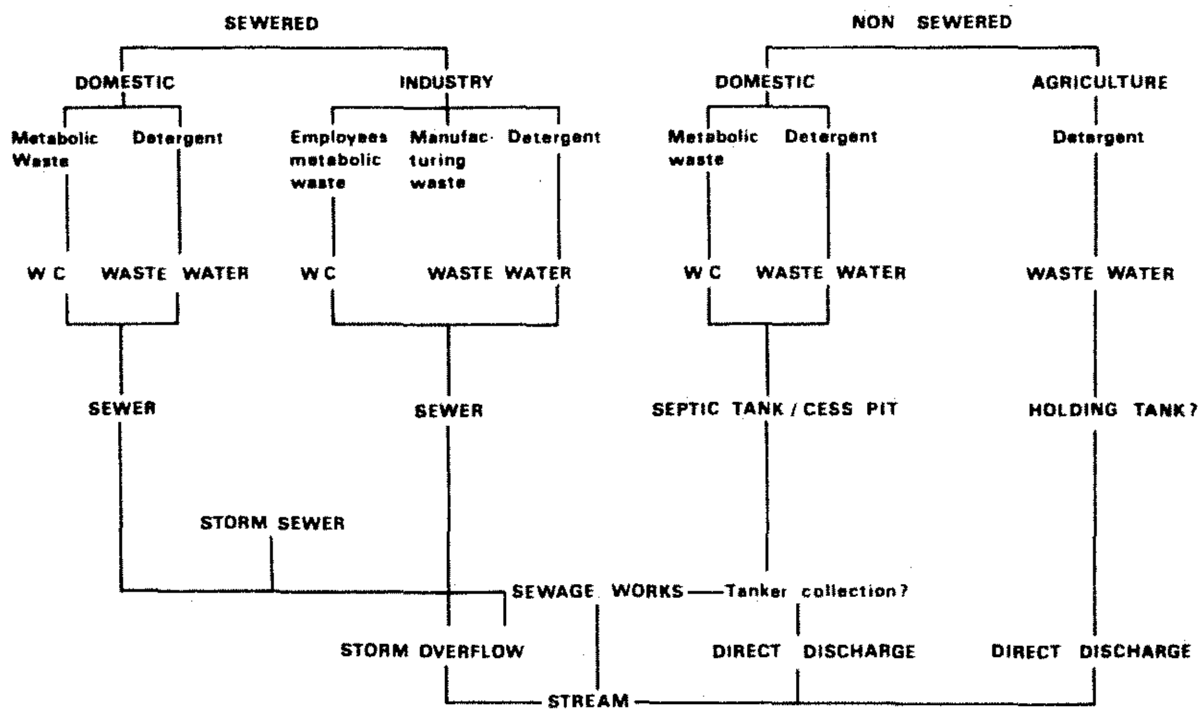
In the case of Lough Erne the available evidence also suggests that P supply from domestic sources is of particular importance. Gibson et al (1980) found a high correlation between urban population density and P loadings and Battarbee (1977) explained the diatom changes in the recent sediment of the lake primarily in terms of nutrient increases following the progressive development of sanitary provision in the catchment. A summary of his findings is presented in figure 3.

This study aims to extend previous work by attempting to document and quantify the output of P from point sources in the catchment over the past 130 years. In doing so it should be possible to estimate the relative contribution of point source output to the P budget through time, enabling the inferences of Battarbee (1977) (Fig. 3) to be evaluated. If successful the results may lead to a better understanding of the causes of cultural eutrophication and allow the formulation of corrective and informed management strategies.

Figure 4 portrays the different types of point source that may be expected to occur in a rural catchment such as that of Lough Erne. It will be noted that with the exception of land drainage, all are intimately concerned with sewer development and sanitary provision. The low density of industry in the area, and the lack of significance postulated for land drainage (eg Burke et al, 1974; Hill, 1976), suggests that consideration of domestic point sources becomes the central theme of this project.

The quanitity of P reaching the lake from domestic point sources depends on:

FIGURE 4 **POINT SOURCES OF P IN A RURAL CATCHMENT**



a) P output of the population. Primarily from metabolic wastes and synthetic detergents;

b) the extent of the drainage or sewerage system which allows such output to enter water courses;

Prior to the consideration of the other factors in future work the following sections consider the role of P output from metabolic wastes.

II DETERMINATION OF POTENTIAL P CONTRIBUTIONS FROM HUMAN METABOLIC WASTES

The changing contribution of human metabolic wastes in domestic effluent to P loadings in Lough Erne may be expected to be a function of temporal variations in population structure - numbers, age, sex - and of changes in diet. By documenting such changes it is possible to calculate potential P contributions from this source through time. The anlaysis of potential P output from metabolic sources serves two purposes:

1) When associated in numerical and cartographic form with developments in sanitation provision and detergent use it allows actual P loadings from domestic effluents to the lake to be determined, thus forming the first logical step in a methodical approach to this project.

2) In compiling such potential P figures the relative importance of population and dietary change per se to the increasing P load of the lake will be revealed, and hence will suggest the magnitude of the effects of the other components concerned with domestic effluents - sanitary development, and use of synthetic detergents.

II.1 P BALANCE IN THE HUMAN BODY

The healthy body contains P as approximately one per cent of body weight. Important in many metabolic processes its main function is in the growth and maintenance of healthy bone (Nordin, 1976).

P is a constituent of all cells and is thus present in all natural foods to the extent that "phosphorus normally presents no problem for the dietician" (Davidson et al. 1973, p 103). Unfortunately this ready availability of P in the human diet has resulted in a paucity of modern studies to determine the relationship between input, retention and output of P in the body.

Such studies generally take the form of balance surveys in which a measured input is compared with a measured output and the retention level deduced accordingly. Before examining results from such experiments it is worth considering the views of Irving (1973) who suggests that the difficulty of collecting and measuring excreta products from a subject may lead to fictitiously high levels of retention and concomitant low output values being recorded. Arithmetically, the weakness of the method is that the answer is often a small difference between two large figures, a small error in either of which may make a substantial difference to the final results. In addition McKay et al (1942) noted that the controlled diets of many balance experiments are only duplicated to a small extent by the population at large, which exhibits great variation in food habits.

When viewed with the lack of representative information through time on input (diet) (see page 14), the shortage, and possible weakness in method, of balance data makes it unrealistic to expect to apportion definitive values for changing contributions from metabolic wastes to the catchment's P loading. It should however be possible to identify and document a <u>minimum potential</u> P figure. Providing the historical information that does exist suggests that the daily minimum requirement of P in the human diet was met, this figure can be regarded as a constant through time. Changes in the minimum potential P output of a catchment's population thus become a direct function of its population structure.

Except in pregnancy, and insofar as girls reach adolescence before boys, differences in minimum metabolic P output is a function not of sex but of age.

Two broad stages are recognised in the literature concerning P utilisation in children, 'pre-adolescence' and the 'growth spurt'. The latter occurs between 10.5 and 13 years in girls and between 12.5 and 15 years in boys (Tanner 1962). In this study constraints imposed by the nature of the available age structure data (see page 26) required that these two stages be redefined as 0-9 and 10-14 respectively, with the term 'adult' referring to the 15 plus age group.

It is accepted that the healthy adult body is maintained in a condition of P equilibrium (eg Round, 1981). At all levels of dietary input "output and intake (are) essentially equal ... indicating excellent adaption" (Nordin, 1976,

p. 25). Hence for adults minimum P requirement equals minimum P output.

TABLE 2 PUBLISHED FIGURES FOR MINIMUM PER CAPITA P INTAKE PER DAY TO MAINTAIN ADULTS IN P EQUILIBRIUM

SOURCE	$Mg.P.Person^{-1}day^{-1}$
League of Nations (1938)	1,000
McKay et al (1942)	1,000
Leichsenring et al (1951)	800
Ohlson et al (1952)	1,250
Sherman (1952)	$12.6\ kg^{-1}$ ($882\ mg.\ 70\ kg^{-1}$)
Patton et al (1953)	1,100
Scholfield et al (1956)	800
Scoular et al (1957)	1,140
Nordin and Smith (1965)	$12.2\ kg^{-1}$ ($854\ mg\ 70\ kg^{-1}$)
Food and Nutrition Board (1974)	800

Table 2 summarises published figures for minimum P requirements to maintain healthy adults in equilibrium. Modern opinion would indicate that the lower figures are the more applicable. Nordin (1976) suggests that figures in the range 854-880 mg P $person^{-1}day^{-1}$ (assuming 70 kg body weight) are too high! Thus for the purpose of this study the minimum daily adult P requirement, and hence the minimum output, is taken as that identified by the Food and Nutrition Board of the United States Academy of Sciences (1974) - 800 mg P $Person^{-1}day^{-1}$.

The relationship between P intake and output for children is less clear. Certainly as the body grows it should be in a state of positive P balance - output should be less than input by the amount retained for growth processes within the body. Thus to obtain minimum output figures for children it is necessary to account for the third factor in the balance equation, retention.

TABLE 3 PUBLISHED FIGURES FROM P BALANCE STUDIES ON CHILDREN

(mg P $Person^{-1} day^{-1}$)

SOURCE	AGE (yrs)	INPUT	OUTPUT	OUTPUT AS A % OF INPUT
Hunscher et al (1933)	3-10	1,300	910	70
" " " "	3-10	2,000	1,433	72
Daniels et al (1935)	3.1-6.1	1,210	1,066	88.1
" " " "	3.6-5.3	1,195	1,056	88.4
Pierce et al (1940)	2.9-5.8	1,215	1,088	89.5
Hawkes et al (1942)	0-5			92.3
Macy (1942)	3.5-.2.4	1,100	863.5	78.5
McKey et al (1946)	3.2-4.6	1,140	1,029	90
Kantha et al (1957)	8-10	421	345	82
" " " "	8-10	796	632	80
Round (1981)	1-10	800	700	87.5
" "	11-17	1,200	800	67

Table 3 summarises published balance data relating to children and expresses output as a percentage of input.

TABLE 4 MINIMUM P OUTPUTS PERSON DAY^{-1}

AGE	MEAN RECOMMENDED INTAKE mg	OUTPUT AS % OF INPUT	MINIMUM OUTPUT mg	MINIMUM OUTPUT AS PROPORTION OF ADULT FIGURE
0-9	747	85	635	0.79
10-14	1,200	67	804	1.005
15+	800	100	800	1.00

Table 4 relates mean percentage P outputs for the 0-9 and 10-14 age groups, determined from Table 3, to the mean daily requirements recommended for these age ranges by the Food and Nutrition Board (1974), summarises the minimum output figure which will henceforth be utilised for all three age ranges, and expresses the output for each group as a proportion of the adult figure of 800 mg P $person^{-1} day^{-1}$.

Estimation of the minimum potential P output from metabolic wastes in the Lough Erne catchment since 1850 therefore requires that:

1) Diets always met minimum P requirements;

2) Population numbers and the age structure are known.

These are considered below.

II.2 DIETARY HISTORY

Only one study providing quantitative information on diet can be identified which relates directly to part or parts of the Lough Erne catchment (Poor Law Commissioners, 1880). Indeed such information is sparse for Ireland as a whole during the last 130 years, compounded by the concentration of historians upon the decade of famine in the mid nineteenth century.

As such, in an attempt to establish whether minimum dietary P requirements were met, analysis has been made of statistics which relate to other areas within Ireland, to Ireland in general, or potentially compatible areas outside Ireland.

By using the information presented in two sets of Food Tables (McCance and Widdowson, 1973; Bowes and Church, 1963), it is possible to calculate the approximate P content of diets from consumption figures. Obviously the application of modern food tables to historical data requires that certain assumptions be made and a margin of error be accepted. In order to err on the right side, toward the underestimation of P content, where alternative values for foodstuff occur the lowest value is referred to, as for instance where differences arise between different cuts of the same meat; between cooked and uncooked, fresh and processed, whole and peeled forms of the same commodity; or between breads with different extraction rates.

The method and sources employed in this attempt to confirm the achievement of a minimum per capita P intake of 800 mg day^{-1} since 1850 are open to criticism on certain accounts.

Davidson et al (1973) question the reliability of food tables in calculating the mineral content of a diet. Short of direct measurement however, there is no alternative.

The diets considered are of course time specific and representative only of a sample of certain socio economic groups. The general bias towards 'labouring' classes should however ensure that a minimum possible figure is recognised.

The National Nutrition Survey of 1946 - 1948 and O.E.C.D. figures for 1954 -64 relate to the Republic of Ireland, thus their consideration in terms of the Lough Erne region assumes a continuity of dietary standards across the Irish border. Similarly the use of annual M.A.F.F. statistics assume a continuity of conditions from similar areas of Great Britain to Northern Ireland and the Irish Republic.

The dietary data under consideration represent four distinct periods:

i) 1859

ii) 1902-1904

iii) 1946-1948

iv) post 1948

<u>i) 1859</u>

Derived from a countrywide investigation by the Poor Law Commissioners into the standard of diet experienced by the labouring classes, this is the only survey to provide quantitative information relating directly to the Lough Erne region (Poor Law Commissioners, 1860). The weekly consumption figures of ten families from Fermanagh and ten from Tyrone portray a diet based on the staples of potatoes, buttermilk (skimmed milk) and oatmeal or indian meal. An example provided of the typical meal composition illustrates the monotony of diet among the poorest rural classes:

Breakfast	Stirabout (meal based porridge and buttermilk)
Dinner	Potatoes and buttermilk
Supper	Stirabout and buttermilk

Yet despite the basic nature of the diet it would seem that in general the minimum dietary P requirement of 800 mg P person^{-1}day^{-1} was met,[1] in some cases very adequately (Appendix 1a) a result of the sheer quantity of the staples consumed and particularly the importance of buttermilk with a high P content of 98 mg P 100 g^{-1} (McCance and Widdowson, 1973) in the diet.

The wide distribution of per capita P intakes portrayed in Appendix 1a may be partly explained by differentials in income and access to home grown produce. But confidence in the results must be tempered by reference to the problems experienced by the collators of the original data. For instance the enumerator responsible for Fermanagh found "people rather unwilling to give the particulars I wanted" (p,40). Confusion was also engendered by the practice of feeding domestic and farm animals in the house.

ii) 1902-1904

Two studies (Cd 2337 1905, Cd 5070 1910) relating to labouring classes in urban areas show the positive relationship between income and P intake under such conditions. The wide variation in per capita daily P intake in the Dublin survey of 1904 (Cd 5070 1910) is attributable to this factor, the mean intake appearing as 906 mg P person^{-1}day^{-1} (Appendix 1b).

The second study relating to 1904 (Cd 2337 1905) examines data not only from Dublin but also from the provincial cities of Drogheda, Waterford, Cork, Limerick, Belfast and Londonderry. Unfortunately no information is presented

1 Owing to the lack of age structure information relating to family composition in this and other surveys, all members of a family are treated as adults and hence per capita daily intakes relate to a general minimum requirement of 800 mg P person^{-1}day^{-1}. Reference to column 4 Table 4 would suggest that any error resulting from this practice is in the optimum direction.

on family size so figures can only be described in terms of mg P family^{-1}day^{-1} (Appendix 1c). In view of the generally large size of families it may by hypothesised that only the income groups exceeding 30 shillings per week approached realisation of 800 mg P person^{-1}day^{-1}.

A third report relating to 1902 (Cd 2376 19)5) presents 37 returns concerning food consumption by farm labourers in Ireland. Hardly a representative sample, this source may however be of greater significance to the Lough Erne region than the contemporary urban studies, particularly as it is claimed that with the exception of potatoes the quantities of articles consumed showed no great variation between the provinces.

A greater variety is apparent in this rural diet compared to 1859, four meals a day are documented in Counties Cavan and Monaghan, yet owing to a decrease in the quantity of staple foods consumed it would seem that P intake had declined (Appendix 1c)the mean daily intake being 4074 mg P family^{-1}.

iii) 1946-1948

The National Nutrition Survey of 1946-1948 (Irish Republic Dept Health 1953) represents the only comprehensive study of Irish diet to date. Diets from a cross section of the population are documented in a manner permitting the ready calculation of per capita daily P intakes (Appendix 1d). All groups enjoyed diets that provided in excess of the daily minimum of 800 mg. The following examples may be of particular relevance to the Lough Erne region:

a) The Congested Districts

Described in the report as "rural slums" these poorest areas of the West Coast experienced rural conditions harsher than anything to be found around Lough Erne. Farms were generally less than 10 acres and of poor quality land. However despite the lack of money to purchase food, and the low fruit and vegetable content of the diet, per capita P intakes were high, especially in autumn (mean 1814 mg P day^{-1}).

b) Farm Workers' Families

Perhaps surprisingly this group experienced the lowest per capita daily intake (mean 1107 mg P day^{-1}), a function largely of the relatively low consumption of milk (5.1 pints P person^{-1}week^{-1}).

c) Farming Families

High P intakes among this group (mean 1734 mg P person^{-1}day^{-1}), reflect the greater purchasing power of farmers as opposed to their labourers and a greater access to home grown produce. Milk and egg consumption were particularly high. Distortion of the general picture may have occurred however, in that all farms surveyed lay within 10 miles of a town. The difficulty involved in purchasing goods presumably increases with distance from a town.

d) Exceptional Rural Families

Consisting primarily of professional families, the greater purchasing power of this group is reflected in the high per capita P intake (mean 1452 mg P day $^{-1}$).

e) Small Town Families

49 towns with a population under 10,000 were examined with the sample excluding professional classes to bias the survey towards the less wealthy sections of the population. High milk and potato, but low meat consumption were considered to reflect an inclination in small towns towards a rural pattern of life.

As with other categories sampled the consumption of the costlier basic foods - milk, eggs, meat, fish, fruit and vegetables, increased with income and decreased with increasing family size.

iv) Post 1948

In an attempt to account for P intake levels since 1948 two sources have been utilised.

a) O.E.C.D. Food Consumption Statistics (O.E.C.D. 1968)

Relating to the period 1954-1964, these figures referring to national food consumption allow an overall trend of per capita P intakes to be drawn for the Irish Republic (Appendix 1e).

Despite the generalised nature of this source the results are both feasible and realistic. In all years a minimum of 800 mg P $person^{-1} day^{-1}$ is well surpassed.

b) Ministry of Agriculture Fisheries and Food, Domestic Food Consumption and Expenditure Tables

An invaluable source for the study of diet in Great Britain, this annual survey does not include Northern Ireland, nor is any similar publication produced in the Irish Republic. Daily per capita P intakes have been calculated for two years from these tables, for areas that may be considered roughly comparable to the Lough Erne region (Appendix 1f). The similar order of magnitude of the 1960 figure (1241 mg P $person^{-1} day^{-1}$), with that from the O.E.C.D. source for the same year (1388 mg P $person^{-1} day^{-1}$) suggests a degree of confidence in the method used to calculate P levels from food tables.

P values are not included in the nutrient analyses of these M.A.F.F. annual reports, figures for per capita daily calcium (Ca) intake do however appear. It is generally considered that P needs are met if Ca intake is adequate (eg McKey et al, 1946). "If the calcium intake is taken care of the phosphorus will take care of itself" (Nordin 1976 p. 26).

Figure 5 presents the mean per capita daily intake of Ca for 'rural' Great Britain and for the region exhibiting the minimum Ca intake in a particular year, and compares these values with the recommended daily adult intake considered appropriate at that time.[1] It may be observed that at no time does the 'rural' intake constitute the regional minimum, nor does either fall below the current recommended adult intake.

The strong implication from these figures is that unless the Lough Erne region fares considerably worse in nutritional terms than the least densely

1 Figures for 1956-1967 are based on British Medical Association nutrient allowances compiled in 1950. For 1968-1971 Department of Health and Social Security allowances compiled in 1969 are referred to.

populated parts of Great Britain, a minimum per capita intake of 800 mg P day^{-1} was achieved between 1956 and 1971.

Differences Between Minimum and Actual P Intake

Concentration on minimum P intake ignores important changes that may occur with developing food technology. Since the war phosphates have been increasingly utilised by food manufacturers in various aspects of food processing, including increasing the water retention capacity of raw and cooked meats, decrease of the thaw drip of frozen meat, and the improvement of the rehydration properties of freeze dried meat (Hamm 1971); stabilization of the flavour, colour and odour in meat, fruit vegetables and seafood (Mahon et al, 1971; Kibbel, 1971); and chemical levening in the baking industry (Stahl and Ellinger, 1971).

In addition phosphates are added to bakery and cereal products in the form of $CaPo_4$ to increase the Ca content of diets. This practice has been legislated for in the Irish Republic since 1946.

The increase in P intake that may be expected from the rising popularity and abailability of processed, particularly frozen, foods, and the central place of bread in a typical diet, (Davidson et al, 1973, consider that some 10% of P in the human diet is derived from phosphates added to food by manufacturers), is not manifest from the diets analysed. This is a result of the practice of consistently employing only the minimum values from food tables.

Despite the shortcomings in the method of determining dietary P intake discussed above and on page 15, the summary of results (Table 5) inspires certain confidence in the methods used, falling largely within a realistic range of 1000-1500 mg P $person^{-1} day^{-1}$. No overall trend towards increasing or decreasing P content in diet is discernible, differences between groups may be largely explained by varying economic status and opportunity.

ZO A

FIGURE 5 **CALCIUM INTAKE - GREAT BRITAIN 1956-71**
Mg. Ca. Person^{-1}. day^{-1}

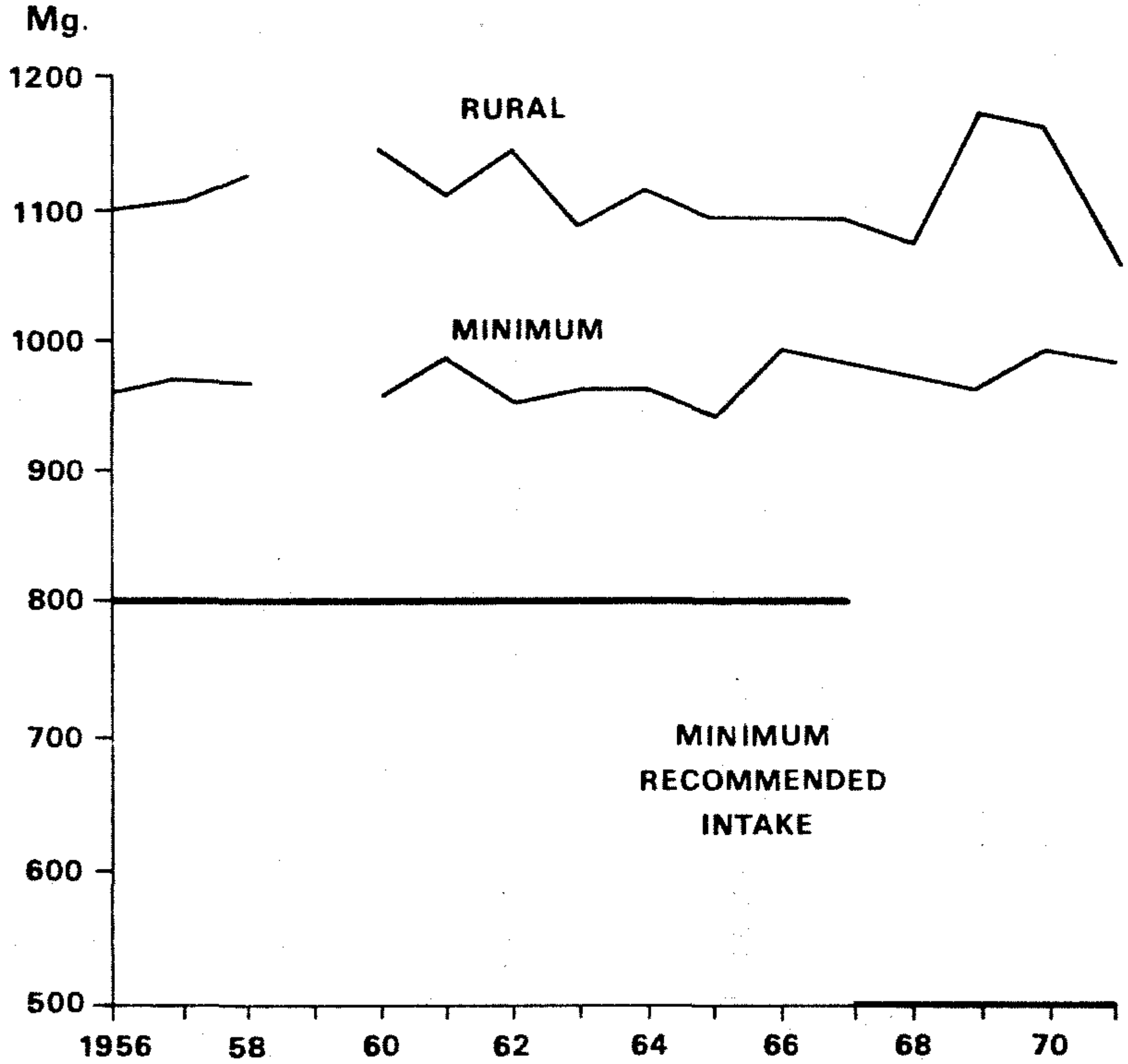


TABLE 5 SUMMARY OF PER CAPITA DAILY P INTAKES

SURVEY	(APPENDIX)	MEAN INTAKE mg P person^{-1}day^{-1}
FERMANAGH/TYRONE LABOURERS 1859	1a	1150
DUBLIN WORKINGMEN 1904	1b	906
CONGESTED DISTRICTS 1946-1948	1d	1508
TOWNS 10,000 + 1946-1948	1d	1120
TOWNS - 10,000 1946-1948	1d	1135
FARMING FAMILIES 1946-1948	1d	1735
FARM WORKERS' FAMILIES 1946-1948	1d	1107
EXCEPTIONAL RURAL FAMILIES 1946-8	1d	1452
DUBLIN SLUMS 1946-1948	1d	1054
DUBLIN ARTISANS 1946-1948	1d	1111
DUBLIN MIDDLE CLASS 1946-1948	1d	1300
O.E.C.D. 1954-1964	1e	1272
M.A.F.F. RURAL 1960	1f	1241
M.A.F.F. -0.5 person acre^{-2} 1979	1f	1027
M.A.F.F. 0.5-3 person acre^{-2}	1f	1039
MEAN		1210.5

The figures of Table 5 compare closely with certain published figures for the measured P content of metabolic wastes in sewage (Table 6). A crude comparison of Tables 5 (unweighted mean-1210.5 mg P person^{-1}day^{-1}) and 6, (unweighted mean - 1280.8 mg P person^{-1}day^{-1}) allows us to conclude that not only was a minimum per capita intake of 800 mg P day^{-1} realised during the study period, but that with further investigation it may be possible to substitute this minimum figure for a more realistic one, in the region of 1200-1400 mg P person^{-1}day^{-1}, at least for the post 1945 period. It is however interesting to note that the lowest measured figure for the P content of sewage in fact relates to a Northern Ireland housing estate, and is not far removed from our minimum figure of 800 mg P $person^{-1} day^{-1}$ (Alexander and Stevens, 1976).

TABLE 6 PUBLISHED FIGURES RELATING TO P CONTENT OF METABOLIC WASTES IN SEWAGE

SOURCE	SEWAGE TYPE	P CONTENT mg P $person^{-1} day^{-1}$
Kolenbrader (in Cooke and Williams 1973)	?	1360
Alexander and Stevens 1976	untreated	900-950[1]
Devey and Harkness 1973	untreated	1000-1400
Hetling and Carcich (in Alexander and Stevens 1976)	untreated	1200
Olsson et al (in Alexander and Stevens 1976)	untreated	1600
Jenkins and Lockett 1943	treated	1300-1500
	MEAN	1280.8

II.3 POPULATION STRUCTURE - THE IRISH CENSUS

Having ensured the validity of employing a constant minimum figure for per capita P contributions from metabolic waste, the application of this concept centres on the examination of changing population structure within a river catchment. In particular it is important to document population numbers and age statistics for small area units which will permit the restructuring of census information into river catchments.

Reliable census enumeration in Ireland dates from 1841 when census commissioners were appointed for the first time (Kennedy 1973), and the Ordnance Survey attained a level of sophistication sufficient to remove problems

1 Assumes excreta:detergent = 1:1

previously caused by the uncertainty of local boundaries (Vaughan and Fitzpatrick, 1978). The availability of census material from 1850-1981 is presented in Table 7.

TABLE 7 THE DATES OF IRISH CENSUSES FROM 1851

CENSUS OF IRELAND	1851		
	1861		
	1871		
	1881		
	1891		
	1901		
	1911		
CENSUS OF NORTHERN IRELAND	1926		
	1937		Townland data unpublished
	1951		
	1961		Townland data unpublished
	1966	(full enumeration)	Townland data unpublished
	1971		Townland data unpublished
	1981	(forthcoming)	
CENSUS OF THE REPUBLIC OF IRELAND	1926	(manuscripts destroyed)	
	1936		Townland data unpublished
	1946		" " "
	1951		" " "
	1956		" " "
	1961		" " "
	1966		" " "
	1971		" " "
	1979		" " "
	1981	(forthcoming)	" " "

The Townland

Fortunately for a study encompassing 130 years of census enumeration, continuity of spatial reference is possible throughout the period by virtue of the practice of recording certain relevant population data at the level of the Townland[1].

The origin of the townland, the smallest Irish territorial division, has never been satisfactorily explained (Mogey 1947). "The townland distribution of Ireland ranks among the most ancient civil divisions of soil in Europe, and has no existing analogue in Great Britain" (Census of Ireland 1871 p.38). In spite of changing boundaries at higher levels in the administrative hierarchy and despite the partition of 1922, which created two census authorities in the Lough Erne region, the boundaries of the townlands within the region have, with a few minor exceptions,[2] remained constant. Thus the population of a townland in 1971 can be directly related to the population of the same area in 1851.

An additional advantage of townlands is that their generally small size (average 121.4 ha. in Fermanagh (Mogey 1947)) allows topographically derived river catchments to be redrawn for purposes of demographic analysis along townland boundaries with the minimum of error. Where a topographic catchment boundary cuts through a townland, that townland is appointed to the river catchment within which the majority of its population lives.

Of the information recorded at townland level central importance is placed on total population numbers - differences by sex being superfluous to this study (see p.11). With townland area and number of inhabited houses, the analysis of population totals permits the calculation of population densities and average household size respectively. It is possible that this last variable may be of major importance in the linking of potential P outputs to developments

1 In the Republic of Ireland Census and the Northern Ireland Census of 1937, 1961 1966 and 1971, this data is unpublished.

2 Generally where townland boundaries have been manipulated to account for expanding urban areas or in cases of land reclamation or erosion.

in sanitary provision, as in the final analysis it is houses and households that are sewered, not individuals. For that part of the study region lying in Northern Ireland, changes in the census definition of the term 'house' since 1851 are slight and do not inhibit intercensal comparison (eg Census of Northern Ireland 1926). In the Republic no information is available on house numbers at townland level between 1936 and 1961. From 1966-1979 figures are presented in terms of 'households'.

The Relationship Between Towns and Townlands

This relationship poses a complication in analysing census material. The problem is not so much one of changing definition of the term 'town' (a group of 20 or more contiguous houses; Vaughan and Fitzpatrick, 1978), as changes in the way in which 'urban'[1] population is recorded.

From 1851 to 1911 town populations are recorded separately from the population of the townland(s) on which they fall, there being no indication of the contribution made by individual townlands to the total town population. From 1926 to 1971 in Northern Ireland town populations are included in figures relating to their constituent townlands as well as being recorded separately.

The major difficulty caused by this inconsistency is one of cartographic representation of variables at townland level. For mapping purposes where the urban population cannot be assigned to constituent townlands it is proposed to divide that population equally among the townlands concerned (eg Figs 13-15).

The practice in the Republic of recording population numbers for certain towns at street level provides an opportunity to examine the changing contribution of P from domestic waste at a spatial level below that even of town or townland.

1 Henceforth the term 'town' and 'urban' in the context of this paper, refer to areas considered to constitute towns for census purposes.

Age Structure

Age statistics are recorded per se or may be gleaned indirectly from a variety of sources, and in varying age groupings from census data throughout the study period. Temporal continuity of age groups is essential for the meaningful interpretation of such data. Such continuity is provided by the documentation of quinquennial age groups. Unfortunately such information is recorded at administrative levels above that of the townland and for different areas through time.

To circumvent this problem the method was devised of constructing representative age structures for river catchments by averaging the proportion of population in each five year group for the administrative areas across which the catchment lay. Thus in 1851 the age structure of the Colebrooke catchment is derived from the weighted mean age structure of the Baronies of Clogher, Clankelly, Magherastephana and Tirkennedy (see Table 8 P 27). This method is resorted to in order to obtain some overview of age structure in a catchment, it would not be justifiable in demographic terms to devolve the same principle to individual townlands.

Handling of Data

The relevant data from all censuses 1851-1979 has been transcribed by hand from record offices in London, Belfast and Dublin to standardised record sheets. The data was then transferred to a Prime 300 computer utilising the Minitab Statistical Package developed at Pannsylvania State University, which facilitates descriptive and statistical analysis of the material.

Cartographic presentation of data stored within Minitab files is subsequently possible using a Ferranti Cetec System-4 digitising table and Hewlett - Packard 7221 flatbed plotter.

Despite certain problems of interpretation and continuity, Irish census data provides an essential source for a major component of this project. It must however be recognised that while permitting analysis of trends along a time series, each census is time specific, referring in the final analysis to one day in a ten or more year period.

TABLE 8 ADMINISTRATIVE AREAS FROM WHICH AVERAGE COLEBROOKE AGE STRUCTURE DERIVED

1851 - 1861	Baronies:	Clankelly	(Fermanagh)
		Clogher	(Tyrone)
		Magherastephana	(Fermanagh)
		Tirkennedy	(Fermanagh)
1871 - 1911	Registrar's Districts	Brookeborough	(Fermanagh)
		Fivemiletown	(Tyrone)
		Lisbellaw	(Fermanagh)
		Lisnaskea	"
		Maguiresbridge	"
		Rosslea	"
1926	Aggregate of Rural districts		
1937 - 1971	Rural Districts	Clogher	(Tyrone)
		Ennsikillen	(Fermanagh)
		Lisnaskea	(Fermanagh)

III POTENTIAL MINIMUM CONTRIBUTIONS FROM METABOLIC WASTES TO THE P LOADING OF THE RIVER COLEBROOKE CATCHMENT

The concepts and methods discussed in the previous section are briefly exemplified below by their application to a river catchment. Apart from the purpose of illustration this exercise will enable the relative importance of population numbers and age structure in the contribution of P from metabolic wastes to be assessed. Furthermore it may also indicate the changing impact of such wastes in their own right on the P loading of Lough Erne.

The Colebrooke

One of the largest catchments in the study area (Fig 2), the River Colebrooke and its principal tributary, the Tempo River, drain some 37,500 Ha of land to the east of Lough Erne.

Consisting of 377 townlands (352 in Fermanagh, 23 in Tyrone, and 2 in Monaghan), the catchment includes five settlements considered by the census to constitute towns (Brookeborough, Fivemiletown, Lisnaskea, Maguiresbridge and Tempo), (Fig. 6).

Analysis of population numbers by townland reveals the changing aggregate situation apparent from Fig. 7. The progressive decline which saw population decline by 60% between 1851 and 1966 was marginally halted between 1966 and 1971. Meanwhile the number of inhabited houses reached a low in 1966 at a level some 40% below the 1851 maximum. Alongside these trends has been a fall in the average household size from 5.63 in 1851 to 3.65 in 1971 (Fig. 8).

From Fig. 9 it may be observed that while fluctuating, generally downward, between 1851 and 1951, the urban population had by 1971 surpassed the 1851 total. Associated with a threefold drop in the rural population (Fig. 9) has thus been a progressive increase in the proportion of the population living in towns (Fig.10), associated with which has been a dramatic increase in urban house building between 1961 and 1971 (Fig. 11). The effect of this trend may eventually prove significant in terms of domestic P loading in the catchment, in that the overall decline in population may be offset by the increased proportion of people living in towns and hence having access to sewerage. (Of the six 'major' sewage works in the catchment in 1974 five were in the towns. D.O.E., 1974). In particular the magnitude of the demographic revival of Lisnaskea warrants that emphasis be given to examining the history of sanitary provision in the town.

Information for the calculation of average age structures for the catchment was drawn from the appropriate administrative areas listed in Table 8. From Figure 12 a general move towards the increasing significance of the adult age groups is apparent during the study period.

The analysis and interpretation of demographic statistics for its own sake falls outside the scope of this research programme. It is appropriate to note however, that the comprehensive documentation of census data within the study region may in itself provide a potentially useful source for demographers. Lying in an intermediary position between the 'poor' West and the 'prosperous' East, with their characteristic population patterns, the Lough Erne region may prove particularly interesting in forming an area of transition between these broad zones (Coward 1981).

The effect of the changing population on the minimum potential P loading from metabolic wastes for the catchment as a whole is summarised in Table 9. Readily apparent is the progressive decline in the daily contribution at this level. Also noticeable however is the relative insignificance of age structure. The average difference obtained in calculating P outputs by treating the entire population as adults and ascribing an across the board figure of 800 mg P person^{-1} day^{-1} rather than account for three age groups, is only 3.2%.

In view of the nominal importance of age structure variation, and in order to obtain an idea of spatial distribution throughout the catchment, a general figure of 800 mg P person^{-1} day^{-1} was utilised to compute potential P contributions at town-land level. The results are mapped in Figures 13-15. In order to account for variability in townland size the data is presented in terms of density of P output.

The use of 'multimodal' class intervals (Evans 1976) derived from the analysis of the frequency curves appertaining to the variable throughout the study period, allows the spatial pattern to be described and directly compared through time. The years for which data is presented were chosen simply to facilitate the equal subdivision of the study period.

The maps confirm that the overall decrease in P output from metabolic sources is characterised by a progressive decline in rural contributions and an increase in the relative importance of towns.

TABLE 9 MINIMUM POTENTIAL P CONTRIBUTION FROM METABOLIC WASTES FOR THE COLEBROOKE CATCHMENT 1851-1971 MG. PERSON^{-1} DAY^{-1}

DATE	0-9	10-14	15+	Total	Total as adults	% Difference
1851	3540	2913	12835	19288	19946	3.4
1861	3185	1802	12226	17213	17823	3.5
1871	2859	1893	10483	15235	15776	3.5
1881	2599	1734	9684	14017	14508	3.5
1891	2026	1391	8698	12115	12497	3.0
1901	1755	1078	7828	10661	10994	3.1
1911	1743	1016	7498	10256	10590	3.2
1926	1588	1014	7125	9726	10028	3.1
1937	1322	904	7046	9271	9522	2.7
1951	1524	775	6666	8965	9259	3.3
1961	1396	862	5914	8172	8438	3.2
1966	1327	791	5692	7810	8063	3.2
1971	1323	776	5730	7829	8082	3.2

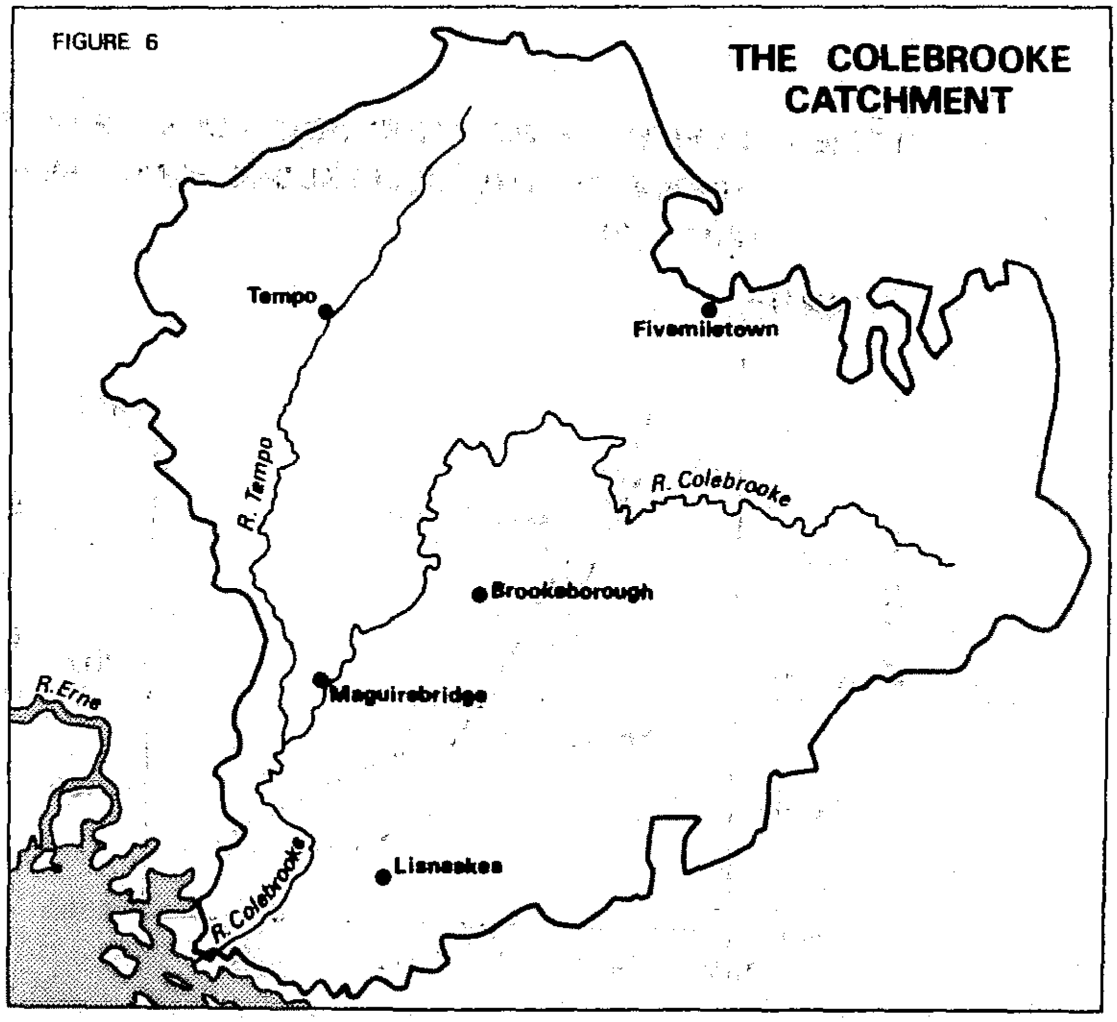


FIGURE 6
THE COLEBROOKE CATCHMENT
Tempo
Fivemiletown
R. Tempo
R. Colebrooke
Brookeborough
Maguiresbridge
R. Erne
Lisnaskea
R. Colebrooke

FIGURE 7 **OVERALL POPULATION AND HOUSE NUMBER TRENDS IN THE COLEBROOKE CATCHMENT 1851 - 1971**

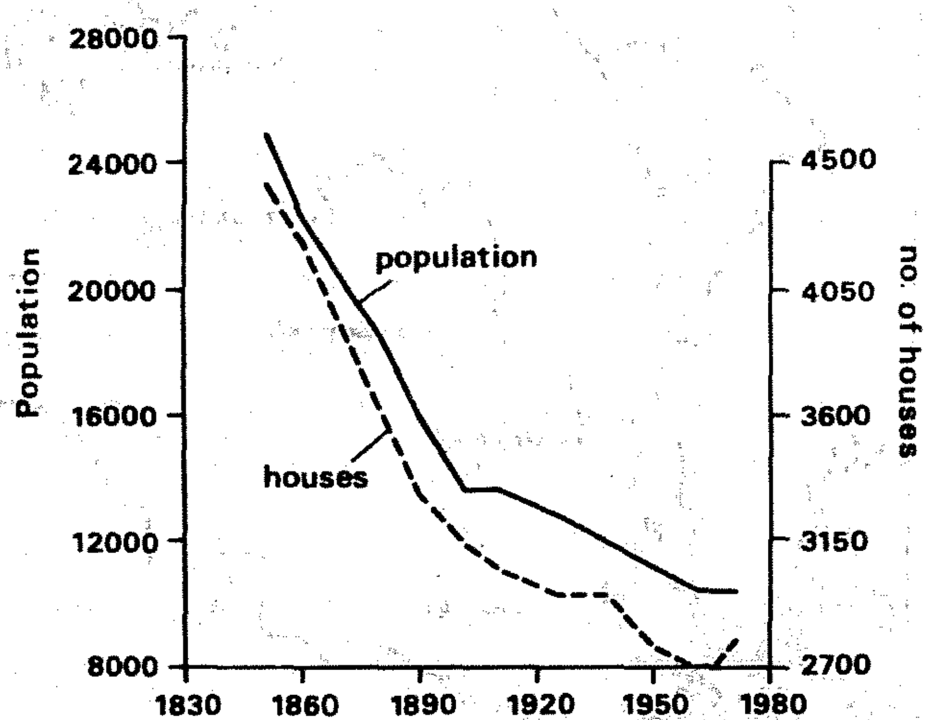


FIGURE 8 **AVERAGE HOUSEHOLD SIZE IN THE COLEBROOKE CATCHMENT 1851-1971**

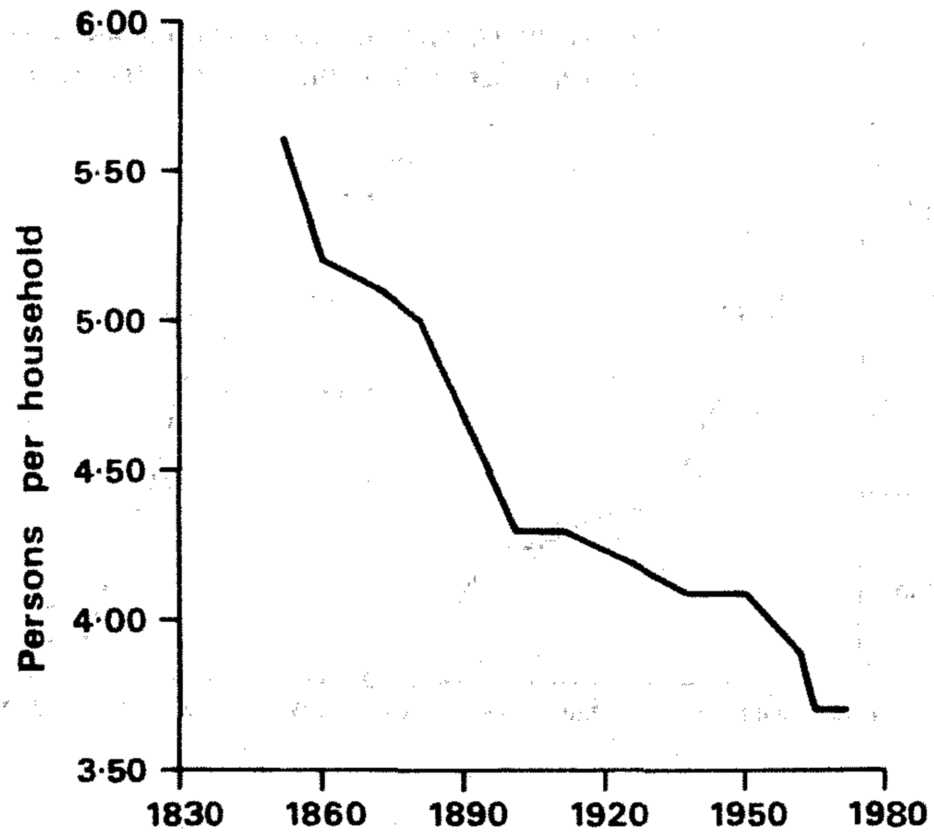


FIGURE 9 **POPULATION TRENDS IN RURAL AND URBAN AREAS OF THE COLEBROOKE CATCHMENT 1851 - 1971**

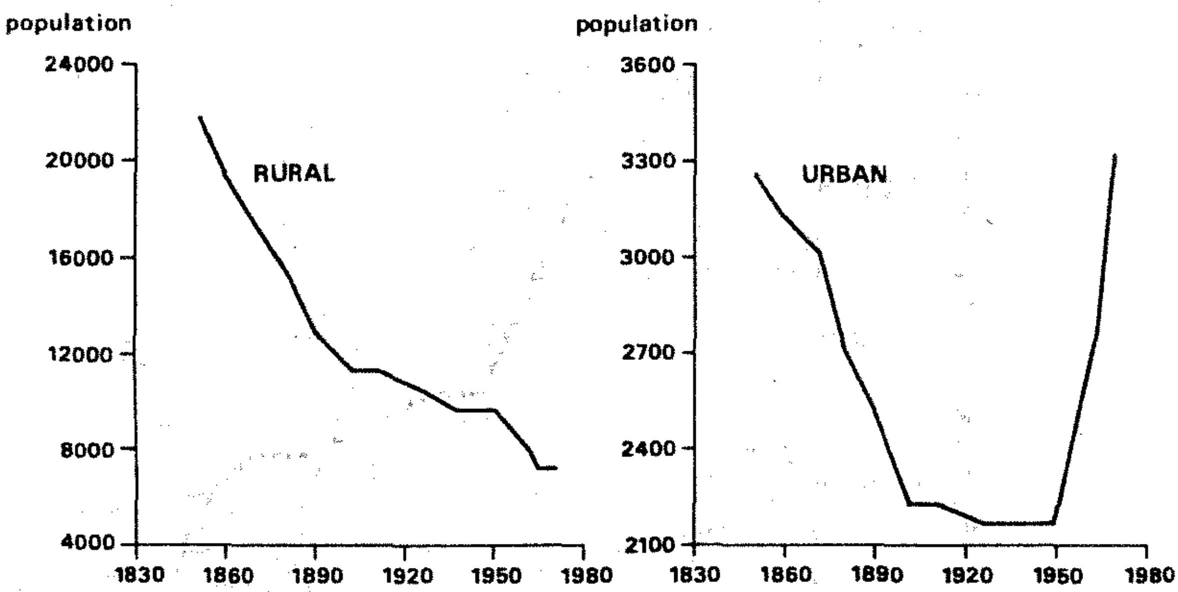


FIGURE 10 **PERCENT OF POPULATION LIVING IN TOWNS IN THE COLEBROOKE CATCHMENT 1851-1971**

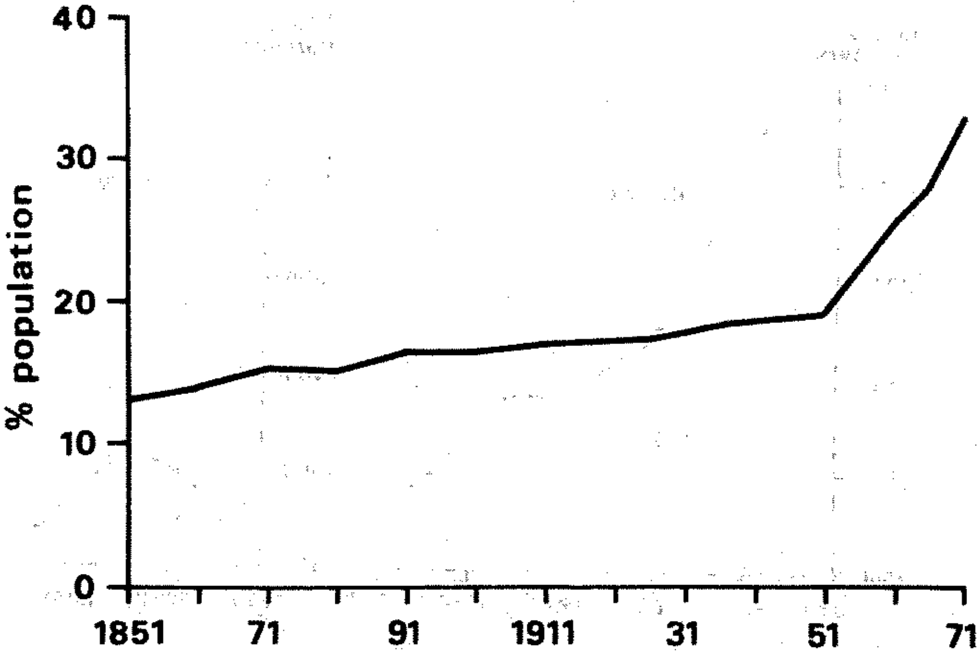


FIGURE 11 HOUSE NUMBER TRENDS IN RURAL AND URBAN AREAS OF THE COLEBROOKE CATCHMENT 1851 - 1971

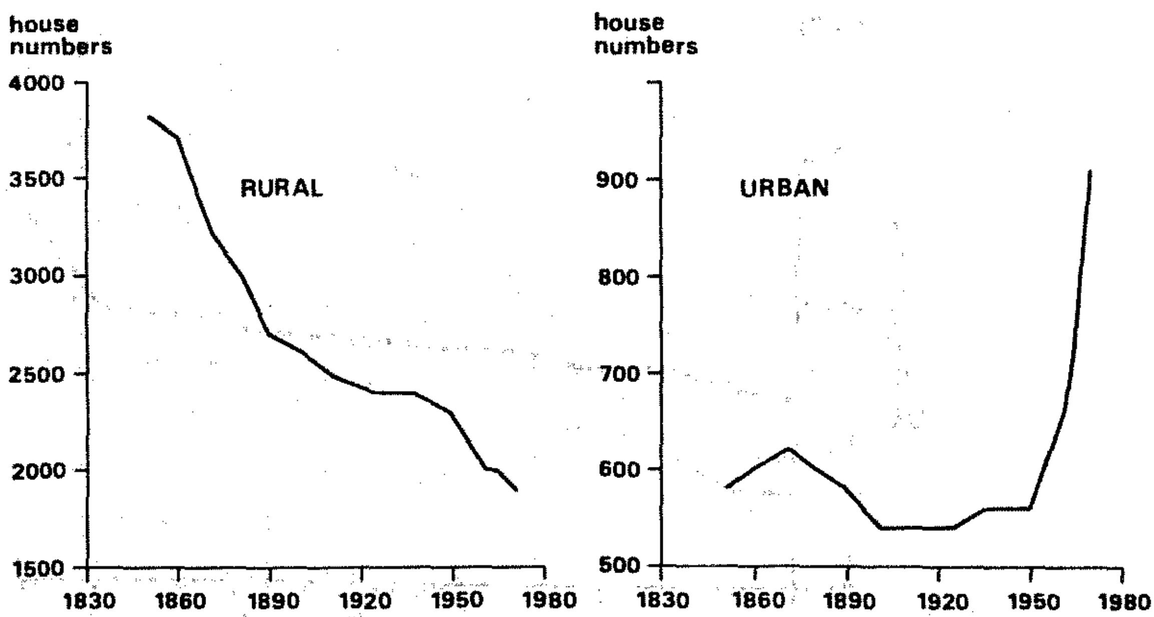


FIGURE 12 **AGE STRUCTURE OF THE COLEBROOKE CATCHMENT 1851 1971**

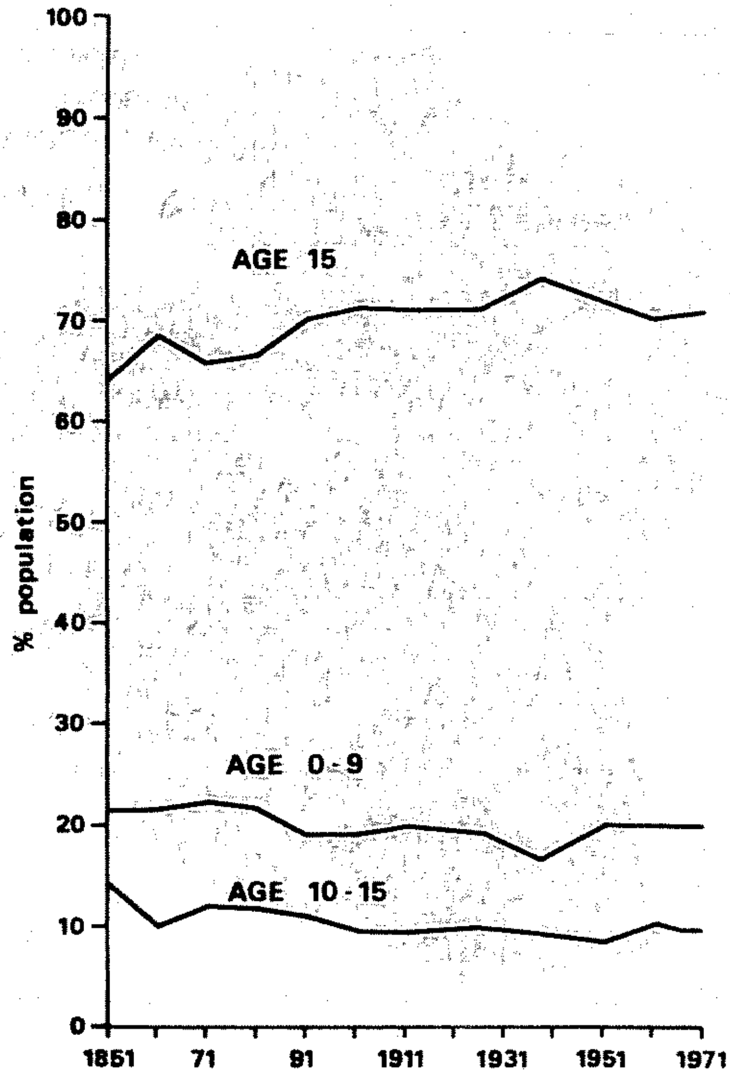


FIGURE 13

DENSITY OF MINIMUM POTENTIAL P OUTPUT IN THE COLEBROOKE CATCHMENT 1851

(Mg. P. Person^{-1}. day^{-1}. Ha^{-2})

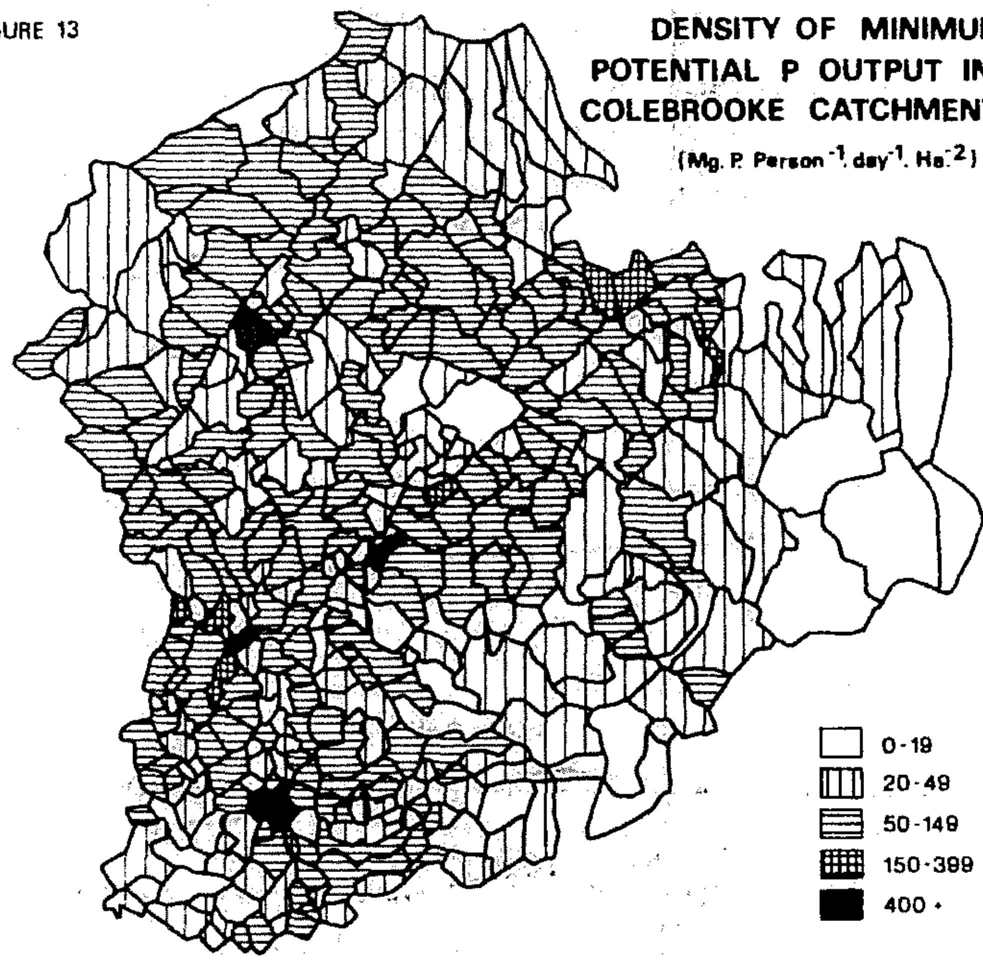


FIGURE 14

DENSITY OF MINIMUM POTENTIAL P OUTPUT IN THE COLEBROOKE CATCHMENT 1911

(Mg. P Person^{-1}. day^{-1}. Ha^{-2})

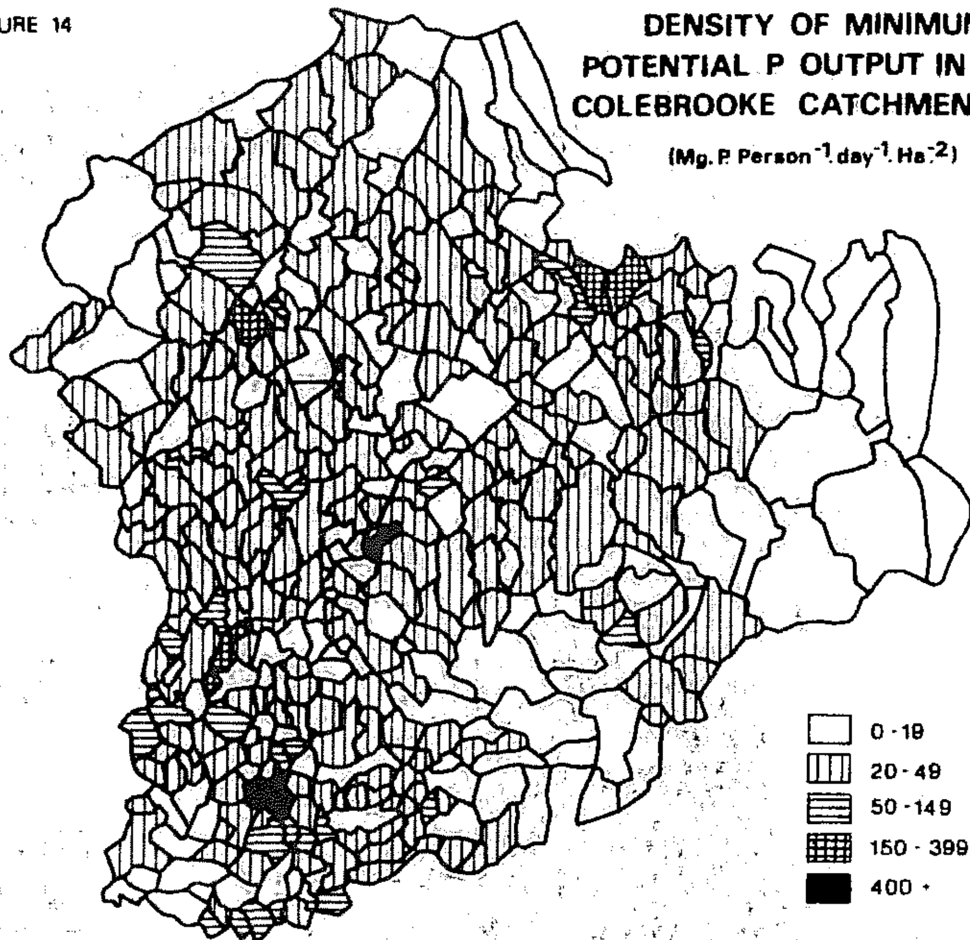
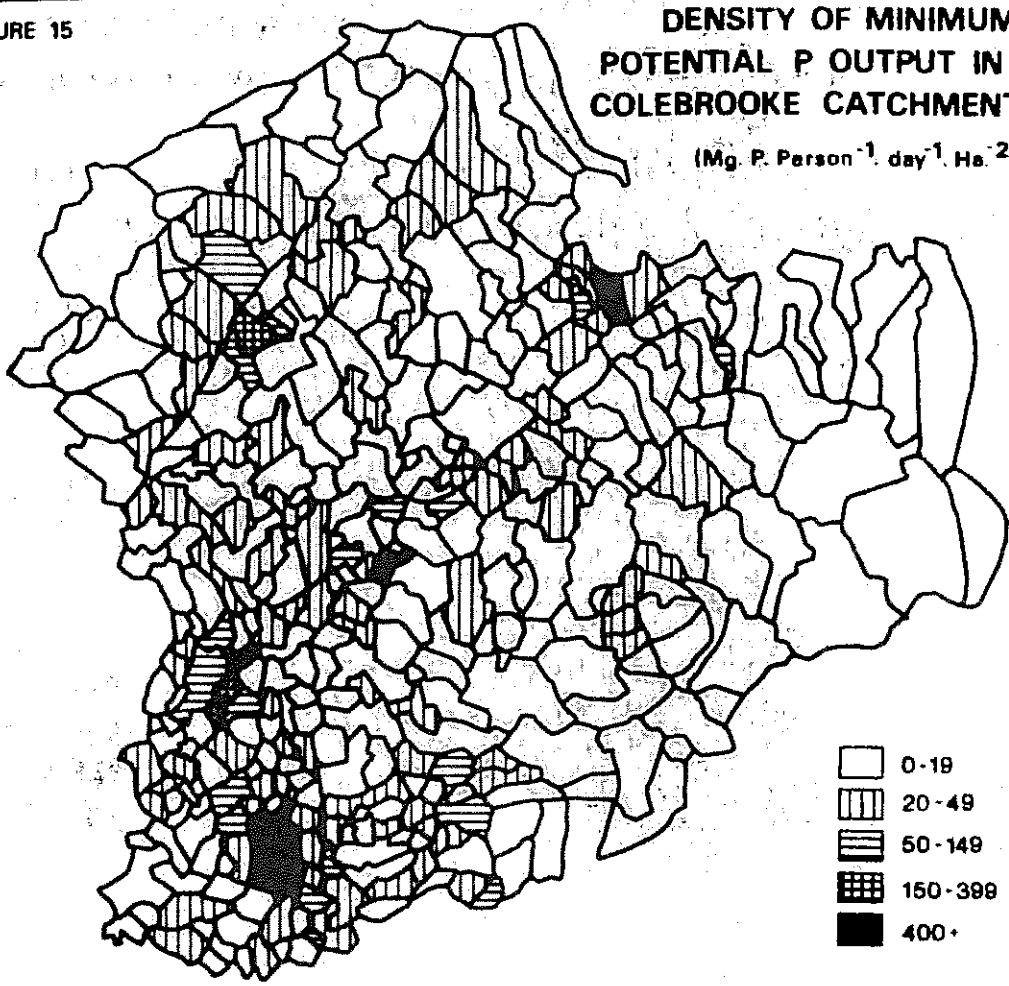


FIGURE 15

DENSITY OF MINIMUM POTENTIAL P OUTPUT IN THE COLEBROOKE CATCHMENT 1971

(Mg. P. Person^{-1}. day^{-1}. Ha.$^{-2}$)



IV. SUMMARY

In itself the calculation of minimum potential P contributions from metabolic wastes is but the first step in the process of estimating changing P contributions from point sources in a river catchment. The figures computed and patterns perceived portray certain underlying trends apparent in considering the role of domestic effluents. These trends as exemplified by the Colebrooke catchment, suggest that if domestic sources are important in the increased loading of P on Lough Erne, it is not through changes in contributions from metabolic wastes themselves, since such contributions are determined by population numbers, which in the Colebrooke at least have markedly declined during the study period, rather it is via the increasing proportion of domestic effluents reaching water-courses, which developments in sanitary provision have permitted. Of particular significance may be the progressive concentration of population in towns where sewer provision can be expected.

In order to build upon the base provided by the concept of potential P contributions it is desirable to seek to determine more realistic figures, rather than a constant minimum, for P output from metabolic wastes, and to link this with contributions from detergents, to estimate the full output of P in domestic effluent. Together with the documentation of developments in sanitary provision, which forms the next major step in this project, such research should enable us to proceed towards the determination of actual P contributions from point sources.

ACKNOWLEDGEMENTS

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Appendix 1.a. P INTAKES CALCULATED FROM LABOURERS' DIETS 1859 (Poor Law Commissioners 1860)

STUDY AREA	STUDY NO.	FAMILY SIZE	INTAKE mg.P $person^{-1}day^{-1}$
FERMANAGH	1	5	1344
	2	6	737
	3	4	1162
	4	5	1044
	5	6	1605
	6	5	1081
	7	5	964
	8	6	821
	9	5	1522
	10	8	1059
TYRONE	1	6	1288
	2	7	969
	3	6	1007
	4	8	593
	5	7	869
	6	6	1129
	7	6	1583
	8	5	1489
	9	6	1246
	10	5	1489
	mean		1150

Appendix 1.b. P INTAKES CALCULATED FROM WORKING MEN'S DIETS, DUBLIN 1904 (CD 5070)

STUDY NO.	MEAN FAMILY INCOME/WEEK	FAMILY SIZE	INTAKE mg.P. $person^{-1}$ day^{-1}
1	£1.13.0	3	1241
2	£1.00.0½	2	1556
3	£1.04.6	2	1662
4	£1.07.0	4	1182
5	£1.15.0	2	1290
6	£1.19.8½	6	764
7	£2.10.0	5	1052
8	£1.15.03½	5	787
9	£1.18.0	6	788
10	£1.19.04	3	1028
11	£1.00.0	4	1195
12	£0.19.0½	5	819
13	£0.17.0	5	731
14	£0.17.7½	3	678
15	£0.18.0	6	570
16	£0.17.0	6	500
17	£0.10.0	2	909
18	£1.03.0	9	529
19	£1.14.1½	10	628
20	£0.10.2	3	579
21	£0.09.0	5	546
MEAN			906

Appendix 1.c. P INTAKES CALCULATED FROM URBAN WORKINGMEN'S AND AGRICULTURAL LABOURERS' DIETS. 1902 - 1904. (CD 2337, CD 2376)

STUDY	MEAN FAMILY INCOME WEEK^{-1}	INTAKE mg.P. person^{-1} day^{-1}
Urban Workingmen	-25/-	3709
	25-30/-	4585
	30-35/-	4810
	35-40/-	4872
	40/- +	6000
Agricultural Labourers (37 families)		4074

Appendix 1.d. P INTAKES CALCULATED FROM NATIONAL NUTRITION SURVEY 1945 - 1948. (IRISH FREE STATE DEPT' HEALTH 1953)

STUDY	SAMPLE SIZE (FAMILIES)	INTAKE mg.P. $person^{-1}$ day^{-1}
Congested Districts	200	
a. Spring		1201
b. Autumn		1814
Towns 10000 +	329	1120
Town - 10000	516	1135
Farming Families	948	1734
Farm Workers' Families	177	1107
Exceptional Rural Families	23	1452
Dublin		
a. Slums	188	1054
b. Artisans	210	1111
c. Middle Class	102	1300

Appendix 1.e. P INTAKES CALCULATED FROM O.E.C.D. DATA 1954 - 1964

YEAR	INTAKE mg. P. person^{-1}day^{-1}
1954	1350
1955	1391
1956	1378
1957	1369
1958	1361
1959	1380
1960	1388
1961	1396
1962	1404
1963	1410
1964	1399
MEAN	1272

Appendix 1.f. P INTAKES CALCULATED FROM M.A.F.F. DOMESTIC FOOD CONSUMPTION AND EXPENDITURE DATA

YEAR	AREA	INTAKE $mg.P.person^{-1}day^{-1}$
1960	rural	1241
1979	-0.5 $persons^{-1}$ $acre^{-2}$	1027
	0.5-3 $persons^{-1}$ $acre^{-2}$	1039

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