An evaluation of nitrogen sources and inputs to tidal waters in Northern Ireland

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Summary

1. An investigation was undertaken to determine the loadings of nitrate, ammonium and dissolved reactive phosphorus (DRP) to the following tidal and sea Loughs: River Foyle, Lough Foyle, Lower Bann, tidal River Lagan, Inner Belfast Lough, Outer Belfast Lough, Quoile Pondage, Strangford Lough and the tidal Newry River.

2. The primary focus of the study was on nitrate loadings, which were partitioned between the following sources: agricultural land, uplands, forest land, other land, waste water treatment works (WWTWs) and industrial inputs. This division was primarily to determine whether the contribution of agricultural land to the total nitrate loading was sufficiently high as to merit designating the catchments of eutrophic or potentially eutrophic waters as Nitrate Vulnerable Zones in compliance with the European Union Nitrates Directive (91/676/EEC).

3. River loads were based on EHS nitrate and ammonium monitoring data for period October 1994 to September 2000. This time-span ensured that data from a mix of high and low nitrate loss years were used. Due to a change in the detection limit, dissolved reactive phosphorus loads are the average of the period October 1998 to September 2002. Concentration data for ammonium and nitrate were available for three of the rivers that drain into Lough Foyle from County Donegal for the year of 1997.

4. Loads were calculated as the product of average flow weighted mean concentration and the annual runoff. Where a water is part of a larger system, the loadings are cumulative i.e. Lough Foyle is sum of inputs to Lough Foyle and the River Foyle.

5. Nutrient loadings from individual WWTWs were calculated as the product of average concentration and annual flows from WWTWs. The latter was based on a statistical relationship with the population equivalent organic loadings to WWTWs.

6. Industry inputs were based on data supplied by EHS. The major industrial input to the Tidal Lagan was the Irish Fertiliser Industries (IFI) factory but this has closed down and may be regarded as a historic rather than current nutrient source. For Foyle system, the largest single nitrogen input was from Du Pont on the River Foyle but loads from this source have been scaled back by 93% since 1993 and loading contributions are based on these lower loads.

7. In all catchments nitrate from agriculture formed the dominant proportion of the annual nitrate loading. The contributions from the catchments were as follows: River Foyle (92%), Lough Foyle (90%), Lower Bann (92%), tidal River Lagan (78%), Inner Belfast Lough (73%), Outer Belfast Lough (76%), Quoile Pondage (94%), Strangford Lough (90%) and tidal Newry River (96%).

8. The loss rates of nitrate from agricultural land in individual river catchments were close to close to a rate of 2.0 tonnes N km^{-2} yr^{-1}. This rate is consistent with a) the use of fertiliser and imported foodstuffs by agriculture within Northern Ireland and b) estimates of nitrate loss from agricultural land based on nutrient export coefficients and the areas of agricultural land in each river catchment.

9. Intensification of agricultural production in Northern Ireland, with its increasing reliance on imported fertilisers and foodstuffs, commenced around 1940. The current agricultural land contributions to nitrate loads calculated in this study therefore include a component that may be considered a natural or background nitrate loading from agricultural land that occurred prior to 1940. The nitrogen output in agricultural produce from Northern Ireland in the period 1925-1940 was only 25% of that in the years 1999 to 2000. If this represents the scale of lower nitrogen inputs to agriculture in the 1925-1940 period, and assuming that nitrate losses to water increase linearly with nitrogen inputs, which is the case for grassland, then approximately 75% of the current agricultural loading can be assigned to an intensification factor. After discounting this background agricultural loading, the agricultural intensification component remained the largest contributor to nitrate loads, representing more than 50% of current catchment nitrate loadings: River Foyle, 69.5%; Lough Foyle, 67.7%; Newry River 72.2%; Quoile, 70.6%; Strangford Lough, 67.5%; Lower Bann, 69.2%; Tidal Lagan, 58.5%; Inner Belfast Lough, 55.2% and Outer Belfast Lough, 57.5%.

10. The contribution of WWTWs to nitrate loadings was less than 10% except in the catchments of the tidal River Lagan (20%), Inner Belfast Lough (24%) and Outer Belfast Lough (21%).

11. WWTWs were the largest source of ammonium in seven catchments: River Foyle (52%), Lough Foyle (55%), tidal River Lagan (42%), Inner Belfast Lough (90%), Outer Belfast Lough (94%), Strangford Lough (75%) and tidal Newry River (94%). In the Quoile catchment agriculture was the largest source. This is reflects the good

treatment of WWTWs in this catchment, which results in comparatively little ammonium in effluent from WWTWs. In the Lower Bann ammonium loss rates were approximately 100% greater than expected.

12. Although WWTWs were a significant source of ammonium, losses of ammonium in rivers were much lower than nitrate losses. Agriculture therefore remained the largest component source of the combined nitrate and ammonium loading or dissolved inorganic nitrogen (DIN) loading as follows: River Foyle (81%), Lough Foyle (81%), Lower Bann (84%), tidal River Lagan (75%), Inner Belfast Lough (57%), Outer Belfast Lough (51%), Quoile Pondage (91%), Strangford Lough (82%) and tidal Newry River (82%).

13. Nitrate losses were highest in the winter reflecting both higher river flows and higher concentrations of nitrate in winter. Loadings of nitrogen from WWTWs remain fairly constant throughout the year. Therefore, if the ecological response of specific water is more sensitive to elevated inputs of nitrogen in the summer, when biological productivity is potentially high, an annual budget may overestimate the ecological importance of nitrate inputs from agriculture. However a summer (April-October) breakdown of DIN inputs found that agriculture was the largest DIN source in the following catchments: River Foyle (72%), Lough Foyle (71%), Lower Bann (70%), tidal River Lagan (53%), Quoile Pondage (80%), Strangford Lough (65%) and tidal Newry River (52%).

14. In the two Belfast Lough catchments, WWTWs were the largest summer source of DIN: Inner Belfast Lough (67%), Outer Belfast Lough (72%).

15. The analysis given above excluded the contribution form the former Irish Fertiliser Industries factory in Belfast. Historically this was the largest source of nitrate and ammonium to the tidal Lagan and Belfast Lough. When the factory was operational the agricultural component to the annual nitrate loading was still comparatively large: tidal River Lagan (42%), Inner Belfast Lough (41%), Outer Belfast Lough (46%).

16. Industrial inputs formed only a small proportion of the DIN load to the River Foyle (0.7%) and Lough Foyle (1.3%)

17. WWTWs represented a significant (>33%) source of DRP in all catchment. The contributions were as follows: River Foyle (42%), Lough Foyle (44%), Lower Bann

(89%), tidal River Lagan (54%), Inner Belfast Lough (72%), Outer Belfast Lough (73%), Quoile Pondage (34%), Strangford Lough (60%) and tidal Newry River (66%).

18. Agricultural land was also generally a large DRP source: River Foyle (51%), Lough Foyle (48%), tidal River Lagan (44%), Inner Belfast Lough (28%), Outer Belfast Lough (26%), Quoile Pondage (65%), Strangford Lough (37%) and tidal Newry River (33%).

19. The exception was the Lower Bann were the contribution was exceptionally small at 4% of the DRP load. The DRP loss rate from the Lower Bann was anomalously low and was considered to reflect the uptake of DRP by the large amounts of algae entering this river from Lough Neagh.

Abbreviations

C_{FWM}	Flow weighted mean concentration for sampling period (g m^{-3})
C_T	Sample concentration at time of sampling T (g m^{-3})
DIN	Dissolved inorganic nitrogen
DRP	Dissolved reactive phosphorus
EC	Export coefficient [of nutrients]
EHS	Environment and Heritage Service
FWMC	Flow weighted mean concentrations
IFI	Irish fertiliser Industries fertiliser factory

Mexport = Catchment export rate (tonnes km-2)

N	nitrogen
NH4	ammonium
NO3	nitrate
PE	Population equivalent (connected to waste water treatment works)
Q_T	Flow at time T of sampling ($m^3 sec^{-1}$)
R	Catchment runoff measured over sampling period (m)
WWTWs	Waste water treatment works

Contents

1.0 Introduction

The report by a DOE-DARD Scientific Committee on the environmental aspects of the applicability of the European Union Nitrates Directive (91/676/EEC) to Northern Ireland identified six tidal waters and sea loughs where marine eutrophication may justify the designation of their catchments as Nitrate Vulnerable Zones (Anon. 2002). The waters were as follows:

Quoile Pondage	Strangford Lough
Newry River	Lower Bann
River Lagan	Belfast Lough
River Foyle	Lough Foyle

The Foyle catchment consists of two distinct areas: the tidal River Foyle, from Strabane downstream to Culmore, and the open water of Lough Foyle. The River Lagan consists of the tidal River Lagan within the city of Belfast but its impact potentially extends into its receiving water, Belfast Lough. This in turn can be divided into Inner Belfast Lough, approximately defined by a line from Hollywood to Whitehouse, and Outer Belfast Lough which is the remaining area, to a line from Orlock Head to Black Head.

The requirement for designation depends on a) the vulnerability of these waters to eutrophication and b) that a significant proportion of the nitrate input originates from agricultural sources. To date this significant proportion has been taken to be 20% of the annual input of nitrate.

This report quantifies the nitrate inputs to these waters and partitions these inputs between urban, industry, agriculture, forestry, uplands and other sources within each catchment. Confining the budget to nitrate provides only an incomplete indication of eutrophication potential as algae can also use ammonium as a nitrogen source. A better indication of eutrophication potential impact requires consideration of the combined input of nitrate and ammonium, termed dissolved inorganic nitrogen (DIN) in this report. For this reason ammonium budgets have also been determined for each water and, from these, DIN budgets calculated.

Nutrient inputs from agricultural land are strongly seasonal, with highest losses in winter reflecting high flows and in the case of nitrate higher than average concentrations. In contrast biological activity of sea loughs and tidal estuaries, in the form of primary production, is at a minimum in the winter due to constraining effects of limited solar radiation, low temperatures and a rapid flushing with associated losses of algae caused by high winter river flows. An annual breakdown of inputs may therefore be misleading if the bulk of the nutrients enter tidal waters, which have very short retention times in the order of days, during the winter and would be expected to be flushed from the system by the advent of spring. For this reason breakdowns of DIN inputs by winter (October to March) and summer (April to September) are also given. Finally while tidal and marine waters are considered to be nitrogen limited this is not a uniform feature of the marine environment and this study includes a breakdown of inputs of dissolved reactive phosphorus to each tidal water.

The main findings of the study are presented in Chapter 3. Detailed breakdowns of nutrient sources between the contributing rivers and direct drainage areas are listed in Appendix A.

Finally the report does not deal with compliance with the Nitrate Directive requirement that surface water concentrations should be less than the 50 mg NO3 L^{-1} as this has already been addressed by the DOE-DARD Scientific Committee report. All the inflowing rivers to the tidal waters covered by the current report were in compliance with the standards for concentration of nitrate in surface waters as set by the Nitrates Directive (Anon, 2002). Neither does the report attempt to assess the ecological impact of any of the nutrient inputs computed. There have been recent assessments of the trophic status of most of the waters covered in this report (Table 1.1). River exports of nutrients from these investigations are however compared with measurements from the current study in Chapter 3.

Table 1.1 Previous investigations on trophic status of the waters covered by this report.

Water	Reference
River Foyle and Lough Foyle	Charlesworth, et al (1999)
River Lagan and Belfast Lough (1)	Charlesworth and Service. (1999)
River Lagan and Belfast Lough (2)	Service and Durrant (1996)
Strangford Lough	Taylor and Service (1997)
Newry River	Taylor et al. (1999)

2.0 Methodology

This chapter summarises the methodology used in calculating the loadings for each of the tidal waters and sea loughs covered by this study.

2.1 River loadings

<u>2.1.1 Calculation of loadings</u> The amount of nutrients entering a water body is termed the nutrient loading and is a product of concentration times flow. Calculating a nutrient loading as average annual flow times the mean annual concentration is liable to systematic bias if flow varies with concentration. Using this model, if high concentrations occur at low flows then the resulting load calculation overestimates the true loading. The opposite occurs, with a bias to underestimating loads, if concentration increases at high flows. The latter situation, of high winter but lower summer concentrations, is typical of the nitrate cycle observed in rivers in Northern Ireland. To overcome these seasonal effects, a more reliable method of calculating loading is to weight each concentration by the flow at time of sampling, termed the flow weighted mean concentration (FWMC) as set out in equation 1 (Lennox *et al*., 1997)

$$C_{FWM} = \Sigma(Q_T C_t)/\Sigma\, Q_T \qquad \text{equation 1}$$

Where C_{FWM} = Flow weighted mean concentration for sampling period (g m^{-3})

Σ = Sum measured over sampling period.

Q_T = Flow at time T of sampling ($m^3 sec^{-1}$)

C_T = Sample concentration at time of sampling T (g m^{-3})

The FWMC concentration is then combined with the average runoff from the catchment to calculate catchment export rates as:

$$M_{EXPORT} = C_{FWM} * R \qquad \text{equation 2}$$

Where M_{EXPORT} = Catchment export rate (tonnes km^{-2})

R = Catchment runoff measured over sampling period (m)

A year is the typical sampling period over which a loading from a catchment is measured. However the Nitrates Report showed that there were large variations in nitrate concentrations and loss rates between years that did not reflect changes in either point source inputs or in agricultural practices but were related to climatic events. In particular, high concentrations nitrate and loss rates of nitrate typically followed dry summers with opposite being the case following wet summers. Since 1971 nitrate loads in the Lough Neagh catchment have followed an approximate six-year cycle of high loadings that followed dry summers with their subsequent peaks in winter nitrate concentrations (Foy, 2002a). To account for this variability and to obtain an estimate of catchment loadings that reflects the extremes of years with high and low nitrate loss rates, the loss rates presented in this report cover the six-year period from October 1994 to September 2000. The convention of starting in October reflects the use of the hydrological year that commences with the increased flows in autumn.

<u>2.1.2 Loadings - Northern Ireland</u> Loadings of nitrate, ammonium and dissolved reactive phosphorus (DRP) relied on concentration data collected by Environment and Heritage Service (EHS) as part of the statutory river monitoring for Northern Ireland. Flows were obtained from the Rivers Agency (Department of Agriculture and Rural Development). Concentration data was available for 14 rivers in Northern Ireland but four of these, all small streams in the Foyle catchment, were not gauged for flows. For these streams, Muff, Burnfoot, Faughanvale and Glenmornan, only time-weighted average concentrations could be calculated. The time weighted average values were converted into estimates of FWMCs using a relationship derived for the gauged rivers in the Foyle catchment (Fig 2.1). Loadings for the four streams were then calculated using average runoff from an adjacent gauged catchment, in this case the Burndennet River.

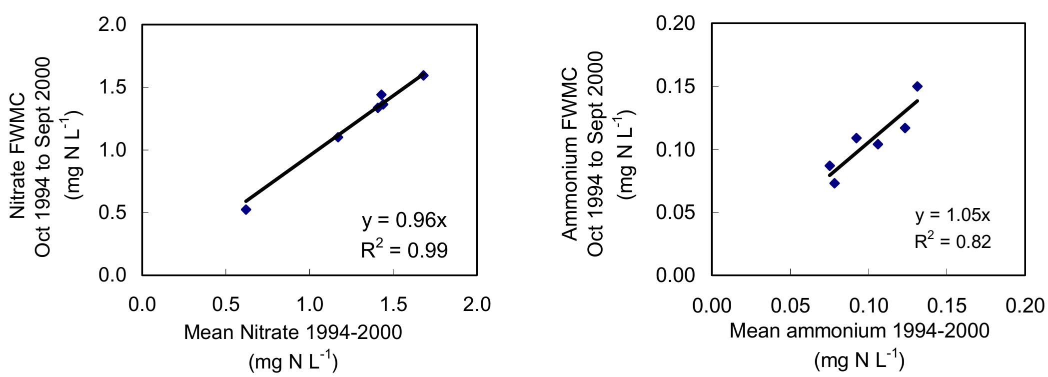

Fig 2.1 Plots of mean concentrations vs FWMCs for period October 1994 to September 2000 used to estimate FWMCs of minor streams in Northern Ireland portion of the Foyle catchment.

2.1.3 Loadings from County Donegal rivers The Foyle catchment drains both Northern Ireland and County Donegal in the Republic of Ireland. The largest river draining the County Donegal portion is the River Finn but this river is monitored by EHS where it forms the border and close to where it discharges into the River Foyle. Estimating flows from this river however proved problematic, as it is not gauged by Rivers Agency. Flows for the Finn are available from the Office of Public Works web site, but these exclude days with high flows, or approximately 33% of the total time period. To calculate flows for the River Finn, flows from the adjacent catchment in Northern Ireland, the River Derg, were used as surrogate flows to estimate FWMCs. Annual runoff from the Finn was then estimated using the ratio of runoff in the two rivers on days on which flows were available for both rivers times the runoff from the Derg.

Other parts of the Donegal catchment form the headwaters of the River Derg, which is part of the River Mourne system and therefore covered by the EHS sampling programme and associated loadings. The remaining areas within County Donegal form the west bank of the River Foyle and western shore of Lough Foyle. The area of these sub-catchments is 400 km^2, which represents approximately 11% and 12% of the catchment areas the River Foyle and Lough Foyle respectively. Donegal County Council supplied nitrate and ammonium concentrations for the largest rivers/streams in this area, the Deele, Swilly Burn and Carrigans Burn. However these data sets covered only the year 1997, which was a year of above average nitrate concentrations in other rivers in the Foyle catchment. To allow for this, the 1997 flow data was converted into an average FWMC using the regression equations between the mean 1997 nitrate and ammonium concentrations vs the flow weighted mean concentrations (Fig 2.2).

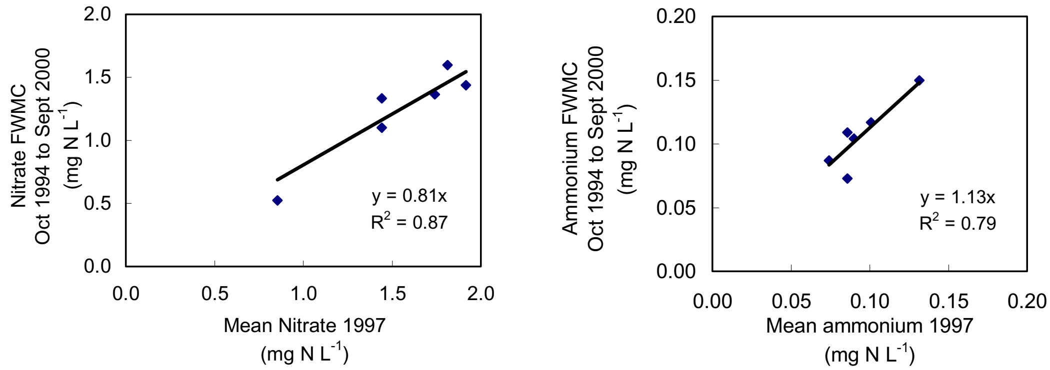

Fig 2.2 Plots of mean concentrations for 1997 vs FWMCs for period October 1994 to September 2000 used to estimate FWMCs of rivers in Co Donegal portion of the Foyle catchment with exception of River Finn.

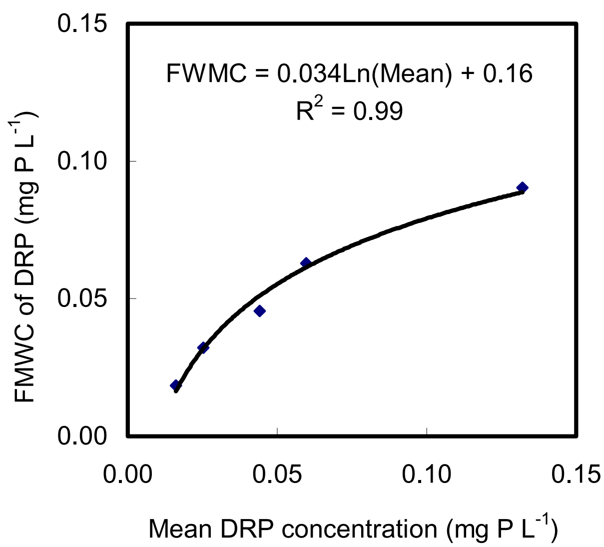

Fig 2.3 Mean DRP concentrations and flow weighted mean concentrations of DRP for rivers within the Foyle system: Mourne, Finn, Burndennet, Faughan and Roe.

2.1.4 Loadings of dissolved reactive phosphorus The methodology as described in section 2.1.1 for determining loadings based on FWMC times annual runoff was also used to estimate loadings of dissolved reactive phosphorus (DRP) from rivers. The data employed was river monitoring concentrations collected by EHS. For the four small streams in the Foyle system that had no flow gauging, a relationship set out in Figure 2.3, between FWMCs of DRP and annual mean concentrations of DRP (time averaged) was used. This equation is based on sampling of other rivers within the Foyle system. DRP loadings could only be determined for the rivers sampled by EHS as comparable data were not available for the rivers of the Foyle catchment that are located in County Donegal.

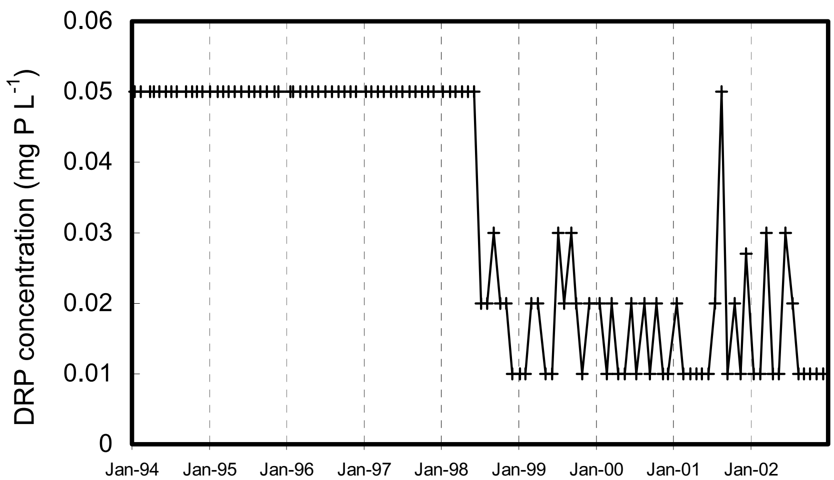

Fig 2.4 Time series of DRP in River Finn showing impact of change in detection limit of DRP in June 1998.

It was found that there had been an un-stated change in the detection level for DRP in the monitored rivers, which prior to July 1998 had been 0.05 mg P L^{-1} and subsequently decreased to 0.01 mg P L^{-1}. Given that the total phosphorus concentration that defines the OECD lower limit for eutrophic waters is 0.035 mg P L^{-1}, a detection limit of 0.05 mg P L^{-1} provides an insensitive indication of the extent to which waters are enriched with P. In some rivers it was evident the many samples probably had concentrations below 0.05 mg P L^{-1} that were not detected prior to July 1998. As a consequence the period over which DRP loading was determined commenced in October 1998 and ended in September 2002. An extreme example is shown in Figure 2.4 for the River Finn, the second largest river in the Foyle system. In this example, the frequent occurrence of samples at the lower detection limit 0.01 mg P L^{-1} after 1999 indicates that even this detection limit was overestimating the actual DRP concentration. The lack of precision in reporting concentration only to the nearest multiple of 0.01 mg P L^{-1} also limits the accuracy of loading estimates from this river.

2.2 Calculations of point source loadings

2.2.1 Data sources in Northern Ireland Concentrations of nitrate and ammonium in the final effluent for all waste-water treatment works (WWTWs) in the catchments were obtained for the period 1997 to 2001. The data originated from Water Service, Department of Regional Development. From these data, mean concentrations of ammonium and nitrate were calculated. The works varied greatly in size from large WWTWs serving Belfast and Derry, with populations in excess of 100000 to small WWTWs serving small rural settlements in the countryside. The number of samples varied with size of WWTWs and for the larger WWTWs the sample numbers were around 250 (i.e. sampled weekly), but could be less than 10 for the smallest WWTWs.

2.2.2 Estimation of flows from WWTWs Flows are required to calculate loadings from WWTWs, but none were available so that alternative methods had to be considered for estimating loadings. The nitrogen (N) load serving the WWTWs can be estimated using a *per capita* approach, which assigns a fixed amount of N per person, which, based on dietary considerations, is reasonably well known. The amounts of nitrate and ammonium could then be calculated on the basis of the ratio of nitrate to ammonium in the treated effluent. For each WWTWs a population equivalent (PE) was supplied by Water Service which reflects the organic loading to each works, taking into account the residential load and the loading from hospitals, schools, offices and industry. Assigning a *per capita* for this load was considered uncertain, as the PE *per capita* need not be the same as the human dietary *per capita*.

The PE values for WWTWs, while correlated with census resident population tend to be larger than the census population, with the discrepancy getting larger at higher populations. A data set for WWTWs in the Foyle catchment is shown for PE vs census population (Fig 2.5). The log-log scale in Figure 2.5 obscures the non-linearity of the relationship between the two data sets as the predicted PE is 87% higher when the census population is 100000, but 14% higher when the census population is 1000. A further disadvantage of the *per capita* approach is that it assumes WWTWs have no losses of nitrogen to the atmosphere whereas such losses not only occur but also are variable from works to works.

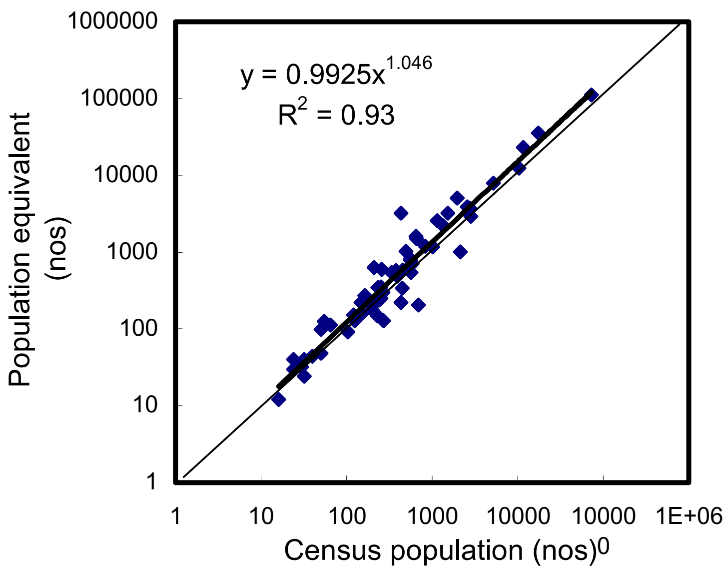

Fig 2.5 Plot of census population (1991) vs Population equivalent for WWTWs in Foyle catchment.

The approach used in this study was to estimate flows from each WWTWs based on PE values and use these estimated flows to calculate loadings based on the measured ammonium and nitrate effluent concentrations. As part of an assessment of the effectiveness of phosphorus reduction in the Lough Neagh catchment, flows have been obtained for WWTWs in the Lough Neagh catchment area. These also show the discrepancy between the PE and human census populations (Table 2.1).

However when PE and populations census are each plotted against daily flows from WWTWs, daily flow was found to be was marginally better correlated with PE and it was decided to use the stronger correlation based on PE (Fig 2.6). Not only was it the stronger relationship, but for many WWTWs serving Derry and Belfast area only PE data was available as it was impossible to obtain the census population serving a specific WWTWs. This was also the case for most of the small WWTWs.

Table 2.1 Census populations and population equivalent for selected WWTWs in Lough Neagh catchment.

Town	1991 Census population	Population Equivalent	Daily flow (m^3/day)
Ballymena[1]	33051	101000	19788
Antrim	20878	33000	11539
Armagh	14108	14482	6603
Ballyclare	13339	10000	4141
Dungannon	11156	21958	9177
Banbridge	10792	19574	7437
Cookstown	9962	12750	6103
Magherafelt	6682	11500	4852
Craigavon[2]	53561	183627	41127
Randalstown	3925	3722	1265
Maghera	2876	4195	1426
Castledawson	1691	1563	531
Moneymore	1206	1500	510
Templepatrick	900	1340	609
Stewartstown	649	1076	366

1) Sum of two works that serve Ballymena

2) Sum of Lurgan, Craigavon and Portadown WWTWs

Each of the regression equations in Figure 2.6 is non-linear, with the PE equation predicting lower flows per person as PE increases. In contrast the correlation between census population and flow predicts higher flows per person as population increased. This divergence presumably reflects an increasing non-residential impact on loading to WWTWs in larger population centres. For both PE and population census relationships the average *per capita* flow for WWTWs was substantially in excess of flows based on daily water use of around 0.18 m^3/day. This value neglects the substantial ingress of storm-water into WWTWs (Table 2.2).

Equation (3) based on the PE vs flow regression was therefore used to estimate flows.

$$\text{Daily flow} = 0.699 * (PE)^{0926} \qquad \text{equation 3}$$

Where Daily Flow = WWTWs mean daily flow (m3 day-1)

PE = Population Equivalent (nos.)

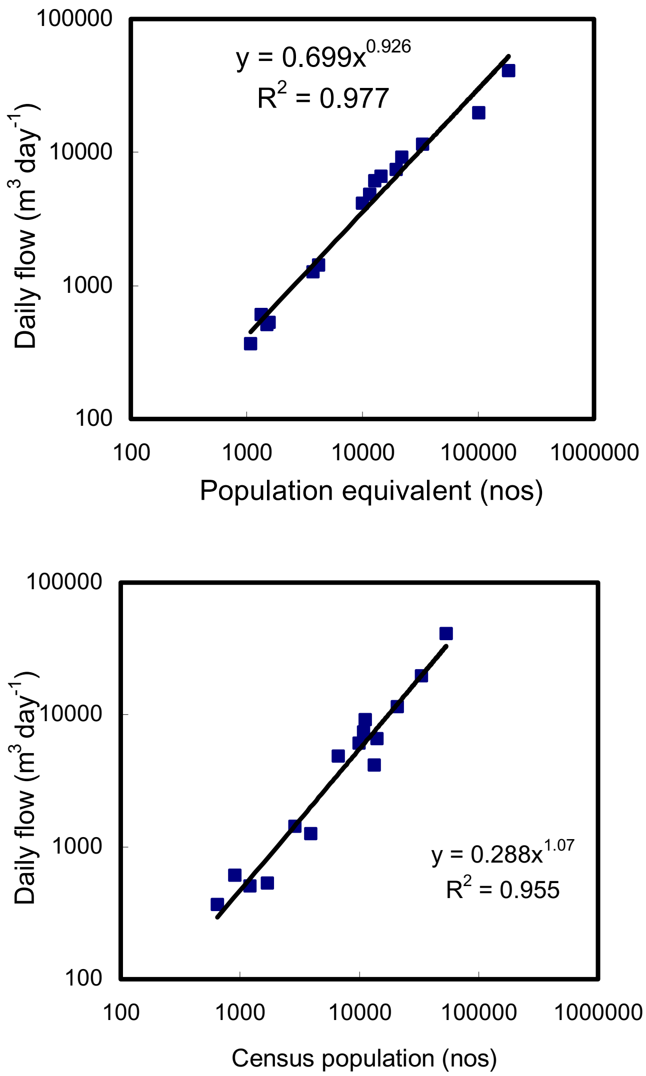

Figure 2.6 Relationships between daily WWTWs flows and (top) Population equivalents and (bottom) census populations .

Table 2.2 Predicted per capita flows to WWTWs based on PE and Census vs flow relationships (equation 3)

Population	PE	Census
	m^3 person^{-1} day^{-1}	
100	0.50	0.40
1000	0.42	0.47
10000	0.35	0.55
100000	0.30	0.65

Table 2.3 Summary of nitrogen and dissolved reactive phosphorus *per capita* values based on population equivalents of the respective WWTWs in each area.

Catchment	Populations equivalents	Nitrogen as N	Phosphorus as DRP
	thousands	kg PE^{-1} yr^{-1}	
River Foyle	202.5	2.05	0.44
Lough Foyle	36.5	2.98	0.88
Lower Bann	54.3	2.02	0.56
Newry River	70.5	2.10	0.45
Strangford Lough	101.7	2.03	0.63
Lagan to Stranmillis	138.5	1.81	0.68
Inner Belfast Lough	290.6	1.44	0.37
Total	894.7	1.85	0.50

2.2.3 *Per capita* nutrient loads Table 2.3 summarises the mean population equivalent per capita loadings from WWTWs in the waters covered by this study. In each instance a few large towns (Appendix A) dominate the catchment averages. The average values based on the total PE of all WWTWs are 1.85 kg N PE^{-1} yr^{-1} and 0.50 kg P PE^{-1} yr^{-1}. In five of the seven waters the per capita N was between 1.8 and 2.0 kg N PE^{-1} yr^{-1} and the average is decreased by a low value for the Belfast Lough catchment. This low could reflect unusually dilute sewage in the Belfast area though P per capita was not unusually low. Alternatively, limited treatment of the organic loading to WWTWs would prevent the full mineralisation of organic P and so depress the concentration of DRP in effluent. In this regard the high PE for DRP in the Strangford Lough and the River Lagan may reflect the higher quality effluent from WWTWs in these catchments. The WWTWs in the Lough Foyle catchments, dominated by Limavady and Drumahoe, had high concentrations of both nitrogen and DRP, which translated into high *per capita* values. Whether this reflects additional nutrient sources within these towns or a lower than average storm flow dilution is unclear.

2.2.4 Loadings from towns in Co Donegal No effluent concentrations or flows were available for the WWTWs that served towns within the Co Donegal portion of the Foyle catchment. Their combined census population in 1991 was however only 4000 persons compared to the Foyle census urban population of over 200,000. The nitrate and ammonium loadings from the WWTWs in County Donegal were estimated on a *per capita* basis, using the average *per capita* for DIN for WWTWs in the Northern Ireland portion of the Foyle catchment and the ratio of nitrate to ammonium in the effluent of these works given in the report of the Foyle Water Quality Management Plan (FCC, 1995).

2.2.5 Industrial inputs Data for three industrial inputs were supplied by EHS. In the Foyle system these were the Du Pont industrial plant at Maydown, which discharges to the River Foyle and the Seagate factory on the River Roe which discharges into Lough Foyle. The Du Pont data consisted of daily concentrations of nitrate and ammonium and flows from which loadings could be directly calculated. For the Seagate factory, only effluent concentration data were supplied with no flow data. In this case the consented discharge flow for the effluent from the Seagate plant was used. Loadings for nitrate, ammonium and dissolved reactive phosphorus were also supplied for the former Irish Fertiliser Industries (IFI) plant in Belfast, which discharged to the Tidal Lagan and also contributed to the loading of Belfast Lough (Appendix A3 Table 7). The loading of the IFI plant had decreased markedly from 1994 until it closed in 2002 with no prospect of reopening as a manufacturing facility. Two sets of catchment loadings have been calculated for the Lagan – Belfast Lough system: one including the average nutrient load from the IFI plant and the other excluding this loading.

Other industrial loadings in the Foyle system were obtained from the Foyle Water Quality Management Report (FCC,1995). It should be noted that some of these values were considered speculative given the absence of flows and effluent concentrations from the sites in question with loadings being based on consent flows and effluent concentrations derived from similar industries. The loadings given for fish farms in the current study were based on: a) the number of farms in each catchment, b) an assumed annual production of 30 tonnes of fish per farm and c) a feed conversion ratio of 1.5. Using nutrient and feed composition values and the composition of effluent from fish farms given by Foy & Rosell (1991 a&b), these assumptions gave predicted annual loading per fish farm of 1.6 tonnes of ammonium-N and 0.38 tonnes of DRP. Catchment industrial loadings for the rivers of the Foyle system are given In Appendix A1, Table 9.

2.3 Diffuse inputs

<u>2.3.1 Land use data</u> Catchment boundaries were defined using GIS based digital terrain routine and these boundaries were overlain on the Corine land use map for Northern Ireland. This also covers the portion of the River Foyle catchment that is in County Donegal. The Corine land use database was accessed to provide land use coverage for each catchment. This data set is divided into classes and for the purposes of this study these were merged into 6 major classes: urban/industrial, arable agriculture, grassland agriculture, rough grazing, forestry and other land (Table 2.4). Due to the absence of digital elevation data, it is not possible to delineate the catchment on the GIS system for the western shore of Lough Foyle in County Donegal. The area of this sub catchment was determined by planimetry and, at 122 km^2, represents only 3% of the Foyle catchment. In this sub-catchment, land use was divided between the major classes, with land below 180 m classed as agricultural, above 180 m as rough grazing apart from areas marked on the 1:50000 maps as being devoted to forestry or used for towns.

<u>2.3.2 Export coefficients</u> Export coefficients (ECs) were used to estimate nutrient loss rates for the major non-agricultural land classes in each catchment (Table 2.5). For nitrate and DRP these were used to estimate loading contributions to the respective budgets for all non-agricultural land classes (Table 2.5). The ECs for uplands and forestry were those used in the Loughs Neagh and Erne budgets and were based on direct of catchments dominated by these land uses (Foy 2002 a&b). An EC for agricultural land that was based on the direct monitoring of grasslands was used to estimate the ammonium export from agricultural (Watson *et al*., 2002).

Table 2.4 Corine land use classes coverage for Northern Ireland and border regions of Republic of Ireland (combined area 17024 km^2) with their amalgamation into six major classes: Urban/industrial, arable, grassland, forest, rough grazing and other land.

CORINE LAND COVER CLASSES 17024 km^2	% total
Urban/Industrial (3.1%)	
1.1.1. Continuous urban fabric	0.3
1.1.2. Discontinuous urban fabric	1.9
1.2.1. Industrial or commercial units	0.2
1.2.2. Road & rail networks and associated land	0.0
1.2.3 & 1.2.4 Sea ports & Airports	0.1
1.3.1 & 1.3.2 Mineral extraction site & Dump	0.2
1.4.1. Green urban areas	0.1
1.4.2. Sport and leisure facilities	0.3
Arable land (2.6%)	
2.1.1.& 2.1.2 Non irrigated and irrigated arable land	2.2
2.4.1. Annual crops associated with permanent crops	0.4
Agricultural grassland (72.9%)	
2.3.1.1. Good pasture	30.3
2.3.1.2. Poor pasture	5.4
2.3.1.3. Mixed pasture	18.7
2.4.2. Complex cultivation patterns	8.6
2.4.3. Land principally occupied by agriculture	5.5
3.2.1. Natural grassland	4.3
Forest (5.6%)	
3.1.1. Broad leaved forest	0.6
3.1.2. Coniferous forest	4.0
3.2.4. Transitional woodland-scrub	0.8
3.1.3. Mixed forest	0.2
Rough grazing (11.9%)	
3.2.2. Moors and heathlands	2.2
4.1.2.1. Unexploited peat bogs	9.4
4.1.2.2. Exploited peat bogs	0.2
Other land and water bodies (4.0%)	
3.3.1. Beaches, dunes, sand	0.1
3.3.3 & 3.3.4 Sparsely vegetated areas & Burnt areas	0.0
4.1.1. Inland marshes	0.2
4.2.1 & 4.2.3 Salt marshes & Intertidal flats	0.0
5.1.1 Stream courses	0.1
5.1.2. Water bodies	3.7

Table 2.5 Nutrient export coefficients used to determine loss rates in catchment budgets.

Nutrient	Land use type	Urban land	Rough grazing	Forest	Other land	Agricultural land
		Nutrient export coefficient				
Nitrate	Tonnes N km^{-2} yr^{-1}	0.20	0.20	0.20	0.20	
Ammonium	Tonnes N km^{-2} yr^{-1}	0.03	0.03	0.03	0.03	0.05
DRP	Tonnes P km^{-2} yr^{-1}	0.03	0.01	0.02	0.03	

2.3.3 Nitrification and ammonium Budgets of ammonium exports from each catchment were constructed based on the measured loading of ammonium from towns and industry and the sum of EC loadings from all land types in each catchment. When compared to measured loss rates of ammonium from catchments in the Lough Neagh drainage area, it was found that the measured exports of ammonium were less than the sum of all individual ammonium inputs to the rivers (Foy, 2002a). This difference was attributed to the microbial oxidation of ammonium to nitrate and therefore represented not only a loss of ammonium but also a balancing increase of nitrate. Therefore, when nitrification appears in the nitrate budget, it is balanced by a corresponding negative amount (i.e. a loss) in the ammonium budget. The opposite situation can occur where the sum of ammonium inputs was less than the measured ammonium export from the river indicating an additional source of ammonium and/or an underestimate of other listed sources. In this study wherever there was a surplus of ammonium in excess of the land plus point source inputs, this extra ammonium has been assigned as 'other source'.

2.3.4 Agricultural nitrate and DRP contributions For nitrate and DRP, loadings from agricultural land were estimated by the difference between the measured nutrient export from a catchment less the sum of all other inputs from WWTWs, industry, upland, forestry, urban land and, in the case of nitrate, any contribution from nitrification. Previous work on the Neagh and Erne catchment has shown that this provides a good estimate of nitrate, given that there are no known other sources of nitrate and the magnitude of nitrogen fertiliser use by agriculture within Northern Ireland (Foy, 2002 a&b). In addition, *per capita* considerations of nitrogen excretion by the rural population indicate that the potential contribution to nitrate exports from septic tank discharges is liable to be low in terms of the measured exports of nitrate from catchments within

Northern Ireland. For DRP, this method for estimating the agricultural contribution is probably less accurate as the potential influence of DRP from septic tanks is likely to be significant. In addition, as point source discharges from WWTWs and industry can be a large proportion of the measured DRP export from rivers, estimating agricultural contribution by difference is sensitive to errors in the accuracy with which point sources are estimated.

2.3.5 Validating agricultural nutrient loadings Estimates of the loadings of nitrate and DRP from agriculture that were calculated by difference were subsequently compared with loss rates based on the ECs for the different categories of agricultural land use determined by Corine. The ECs for agricultural land classes listed in Table 2.6 were taken from the PhD thesis of McGuckin (2000) and are based on a regression based analysis of nutrient exports from rural streams in the Colebrooke and Upper Bann catchments in Northern Ireland. In that study, a pre-screening exercise excluded those streams that were seriously impacted by point source farm pollution, which would elevate nutrient loss rates and in particular DRP. It would be expected therefore that the agricultural loss rates based on these ECs would tend to underestimate the true loss rates where there is a significant incidence of farm pollution. Nitrate and DRP loadings derived from ECs are compared with the appropriate agricultural loadings calculated by difference and also with measured nutrient loadings from the rivers.

Table 2.6 Nitrate and dissolved reactive phosphorus (DRP) export coefficients from agricultural land use types.

Corine Level	Corine land use type	Export coefficient	
		DRP	Nitrate- N
		tonnes km^2 yr^{-1}	
2.1.1.	Non irrigated arable land	0.229	4.367
2.4.1.	Annual crops associated with permanent crops	0.030	2.036
2.3.1.1.	Good pasture	0.030	2.036
2.3.1.2.	Poor pasture	0.036	0.747
2.3.1.3.	Mixed pasture	0.033	1.511
2.4.2.	Complex cultivation patterns	0.104	2.759
2.4.3.	Land principally occupied by agriculture	0.025	0.829

2.4 Direct drainage areas

Each of the tidal and coastal waters had a proportion of their drainage basin that was not covered by any river monitoring, typically because runoff from these areas consists of small streams and drains that are not included within the EHS monitoring programme. With the exception of Strangford Lough these areas represent only a small proportion of the catchment. For these direct drainage areas the inputs from WWTWs point sources were known. The ECs listed in table 2.5 were used to determine inputs from non-agricultural land and for ammonium an EC was also used for agricultural land. These inputs were therefore calculated in exactly the same manner as for river catchments. Rates of nitrate and dissolved reactive phosphorus from the agricultural land in the direct drainage areas were assumed to be the average of the monitored rivers draining into each sea lough. Thus for the direct drainage to Belfast Lough, the loss from agricultural land was assumed to be that of the River Lagan, while for Strangford Lough it was assumed to be the average found for the three monitored rivers draining into this Lough: the Quoile, Enler and Blackwater rivers.

3.0 Nutrient sources and inputs to tidal waters and sea loughs

3.1 Introduction

This chapter summarises the sources and input loadings of nitrate, ammonium, DIN and dissolved reactive phosphorus to the tidal waters and sea loughs. Loadings given in this chapter are cumulative in that they include areas/inputs from associated tidal waters. Thus the loadings to Lough Foyle include the nutrient inputs from the River Foyle. Strangford Lough includes the inputs to the Quoile Pondage. The tidal Lagan contributes to Inner Belfast Lough, which in turn contributes to outer Belfast Lough. Seasonal variation, in the form of summer and winter budgets of DIN are also given. The data presented for each loading does not sub-divide the loading between the contributing rivers of each catchment. Detailed breakdowns of the nutrient sources by the contributing rivers and their associated drainage areas are given for each water body in appendices A1-5. For the Lower Bann two sets of data are given in this chapter. The first is the loading from the catchment of the Lower Bann river which only extends downstream from Lough Neagh to the sea while the second includes the additional nutrient loading the river receives from Lough Neagh.

3.2 Catchment land use

Agricultural land, representing the combined area of grassland and arable land was the largest category of land cover in all catchments ranging from a minimum of 64% in the River Foyle catchment to 93% in the Quoile Pondage catchment. Only in the Foyle and Lagan/ Belfast Lough catchments were there significant areas (<10%) of non-agricultural land categories (Table 3.1). In the Lough Foyle and River Foyle catchments rough grazing represented slightly in excess of 25% of the area. In this case the River Foyle drainage area accounted for 70% of the Lough Foyle catchment area (Appendix A1 Table 2). The drainage of the tidal Lagan represented large proportions of the Inner and Outer Belfast Lough catchment and, in each of these catchments, between 20% and 23% of the land was urban-industrial (Appendix A3 Table 2).. It should be noted that in all catchments the arable component of agricultural land was small representing less than 10% of each catchment area. The largest percentage (8%) was found in the catchment of Strangford Lough, although it should be noted that in the drainage of the

Quoile Pondage (the largest river basin draining into Strangford Lough) the proportion of arable land was the lowest of all waters.

Table 3.1 Major land use categories in catchment of tidal waters

Catchment	Area	Urban-Industrial	Arable	Grass	Rough grazing	Forest	Other land
	km^2	% of area					
River Foyle	2905	1.4	2.2	61.8	26.2	7.6	0.7
Lough Foyle	3929	1.5	3.4	61.4	25.5	7.4	0.7
Newry	304	5.6	2.3	89.4	1.1	1.3	0.3
Quoile	268	3.6	1.8	91.4	0.0	1.7	1.4
Strangford	588	5.2	8.0	84.2	0.1	1.8	0.7
Lower Bann	922	2.1	3.1	78.6	8.4	6.3	1.6
Tidal Lagan	592	20.2	4.5	72.9	1.2	0.7	0.6
Inner Belfast Lough	759	21.7	3.9	70.9	1.0	1.9	0.6
Outer Belfast Lough	805	23.4	3.7	69.3	1.0	2.1	0.6

3.3 Dissolved inorganic nitrogen (DIN) loads

The DIN loadings presented in Table 3.2 are the combined loading of nitrate and ammonium. As noted above, two breakdowns are given for the Lower Bann; the second includes the contribution from Lough Neagh. Two sets of data are also given for each of the tidal Lagan and Belfast Lough loadings. The second of these includes the DIN input from the Irish Fertiliser Industries (IFI) fertiliser factory that discharged into the tidal Lagan and hence also contributed to the loading to Inner and Outer Belfast Lough. This input ceased in 2002 when the plant closed own and, as it seems unlikely to reopen as a manufacturing facility factory, its effect on the tidal Lagan and Belfast may be regarded as a historic loading rather than the current loading.

Table 3.2 Mean annual DIN load October 1994 – Sept 2000 and DIN sources to tidal waters. Notes: IFI refers to historical contribution of Irish Fertiliser Industry factory to Lagan and Belfast Lough loadings. NO3 % refers to percentage of DIN loading from nitrate.

	Total N Load	Industry	Urban	Rough grazing	Forest land	Other land	Agric land	Other Inputs	NO3 %
	tonnes N y^{-1}	% annual DIN loading							
River Foyle	4492	0.7	9.8	3.9	1.1	0.3	81.1	3.0	84.3
Lough Foyle	5872	1.3	10.1	3.9	1.1	0.4	80.9	2.3	86.1
Newry River	847	0.0	17.4	0.1	0.1	0.5	81.9	0.0	83.7
Quoile	499	0.0	7.0	0.0	0.2	0.6	91.2	0.9	94.8
Strangford Lough	1251	0.0	16.5	0.0	0.2	0.6	82.2	0.4	89.4
Lower Bann	1836	0.0	8.5	1.0	0.7	0.4	84.4	5.0	89.7
L. Bann (+ L. Neagh)	4286	0.0	3.6	0.4	0.3	0.2	36.1	59.3[1]	95.6
Tidal Lagan	1189	0.0	21.1	0.1	0.1	2.4	75.3	1.0	94.4
Inner Belfast Lough	1653	0.0	40.6	0.1	0.1	2.0	56.5	0.7	75.0
Outer Belfast L.	2253	0.0	46.3	0.1	0.2	2.0	51.0	0.5	65.1
Tidal Lagan (+IFI)	4354	72.7	5.8	0.0	0.0	0.6	20.6	0.3	48.3
Inner Belfast L. (+ IFI)	4818	65.7	13.9	0.0	0.0	0.7	19.4	0.2	46.1
Outer Belfast L. (+ IFI)	5417	58.4	19.2	0.0	0.1	0.8	21.2	0.2	45.2

[1] Includes outflow loading of DIN from Lough Neagh = 57% of DIN loadings.

When operating, the IFI input was by far the largest source of DIN to the Lagan/ Belfast Lough system, ranging from 73% of the loading to the tidal Lagan to 58% of the loading to outer Belfast Lough. Excluding this input therefore markedly reduces the DIN loading to these waters. In the absence of the IFI input, agricultural land (grassland plus arable) was the largest source of DIN, accounting for 75% of the input to the tidal Lagan and 57% and 51% of the loadings to Inner and Outer Belfast Lough. These contributions are relatively low in comparison to other catchments, where the agricultural contribution exceeded 80%, and reflects the presence of large urban contributions to the DIN loading. The urban contribution of 21% to the DIN loading of the tidal Lagan may seem small given that the catchment drains Belfast and its large urban area. However much of the sewage derived DIN from Belfast discharges directly to Belfast Lough and so makes only a small contribution to the loading to the tidal Lagan. This is reflected in the larger urban contributions to the DIN loading in excess of 40% for Inner Belfast Lough and Outer Belfast Lough.

The agricultural contribution to the Lower Bann was 84% but, when the input from Lough Neagh is included, this contribution declines to 36%. Lough Neagh contributes 57% of the DIN load but it should be noted that, of the DIN entering Lough Neagh, 80% originates from agriculture.

3.4 Nitrate sources

The final column of Table 3.2 indicates that, with the exception of the tidal Lagan/Belfast Lough catchment loads which included the contribution from IFI, DIN loadings were dominated by nitrate which contributed over 84% of the DIN inputs. This indicates that ammonium loading were much lower than those for nitrate. As a consequence of this both the loadings of nitrate sources listed in Table 3.3 and the size of specific sources was very similar to that of DIN. In the Foyle, Newry, Quoile, Strangford and Lower Bann catchments the agricultural contribution to the nitrate inputs was no lower than 89.6% with urban sources contributing less than 10% of the loading.

Table 3.3 Mean annual nitrate load October 1994 – Sept 2000 and nitrate sources to tidal waters. Note: Nitrificat'n refers to % of nitrate loading estimated to be result of nitrification of ammonium in rivers.

	Nitrate Load	Industry	Urban	Rough grazing	Forest land	Other land	Agric. Land	Other inputs	Nitrificat'n
	tonnes N yr^{-1}	% annual nitrate loading							
River Foyle	3785	0.2	1.9	4.0	1.2	0.3	92.3	0.0	0.1
Lough Foyle	5057	0.8	2.7	4.0	1.2	0.4	89.9	0.0	1.0
Newry River	709	0.0	2.7	0.1	0.1	0.5	95.8	0.0	0.8
Quoile	473	0.0	5.6	0.0	0.2	0.6	93.7	0.0	0.0
Strangford Lough	1118	0.0	9.5	0.0	0.2	0.6	89.6	0.0	0.0
Lower Bann	1646	0.0	6.2	0.9	0.7	0.4	91.8	0.0	0.0
L. Bann (+ L. Neagh)	3900	0.0	2.6	0.4	0.3	38.8	0.2	57.8[1]	0.0
Tidal Lagan	1122	0.0	19.9	0.1	0.1	2.2	77.7	0.0	0.0
Inner Belfast Lough	1240	0.0	24.1	0.1	0.1	2.4	73.3	0.0	0.0
Outer Belfast L.	1467	0.0	20.7	0.1	0.2	2.6	76.3	0.0	0.0
Tidal Lagan (+ IFI)	2102	46.6	10.6	0.1	0.0	1.2	41.5	0.0	0.0
Inner Belfast L. (+ IFI)	2220	44.1	13.5	0.1	0.1	1.3	41.0	0.0	0.0
Outer Belfast L. (+ IFI)	2447	40.0	12.4	0.1	0.1	1.6	45.7	0.0	0.0

1 Includes outflow loading of nitrate from Lough Neagh = 58% of nitrate loadings

3.5 Ammonium sources

To a certain degree the low contribution of urban sewage to the nitrate loadings indicates the high concentrations of ammonium and low levels of nitrate in many discharges from sewage treatment works and sewage outfalls, particularly for direct discharges to tidal waters. This is reflected in the much greater contribution of urban inputs to the ammonium budgets of all the tidal waters. With the exception of the Quoile and Lower Bann catchments, the largest source of ammonium was from urban discharges (Table 3.4). The highest urban contributions were to the Newry River and Outer Belfast Lough and reflect the poor quality of the major sewage discharges to these waters. In contrast the relatively low contribution of urban sources of 33% in the Quoile catchment reflects the high proportion of nitrate in the discharges from Downpatrick WWTW (See Appendix A4).

Table 3.4 Mean annual ammonium load October 1994 – Sept 2000 and ammonium sources to tidal waters. Note: Nitrificat'n refers to net loss of ammonium loading estimated as a result of nitrification of ammonium.

	Ammonium Load	Industry	Urban	Rough grazing	Forest land	Other land	Agric land	Other inputs	Nitrificat'n
	tonnes N y^{-1}	% annual ammonium loading							
River Foyle	707	3.6	52.2	3.2	0.9	0.3	21.1	19.0	-0.4
Lough Foyle	815	4.3	55.4	3.7	1.1	0.3	25.0	16.6	-6.3
Newry River	138	0.0	93.5	0.1	0.1	0.4	10.1	0.0	-4.2
Quoile	26	0.0	32.5	0.0	0.5	1.5	47.6	17.9	0.0
Strangford Lough	133	0.0	75.0	0.0	0.2	0.8	20.4	3.8	-0.2
Lower Bann	189	0.0	28.7	19.9	1.2	0.9	0.5	48.8	0.0
L. Bann (+ L. Neagh)	387	0.0	14.1	0.6	0.4	0.3	9.7	74.9[1]	0.0
Tidal Lagan	67	0.0	42.0	0.3	0.2	5.5	34.2	17.8	0.0
Inner Belfast Lough	413	0.0	90.2	0.1	0.0	1.1	5.8	2.9	0.0
Outer Belfast L.	786	0.0	93.9	0.0	0.1	0.7	3.7	1.5	0.0
Tidal Lagan (+ IFI)	2252	97.0	1.2	0.0	0.0	0.2	1.0	0.5	0.0
Inner Belfast L. (+IFI)	2597	84.1	14.3	0.0	0.0	0.2	0.9	0.5	0.0
Outer Belfast L.(+IFI)	2970	73.5	24.8	0.0	0.0	0.2	1.0	0.4	0.0

[1] Includes outflow loading of ammonium from Lough Neagh = 51% of ammonium loadings.

The contributions of ammonium from the land use types listed in Table 3.4 were derived from export coefficients. To balance the sum of these loadings plus urban and industrial inputs with the measured ammonium loadings from rivers, an additional loading from 'other inputs' or a loss of ammonium defined as 'nitrification' was included in each ammonium breakdown. Losses of ammonium attributed to nitrification were small (<6%) and were only observed in the Foyle, Newry River and Strangford Lough catchments and then not in all of the rivers contributing to these waters (See Appendix A1, A4 & A5). More commonly there was an excess of ammonium loading measured in the rivers, representing either additional sources of ammonium and/or that the land use inputs were underestimated. With the exception of the Lower Bann the size of the 'other sources' contribution was less than 20% of the loadings suggesting that estimates based on export coefficients were not greatly in error. With one exception, the 'other sources' contribution was a small percentage of close to 1% of annual DIN loading.

The Lower Bann loading of ammonium was the exception where the 'other sources' was large at 49% indicating that the measured ammonium loading was almost 100% higher than expected. It should be noted however that this additional ammonium of 95 tonnes of N year represented only 5% of the DIN (ammonium plus nitrate) loading from the catchment. There are a number of possible reasons for this discrepancy between measured and predicted ammonium loadings. It may simply reflect the degree of uncertainty associated with the loading estimate calculations which, in the case of the Lower Bann, is large given that the catchment loading is the difference between two large values: the loading of ammonium leaving Lough Neagh at Toome and the loading of ammonium at the Cutts where the Lower Bann becomes a tidal river. A further unique feature of the Lower Bann is that, in comparison to the other river catchments, it receives a large particulate organic nitrogen loading in the form of algae exported from Lough Neagh. The fate of these algae in the river environment is uncertain – if they suffer losses through grazing or cell lysis the result would be a release of ammonium into the Lower Bann. The particulate organic nitrogen loading associated with algae exported from Lough Neagh is in the order of 1500 tonnes of nitrogen per year and is much larger than the additional ammonium observed in the Lower Bann of 90 tonnes N year.

As was the case for DIN and nitrate the IFI contribution to the ammonium loadings of the tidal Lagan and Belfast Lough were very large and dwarfed all other source of ammonium to these waters.

3.6 Summer and winter loadings

Summer and winter loadings of DIN are given in Tables 3.5 and 3.6. Losses of nitrate from agriculture in rivers in Northern Ireland are typically largest in the winter, reflecting both high winter flows and high concentrations. Higher winter concentrations were observed in rivers although the effect was least apparent in the rivers of the Foyle catchment (See appendix A1). In the rivers studied, winter (October to March) flows accounted from between 71% and 77% of annual runoff, indicating an approximate ratio in flows between winter and summer (April-September) of 3:1. These properties increase the role of ammonium as a proportion of DIN but, although higher than in the winter, nitrate formed most of the summer DIN loadings.

In comparison to the annual data listed in Table 3.2, higher proportions of the summer loadings were attributed to urban sources but, with the exception of Inner and Outer Belfast Lough, agriculture remained the largest single source of DIN contributing over

53% of the summer loading. Given that the winter loadings are much larger than those of the summer months and so approach the magnitude of the annual loadings, the breakdown of winter loadings was not markedly different from the annual loadings (Tables 3.2 and 3.6).

Table 3.5 Mean summer (April-September) DIN load (April 1995 – Sept 2000) and nitrogen sources to tidal waters.

	Total N load tonnes N y^{-1}	Industry	Urban	Rough grazing	Forest land	Other land	Agric land	Other inputs	NO3 %
		% summer DIN loading							
River Foyle	1135	1.5	19.4	4.1	1.2	0.3	72.1	1.5	77
Lough Foyle	1538	2.5	19.8	4.1	1.2	0.4	71.0	1.1	80
Newry River	156	0.0	47.2	0.1	0.1	0.6	51.9	0.0	60
Quoile	93	0.0	18.7	0.0	0.3	0.9	80.2	0.0	92
Strangford Lough	298	0.0	34.6	0.0	0.2	0.6	64.6	0.0	82
Lower Bann	342	0.0	22.7	1.2	3.9	2.3	69.8	0.0	94
L. Bann (+ L. Neagh)	610	0.0	12.8	0.7	2.2	1.3	39.2	43.9[1]	94
Tidal Lagan	284	0.0	44.2	0.1	0.1	2.6	52.9	0.0	94
Inner Belfast Lough	502	0.0	66.9	0.1	0.1	1.8	31.2	0.0	61
Outer Belfast L.	727	0.0	71.7	0.1	0.1	1.6	26.5	0.0	48
Tidal Lagan (+ IFI)	1866	84.8	6.7	0.0	0.0	0.4	8.1	0.0	41
Inner Belfast L. (+IFI)	2084	75.9	16.1	0.0	0.0	0.4	7.5	0.0	38
Outer Belfast L.(+IFI)	2309	68.5	22.6	0.0	0.0	0.5	8.3	0.0	36

[1] Includes outflow loading of DIN from Lough Neagh = 43.9 % of summer DIN loadings.

Table 3.6 Mean winter (October – March) DIN load (October 1994 – March 2000) and nitrogen sources to tidal waters.

	Total N load tonnes N y^{-1}	Industry	Urban	Rough grazing	Forest land	Other land	Agric land	Other inputs	NO3 %
		% winter DIN loading							
River Foyle	3515	0.5	6.3	3.7	1.1	0.3	84.5	3.7	87
Lough Foyle	4591	0.8	6.6	3.7	1.1	0.3	84.6	2.8	88
Newry River	603	0.0	12.2	0.1	0.1	0.5	86.6	0.5	87
Quoile	407	0.0	4.3	0.0	0.2	0.6	93.6	1.4	95
Strangford Lough	958	0.0	10.8	0.0	0.2	0.5	87.8	0.8	92
Lower Bann	1459	0.0	5.3	0.9	0.7	0.4	85.6	7.0	89
L. Bann (+ L. Neagh)	3474	0.0	2.2	0.4	0.3	0.2	35.9	61.0[1]	95
Tidal Lagan	2464	64.2	5.1	0.0	0.0	0.8	29.3	0.5	54
Inner Belfast Lough	2709	58.4	12.4	0.0	0.0	0.9	27.8	0.4	52
Outer Belfast L.	3077	51.4	16.9	0.0	0.1	1.1	30.1	0.4	51
Tidal Lagan (+IFI)	881	0.0	14.3	0.1	0.1	2.4	81.8	1.3	95
Inner Belfast L. (+IFI)	1126	0.0	29.8	0.1	0.1	2.2	66.8	1.0	81
Outer Belfast L.(+IFI)	1495	0.0	34.9	0.1	0.2	2.2	61.9	0.8	73

[1] Includes outflow loading of DIN from Lough Neagh = 58.0 % of winter DIN loadings.

3.7 Dissolved reactive phosphorus sources

As described in Chapter 2, a shorter period of 3 years (October 1998 to September 2001) was used to estimate loadings of dissolved reactive phosphorus (DRP). Mean annual runoff during this period was between 11-13% higher that the period, October 1994 to September 2000, over which the loadings of nitrate and ammonium in the rivers had been determined. The consequence of this would be to increase the relative proportion of DRP attributed to agricultural sources in comparison to period of lower flows.

The breakdown of DRP sources shows that the urban contributions to the DRP loadings were much larger than for DIN or nitrate (Table 3.7). However in the Foyle catchments and in the Quoile Pondage, agricultural land remained the largest single source of DRP. In all the remaining catchments the urban sources contributed in excess of 50% of the loading.

Table 3.7 Summary of dissolved reactive phosphorus (DRP) for tidal waters (annual loadings).

	DRP Load tonnes P y^{-1}	Industry	Urban	Rough grazing	Forest land %	Other land	Agric land	L. Neagh
River Foyle	224	2.2	41.8	2.7	1.6	0.8	50.9	
Lough Foyle	292	3.0	43.7	2.8	1.6	0.9	48.0	
Newry River	48	0.0	66.4	0.1	0.1	0.1	33.4	
Quoile	33	0.0	34.0	0.0	0.2	1.0	64.7	
Strangford Lough	126	0.0	60.1	0.0	0.1	0.7	36.6	
Lower Bann	34	0.0	88.9	1.8	2.7	2.5	4.1	
L. Bann (+ L. Neagh)	315	0.0	9.7	0.2	0.3	0.3	0.4	89.1
Tidal Lagan	174	0.0	53.8	0.0	0.0	1.8	44.3	
Inner Belfast Lough	284	0.0	70.8	0.0	0.0	1.3	27.9	
Outer Belfast L.	354	0.0	72.9	0.0	0.1	1.4	25.7	
Tidal Lagan (+IFI)	368	52.7	25.5	0.0	0.0	0.8	21.0	
Inner Belfast L. (+IFI)	486	39.9	41.4	0.0	0.0	0.8	17.9	
Outer Belfast L.(+IFI)	548	35.4	47.1	0.0	0.0	0.9	16.6	

There are number of points to note with respect to the DRP sources. For the tidal Lagan and Belfast Lough, when the IFI input was included, it represented the largest single source of DRP, accounting for 53% of the annual loading case of the tidal Lagan. The Lower Bann loading estimate also stands out as being anomalous in terms of the very small proportion of DRP attributed to agricultural sources (4.1%). The catchment loading of DRP to the Lower Bann was only 34 tonnes P. This includes the loading of DRP from Coleraine that discharges to the tidal river. When Coleraine is excluded, freshwater DRP catchment loading was only 10 tonnes of P. As this had to accommodate a DRP loading of 9 tonnes P from the remaining towns in the catchment, only a small loading of 1 tonnes DRP was left to be allocated to agriculture and other land use types. The loading rate of DRP from agricultural land of 0.002 tonne P km^{-2} was therefore much lower than in any other catchment (Table 3.8).

Rather than considering agriculture in the catchment of the Lower Bann as being especially efficient at retaining P, the computed low loss rate of DRP from agriculture is almost certainly another artefact of the large concentrations of algae that enter the Lower Bann from Lough Neagh. In the spring and early summer, from March to June, these algae are P limited and as a consequence have depleted DRP in the water to trace concentrations (Fig 3.1). Spring inputs of DRP to the Lower Bann downstream of Lough Neagh from all sources will be taken up by P limited algae thereby preventing any increase in DRP concentrations or loadings in the river

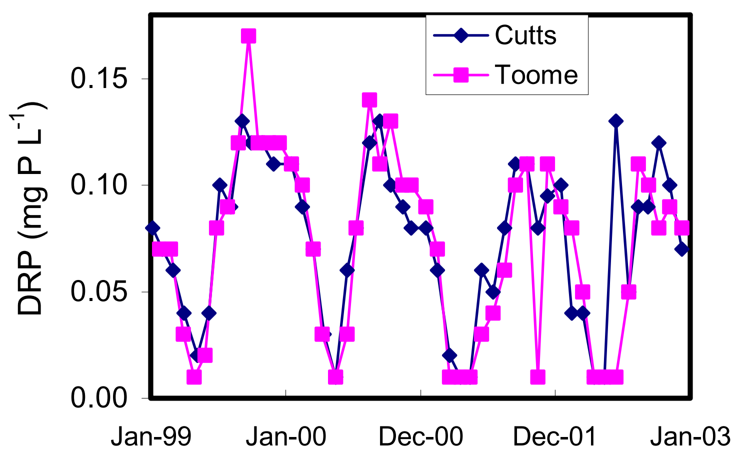

Figure 3.1 Annual cycles of dissolved reactive phosphorus in the Lower Bann where it leaves Lough Neagh at Toome and at the end of the freshwater section at The Cutts.

3.8 Magnitude of nutrient loss rates from agriculture

The catchment budgets of nitrate and dissolved reactive phosphorus (DRP) provide no indication as to whether nutrient losses from agricultural land were high or low with respect to rates observed in other catchments. In addition, loss rates from certain rivers may be higher than the average for the catchment. Rates of nitrate and DRP loss from agricultural land for each river catchment included in this study are listed in Table 3.8.

Table 3.8 Summary of river exports of nitrate and DRP. 'Agric land' is the computed loss nutrient rate from the area of arable and grass within each river catchment.
CV = coefficient of variation as % of mean.

Catchment	River	Area km^2	Nitrate conc mg N L^{-1}	Run-off[2] mm $year^{-1}$	Catchment nitrate loss rate tonnes N km^{-2}	Agric land nitrate loss rate tonnes N km^{-2}	Catchment DRP loss rate tonnes P km^{-2}	Agric land DRP loss rate tonnes P km^{-2}
R FOYLE								
	Mourne	1856	1.44	0.97	1.40	2.04	0.067	0.075
	Burndennet	149	1.60	0.85	1.36	1.86	0.030	0.031
	Finn	495	0.53	1.41	0.74	1.29	0.029	0.037
	Deele	125	1.87	*0.85*	1.60	2.08		
	Swilly Burn	49	1.15	*0.85*	0.98	0.98		
	Carrigans	44	1.73	*0.85*	1.47	1.51		
	Glenmornan	32	1.92	*0.85*	1.64	2.03	0.081	0.062
L FOYLE								
	Faughan	296	1.37	0.91	1.25	1.72	0.045	0.025
	Roe	385	1.34	0.81	1.08	1.12	0.083	0.034
	Muff R.	15	1.87	*0.85*	1.59	1.91	0.050	0.026
	Burnfoot R.	14	3.14	*0.85*	2.68	2.84	0.050	0.029
	Faughanvale R.	13	1.35	*0.85*	1.15	1.54	0.059	0.079
LAGAN								
	River Lagan	500	3.94	0.54	2.14	1.91	0.283	0.106
NEWRY								
	Clanrye River	275	4.72	0.50	2.37	2.44	0.086	0.057
STRANGFORD								
	Quoile River	234	3.00	0.59	1.78	1.78	0.130	0.086
	Enler River	63	4.75	0.37	1.76	1.95	0.082	0.076
	Blackwater R.	50	3.26	*0.59*	1.93	1.94	0.128	0.087
LOWER BANN								
	Cutts	5276	1.21	0.59	0.71	2.01[1]	0.057	0.002[1]
	Toome	4449	0.88	0.58	0.51		0.063	
	CV (%)		58	30	38	24	75	56

[1] Calculated loss rates for Lower Bann net of loading contribution from Lough Neagh.

[2] Runoff values in italics based on runoff from adjacent catchments

3.8.1 Nitrate An indication as to the variability in nitrate concentrations and losses of nitrate between catchments is given by the coefficient of variation (CV) calculated as the standard deviation of the data-set expressed as a percentage of the mean value. Mean nitrate concentrations ranged from 0.5 mg N L^{-1} in the River Finn, which is part of the Foyle system, to a maximum of 4.75 mg N L^{-1} in the Enler or Comber River which drains into Strangford Lough. All the rivers draining into Strangford Lough, the Newry River and the Tidal Lagan/Belfast Lough had concentrations of 3.7 mg N L^{-1} or greater. In contrast, all streams in the Foyle system, with one exception, had mean nitrate concentrations of less than 2 mg N L^{-1}. The sole exception was the very small Burnfoot River, which had a concentration of 3.1 mg N L^{-1}. Concentrations in the Lower Bann were close to 1 mg N L^{-1} but this reflected in part the low nitrate concentration of 0.9 mg N L^{-1} in the lake water leaving Lough Neagh.

Whereas nitrate concentrations varied between rivers almost by an order of magnitude, loss rates of nitrate from catchments were much less variable as is evident by the lower CV values. The lowest variability was in the calculated loss rate of nitrate from agricultural land. This statistic ranged from 1.0 tonne N km^{-2} yr^{-1} in the Swilly Burn to a maximum of 2.4 tonnes N km^{-2} yr^{-1} in the Clanrye River. Outside the Foyle system, nitrate loss rates were quite uniform in all rivers in the range of 1.8 to 2.4 tonnes N km^{-2} yr^{-1}. In the Foyle system, 6 of the 12 streams where within this range including the largest river, the River Mourne which drains more than 50% of the Lough Foyle catchment. Of the large rivers within the Northern Ireland portion of the Foyle, the nitrate loss rate from River Roe of 1.1 tonnes N km^{-2} yr^{-1} appears to be markedly below average.

High nitrate concentrations in rivers did not therefore translate into high nitrate loss rates. Although it ranked highest in terms of concentration, the Enler River ranked 7th in terms of nitrate loss rates. In this river, while nitrate concentrations were high, the runoff or volume of water draining from the catchment was the lowest of all rivers and 60% lower than in the River Mourne which had a higher nitrate loss rate from agricultural land despite a low nitrate concentration. Thus the low runoff observed in the Enler counterbalanced the high nitrate concentration. For the River Mourne, high diluting flows and a large proportion of unproductive uplands concealed high nitrate loss rates from agricultural land.

3.8.2 Dissolved reactive phosphorus DRP loss rates from catchments were proportionally more variable than was the case for catchment nitrate loss rates (CV-DRP of 75% vs CV- NO3 of 38%). The highest loss rate of DRP was in the River Lagan, but 65% of this loss was attributable to discharges from WWTWs in the catchment. However, even when the WWTWs loading was removed, the DRP loss attributed to agricultural land was the highest of all catchments. This high value may reflect uncertainty in determining the DRP loading from WWTWs as if this loading was underestimated by 20%, this would lower the DRP loss rate from agricultural land in the River Lagan to 0.08 tonnes P km^{-2} yr^{-1}.

It is apparent that the loss rate of only 0.002 tonnes P km^{-2} yr^{-1} attributable to agriculture in the Lower Bann was unusually low compared to other direct measurements from agricultural land and almost certainly reflects the influence of algae growing within the Lower Bann. Agricultural loss rates of the remaining rivers tended to fall into two groups. Six of the nine rivers in the Foyle system had low agricultural loss rates of less than 0.04 tonnes P km^{-2} yr^{-1}. The remaining rates in the Foyle and in the other tidal waters were all greater than 0.055 tonnes P km^{-2} yr^{-1}. The DRP from agricultural land in the River Mourne was high at 0.075 tonnes P km^{-2} yr^{-1}, which was similar to loss rates in the three rivers that drained into the Strangford Lough system.

3.9 Modelled loss rates of nutrients from agriculture

Contributions of nutrients to the loadings from agricultural land have been calculated by difference and are therefore dependent on the accuracy of both the catchment load and the loadings from point sources. In comparison to the measured river loadings of nitrate, losses of nitrate from WWTWS were low so that even large percentage errors in their estimation makes only a small difference to the estimate of nitrate loss from agricultural land that would challenge the assumption that agricultural land is by far the largest source of nitrate in river catchments. This assumption can be tested against the use of nitrogen within agriculture in Northern Ireland. Previous research has found that nitrate lost from grassland is on average 13% of the N fertiliser added (Watson et al., 2002). In Northern Ireland the average nitrogen fertiliser added to agricultural land between 1994 and 1999 was 13.4 tonnes N km^{-2} yr^{-1}. When nitrogen brought on to farms in the form of imported feed-stuffs is included, the input nitrogen to agricultural land averaged 17.6 tonnes N km^{-2} yr^{-1}. Using a loss factor of 13% for these two input values give predicted nitrate loss rates from agricultural land of 1.7 and 2.3 tonnes N km^{-2} yr^{-1}. Therefore, with two exceptions, losses rates of nitrate from agricultural land measured in the study were within this range in all the rivers that drained catchments that were within or almost entirely within Northern Ireland (Table 3.8). The exceptions were the River Roe and the small Faughanvale River in the Foyle catchment. Three of the County Donegal rivers were also below this range.

Agricultural losses of nitrate derived from the river monitoring data were compared with losses derived from the export coefficients for agricultural land listed in Table 2.6 and the areas of the different CORINE categories of agricultural land. The results of this comparison are given in Tables 3.9. A similar exercise was undertaken for dissolved reactive phosphorus (Table 3.10).

<u>3.9.1 Nitrate losses derived from export coefficients</u> Agricultural nitrate loadings based on export coefficients were in all cases large and accounted for upwards of 50% of the measured river catchment loss rates. In five rivers: Quoile, Enler, Swilly Burn, Carrigans Burn and Muff Rivers, the predicted loss rates of nitrate from agricultural land were in excess of the total catchment loss rate of nitrate. Two of these rivers, Swilly Burn and Carrigans Burn were in the group of three rivers that drained catchments entirely within County Donegal and for which there was only data from one year. In contrast in the third river, the EC loading from agriculture in the Deele River was substantially underestimated by 50%. In combination the EC loading of nitrate from these three Donegal streams of 313 tonnes N $year^{-1}$ was close to the nitrate load of 298 tonnes N $year^{-1}$ calculated by difference.

Of the 15 remaining rivers in the study, all of which were sampled by EHS, catchment loadings based on EC estimates plus the input from point sources were within ±20% of the measured catchment loading for 10 rivers. A further 3 rivers were within ± 30% of the measured nitrate loading. For the two remaining rivers, Enler and Muff Rivers, the EC predicted loads were approximately 40% greater than the observed loading. In total, the nitrate load based on EC's was 6796 tonnes N $year^{-1}$ for the rivers sampled within Northern Ireland compared to a measured nitrate load of 7066 tonnes N $year^{-1}$. The export coefficient methodology therefore provides estimates of nitrate loading that were quantitatively consistent with the nitrate loads estimated by difference.

Table 3.9 Contributions of agricultural land to river nitrate loadings based on:

1) Agricultural loading by difference refers to loadings calculated for this study to ensure a 100% balance in catchment exports.
2) Agricultural loading by export coefficients based on nitrate export coefficient loads for arable and grassland.

Northern Ireland total refers to sum of rivers sampled by EHS and so includes River Finn. County Donegal rivers are Deele, Swilly Burn and Carrigans Burn

River	Catchment export	Agricultural loading by difference		Agricultural loading by export coefficients.	
	tonnes N yr^{-1}	tonnes N yr^{-1}	% total	tonnes N yr^{-1}	% total
Northern Ireland River samples					
River Mourne	2593	2408	93	1865	72
Burndennet R.	203	191	94	171	84
Finn	367	316	86	362	99
Glenmornan	52	47	90	35	67
Faughan	368	309	84	316	86
Roe	415	282	68	403	97
Muff R.	23	22	92	30	130
Burnfoot R.	39	37	96	30	77
Faughanvale R.	15	14	95	14	94
River Lagan	1070	837	78	968	91
Clanrye River	653	631	97	602	92
Quoile River	415	388	94	470	113
Enler River	110	108	98	157	142
Blackwater R.	97	94	97	87	90
Cutts	1496	1382	92	1286	86
County Donegal rivers samples					
Deele	200	193	97	100	50
Swilly Burn	48	45	95	105	220
Carrigans	64	60	93	108	168
Total N. Ireland	**7915**	**7066**	**89**	**6796**	**86**
Total Donegal	**312**	**298**	**96**	**313**	**100**
Total all	**8227**	**7364**	**90**	**7109**	**86**

Table 3.10 Comparison of contributions of agricultural land to river dissolved reactive phosphorus loadings by:

Budget =Budgeted loss as calculated by difference
EC1 = Using DRP export coefficients for agricultural land as per Table 2.8
EC2 = As for EC1 but using a lower export coefficient loss from arable land of 0.03 tonnes P km^{-2} compared to 0.22 tonnes P km^{-2}.
Agricultural losses are expressed as annual catchment loads and as a % of river loads

	River DRP load	Losses from agriculture			Loss as % of river load		
		Budget	EC 1	EC 2	Budget	EC 1	EC 2
	tonnes P $year^{-1}$					%	
Mourne	124.6	84.4	39.1	37.1	68	31	30
Burndennet	4.4	3.2	3.7	3.2	71	83	71
Finn	14.5	8.8	9.2	8.2	61	64	57
Glenmornan	2.6	0.8	0.7	0.7	30	28	27
Faughan	13.4	4.1	8.0	6.0	31	60	45
Roe	32.1	8.2	12.5	9.5	26	39	30
Muff River	0.7	0.3	1.2	0.3	40	165	48
Burnfoot River	0.7	0.4	0.9	0.4	52	125	57
Faughanvale R.	0.8	0.7	0.3	0.3	96	45	40
R. Lagan	141.4	46.3	30.1	24.9	33	21	18
Clanrye R.	23.6	14.9	18.7	17.4	63	79	73
Quoile R.	30.5	18.7	13.0	12.0	62	43	39
Enler R.	5.1	4.2	5.9	2.8	82	115	54
Blackwater River	6.4	4.2	2.0	1.9	66	32	30
Lower Bann	21.5	1.3	31.2	26.7	6	145	124

3.9.2 Dissolved reactive phosphorus losses derived from export coefficients Agricultural loadings of DRP based on EC calculations indicated that agriculture was a major source in all river catchments (Table 3.10). However even when the algal-impacted estimate of agricultural DRP loading in the Lower Bann is discounted there remain a number of quite large discrepancies between DRP loads estimated by difference and agricultural loadings estimated by ECs. In three rivers: Mourne, Faughanvale and Blackwater, the EC estimate was less than 50% of that expected suggesting either that the agriculture was losing higher than predicted amounts of P and/or that the estimates of DRP loading from point sources was underestimated. It should be noted that the training set of streams used to determine the EC for DRP, streams which had significant pollution from farm yard point sources, were excluded so that it would be expected that the EC coefficient approach would be an underestimate. Nonetheless the difference in loadings observed for the River Mourne was surprising given that this drains a large catchment and would be expected to approach an average loading. The EC predicted loadings of nitrate from the Mourne catchment were also lower than predicted, in this case by 25%, so it does seem that the EC methodology has a tendency to underestimate nutrient loads from agriculture in this catchment.

At the other extreme, in a number of catchments the EC approach gave higher than observed loadings of DRP from agricultural land. In some case the discrepancy was sufficiently large that the estimated EC catchment loads of DRP from agriculture exceeded the observed DRP load from the whole catchment including inputs from point sources. This data set consisted of the Enler River and two small streams draining into Lough Foyle: the Muff and Burnfoot Rivers. In each of these rivers there was a significant component of arable land. The listed EC for DRP assigns a loss rate from non-irrigated arable land that is up to seven times higher than from grassland or arable land associated with permanent crops (Table 2.6). Therefore although the arable area is relatively small in these rivers, it has a disproportionately large impact on the predicted catchment DRP. When a lower EC from arable land of 0.3 tonnes P km^{-2}, the loss rate for arable land associated with permanent crops, was substituted for the high loss rate, this effectively eliminated the over-estimation of agricultural land loadings in the Muff and Burnfoot Rivers. In the Enler River the lower EC loss rate reduced the catchment loading to below that observed.

3.10 Back ground loadings

A consequence of calculating agricultural loss rates by either difference, or from published EC loss rates for agricultural land, is that each set of loss rates will contain a component that is the natural or background loss rate from agricultural land. If, in comparison to the calculated agricultural loss rate, a back-ground loss rate is a significant quantity, then there will not only be an overestimate of the amount by which agriculture has increased catchment loss rates but also an unrealistically high estimate by which catchment nutrient losses from agricultural land could be reduced. Estimating background loss rates is however difficult and depends on various assumptions. The first is in deciding what the natural land-use for agricultural land is. If in Ireland, it is assumed that the lowland areas now used for agriculture were forested in their natural state, typically with deciduous trees, then the current loss rates can be compared with EC loss rates for forested land that are currently used for the Corrine land classes that cover forestry (Table 3.11).

Given that significant deforestation in Ireland began with neolithic agriculture, approximately 5000 years ago, and that lowlands have largely been cleared of trees for over 1500 years, an alternative and more realistic assumption is that background loss rates should be those from agricultural land before the intensification of agriculture. This intensification relies on both imported fertilisers and animal feedstuffs. It has marked agriculture in Northern Ireland during the twentieth century and in particular the last 60 years. A recent paper compared inputs and outputs of nutrients from agriculture in Northern Ireland since 1925 (Foy et al., 2002). Intensification began around 1940 but that even before that there were imports of animal feedstuffs and fertilisers to farms. The scale of the intensification can be ascertained from both the increase in outputs and inputs as discussed below.

3.10.1Nitrate Agricultural output, expressed as N exported from farms in product was 307% higher in the period 1990 to 1999 compared to the average for 1925 to 1940 (7.4 kg N ha^{-1} yr^{-1} vs 30.0 kg N ha^{-1} yr^{-1}). Inputs of N from imported fertilisers and foodstuffs increased by 1546% over the same period (10 vs 171 kg N ha^{-1} yr^{-1}). The fact that the input percentage increase is five times greater than the output percentage increase suggests that modern agriculture is markedly less efficient at utilising N and could support the contention that modern systems are proportionately more vulnerable to nitrate leaching. However, the apparent inefficiency of N use by modern agriculture may be largely illusionary and as these calculated inputs ignore N inputs from biological N fixation. These must have sustained agricultural production in the pre-fertiliser era but, as the addition of N fertilisers depresses biological N fixation associated with clover, legumes and soil algae, fertilisation in part displaces one form of input (N fixation) for another (N fertilisers). At the levels of N efficiency use recorded for agriculture in the 1980s and 1990s, a relatively modest N fixation rate of around 20 kg N ha^{-1} yr^{-1} would have been sufficient to sustain N outputs pre 1940.

None the less there has been large increase inputs and outputs. Research has shown that nitrate losses to water from grassland increase in near linear fashion with inputs

(Watson *et al*., 2000). If N inputs (including N fixation) are assumed to have increases in parallel with outputs of N, then nitrate exports from agricultural land in the period 1925-1940 would be expected to be 24.6% of those measured in the 1990s. Thus 75.4% of the agricultural contributions to catchment nitrate losses listed in Table 3.3 is attributed to intensification of agriculture.

After discounting the background contribution, this intensification of agriculture remains as the largest nitrate source in all water bodies, contributing over 50% of the current nitrate input. Using the agricultural land contributions given in Table 3.3, intensification contributions were as follows: River Foyle, 69.5%; Lough Foyle, 67.7%; Newry River 72.2%; Quoile, 70.6%; Strangford Lough, 67.5%; Lower Bann, 69.2%; Tidal Lagan, 58.5%; Inner Belfast Lough, 55.2% and Outer Belfast Lough, 57.5%.

As noted in section 3.8 current nitrate losses are around 2.0 tonne N km^{-2} yr^{-1} (Table 3.8). If background losses are taken to be 24.6% of this value, the estimated back-ground loss rate is 0.5 tonnes N km^{-2} yr^{-1}. This value is therefore considerably higher, in percentage terms, than the nitrate loss rates from forested land that are given in Table 3.11, which are less than 0.1 tonnes N km^{-2} yr^{-1}. On this basis agricultural nitrate is 'new' nitrate to the system.

Table 3.11 Nitrate and dissolved reactive phosphorus (DRP) export coefficients from forest land use categories.

Corrine Level	Corrine land use type	Export coefficient DRP	Nitrate- N
		Tonnes km^{2} yr^{-1}	
3.1.1.	Broad-leaved forest	0.013	0.000
3.1.2.	Coniferous forest	0.005	0.086
3.1.3.	Mixed forest	0.013	0.000
3.2.4.	Transitional woodland-scrub	0.013	

<u>3.10.2 Dissolved reactive phosphorus</u> Agricultural P output from 1991-2000 was 352% higher in comparison to outputs from 1925-1940. This somewhat smaller increase of P, in comparison to N, reflects the different out-put mix of agricultural products in the 1990s. The increase inputs in P was 312% over the same period. Relative to N inputs,

the smaller increase in P inputs reflects the absence of significant gaseous inputs of P from the atmosphere that are analogous to N fixation. As the percentage increase of P output exceeds the percentage increase of P input, this could suggest that for P, agriculture has become more efficient in translating P inputs into agricultural P outputs. Again this is also a misleading conclusion as much of surplus P added over the years has accumulated in the soils, and in fact P inputs have remained fairly static since 1950. Growing crops now have much larger available soil reserves to draw on. These reserves are also subject to loss to water that is independent of the current level of P input. It is therefore difficult to estimate how much P losses have increased from the increase of P inputs and due the increase in soil P.

If it assumed that DRP loss rates have increased in proportion to the % increase of P output, then losses pre 1940 would be assumed to be 24.1% of those in the 1990s. While this intensification factor for agricultural P is similar to that of nitrate, the intensification influence on catchment DRP loads is less, as point sources of P are much more important in determining overall DRP loads than is the case for point source to catchment nitrate loads. As described in section 3.8 the estimated rates of DRP loss were more variable between catchments than those of nitrate and were in the range 0.023 to 0.11 tonnes P km^{-2} yr^{-1}. If the these losses are reduced by the DRP intensification factor, then background rates are in the range 0.01 to 0.03 tonnes P km^{-2} yr^{-1}. The lower of these values is therefore quite close to the DRP loss rate assumed for forested land (Table 3.11).

3.11 Trophic status estimates of nutrient loadings

The trophic status studies referred to Chapter 1 contain information on the nutrient loadings to the sea loughs based on sampling of inflowing rivers. Loadings of nitrate, ammonium and DRP from the respective reports are presented in Table 3.11. In the Lagan (1) study by Charlesworth and Service (1999), loadings from the River Lagan were not given explicitly and those for nitrate and ammonium have been back-calculated from pi diagrams in that report of loadings from industry and WWTWs given by Charlesworth and Service (1999). However from this study it was not possible to deduce the river loading of DRP.

Table 3.11 Nitrate, ammonium and dissolved reactive phosphorus (DRP) loadings from this study and the trophic status studies of tidal waters sea Loughs set out in Table 1.1.

Trophic Status sample period	River	Nitrate- N		Ammonium-N		DRP	
		This study	Trophic Status	This study	Trophic Status	This study	Trophic Status
				Tonnes km^{-2} yr^{-1}			
Foyle system - Charlesworth *et al*. (1999).							
1997	Mourne	1.40	1.54	0.15	0.090	0.067	0.050
1997	Burndennet	1.36	1.32	0.07	0.023	0.030	0.013
1997	Finn	0.74	**3.39**	0.10	0.137	0.029	0.102
1997	Deele	1.60	**0.65**	0.33			0.012
1997	Swilly Burn	0.98	**1.94**	0.45	0.192		0.015
1997	Carrigans[1]	1.47	**2.96**	0.06	0.063		0.017
1997	Glemmornan	1.64	1.80	0.23	0.116	0.081	0.072
1997	Faughan	1.25	1.41	0.10	0.070	0.045	0.029
1997	Roe	1.08	1.05	0.09	0.112	0.083	0.050
Newry -Taylor et al. (1999)							
1997	Newry	2.37	**3.12**	0.04	0.129	0.086	0.103
Strangford Lough - Taylor & Service (1997)_							
1991-1995	Quoile	1.78	**1.24**	0.11	0.084	0.130	0.085
1991-1995	Enler	1.76	1.82	0.08	0.071	0.082	0.065
1991-1995	Blackwater	1.93	**1.36**	0.12	0.077	0.128	0.079
Belfast Lough (1) Charlesworth and Service. (1999)							
Belfast Lough (2) Service and Durrant (1996)							
1) 1993-1997	Lagan	2.14	1.90	0.13	0.10	0.283	
2) 1992-1994	Lagan	2.14	1.79	0.13	0.10	0.283	0.177

<u>3.11.1 River nitrate loadings</u> Rivers loading of nitrate are highlighted in bold type wherever the loading of the current study and the trophic state investigation differed by more than ± 20%. The differences for the Rivers Newry (+31%), Quoile (-30%) and Blackwater (-29%) are not unexpected given the periods over which these rivers were monitored for the trophic state studies and the large year-to-year variation that is observed within single river between years. Nitrate loadings presented in this study are the average of a six-year period whereas the Newry River trophic state study was carried out in 1997, which was a year with higher than average nitrate concentrations

(See Fig 1 Appendix A5). An opposite effect may explain the comparatively low nitrate loss rates for the Quoile and Blackwater Rivers found by Taylor and Service (1999), the trophic state study of Strangford Lough covered the period 1991-1995 which missed years with the highest nitrate concentrations.

The remaining rivers where large differences in nitrate loss rate were recorded are those rivers that drain County Donegal. The discrepancy is surprising as there was excellent agreement for the other rivers in the Foyle system that drain from Northern Ireland. Compared to the catchment loss rates presented in the current study, the nitrate loss rate of 3.4 tonnes N km^{-2} yr^{-1} from the River Finn calculated by Charlesworth *et al*. (1999) is implausibly high as it is highest recorded nitrate loss rate for all rivers. Yet the DOE monitoring shows that nitrate concentrations for the River Finn were the lowest of all rivers in this study. Based on a mean annual runoff of 1.5 m, a loss rate of 3.4 tonnes N km^{-2} yr^{-1} requires a flow weighted nitrate concentration in excess of 2.0 mg N L^{-1} whereas the average was less than 1.0 mg N L^{-1}. The parallel DRP loss rate computed for the Finn of 0.1 tonnes P km^{-2} yr^{-1} is also implausible as it implies a flow weighted mean DRP concentration of 0.07 mg P L^{-1} whereas DRP concentrations in the river were close to 0.02 mg P L^{-1} (Fig 3.1).

The nitrate loss rates for the adjacent rivers entering the River Foyle from Co. Donegal are also at variance with the concentrations reported here. The catchment export rate from the River Deele of 0.65 tonnes N km^{-2} yr^{-1} appears to be too small, as it implies a mean nitrate concentration of around 0.6 mg N L^{-1} whereas the actual nitrate concentrations were in excess of 2.0 mg N L^{-1} (Appendix A1 Fig 6). The loss rates for the adjacent rivers Carrigans and Swilly Burn are also at variance with the concentrations reported here. These two rivers are small and differences in their loss rates have little impact on the determination of total loss rates of nitrate to Lough Foyle. However the Finn is the second largest river in the Foyle and so that differences in loss rates of the magnitude shown in the Table 3.11 in loading do significantly alter the computed loadings. In this study the nitrate load from the Finn was 367 tonnes N $year^{-1}$ out of a total of 5057 tonnes N $year^{-1}$ while the equivalent values for the trophic status study given by Charlesworth *et al*. (2000) are 1677 and 6994 tonnes N $year^{-1}$.

An explanation for the anomalistic Finn loadings given by Charlesworth *et al*. (2000) is that samples taken in 1997 were mis-sampled and not taken from the Finn River at all. This assertion is based on the geo-location given for the Finn River by Charlesworth *et* *al*. (1999) which is the Foyle Bridge, which connects Lifford and Strabane and crosses the River Foyle at a point downstream of the confluence of the River Finn with the River Mourne. As the latter is a very much larger river than the Finn, it would be expected that samples from this location would resemble concentrations from the River Mourne. A comparison of the nitrate concentrations used by Charlesworth et al (1999), with those of the Mourne and Finn as sampled by DOE shows that this is the case (Fig 3.2). Nitrate concentrations from the River Mourne show close agreement with concentrations assumed by Charlesworth *et al*. (1999) to be from the River Finn. Further scrutiny of sample points given by Charlesworth *et al*. (1999), suggests that samples given for the Swilly Burn were taken from a small stream close to St. Johnstown. A location for the Deele is not given. In contrast, the sample locations given by Charlesworth *et al*. (1999) for the Foyle inflowing rivers that are within Northern Ireland are in agreement with sampling locations given by the current study. In these rivers there is good agreement between the two studies further strengthening the conclusion that the disparity in loadings of the Co. Donegal rivers does not reflect an analytical problem in the determination of nitrate.

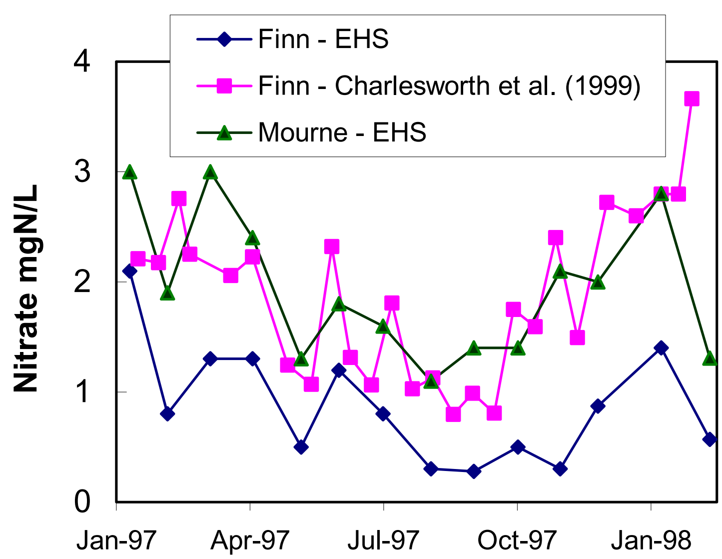

Fig 3.2 Comparison of River Finn nitrate concentrations as used by Charlesworth et al (1999) with concentrations from River Mourne and Finn as sampled by DOE-EHS and used in current study.

3.11.2 River ammonium and DRP loadings Ammonium loss rates from this study and the trophic status studies are in agreement in that they indicate that losses are low in comparison to losses of N as nitrate. With the exception of the River Finn, dissolved reactive phosphorus (DRP) loss rates were generally well correlated with each other, but there was a clear trend for the current study to give DRP loss rate that exceeded those found by the trophic status investigations (Fig 3.3).

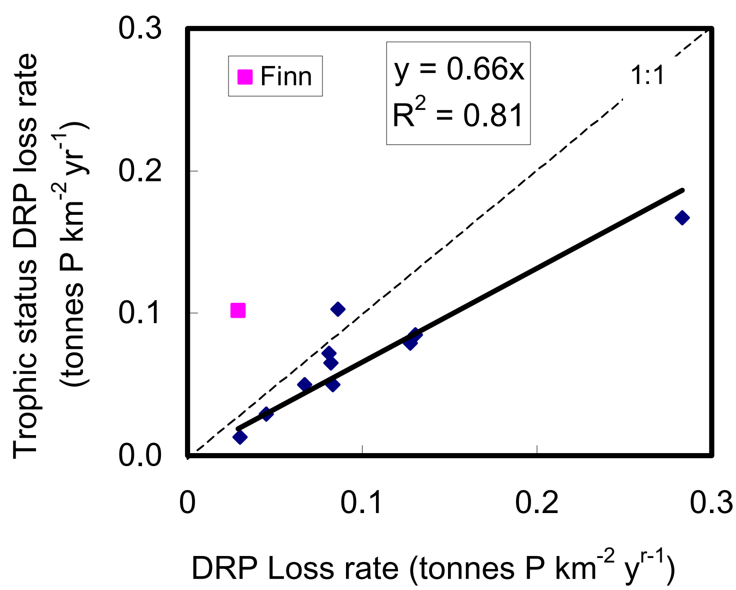

Fig 3.3 Plot of rivers loss rates of DRP from current study (x axis) vs loss rates from trophic status investigations. River Finn loss rates highlighted and not included in regression equation. Dashed line shows 1:1 relationship.

The regression slope of the two estimates suggests that trophic status estimates of DRP loss rates were in the region of 66% of those measured by the current study. The only river where the estimate from the trophic status study was the larger of the two was the Newry River. There are a number of potential reasons why this pattern should have emerged. The first is that the higher values reflect the general rise in DRP loss rates that has been observed in the rivers flowing into Lough Neagh and Lough Erne. A second relates to differences in the way the two sets of loading were determined. The trophic status studies all employed a load regression approach of log load vs log flow to predict loads on days when concentration was not measured. However the logarithmic transformation of the data that this method involves creates an inherent bias towards underestimating loadings. From the reports it is not clear if this bias was allowed for in the DRP loadings presented. In addition the use of an annual data set in the trophic status would, on the basis of experience with Lough Neagh rivers, tend to give lower loading estimates in comparison to dividing the data into summer and winter date sets winter (Lennox *et al*., 1997). (The DRP load vs flow relationships differ between summer and winter). A final point to note is that the low estimates of DRP given by the trophic status study predicts a river DRP export of 83 tonnes P year^{-1} for the River Lagan. This is is less than the computed DRP loading of 94 tonnes P year^{-1} from WWTWs discharging to the freshwater River Lagan. In the Burndennet, the use of the lower DRP loss rates results in a predicted DRP loss rate from agriculture (which includes any septic tank contributions) that is close to zero.

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Appendix A Nutrient budgets and associated data for tidal waters and sea loughs in Northern Ireland

Separate appendices are provided for the following tidal waters and sea loughs:

A1 River Foyle

A2 Lower Bann

A3 Lagan, Inner Belfast Lough and Outer Belfast Lough

A4 Quoile Pondage and Strangford Lough

A5 Newry River

Each appendix contains the following information:

A map showing the major river catchments for each water, the largest towns (shown in italics) and land use. The colour scheme simplifies the Corrine classes as follows; Pink denotes urban and industrial areas, purple denotes heath, moor-land and peat bogs. agricultural land is denoted as green and blue is surface waters.

Table 1 Catchment water quality sampling stations and measured loss rates of nitrate, ammonium and dissolved reactive phosphorus.

Table 2 land use breakdown

Table 3 Nitrate sources,

Table 4 Ammonium sources

Table 5 Dissolved inorganic nitrogen sources

Table 6 List of WWTWs in catchments, PE values, estimated daily flows and loadings of nitrate, ammonium and dissolved reactive phosphorus.

Table 7 Loadings of nitrate, ammonium and dissolved reactive phosphorus from industrial point sources (Foyle and Lagan only).

For each of the rivers monitored, sample nitrate and ammonium concentrations are from 1994 to 2002 are plotted, plus the average annual cycle (by month) and estimates of FWMCs.

Appendix A-1 River Foyle and Lough Foyle

Description

The Lough Foyle catchment is the second largest in Northern Ireland draining 2989 km^2. Another 1030 km^2 is located within County Donegal (Table 1a). The drainage is dominated by the River Foyle, which forms 74% of the drainage area of Lough Foyle. In turn, the River Mourne dominates the drainage basin of the River Foyle accounting for 64% of the River Foyle area and 44% of the Lough Foyle basin. Accordingly nutrient loads are dominated by inputs from this river. Derry is the largest urban area in the catchment and drains into the River Foyle, with the exception of the eastern suburbs, which drain into the River Faughan at Drumahoe. Strabane is the third largest town also discharges directly into the River Foyle. Omagh, the second largest towns, drains into the Mourne.

Map A1 Foyle and Lough Foyle catchments. Numbered catchments shown draining into Lough Foyle are as follows: 1 Muff River; 2 Faughanvale and 3 Burnfoot.

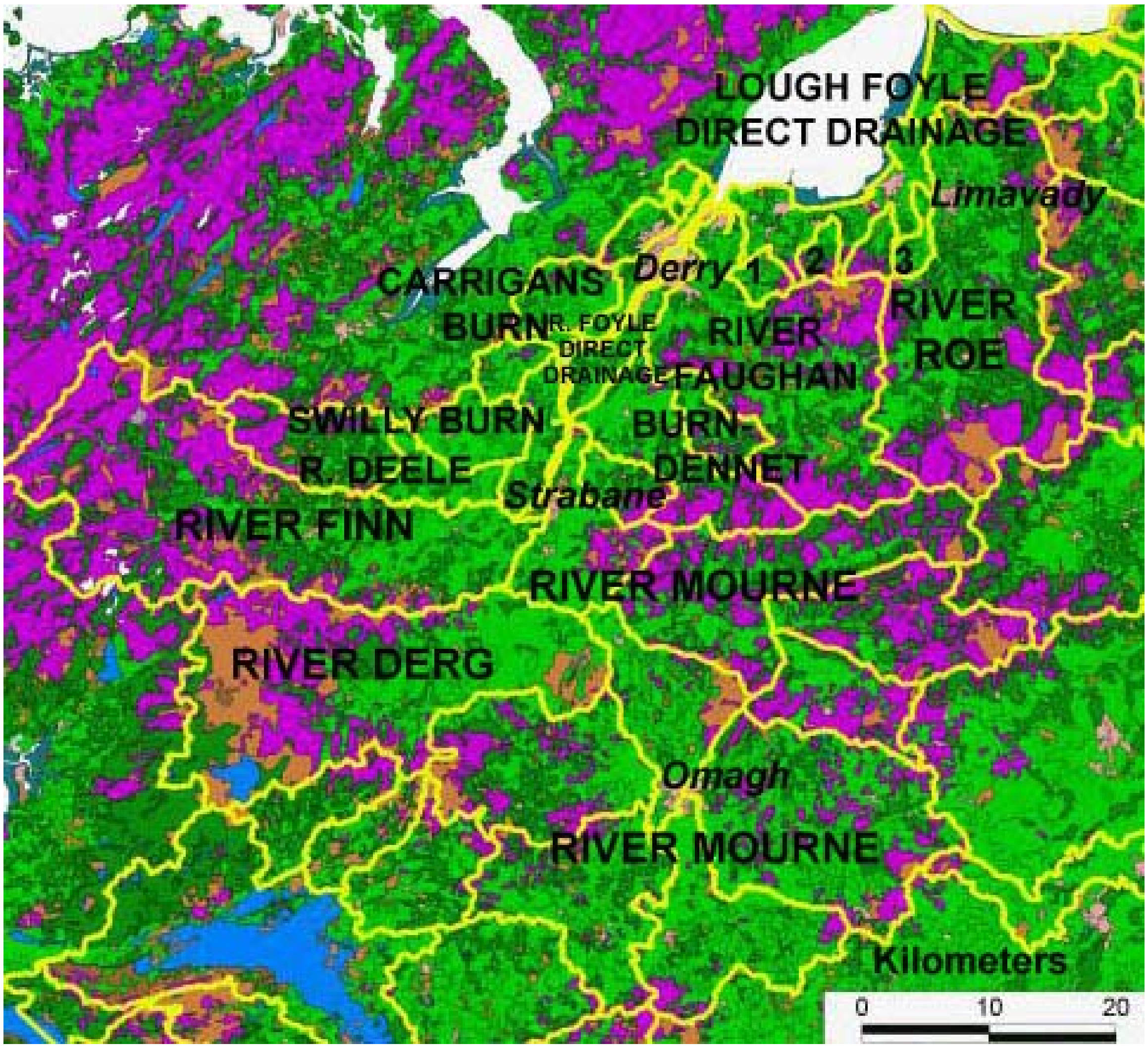


Table 1A River sampling locations, catchment areas, runoff and nitrate (NO3), ammonium (NH4) and dissolved reactive phosphorus (DRP) nutrient losses for rivers in River Foyle and Lough Foyle catchments.

River	Sampling point	Grid ref	Area	Runoff	Loss rate[2]			Catchment loss[2]		
					NO3	NH4	DRP	NO3	NH4	DRP
			km^2	mm yr^{-1}	tonnes km^{-2} yr^{-1}			tonnes yr^{-1}		
R FOYLE CATCHMENTS										
Mourne	Strabane Bridge	H345975	1856	0.97	1.40	0.15	0.067	2593	269.9	124.6
Burndennet	B'dennet Bridge	C374048	149	0.85	1.36	0.07	0.030	203	11.0	4.4
Finn	Clady Bridge	H293940	495	1.41	0.74	0.10	0.029	367	50.9	14.5
Deele River	Bridge d/s Convoy	C223012	125	0.85[1]	1.60	0.33		200	41.1	
Swilly Burn	Maghera-haan	C264019	49	0.85[1]	0.98	0.44		48	21.3	
Carrigans	Carrigans	C365117	44	0.85[1]	1.47	0.06		64	2.8	
Glenmornan	Ballyma-gorry Br.	C368016	32	0.85[1]	1.64	0.23	0.081	52	7.2	2.6
LOUGH FOYLE CATCHMENTS										
Faughan R.	Carrakeel Bridge	C493206	296	0.91	1.25	0.10	0.045	368	29.3	13.4
Roe	Roe Bridge	C670296	385	0.81	1.08	0.09	0.083	415	36.4	32.1
Muff R	Mill Bridge	C524188	15	0.85[1]	1.59	0.07	0.050	23	1.0	0.7
Burnfoot River	Rush Hall	C646241	14	0.85[1]	2.68	0.09	0.050	39	1.3	0.7
Faughan-vale R.	Faughan-vale Br.	C578214	13	0.85[1]	1.15	0.10	0.059	15	1.3	0.8

1) Rivers not gauged flows and Burndennet runoff rate assumed.

2) Nutrient losses for nitrate, ammonium and dissolved reactive P expresses as tonnes of N or P.

Table 1B. Catchment areas associated with sampling points expressed as percentage of River Foyle and Lough Foyle catchment areas

River basin / river	Sampling point Grid ref	Area km2	% in RoI	R Foyle area %	R Foyle area cumulative	L. Foyle area %	L. Foyle area cumulative
River Foyle							
Mourne	Strabane Bridge H345975	1856	8	63.9	63.9	47.2	47.2
Finn	Clady Bridge H293940	495	97	17.0	80.9	12.6	59.8
Burndennet	Bundennet Br. C374048	149	0	5.1	86.0	3.8	63.6
Deele River	Convoy C223012	125	100	4.3	90.3	3.2	66.8
Swilly Burn	Magherahaan C264019	49	100	1.7	92.0	1.2	68.0
Carrigans	Carrigans C365117	44	100	1.5	93.5	1.1	69.2
Glenmornan	Ballymagorry Br. C368016	32	0	1.1	94.6	0.8	70.0
R Foyle Remainder		157	43	5.4	100.0	4.0	73.9
R Foyle	Total	2905	31				
R Foyle (N. Ireland)	Total	2000					
LOUGH FOYLE							
Roe	Roe Bridge C670296	296	0			7.5	81.5
Faughan R.	Carrakeel Br. C493206	385	0			9.8	91.3
Muff R	Mill Bridge C524188	15	0			0.4	91.6
Burnfoot River	Rush Hall C646241	14	0			0.4	92.0
Faughan-vale R.	Faughanvale Br C578214	13	0			0.3	92.3
Lough Foyle Remainder		301	37			7.7	100.0
Lough Foyle	Total	3929	26				
L. Foyle (N. Ireland)	Total	2899					

Table 2 Land use in sub-catchments of River Foyle and Lough Foyle. D'gal refers to percentage of catchment area draining Co. Donegal.

	Urban-industrial	Arable	Grass	Agric land % area	Rough grazing	Forest	Other land	Area Total km^2	D'gal % area
RIVER FOYLE									
Mourne	1.0	0.6	63.0	63.6	25.8	9.0	0.7	1855.6	7.6
Burndennet	0.6	1.8	67.1	68.9	29.9	0.6	0.0	149.2	0.0
Finn	0.4	1.0	48.4	49.4	39.6	9.0	1.6	494.7	96.9
Deele	0.3	2.7	71.5	74.2	21.2	4.1	0.2	125.1	100.0
Swilly Burn	0.7	12.8	82.3	95.1	2.3	1.9	0.0	48.7	100.0
Carrigans Burn	0.0	27.2	64.0	91.2	6.4	1.2	1.2	43.8	100.0
Glenmornan R.	1.2	0.6	71.5	72.2	26.7	0.0	0.0	31.7	0.0
R. Foyle direct drainage	12.0	16.2	67.8	84.0	2.2	1.4	0.4	156.6	43.3
R Foyle total	1.4	2.2	61.8	64.0	26.2	7.6	0.7	2905.4	31.2
LOUGH FOYLE									
Faughan	1.7	3.4	57.4	60.8	31.0	6.5	0.1	295.5	0.0
Roe	1.4	4.0	61.7	65.7	23.6	9.2	0.2	385.3	0.0
Muff River	0.0	29.3	47.9	77.2	13.4	9.4	0.0	14.7	0.0
Burnfoot River	0.1	17.2	73.4	90.6	3.7	5.6	0.0	14.4	0.0
Faughanvale R	0.0	1.5	69.4	70.9	25.6	3.5	0.0	13.1	0.0
L Foyle direct drainage	2.8	11.7	60.7	72.4	17.9	4.6	2.2	300.8	41.4
Lough Foyle Totals									
Ex. R Foyle	1.8	6.6	60.2	66.8	23.7	6.9	0.7	1023.8	12.2
Inc R Foyle	1.5	3.4	61.4	64.8	25.5	7.4	0.7	3929.3	26.2

Table 3 Nitrate loading sources to River Foyle and Lough Foyle.

	Industry	Urban	Rough grazing	For-estry	Other land	Agric land	Nitrific ation	Total
	Nitrate tonnes N $year^{-1}$							
RIVER FOYLE								
Mourne	3.3	46.5	95.6	33.3	6.3	2408.1	0.0	2593
Burndennet	0.0	2.2	8.9	0.2	0.2	191.1	0.1	203
Finn	0.8	0.2	39.2	8.9	1.9	315.9	0.0	367
Deele	0.0	0.4	5.3	1.0	0.1	192.7	0.0	200
Swilly Burn	0.0	1.9	0.2	0.2	0.1	45.2	0.0	48
Carrigans	0.7	0.0	0.6	0.1	0.1	60.2	2.8	65
Glenmornan	1.8	1.8	1.7	0.0	0.1	46.5	0.0	52
River Foyle Direct drainage	1.3	17.3	0.7	0.4	3.9	235.2	0.0	259
River Foyle Total	8.0	70.4	152.2	44.2	12.6	3495.0	2.9	3785
%	0.2	1.9	4.0	1.2	0.3	92.3	0.1	100
LOUGH FOYLE								
Faughan	0.0	23.0	18.3	3.8	1.0	309.1	13.1	368
Roe	33.7	38.7	18.2	7.1	1.2	282.1	34.1	415
Muff R.	0.0	0.4	0.4	0.3	0.0	21.6	0.6	23
Burnfoot R.	0.0	0.6	0.1	0.2	0.0	37.1	0.6	39
Faughanvale R.	0.0	0.0	0.7	0.1	0.0	14.3	0.0	15
Lough Foyle Direct drainage	0.0	5.8	10.8	2.8	3.0	389.2	0.0	412
Lough Foyle Total	41.7	138.9	200.6	58.4	17.9	4548.5	51.3	5057
%	0.8	2.7	4.0	1.2	0.4	89.9	1.0	100

Table 4 Breakdown of annual ammonium loading to River Foyle and Lough Foyle

	Industry	Urban	Rough grazing	Forestry	Other land	Agric land	Other	Nitrification	Total
				Ammonium	tonnes N $year^{-1}$				
RIVER FOYLE									
Mourne	18.0	60.8	14.3	5.0	0.9	94.4	76.4	0.0	270
Burndennet	0.0	1.6	1.3	0.0	0.0	8.2	0.0	-0.1	11
Finn	0.3	13.8	5.9	1.3	0.3	19.5	9.8	0.0	51
Deele	0.0	2.7	0.8	0.2	0.0	7.4	30.0	0.0	41
Swilly Burn	0.0	1.8	0.0	0.0	0.0	3.7	15.7	0.0	21
Carrigans	2.3	0.0	0.1	0.0	0.0	3.2	0.0	-2.8	3
Glenmornan	0.7	1.9	0.3	0.0	0.0	1.8	2.5	0.0	7
River Foyle Direct drainage	4.3	286.7	0.1	0.1	0.6	10.5	0.0	0.0	302
River Foyle Total	25.6	369.1	22.8	6.6	1.9	148.8	134.5	-2.9	707
%	3.6	52.2	3.2	0.9	0.3	21.1	19.0	-0.4	100
LOUGH FOYLE									
Faughan	1.6	23.0	2.7	0.6	0.2	14.4	0.0	-13.1	29
Roe	7.6	38.7	2.7	1.1	0.2	20.2	0.0	-34.1	36
Muff R.	0.0	0.7	0.1	0.0	0.0	0.9	0.0	-0.6	1
Burnfoot R.	0.0	0.8	0.0	0.0	0.0	1.0	0.0	-0.6	1
Faughanvale R.	0.0	0.0	0.1	0.0	0.0	0.7	0.4	0.0	1
Lough Foyle Direct drainage	0.0	19.0	1.6	0.4	0.5	17.4	0.0	0.0	39
Lough Foyle Total	34.8	451.3	30.1	8.8	2.7	203.6	134.9	-51.3	815
%	4.3	55.4	3.7	1.1	0.3	25.0	16.6	-6.3	100

Table 5 Loadings of dissolved reactive phosphorus to River Foyle and Lough Foyle.

	Industry	Urban	Rough grazing	Forestry	Other land	Agric land	Total
	Dissolved reactive P tonnes P $year^{-1}$						
RIVER Foyle							
Mourne	3.53	29.30	3.82	2.67	0.94	84.37	124.6
Burndennet	0.00	0.87	0.36	0.01	0.03	3.16	4.4
Finn	0.20	2.89	1.57	0.72	0.29	8.79	14.5
Deele	0.00	0.62	0.21	0.08	0.02	5.10	6.0
Swilly Burn	0.00	0.75	0.01	0.02	0.01	2.54	3.3
Carrigans	0.56	0.00	0.02	0.01	0.02	2.19	2.8
Glenmornan	0.66	1.06	0.07	0.00	0.01	0.77	2.6
River Foyle Direct Drainage	0.00	58.35	0.03	0.04	0.58	7.23	66.2
River Foyle Total	4.95	93.84	6.09	3.54	1.89	114.16	224.5
%	2.21	41.81	2.71	1.58	0.84	50.86	100.0
LOUGH Foyle							
Faughan	0.37	7.74	0.73	0.31	0.15	4.12	13.4
Roe	3.56	18.82	0.73	0.57	0.18	8.21	32.1
Muff R.	0.00	0.40	0.02	0.02	0.00	0.29	0.7
Burnfoot R.	0.00	0.32	0.00	0.01	0.00	0.37	0.7
Faughanvale R.	0.00	0.00	0.03	0.01	0.00	0.73	0.8
Lough Foyle Direct drainage	0.0	6.4	0.4	0.2	0.5	12.0	19.5
Lough Foyle Total	8.89	127.50	8.03	4.67	2.69	139.86	291.6
%	3.0	43.7	2.7	1.6	0.9	48.0	100.0

Table 6a (part 1 of 3) Loadings from WWTWs in Northern Ireland portion of River Foyle catchment.

River/Name	PE	Flow	Concentration			Loading			Per capita	
Mourne(1)			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
	Nos	$m^3 d^{-1}$	mg L^{-1}			tonnes $year^{-1}$			kg $year^{-1}$	
OMAGH	35237	11384	5.5	5.8	3.1	22.88	24.02	12.73	1.3	0.36
CASTLEDERG	3865	1470	8.3	4.8	3.5	4.43	2.58	1.87	1.8	0.48
SION MILLS	3200	1234	8.5	4.6	4.6	3.82	2.07	2.05	1.8	0.64
FINTONA	2563	1004	8.1	7.5	4.1	2.95	2.75	1.50	2.2	0.59
NT'NSTEWART	2200	872	11.4	2.4	4.0	3.62	0.78	1.27	2.0	0.58
DROMORE	1600	649	4.7	7.1	3.3	1.12	1.68	0.78	1.8	0.49
CARRICKMORE	1020	428	7.5	2.1	1.9	1.17	0.33	0.30	1.5	0.29
BERAGH	820	350	7.2	8.4	4.0	0.92	1.08	0.51	2.4	0.62
DRUMQUIN	784	335	3.0	11.9	4.7	0.37	1.46	0.57	2.3	0.73
SPAMOUNT	703	303	14.3	2.1	4.8	1.59	0.24	0.53	2.6	0.76
GORTIN	632	275	12.1	12.1	7.0	1.21	1.21	0.71	3.8	1.12
SIXMILECROSS	600	262	15.0	2.8	5.1	1.44	0.26	0.48	2.8	0.81
TRILLICK new	528	232	6.2	15.0	4.3	0.52	1.27	0.36	3.4	0.69
TRILLICK	528	232	8.4	12.0	7.5	0.72	1.02	0.63	3.3	1.20
PLUMBRIDGE	356	161	12.2	1.5	2.2	0.72	0.09	0.13	2.3	0.37
KILLEN	350	159	21.6	3.1	5.1	1.25	0.18	0.29	4.1	0.84
MOUNTFIELD	302	139	6.6	15.1	5.9	0.33	0.76	0.30	3.6	0.99
SESKINORE	300	138	3.1	14.6	3.9	0.15	0.73	0.19	3.0	0.65
L'MACRORY	272	126	15.6	4.4	4.5	0.71	0.20	0.21	3.4	0.77
DOOISH	220	103	3.7	9.4	3.4	0.14	0.36	0.13	2.3	0.59
GREENCASTLE	206	97	6.4	6.4	3.0	0.23	0.23	0.11	2.2	0.52
KILLETER	200	95	5.9	12.0	3.8	0.20	0.41	0.13	3.1	0.65
ARDSTRAW	175	84	36.8	4.1	10.3	1.12	0.13	0.32	7.1	1.80
CAMUS	160	77	10.0	17.0	8.3	0.28	0.48	0.23	4.7	1.46
DOUGLAS BR.	150	72	3.8	11.7	4.2	0.10	0.31	0.11	2.7	0.75
DRUMAKILLY	128	63	26.8	7.8	12.4	0.61	0.18	0.28	6.2	2.21
VICTORIA BR.	128	63	8.3	5.2	5.5	0.19	0.12	0.13	2.4	0.99
CRANAGH	120	59	33.3	1.1	7.0	0.72	0.02	0.15	6.2	1.25
MOUNTJOY	120	59	5.5	5.1	1.7	0.12	0.11	0.04	1.9	0.30
CAVANACAW	112	55	13.2	4.3	4.4	0.27	0.09	0.09	3.2	0.80
ARVALEE	100	50	31.7	2.3	6.6	0.58	0.04	0.12	6.2	1.21
GARVETAGH	98	49	11.4	3.9	3.7	0.20	0.07	0.07	2.8	0.67
GARVAGHEY	98	49	4.4	6.3	1.9	0.08	0.11	0.03	2.0	0.34
LETTERBIN	91	46	22.1	1.1	7.5	0.37	0.02	0.12	4.2	1.36
T'TYSALLAGH	88	44	44.1	5.7	12.2	0.71	0.09	0.20	9.1	2.23
DRUMENNY	84	42	25.9	8.0	10.4	0.40	0.12	0.16	6.2	1.91

Table 6a (part 2 of 3) Loadings from WWTWs in Northern Ireland portion of River Foyle catchment.

River/ Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
Mourne (2)	nos	$m^3 d^{-1}$		mg L^{-1}			tonnes $year^{-1}$		kg $year^{-1}$	
KILSKERRY	68	35	31.0	3.2	12.1	0.39	0.04	0.15	6.4	2.26
KNOCKBRACK	60	31	4.1	11.8	1.8	0.05	0.13	0.02	3.0	0.35
DRUMLEGAGH	50	26	16.4	0.9	6.5	0.16	0.01	0.06	3.3	1.24
GREENVILLE	50	26	10.1	5.3	2.0	0.10	0.05	0.02	3.0	0.38
EDENDERRY	48	25	19.9	2.9	5.7	0.18	0.03	0.05	4.4	1.10
MAGHERA-COLTON	45	24	15.3	9.2	7.0	0.13	0.08	0.06	4.7	1.34
ROUSKEY	44	23	26.9	9.5	7.6	0.23	0.08	0.06	7.0	1.46
CREWE BR.	40	21	33.7	4.6	14.4	0.26	0.04	0.11	7.5	2.80
KNOCKMOYLE	40	21	12.8	12.9	9.8	0.10	0.10	0.08	5.0	1.91
CRAIGHCORR	35	19	9.4	6.3	3.1	0.06	0.04	0.02	3.1	0.61
CORRICKMORE	32	17	32.0	4.4	13.7	0.20	0.03	0.09	7.2	2.71
CORKHILL	32	17	28.2	8.9	9.4	0.18	0.06	0.06	7.3	1.86
CORNAMUCK	32	17	68.5	0.2	9.7	0.43	0.00	0.06	13.6	1.92
TERNAQUIN	32	17	22.7	1.6	4.6	0.14	0.01	0.03	4.8	0.91
LISNARRAGH	28	15	36.8	9.8	11.7	0.21	0.05	0.07	9.3	2.33
TUMMERY	28	15	45.5	0.2	11.6	0.25	0.00	0.06	9.1	2.32
GL'NMOOLAND	26	14	28.6	1.0	6.6	0.15	0.01	0.03	5.9	1.32
LOUGHAN RD	26	14	21.7	6.2	9.6	0.11	0.03	0.05	5.6	1.92
HUNTERS BUNGALOWS	25	14	26.1	2.1	6.3	0.13	0.01	0.03	5.7	1.27
LEGACURRY	24	13	34.9	1.6	10.0	0.17	0.01	0.05	7.4	2.02
TURSALLAGH	24	13	46.0	1.3	15.2	0.22	0.01	0.07	9.5	3.07
BADONEY	24	13	15.5	0.4	4.2	0.07	0.00	0.02	3.2	0.85
BELTRIM	20	11	7.6	10.0	7.4	0.03	0.04	0.03	3.6	1.51
MOUNTCASTLE	18	10	44.2	5.3	14.6	0.16	0.02	0.05	10.2	3.01
CASTLEMELLON UPPER	18	10	50.1	0.4	5.7	0.19	0.00	0.02	10.4	1.17
CARNALEA	16	9	29.8	4.5	10.2	0.10	0.01	0.03	7.1	2.11
CREVANAGAR	16	9	27.8	8.1	9.4	0.09	0.03	0.03	7.5	1.96
GORTMESSON	15	9	3.8	8.2	1.1	0.01	0.03	0.00	2.5	0.23

Table 6a (part 3 of 3) Loadings from WWTWs in Northern Ireland portion of River Foyle catchment.

Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
	nos	$m^3 d^{-1}$		mg L^{-1}			tonnes $year^{-1}$		kg $year^{-1}$	
Burndennet										
DONEMANA	1498	611	3.4	8.8	2.8	0.76	1.97	0.63	1.8	0.42
ARDMORE	152	73	24.8	5.5	7.8	0.67	0.15	0.21	5.3	1.38
BALLYHEATHER	50	26	5.4	4.1	1.5	0.05	0.04	0.01	1.8	0.30
ALTNASHANE	40	21	1.6	0.6	0.2	0.01	0.00	0.00	0.4	0.04
TULLYARD	12	7	24.9	1.5	6.9	0.06	0.00	0.02	5.6	1.47
River Foyle east shore (N Ireland)										
CULMORE	110584	32839	18.9	1.0	3.5	227.0	11.98	41.64	2.2	0.38
STRABANE	22891	7634	16.0	0.8	3.9	44.7	2.26	10.76	2.1	0.47
NEWBUILDINGS	5080	1893	6.8	2.2	3.2	4.71	1.50	2.23	1.2	0.44
BA'LYMAGORRY	583	255	7.4	8.0	4.4	0.68	0.74	0.41	2.4	0.71
M'MASON	482	214	15.8	0.9	4.0	1.23	0.07	0.31	2.7	0.65
CAMPSIE	300	138	15.3	2.0	3.3	0.77	0.10	0.17	2.9	0.56
PREHEN	160	77	12.6	0.9	4.1	0.35	0.03	0.12	2.4	0.72
M'CANNON	52	27	32.0	1.7	10.6	0.32	0.02	0.10	6.4	2.01
DONAGHEADY	50	26	25.9	2.9	6.2	0.25	0.03	0.06	5.5	1.19
KEENAGHAN	24	13	30.2	5.2	10.2	0.15	0.03	0.05	7.2	2.06
GORTIVEA	12	7	33.0	1.6	5.4	0.08	0.00	0.01	7.3	1.15
CASLTETOWN	12	7	41.1	0.3	11.5	0.10	0.00	0.03	8.8	2.44
Glenmornan stream										
ARTIGARVAN N.	570	250	8.3	18.6	8.7	0.75	1.69	0.79	4.3	1.38
GLENMORAN	126	62	36.3	5.4	8.8	0.82	0.12	0.20	7.5	1.57
ARTIGARVAN L.	35	19	43.9	1.3	11.4	0.30	0.01	0.08	8.9	2.25
R Foyle summary (N. Ireland)										
Mourne	59054	21351				60.8	46.5	29.3	1.82	0.50
Burndennet	1752	739				1.6	2.2	0.9	2.12	0.50
River Foyle east	140961	43460				282.1	18.6	57.0	2.13	0.40
Glenmornan	731	330				1.9	1.8	1.1	5.06	1.46
River Foyle (N. Ireland total)	202498	65879				346	69	88	2.05	0.44

Table 6b (part 1 of 2) Loadings from WWTWs in Northern Ireland portion of Lough Foyle catchment.

Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
	nos	$m^3\ d^{-1}$	$mg\ L^{-1}$			tonnes $year^{-1}$			kg $year^{-1}$	
River Faughan										
DRUMAHOE	8000	2883	3.4	18.7	5.7	3.57	19.69	6.04	2.9	0.75
CLAUDY	1200	497	4.6	11.1	4.1	0.83	2.01	0.75	2.4	0.62
PARK	223	105	6.9	9.3	4.2	0.26	0.35	0.16	2.8	0.71
KINCULBRACK	200	95	6.2	4.4	2.6	0.21	0.15	0.09	1.8	0.45
OGHILL 1	120	59	6.2	8.1	3.0	0.13	0.17	0.06	2.6	0.53
ARDGROUND	100	50	19.2	5.9	7.5	0.35	0.11	0.14	4.6	1.36
KILLALOO	90	45	31.7	1.8	7.7	0.52	0.03	0.13	6.1	1.42
G'TREGGAN	90	45	2.1	1.8	0.0	0.03	0.03	0.00	0.7	0.00
GOSHADEN 1	63	32	16.1	5.2	6.1	0.19	0.06	0.07	4.0	1.14
MULDERG	60	31	8.0	11.8	4.7	0.09	0.13	0.05	3.7	0.89
KILLYCORR	60	31	33.6	2.2	9.8	0.38	0.03	0.11	6.8	1.86
LEGAHORRY	60	31	12.7	10.8	7.3	0.14	0.12	0.08	4.4	1.37
GOSHADEN 2	45	24	19.5	11.2	7.5	0.17	0.10	0.06	5.9	1.44
River Roe										
LIMAVADY	12449	4342	8.7	17.3	8.4	13.82	27.38	13.33	3.3	1.07
DUNGIVEN	2933	1138	5.6	13.0	6.0	2.31	5.40	2.49	2.6	0.85
FEENEY	543	239	4.3	18.3	6.8	0.37	1.60	0.59	3.6	1.09
BALLYMONIE	470	209	13.3	6.1	6.4	1.01	0.46	0.49	3.1	1.04
AGHANLOO	435	194	4.9	8.1	3.4	0.35	0.58	0.24	2.1	0.55
DRUMSURN	342	155	4.2	14.5	7.1	0.24	0.83	0.41	3.1	1.19
GORTNAGHEY	253	118	6.9	15.8	5.9	0.30	0.68	0.25	3.9	1.00
BONNABOIGH	240	112	6.9	10.8	5.4	0.28	0.44	0.22	3.0	0.93
ARGARVAN	210	99	7.8	13.7	7.4	0.28	0.49	0.27	3.7	1.28
DERNAFLAW	150	72	3.4	12.3	2.8	0.09	0.33	0.07	2.8	0.49
BOLEA	110	54	8.3	4.1	3.9	0.16	0.08	0.08	2.2	0.71
BALLYQUIN	90	45	3.1	7.2	1.9	0.05	0.12	0.03	1.9	0.34
DRUMNEECHY	90	45	28.5	1.8	5.6	0.47	0.03	0.09	5.5	1.03
B'MACALLION	60	31	15.5	10.0	7.3	0.18	0.11	0.08	4.8	1.37
LISNAKILLY	60	31	16.2	6.8	6.1	0.18	0.08	0.07	4.3	1.16
OWENBEG	45	24	17.5	9.5	9.3	0.15	0.08	0.08	5.2	1.80
FINCAIRN	30	16	13.4	4.1	3.9	0.08	0.02	0.02	3.5	0.77

Table 6b (part 2 of 2) Loadings from WWTWs in Northern Ireland portion of Lough Foyle catchment.

Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
	nos	$m^3\ d^{-1}$		$mg\ L^{-1}$			tonnes $year^{-1}$		kg $year^{-1}$	
Burnfoot River										
DROMORE (D)	180	86	20.8	14.2	10.3	0.65	0.45	0.32	6.1	1.80
D'MREIGHLAD	100	50	9.4	8.1	4.2	0.17	0.15	0.08	3.2	0.77
Muff River										
OGHILL 2	120	59	15.9	7.1	8.3	0.34	0.15	0.18	4.1	1.49
T'NEYREAGH	60	31	7.4	4.6	2.3	0.08	0.05	0.03	2.2	0.44
L Foyle Direct Co Londonderry										
BALLYKELLY	3760	1433	9.4	1.8	3.6	4.91	0.96	1.86	1.6	0.49
GREYSTEEL	1163	483	4.9	13.3	4.9	0.87	2.35	0.87	2.8	0.75
D'BREWER	1001	420	15.5	1.8	4.1	2.38	0.27	0.62	2.7	0.62
DRUMVALLEY	342	155	38.2	1.9	10.7	2.17	0.11	0.61	6.7	1.78
GLACK	200	95	3.5	18.2	6.4	0.12	0.63	0.22	3.8	1.11
AUGHILL	130	63	17.3	7.7	10.7	0.40	0.18	0.25	4.4	1.91
LARGY	90	45	15.2	8.3	7.4	0.25	0.14	0.12	4.3	1.35
MYROE	90	45	35.6	0.5	9.0	0.59	0.01	0.15	6.6	1.66
LONGFIELD	75	38	2.3	5.5	0.4	0.03	0.08	0.01	1.4	0.08
KILLYLANE	60	31	10.2	8.5	3.5	0.12	0.10	0.04	3.5	0.66
CLAGAN	60	31	21.9	16.9	10.9	0.25	0.19	0.12	7.3	2.05
GLENABBEY	60	31	13.0	14.8	7.4	0.15	0.17	0.08	5.2	1.40
MOLENAN	54	28	24.6	4.4	9.6	0.25	0.05	0.10	5.5	1.82
NIXONS C.	50	26	9.9	15.1	5.8	0.09	0.14	0.05	4.8	1.10
DRUMMOND	36	19	8.0	24.1	6.2	0.06	0.17	0.04	6.3	1.21
CREBARKEY	36	19	21.9	1.7	7.6	0.15	0.01	0.05	4.6	1.49
CARNABANE	15	9	3.4	13.4	3.5	0.01	0.04	0.01	3.5	0.74
CAUGH HILL	15	9	1.5	0.7	0.3	0.00	0.00	0.00	0.5	0.06
B'NAMULLAN	8	5	25.4	1.2	5.3	0.04	0.00	0.01	5.8	1.17
L Foyle Summary										
Faughan	10431	3928				6.89	22.99	7.74	2.9	0.74
Roe	18510	6925				20.32	38.71	18.82	3.2	1.02
Burnfoot River	280	136				0.82	0.59	0.40	5.1	1.43
Muff River	180	86				0.65	0.45	0.32	6.1	1.80
L Foyle (County L'derry)	7125	2933				12.28	5.20	4.92	2.5	0.69

Table 6c Loadings from WWTWs in Co Donegal catchments of River Foyle and Lough Foyle.

Catchment	Town	Population Census	PE	NH4	NO3	DRP
				Tonnes $year^{-1}$		
Lough Foyle (Co. Donegal)						
	Greencastle	584	777			
	Moville	1301	1796			
	Muff	257	329			
	Total	2142	2902	6.7	0.6	1.5
River Foyle (Co. Donegal)						
	Lifford	1359	1880			
	Carrigans	218	277			
	St Johnstown	468	616			
	Total	2045	2773	6.4	0.5	1.4
Swilly Burn	Raphoe	1090	1492	1.8	1.9	0.7
River Deele	Convoy	911	1237	2.7	0.4	0.6
River Finn						
	Stranolar	2972	4261			
	Castlefinn	692	928			
	FinnView	75	91			
	Clady	376	490			
	Total	4115	5770	13.8	0.2	2.9

Table 7 Summary of industrial loadings from industry in Foyle catchments.

Note For Du Pont discharge to River Foyle the loading for Jun 2001 to May 2003 was used in the budgets

River	Industry	Ammonium N	Nitrate-N	DRP
		Tonnes year^{-1}		
Mourne				
	Fishfarms (6)	9.6	0.0	2.2
	Master Meats	7.3		Not given
	Nestle	0.7	1.9	0.7
	Strathroy Creamery	0.5	1.4	0.5
	TOTAL	18.0	3.3	3.5
Glenmornan				
	Artigarvan creamer	0.7	1.8	0.7
Carrigans Burn				
	Carrigans Meats	2.3	0.7	0.6
River Roe				
	Fish farm (1)	1.6	0.0	0.4
	Seagate	6.0	33.7	3.2
	TOTAL	7.6	33.7	3.6
River Faughan				
	Fish farm (1)	1.6	0.0	0.4
River Finn				
	Killygordon Creamery	0.3	0.8	0.2
River Foyle				
	Du Pont -periods			
	Jan 1993-Aug 1998	52.5	23.6	Not given
	Sept 1998 - May 2001	7.6	11.7	Not given
	Jun 2001 - May 2003	4.3	1.3	Not given

Table 8 Distribution of sewered human population within Foyle and Lough Foyle catchments. Values expressed as population equivalents (PE).

Basin/river	PE nos	R. Foyle %	L. Foyle %	Basin/river	PE nos	L. Foyle %
River Foyle				**LOUGH FOYLE**		
Mourne	59054	27.7	23.4	Faughan	10431	4.1
Finn	5770	2.7	2.3	Roe	18510	7.3
Burndennet	1752	0.8	0.7	Muff River	180	0.1
Deele Donegal	1237	0.6	0.5	Burnfoot River	280	0.1
Swilly Burn	1492	0.7	0.6	Faughanvale R.	0	0.0
Carrigans	0	0.0	0.0	L Foyle DD	10027	4.0
Glenmornan R.	731	0.3	0.3			
R Foyle DD	143003	67.1	56.6			
R Foyle Total	213040	100	84.4	L Foyle total	252468	100

Figure 1 River Mourne nitrate and ammonium data.

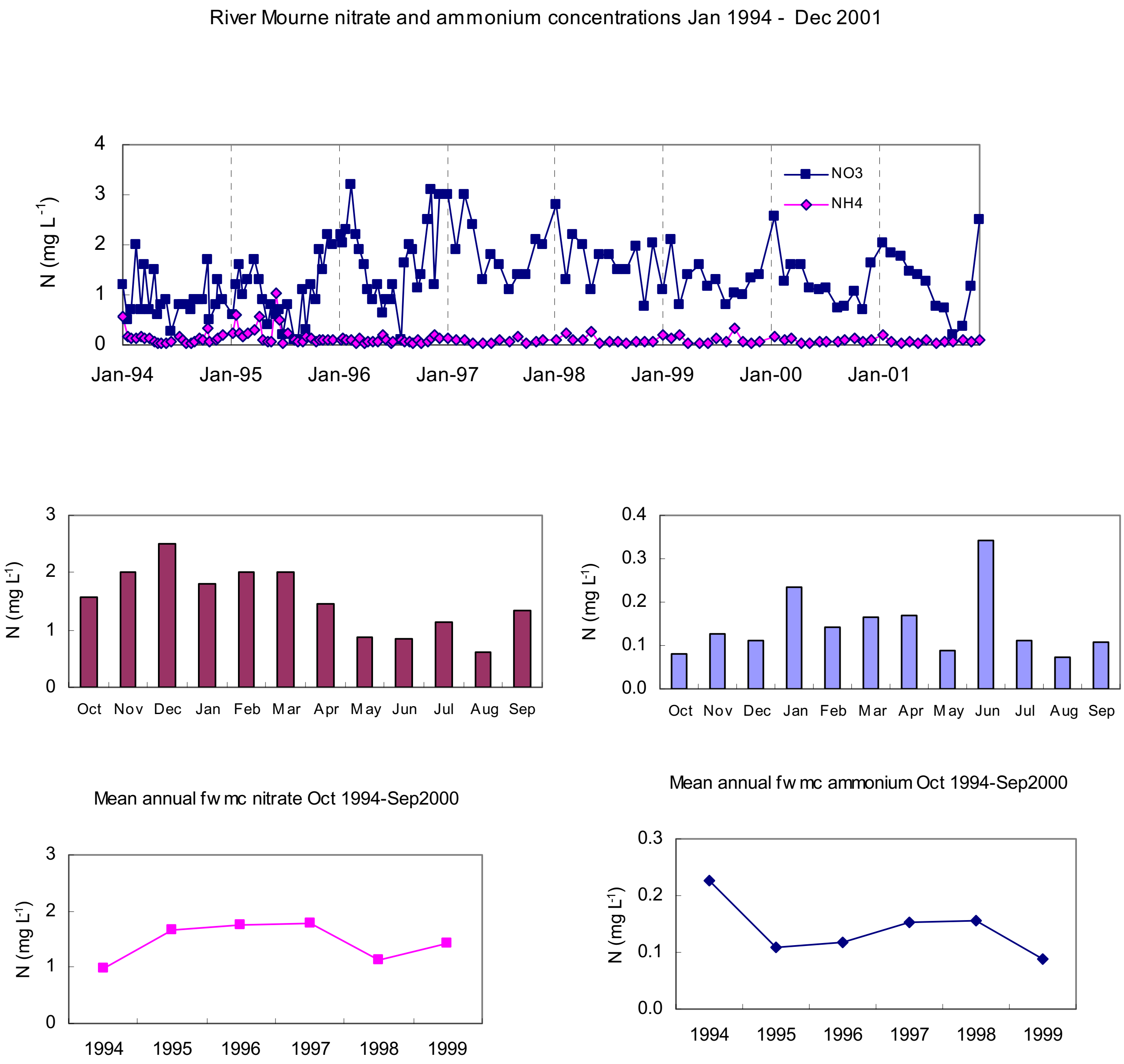


Figure 2 River Finn nitrate and ammonium data.

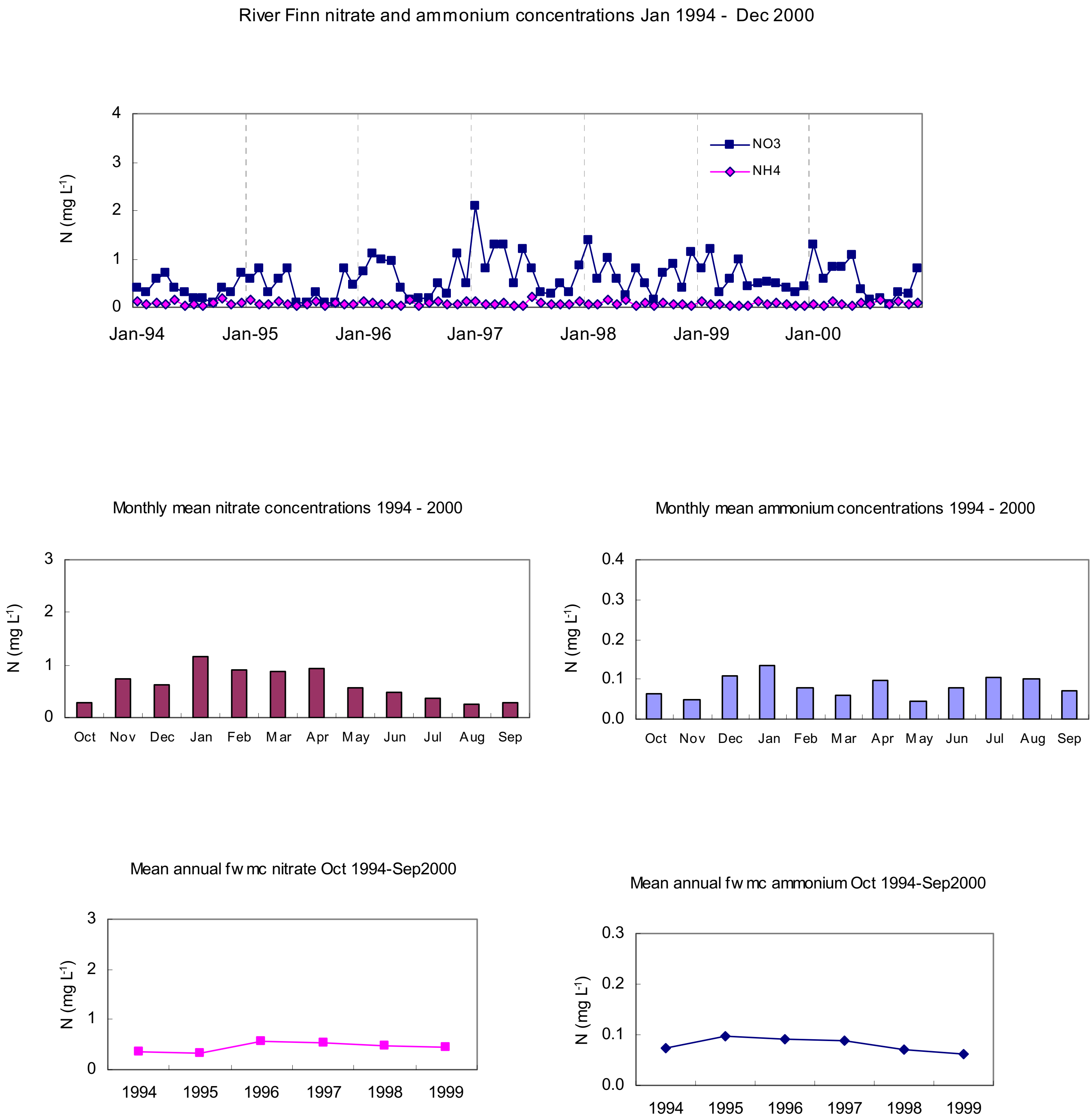
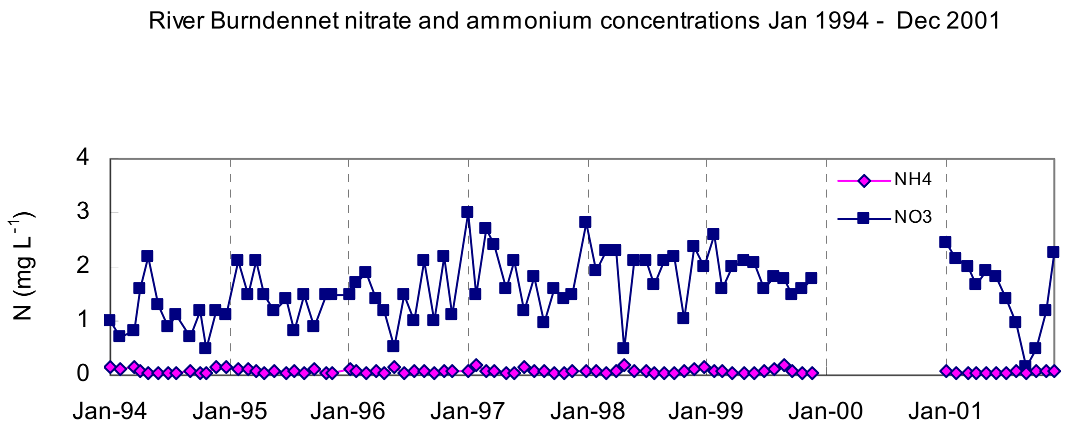
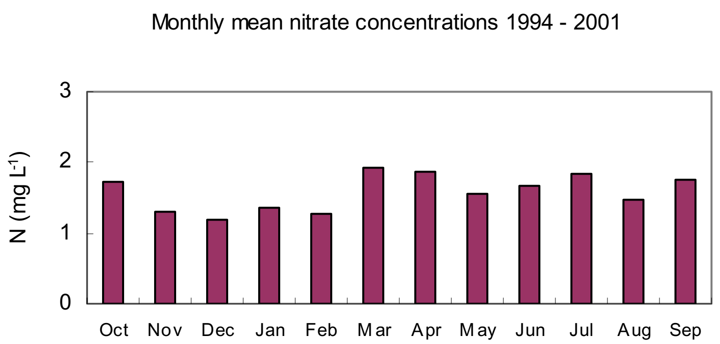
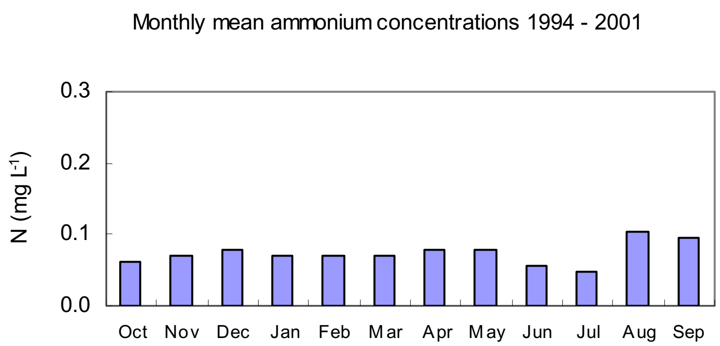
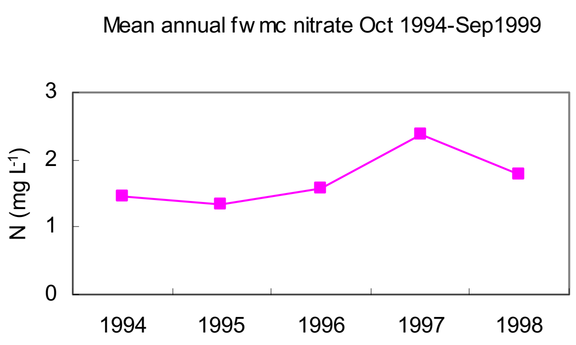


Fig3 Burndennet nitrate and ammonium data.









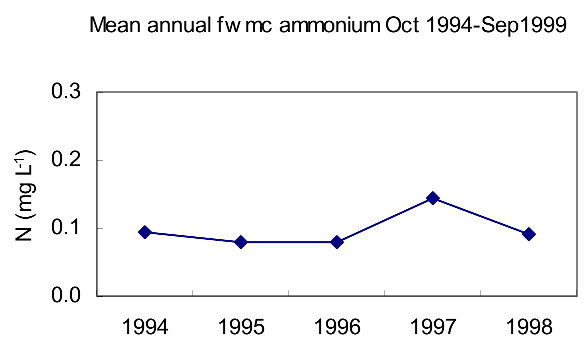
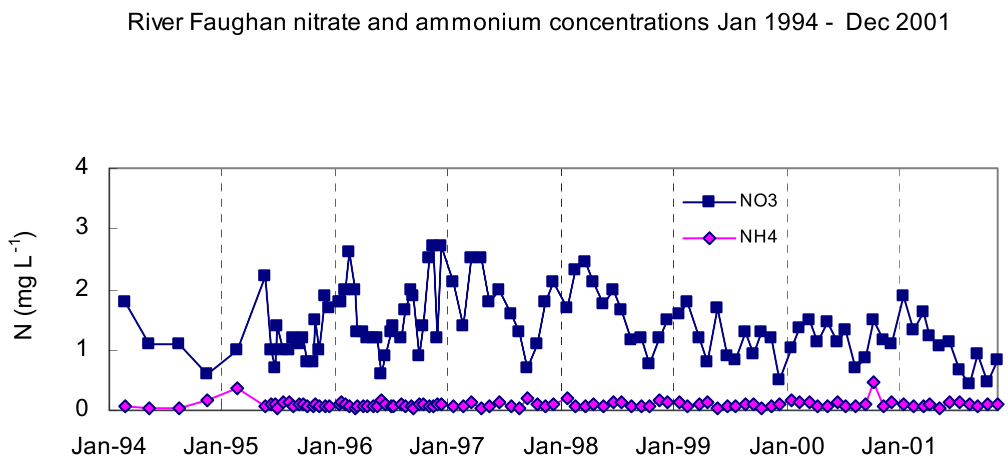
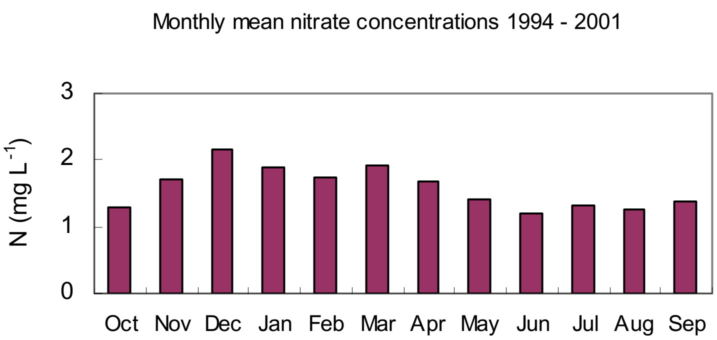
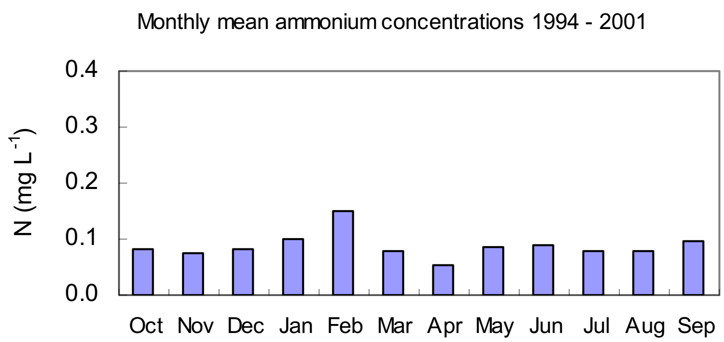
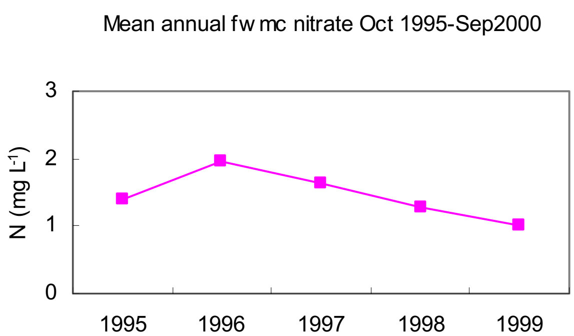


Figure 4 Faughan nitrate and ammonium data.









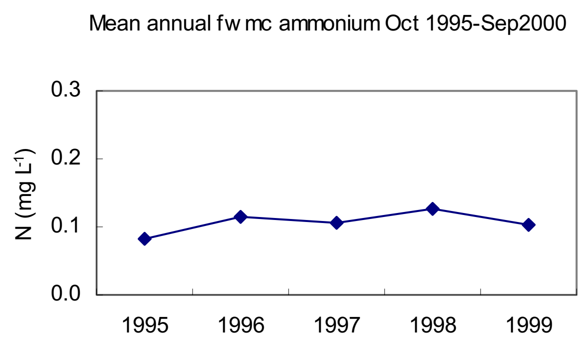
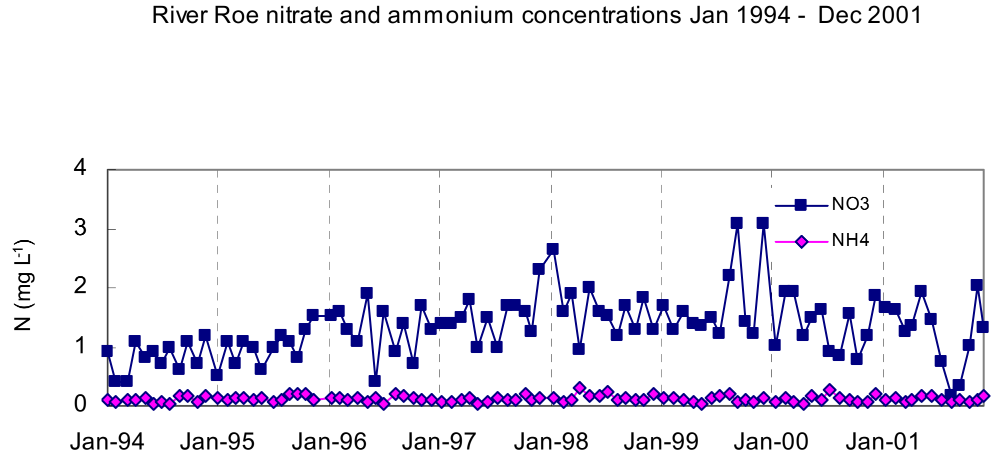
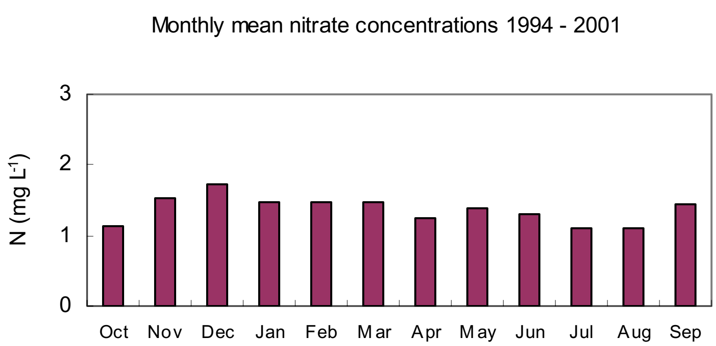
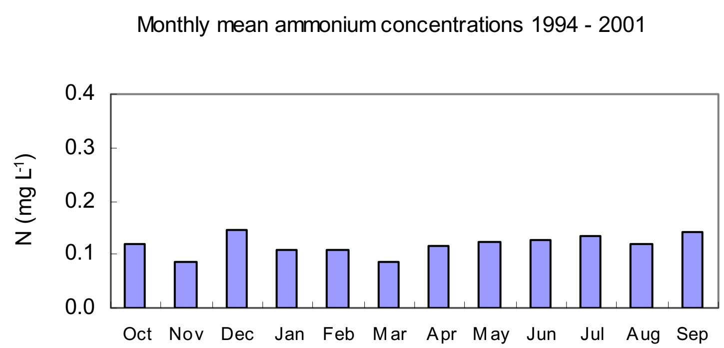
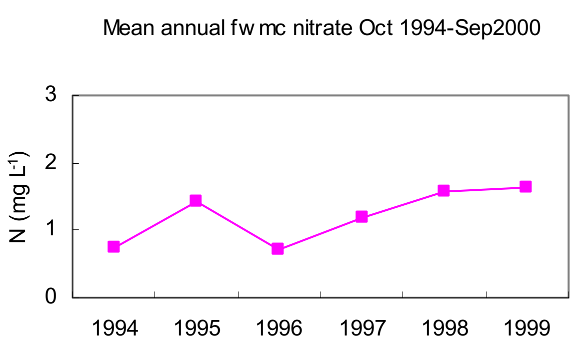


Figure 4 River Roe nitrate and ammonium data.









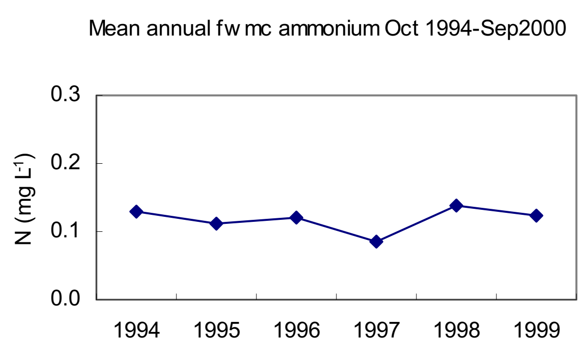
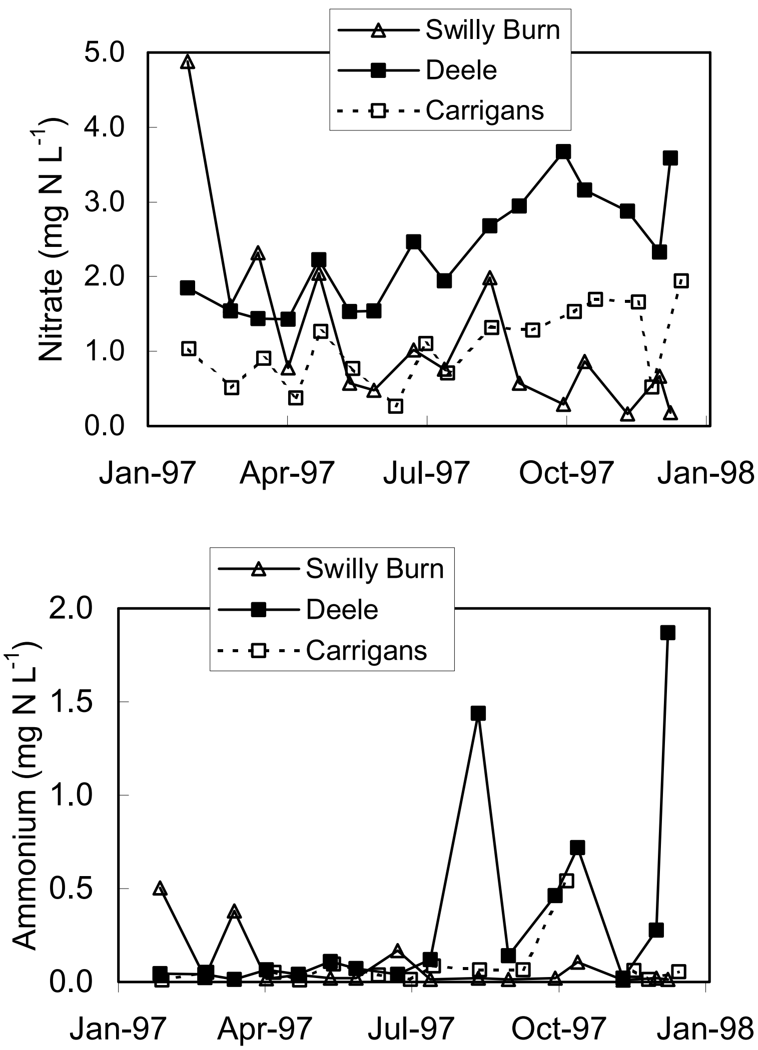


Figure 5 Nitrate and ammonium concentrations for the Deele, Swilly Burn and Carrigans Rivers.



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Appendix A-2 Lower Bann

As set out in Chapter 3, nutrient inputs in the Lower Bann are dominated by drainage from Lough Neagh, which flows into the Lower Bann at Toome. The final section of the river downstream of The Cuts is tidal. This section also contains the largest town in the catchment, Coleraine, which has a population that substantially exceeds the sum of all other towns and villages. In contrast the direct drainage area downstream of The Cuts represents only a small percentage (9%) of the river drainage area.

Map A2 Lower Bann catchment

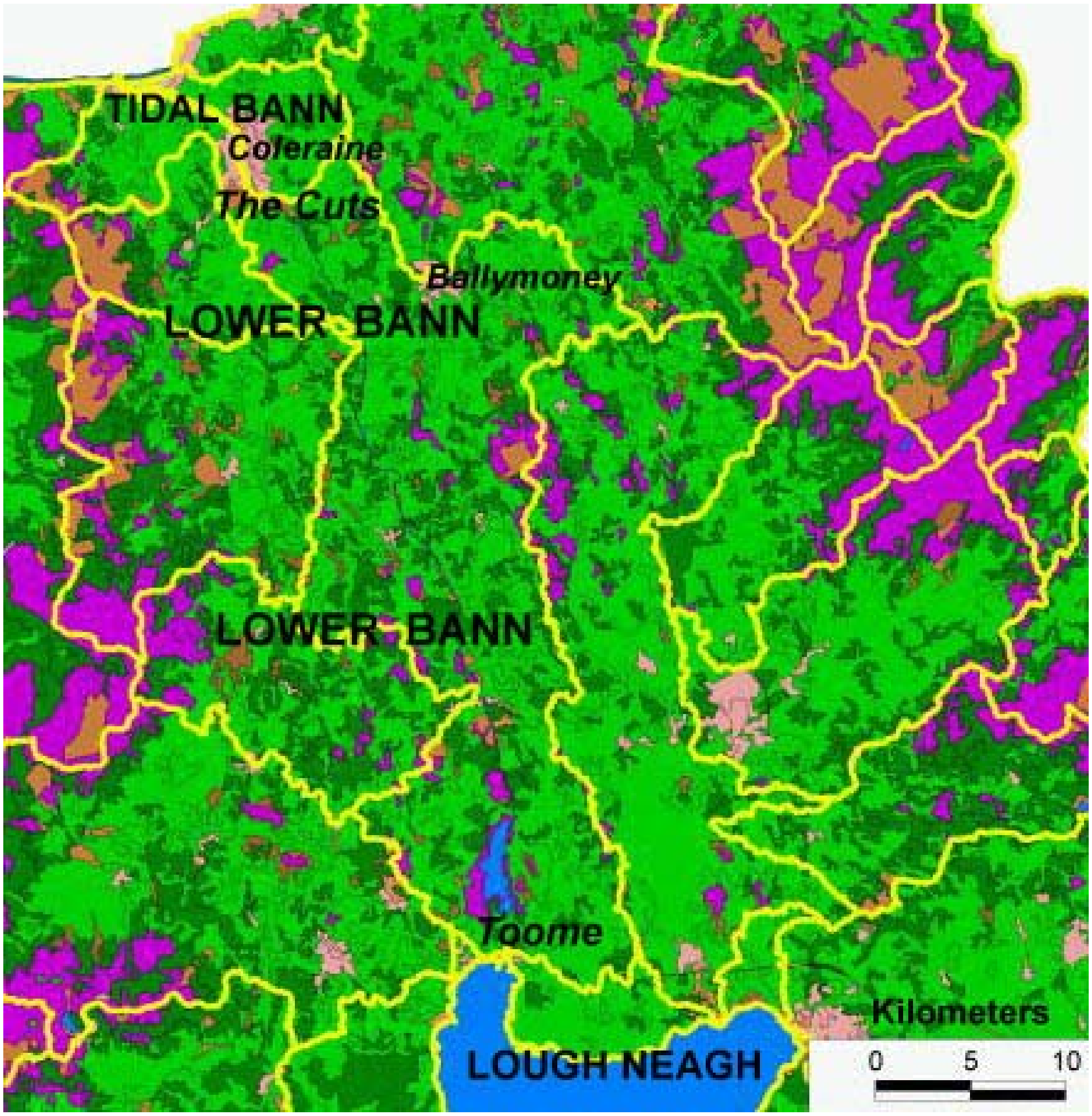


Table 1 River sampling locations, catchment areas, runoff and nitrate (NO3), ammonium (NH4) and dissolved reactive phosphorus (DRP) nutrient losses for rivers in Lower Bann. Nutrient losses for Lower Bann calculated by difference between loadings at The Cutts, which is the tidal limit of Lower Bann, and source of Lower Bann at Toome where Lower Bann exits from Lough Neagh

River	Sampling point	Grid ref	Area	Runoff	Loss rate[2]			Catchment loss[2]		
				mm	NO3	NH4	DRP	NO3	NH4	DRP
			km^2	yr^{-1}	tonnes km^{-2} yr^{-1}			tonnes yr^{-1}		
Lower Bann	The Cuts	C855303	5276	0.586	0.71	0.07	0.057	3735	344	302.4
Lower Bann	Toome Bridge	H989908	4449	0.575	0.51	0.04	0.063	2253	197	280.8
Lower Bann (By difference Cutts less Toome			827	0.641	1.79	0.18	0.026	1482	147	21.5

Table 2 Land use in sub-catchments of Lower Bann. Area of Lough Neagh land catchment included under 'Other land'

	Urban-industrial	Arable	Grass	Agric land	Rough grazing	Forest	Other land	Area Total
			% area					km^2
Lower Bann at The Cutts	1.0	2.7	79.6	82.3	8.9	6.2	1.6	835
Lower Bann (Tidal)	12.7	6.4	69.0	75.4	3.1	7.1	1.7	87
Lower Bann all	2.1	3.1	78.6	81.7	8.4	6.3	1.6	922
Lower Bann including catchment of Lough Neagh	0.4	0.5	13.5	14.0	1.4	1.1	83.1	5371

Table 3 Nitrate loading sources to Lower Bann. Loading from Lough Neagh included under 'Other land'

	Urban	Rough grazing	For-estry	Other land	Agric land	Nitrification	Total
			Nitrate tonnes N year^{-1}				
EXCLUDING LOUGH NEAGH							
Bann at Cutts	87.3	14.9	10.3	4.3	1379.1	0.0	1496
Tidal Bann	14.0	0.5	1.2	2.5	132.1	0.0	150
Lower Bann total	101.3	15.4	11.6	6.8	1511.3	0.0	1646
%	6.2	0.9	0.7	0.4	91.8	0.0	100
INCLUDING LOUGH NEAGH							
Bann at Cutts	87.3	14.9	10.3	2257.5	1379.1	0.0	3749
Tidal Bann	14.0	0.5	1.2	2.5	132.1	0.0	150
Lower Bann total	101.3	15.4	11.6	2260.0	1511.3	0.0	3900
%	2.6	0.4	0.3	58.0	38.8	0.0	100

Table 4 Ammonium loading sources to Lower Bann. Note Loading from Lough Neagh included under 'Other land'

	Urban	Rough grazing	Forestry	Other land	Agric land	Other	Total
			Ammonium tonnes N $year^{-1}$				
EXCLUDING LOUGH NEAGH							
Bann at Cutts	17.1	2.2	1.6	0.6	34.3	92.5	148
Tidal Bann	37.2	0.1	0.2	0.4	3.3	0.0	41
Lower Bann total	54.3	2.3	1.7	1.0	37.6	92.5	189
%	28.7	1.2	0.9	0.5	19.9	48.8	100
INCLUDING LOUGH NEAGH							
Bann at Cutts	17.1	2.2	1.6	0.6	34.3	289.5	345
Tidal Bann	37.2	0.1	0.2	0.4	3.3	0.0	41
Lower Bann total	54.3	2.3	1.7	1.0	37.6	289.5	387
%	14.1	0.6	0.4	0.3	9.7	74.9	100

Table 5 Dissolved reactive phosphorus loading sources to Lower Bann. Loading from Lough Neagh included under ‘Other land’

	Urban	Rough grazing	Forestry	Other land	Agric land	Total
		Dissolved reactive P tonnes P $year^{-1}$				
EXCLUDING LOUGH NEAGH						
Bann at Cutts	18.3	0.6	0.8	0.5	1.3	21.5
Tidal Bann	12.4	0.0	0.1	0.3	0.1	12.9
Lower Bann total	30.6	0.6	0.9	0.9	1.4	34.4
%	88.9	1.8	2.7	2.5	4.1	100.0
INCLUDING LOUGH NEAGH						
Bann at Cutts	18.3	0.6	0.8	281.4	1.3	581.9
Tidal Bann	12.4	0.0	0.1	0.3	0.1	12.8
Lower Bann total	30.6	0.6	0.9	281.7	1.4	315.3
%	9.7	0.2	0.3	89.3	0.4	100.0

Table 6 (part 1 of 3) Loadings from WWTWs in Lower Bann catchment. Loading from Coleraine enters downstream of freshwater water quality sampling point at Cutts.

Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
	Nos.	$m^3\ d^{-1}$	$mg\ L^{-1}$			$tonnes\ year^{-1}$			$kg\ year^{-1}$	
COLERAINE	32000	10403	9.8	3.7	3.3	37.19	13.99	12.36	1.6	0.39
BALLYMONEY	6900	2512	1.9	12.0	4.2	1.78	11.04	3.82	1.9	0.55
GARVAGH	1876	752	0.6	13.3	4.1	0.17	3.66	1.12	2.0	0.60
KILREA	1847	741	3.8	12.6	6.2	1.02	3.41	1.68	2.4	0.91
P'GLENONE	1416	579	5.3	13.1	5.1	1.12	2.76	1.08	2.7	0.76
RASHARKIN	1276	526	2.8	12.0	4.2	0.54	2.31	0.81	2.2	0.64
ARTICLAVE	1000	420	4.4	15.9	6.3	0.68	2.43	0.97	3.1	0.97
MACOSQUIN	1000	420	2.3	10.7	5.6	0.35	1.63	0.86	2.0	0.86
TOOME	737	316	8.1	12.4	7.2	0.94	1.43	0.83	3.2	1.12
SWATRAGH	616	268	10.4	10.0	6.6	1.01	0.98	0.64	3.2	1.04
ARTIGARVAN	570	249	8.4	19.2	8.8	0.76	1.75	0.80	4.4	1.40
BALNAMORE	539	237	5.4	10.7	3.9	0.46	0.93	0.34	2.6	0.62
GULLADUFF	274	127	7.6	9.2	5.0	0.35	0.43	0.23	2.8	0.85
GLENONE	255	118	15.3	6.3	9.6	0.66	0.27	0.41	3.7	1.62
CLAREHILL	217	102	2.7	12.8	3.6	0.10	0.48	0.13	2.7	0.61
BENDOORAGH	189	90	6.1	20.1	7.2	0.20	0.66	0.24	4.5	1.25
KILLYRAMMER	186	88	17.3	6.0	6.7	0.56	0.20	0.22	4.1	1.16
INNISHRUSH	166	80	9.9	18.2	7.0	0.29	0.53	0.20	4.9	1.22
UPPERLANDS	152	73	12.2	6.5	6.4	0.33	0.17	0.17	3.3	1.13
MONEYGLASS	150	72	2.1	21.2	5.6	0.06	0.56	0.15	4.1	0.98
CULNADY	149	72	7.3	13.4	6.5	0.19	0.35	0.17	3.7	1.14
BELLANEY	146	71	10.6	13.7	7.0	0.27	0.35	0.18	4.3	1.24
MAYBOY	145	70	3.5	20.1	5.9	0.09	0.52	0.15	4.2	1.05
MACFIN	143	69	19.7	6.1	7.8	0.50	0.15	0.20	4.6	1.39
KILROSS	138	67	3.0	9.3	4.9	0.07	0.23	0.12	2.2	0.86
W'FOOT RD	125	61	4.5	12.7	4.4	0.10	0.28	0.10	3.1	0.78
T' O'CRILLY	116	57	3.1	11.6	5.4	0.07	0.24	0.11	2.6	0.98
KNOCKANS	107	53	4.1	9.7	6.2	0.08	0.19	0.12	2.5	1.11
CULCROW	98	49	6.9	22.5	10.1	0.12	0.40	0.18	5.3	1.84
MULLANS	96	48	3.7	13.0	6.1	0.06	0.23	0.11	3.0	1.11
SEACON	95	47	29.1	1.5	9.2	0.50	0.03	0.16	5.6	1.67
BROCKABUOY	95	47	4.7	17.1	3.4	0.08	0.30	0.06	4.0	0.62
MONEYDIG	76	39	2.9	12.0	3.6	0.04	0.17	0.05	2.8	0.67
DEMPSEY PK.	73	37	14.0	6.2	7.5	0.19	0.08	0.10	3.8	1.40

Table 6 (part 2 of 3) Loadings from WWTWs in Lower Bann catchment. Loading from Coleraine enters downstream of freshwater water quality sampling point at Cutts.

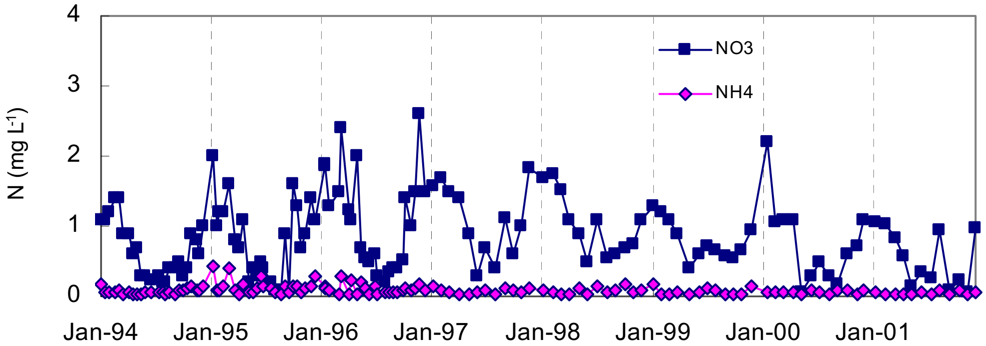
Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
	nos.	$m^3\ d^{-1}$		$mg\ L^{-1}$			tonnes $year^{-1}$		kg $year^{-1}$	
DRUMAHISKEY	70	36	10.3	9.7	5.9	0.13	0.13	0.08	3.7	1.09
BOVEEDY	63	32	0.6	10.7	4.8	0.01	0.13	0.06	2.1	0.89
BALLYHOLME	62	32	9.2	12.8	9.1	0.11	0.15	0.11	4.1	1.72
LONGSGLEBE	62	32	17.9	1.5	3.8	0.21	0.02	0.04	3.7	0.71
DONDOOAN	58	30	41.1	0.0	7.4	0.45	0.00	0.08	7.8	1.41
B'RNQUARTER	52	27	24.2	1.0	7.1	0.24	0.01	0.07	4.8	1.36
BALLYLINTAGH	51	27	3.2	15.3	10.1	0.03	0.15	0.10	3.5	1.93
LISNAMUCK	50	26	4.2	8.8	3.5	0.04	0.08	0.03	2.5	0.68
NOONVALE	50	26	7.2	9.2	7.4	0.07	0.09	0.07	3.1	1.42
BALLYCORR G.	50	26	31.7	3.5	14.1	0.30	0.03	0.13	6.7	2.70
BEAGH	46	24	3.4	24.3	4.5	0.03	0.21	0.04	5.3	0.87
ROSNASHANE	46	24	10.2	21.3	13.9	0.09	0.19	0.12	6.1	2.67
DONNELLY PK.	40	21	18.9	0.5	3.9	0.15	0.00	0.03	3.8	0.76
AIRD	40	21	1.9	14.8	3.5	0.02	0.11	0.03	3.2	0.69
COLDAGH	38	20	35.7	6.6	12.3	0.26	0.05	0.09	8.2	2.39
TROMARA	37	20	3.8	9.7	3.1	0.03	0.07	0.02	2.6	0.60
LISMOYLE	32	17	3.6	7.9	5.5	0.02	0.05	0.03	2.3	1.08
LISNAMUCK	28	15	1.0	13.6	3.2	0.01	0.08	0.02	2.9	0.64
GORTEREGHY	28	15	3.3	5.9	2.9	0.02	0.03	0.02	1.8	0.57
ROCKTOWN	27	15	20.4	13.6	8.1	0.11	0.07	0.04	6.8	1.63
C'NAGREE	26	14	4.8	9.2	3.3	0.02	0.05	0.02	2.8	0.65
BALLINTEER	25	14	0.6	10.9	3.3	0.00	0.05	0.02	2.3	0.66
FISHLOUGHAN	25	14	3.6	7.7	2.2	0.02	0.04	0.01	2.3	0.44
COOLGLEBE	24	13	3.0	8.3	2.1	0.01	0.04	0.01	2.3	0.43
K'NATAVANNA	24	13	24.6	9.2	7.1	0.12	0.04	0.03	6.8	1.42
TOBERKEIGH	24	13	16.0	23.5	16.7	0.08	0.11	0.08	8.0	3.37
BALLYNEESE	23	13	16.8	14.3	5.9	0.08	0.07	0.03	6.3	1.19
GARRYDUFF	20	11	21.8	18.1	7.9	0.09	0.07	0.03	8.2	1.61
KILLOGUE	20	11	12.9	2.6	5.8	0.05	0.01	0.02	3.2	1.18
AUGHAGASH	20	11	26.7	7.3	7.7	0.11	0.03	0.03	7.0	1.57
DR'MAGARNER	19	11	2.1	9.7	2.3	0.01	0.04	0.01	2.4	0.46
BALLYAGAN	18	10	7.7	6.0	2.4	0.03	0.02	0.01	2.8	0.50
DARTRESS	17	10	22.9	1.1	4.4	0.08	0.00	0.02	5.0	0.90
C'REAGH	17	10	7.4	17.5	10.7	0.03	0.06	0.04	5.1	2.22
RITCHIE VS	16	9	3.1	6.3	5.1	0.01	0.02	0.02	2.0	1.05
MANAGHER	15	9	4.6	19.4	5.6	0.01	0.06	0.02	5.0	1.18

Table 6 (part 3 of 3) Loadings from WWTWs in Lower Bann catchment. Loading from Coleraine enters downstream of freshwater water quality sampling point at Cutts.

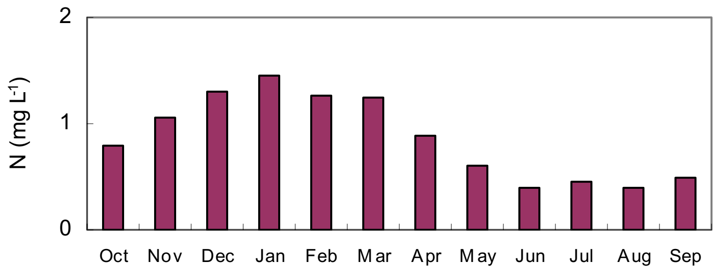
Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Tot. N	DRP
	nos.	$m^3\ d^{-1}$	mg L^{-1}			tonnes $year^{-1}$			kg $year^{-1}$	
AIKENS T'N P'S	14	8	15.5	2.3	5.6	0.05	0.01	0.02	3.7	1.18
MONEYCARRIE	14	8	3.5	19.0	3.0	0.01	0.06	0.01	4.7	0.63
G'NMAKEERAN	13	8	17.1	11.3	11.9	0.05	0.03	0.03	6.0	2.51
NAVERY RD	12	7	14.9	9.1	7.5	0.04	0.02	0.02	5.1	1.59
COOLKEERAN	8	5	2.6	7.6	3.4	0.00	0.01	0.01	2.2	0.75
BALLYVEELY	7	4	37.7	0.7	13.4	0.06	0.00	0.02	8.5	2.95
DUNGORBERY	7	4	27.1	8.6	14.4	0.04	0.01	0.02	7.9	3.17
GLASSMULLAN	7	4	15.4	8.5	5.2	0.02	0.01	0.01	5.3	1.14
DRUMCROONE	6	4	2.0	5.3	4.2	0.00	0.01	0.01	1.6	0.93
MCCLEARY	6	4	27.3	2.7	13.5	0.04	0.00	0.02	6.7	3.01
Lower Bann to Cutts	22325	9286				17	41.68	18.27	2.6	0.82
Lower Bann downstream Cutts	32000	10403				37.19	13.99	12.36	1.6	0.39
Lower Bann total	54325	19689				54.33	55.67	30.63	2.0	0.56

Fig 1 Nitrate and ammonium concentrations on Lower Bann at The Cutts

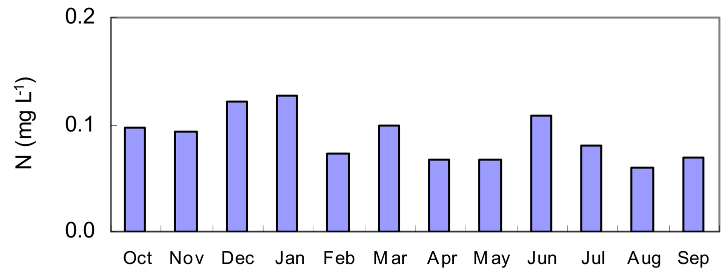
Cutts nitrate and ammonium concentrations Jan 1994 - Dec 2001



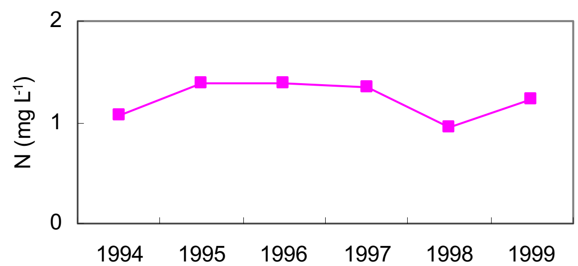
Monthly mean nitrate concentrations 1994 - 2001



Monthly mean ammonium concentrations 1994 - 2001



Mean annual fw mc nitrate Oct 1994-Sep2000



Mean annual fw mc ammonium Oct 1994-Sep2000

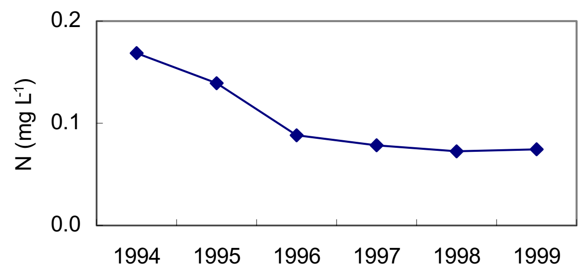
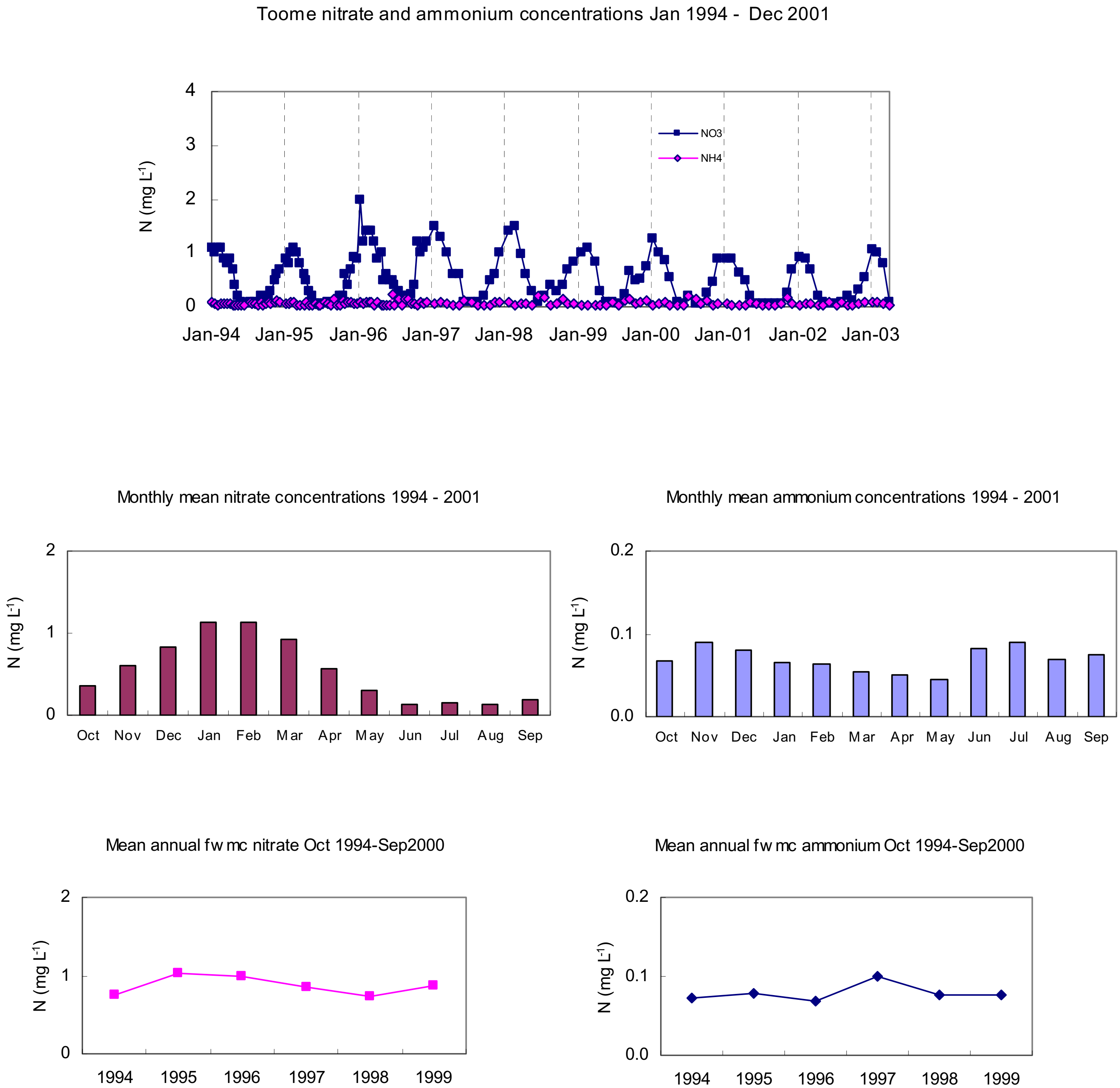


Fig 2 Nitrate and ammonium concentrations on Lower Bann at Toome



Appendix A3 Nutrient budgets for Tidal Lagan, Inner Belfast Lough and Outer Belfast Lough.

The River Lagan is the only monitored river in these drainage basin. It dorms 85% of drainage of Lagan system and also represents the dominant freshwater input to Belfast Lough. However, the cumulative direct drainage area becomes more important for Inner Belfast Lough (28%) and Outer Belfast Lough (38%). Both the tidal Lagan and Belfast Lough catchments are heavily urbanised. The freshwater Lagan receives high WWTW of DRP from Lisburn and the southern suburbs of Belfast.

Map A3 Map of river Lagan and Belfast Lough

Table 1 River sampling location, catchment areas, runoff and nitrate (NO3), ammonium (NH4) and dissolved reactive phosphorus (DRP) nutrient losses for freshwater portion of River Lagan.

River	Sampling point	Grid ref	Area	Runoff	Loss rate[2]			Catchment loss[2]		
				mm	NO3	NH4	DRP	NO3	NH4	DRP
			km^2	yr^{-1}	tonnes km^{-2} yr^{-1}			tonnes yr^{-1}		
Lagan	Shaw's Br	J325690	499.6	0.540	2.14	0.13	0.283	1070	63.7	141.4

Table 2 Land use in the tidal Lagan and Inner and Outer Belfast Lough catchments. Totals for Inner and Outer Belfast Lough includes contribution from Tidal Lagan

	Urban-industrial	Arable	Grass	Agric land	Rough grazing	Forest	Other land	Area Total
				% area				km^2
Lagan – freshwater	9.9	5.2	82.4	87.6	0.9	0.8	0.7	499.6
Lagan – tidal	75.6	0.3	21.5	21.8	2.4	0.3	0.0	92.3
Inner Belfast Lough	30.3	0.2	58.3	58.5	0.5	10.2	0.6	103.7
Outer Belfast Lough	34.3	3.0	60.3	63.3	0.5	1.6	0.2	108.9
Tidal Lagan Total	20.2	4.5	72.9	77.3	1.2	0.7	0.6	591.9
Inner Belfast Lough Total	21.7	3.8	70.7	74.5	1.0	2.1	0.6	695.6
Outer Belfast Lough Total	23.4	3.7	69.3	73.0	1.0	2.1	0.6	804.5

Table 3 Breakdown of annual nitrate loading to the Tidal Lagan and Inner and Outer Belfast Lough catchments. Two sets of data are given, the second including the contribution from Irish Fertiliser Industries plant in Belfast

Totals for Inner and Outer Belfast Lough includes contribution from Tidal Lagan.

	Industry	Urban	Rough grazing	For-estry	Other land	Agric land	Total
			Nitrate tonnes N $year^{-1}$				
TIDAL LAGAN							
Freshwater input		223.2	0.9	0.8	10.6	833.9	1070
Tidal inputs		0.0	0.4	0.1	13.9	38.3	53
Total		223.2	1.4	0.9	24.6	872.3	1122
%		19.9	0.1	0.1	2.2	77.7	100
INNER BELFAST LOUGH							
Direct drainage		75.8	0.1	2.1	6.4	115.6	200
Total		299.1	1.5	3.0	31.0	987.8	1322
%		22.6	0.1	0.2	2.3	74.7	100
OUTER BELFAST LOUGH							
Direct drainage		5.1	0.1	0.4	7.5	131.4	145
Total		304.2	1.6	3.3	38.5	1119.2	1467
%		20.7	0.1	0.2	2.6	76.3	100
INCLUDING IRISH FERTILISER INDUSTRIES							
TIDAL LAGAN							
Freshwater input		223.2	0.9	0.8	10.6	833.9	1070
Tidal inputs	979.8	0.0	0.4	0.1	13.9	38.3	1033
Total	979.8	223.2	1.4	0.9	24.6	872.3	2102
%	46.6	10.6	0.1	0.0	1.2	41.5	100
INNER BELFAST LOUGH							
Direct inputs	0.0	75.8	0.1	2.1	6.4	115.6	200
Total	979.8	299.1	1.5	3.0	31.0	987.8	2302
%	42.6	13.0	0.1	0.1	1.3	42.9	100
OUTER BELFAST LOUGH							
Direct inputs	0.0	5.1	0.1	0.4	7.5	131.4	145
Total	979.8	304.2	1.6	3.3	38.5	1119.2	2447
	40.0	12.4	0.1	0.1	1.6	45.7	100

Table 4 Breakdown of annual ammonium loading to the Tidal Lagan and Inner and Outer Belfast Lough catchments. Two sets of data are given, the second including the contribution from Irish Fertiliser Industries plant in Belfast
Totals for Inner and Outer Belfast Lough includes contribution from Tidal Lagan.

	Industry	Urban	Rough grazing	Forestry	Other land	Agric land	Other	Total
			Ammonium tonnes N $year^{-1}$					
TIDAL LAGAN								
Freshwater input		28.1	0.1	0.1	1.6	21.9	11.9	52
Tidal inputs			0.1	0.0	2.1	1.0		3
Total		28.1	0.2	0.1	3.7	22.9	11.9	55
%		51.1	0.4	0.2	6.7	41.6	21.6	100
INNER BELFAST LOUGH								
Direct drainage								
Total		344.0	0.0	0.3	1.0	3.0	0.0	348
%		372.1	0.2	0.4	4.7	25.9	11.9	403
		92.3	0.1	0.1	1.2	6.4	2.9	100
OUTER BELFAST LOUGH								
Direct drainage		365.8	0.0	0.1	1.1	3.4	0.0	370
Total		737.9	0.2	0.5	5.8	29.4	11.9	774
%		95.4	0.0	0.1	0.7	3.8	1.5	100
INCLUDING IRISH FERTILISER INDUSTRIES								
TIDAL LAGAN								
Freshwater input		28.1	0.1	0.1	1.6	21.9	11.9	52
Tidal inputs	2184.8	0.0	0.1	0.0	2.1	1.0		2188
Total	2184.8	28.1	0.2	0.1	3.7	22.9	11.9	2252
%	97.0	1.2	0.0	0.0	0.2	1.0	0.5	100
INNER BELFAST LOUGH								
Direct inputs	0.0	344.0	0.0	0.3	1.0	3.0	0.0	348
Total	2184.8	372.1	0.2	0.4	4.7	25.9	11.9	2600
%	84.0	14.3	0.0	0.0	0.2	1.0	0.5	100
OUTER BELFAST LOUGH								
Direct inputs	0.0	365.8	0.0	0.1	1.1	3.4	0.0	370
Total	2184.8	737.9	0.2	0.5	5.8	29.4	11.9	2970
	73.5	24.8	0.0	0.0	0.2	1.0	0.4	100

Table 5 Breakdown of annual dissolved reactive phosphorus loadings to Tidal Lagan and Inner and Outer Belfast Lough catchments. Two sets of data are given, the second including the contribution from Irish Fertiliser Industries plant in Belfast
Totals for Inner and Outer Belfast Lough includes contribution from Tidal Lagan.

	Industry	Urban	Rough grazing	Forestry	Other land	Agric land	Total
		Dissolved reactive phosphorus tonnes P year^{-1}					
TIDAL LAGAN							
Freshwater input		93.7	0.0	0.1	1.3	46.3	141
Tidal inputs		0.0	0.0	0.0	1.7	31.0	33
Total		93.7	0.1	0.1	3.1	77.2	174
%		53.8	0.0	0.0	1.8	44.3	100
INNER BELFAST LOUGH							
Direct drainage							
Total		107.6	0.0	0.2	0.8	6.4	115
%		201.3	0.1	0.2	3.9	83.6	289
		69.6	0.0	0.1	1.3	28.9	100
OUTER BELFAST LOUGH							
Direct drainage		56.7	0.0	0.0	0.9	7.3	65
Total		258.0	0.1	0.3	4.8	90.9	354
%		72.9	0.0	0.1	1.4	25.7	100
INCLUDING IRISH FERTILISER INDUSTRIES							
TIDAL LAGAN							
Freshwater input	0.0	93.7	0.0	0.1	1.3	46.3	141
Tidal inputs	193.8	0.0	0.0	0.0	1.7	31.0	227
Total	193.8	93.7	0.1	0.1	3.1	77.2	368
%	52.7	25.5	0.0	0.0	0.8	21.0	100
INNER BELFAST LOUGH							
Direct inputs	0.0	107.6	0.0	0.2	0.8	6.4	115
Total	193.8	201.3	0.1	0.2	3.9	83.6	483
%	40.1	41.7	0.0	0.0	0.8	17.3	100
OUTER BELFAST LOUGH							
Direct inputs	0.0	56.7	0.0	0.0	0.9	7.3	65
Total	193.8	258.0	0.1	0.3	4.8	90.9	548
	35.4	47.1	0.0	0.0	0.9	16.6	100

Table 6a Loadings from WWTWs in tidal Lagan catchment.

River/ Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Total N	DRP
	nos.	$m^3 d^{-1}$	mg L^{-1}			Tonnes $year^{-1}$			kg $year^{-1}$	
N'TOWNBREDA	27650	9086	0.4	14.5	4.7	1.33	48.13	15.58	1.8	0.56
DUNMURRY	44518	14125	0.3	14.0	6.4	1.58	71.94	32.99	1.7	0.74
NEW HOLLAND	38004	12199	0.3	13.3	5.0	1.40	59.16	22.25	1.6	0.59
MOIRA	6027	2216	2.9	14.2	8.4	2.32	11.45	6.83	2.3	1.13
DROMORE	4801	1795	11.0	1.6	2.4	7.20	1.07	1.57	1.7	0.33
WARINGSTOWN	3317	1274	6.8	15.4	7.3	3.15	7.15	3.40	3.1	1.03
HILLSBOROUGH	3000	1161	4.2	12.9	5.4	1.79	5.46	2.29	2.4	0.76
DRUMBEG	2070	823	1.3	14.3	5.0	0.38	4.31	1.50	2.3	0.73
ANNAHILT	1600	649	3.8	6.6	5.4	0.90	1.56	1.27	1.5	0.79
MAGHABERRY	1420	581	3.0	11.1	4.2	0.64	2.35	0.90	2.1	0.63
MAGHERALIN	1233	510	3.7	15.5	6.3	0.69	2.89	1.16	2.9	0.94
DROMARA	900	381	2.5	5.1	2.9	0.35	0.72	0.41	1.2	0.45
RAVERNETTE	730	314	10.4	14.4	6.7	1.19	1.65	0.77	3.9	1.05
GRAVEL HILL	455	202	3.8	7.5	3.7	0.28	0.56	0.27	1.8	0.59
EDENDERRY	405	182	10.8	8.8	5.5	0.72	0.59	0.37	3.2	0.91
MULL'GLASS 1	250	116	6.5	14.0	6.4	0.27	0.59	0.27	3.5	1.09
MULL'GGLASS 2	250	116	2.6	22.4	7.6	0.11	0.95	0.32	4.2	1.29
POUNDBURN	225	105	4.2	11.8	3.8	0.16	0.45	0.15	2.7	0.65
MULLAGHGLASS	224	105	18.5	1.9		0.71	0.07		3.5	
MONEYSLANE	185	88	11.0	6.1		0.35	0.20		3.0	
KINALLEN	183	87	9.8	10.9		0.31	0.35		3.6	
BLACKSKULL	156	75	4.1	22.5	9.3	0.11	0.62	0.26	4.7	1.64
WARINGSFORD	150	72	11.5	3.0	4.0	0.30	0.08	0.11	2.5	0.71
DRUMLOUGH	140	68	16.7	3.8	5.3	0.41	0.10	0.13	3.6	0.94
BALLINADOLLY	135	66	15.5	6.9	7.2	0.37	0.17	0.17	4.0	1.27
LEGACURRY	120	59	10.4	10.8	5.6	0.22	0.23	0.12	3.8	1.01
DRUMNAFERRY	106	52	12.7	0.9		0.24	0.02		2.5	
ST. JAMES	100	50	2.6	17.2	6.7	0.05	0.31	0.12	3.6	1.22
BALLYCAIRN	50	26	39.7	1.9	9.8	0.38	0.02	0.09	7.9	1.87
BRESAGH	30	16	6.4	5.6	2.4	0.04	0.03	0.01	2.4	0.48
C'NASASONAGH	20	11	8.3	10.5	3.5	0.03	0.04	0.01	3.8	0.71
B'MACORMICK	19	11	2.3	9.7		0.01	0.04		2.5	
C'NAVEAGH	15	9	19.0	2.6	5.4	0.06	0.01	0.02	4.5	1.13
Tidal Lagan	138488	46630				28.1	223.2	93.7	1.8	0.68

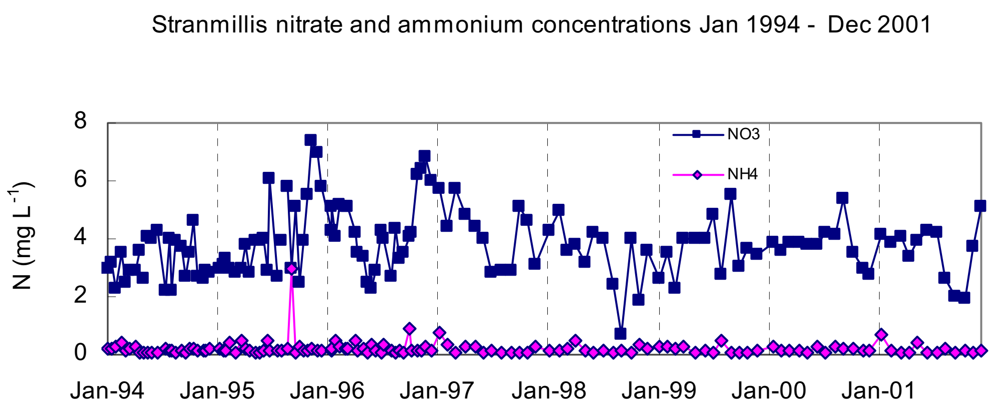
Table 6b Loadings from WWTWs in Inner and Outer Belfast Lough catchments. Totals given are cumulative and include loading from tidal Lagan.

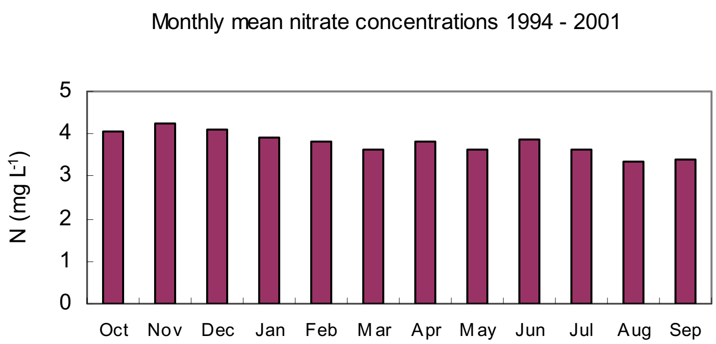
	PE	Flow	Concentration			Loading			Per capita	
River/ Name			NH4	NO3	DRP	NH4	NO3	DRP	Total N	DRP
	nos.	$m^3\ d^{-1}$	mg L^{-1}			tonnes $year^{-1}$			kg $year^{-1}$	
Inner Belfast Lough										
BELFAST WWTW	117500	34707	5.6	3.2	3.2	70.4	41.0	40.4	0.9	0.34
KINNEGAR	108130	32136	13.8	2.0	3.3	161.9	23.8	38.9	1.7	0.36
WHITEHOUSE	65010	20059	15.3	1.5	3.9	111.7	11.0	28.3	1.9	0.43
Outer Belfast Lough										
BRIGGS ROCK	75160	22944	33.5	0.0		280.9	0.00		3.7	
C'FERGUS	19480	6569	21.6	1.1	5.1	51.8	2.7	12.26	2.8	0.63
BLACKARCH SO	6390	2339	24.2	1.2		20.6	1.0		3.4	
Subtotals										
Outer Belfast L.	106555	34000				365.8	5.1	56.7	3.5	0.63
Inner Belfast L.	290640	86902				344.0	75.8	107.6	1.4	0.37
Totals										
Tidal Lagan	138488	46630				28.1	223.2	93.7	1.8	0.68
Inner Belfast L.	429128	133532				372.1	299.1	201.3	1.6	0.47
Outer Belfast L.	535683	167532				737.9	304.2	258.0	1.9	0.48

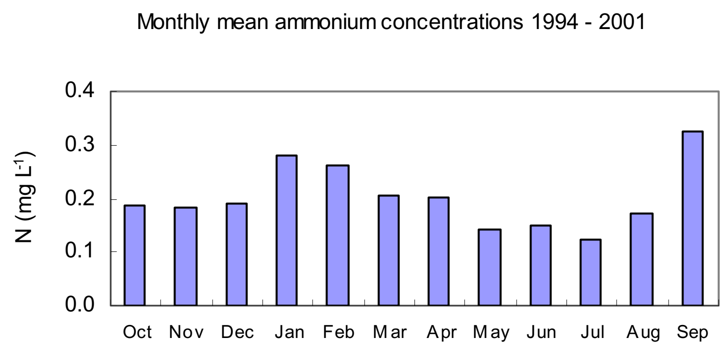
Table 7 Loading of ammonium, nitrate and phosphate from IFI plant to tidal Lagan 1994-2001.

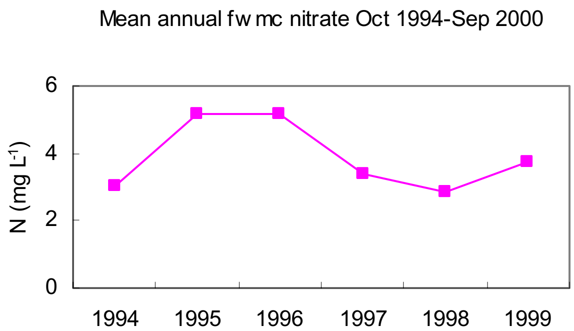
Year	Ammonium-N	Nitrate-N	Phosphate-P
		tonnes $year^{-1}$	
1994	3180	1423	na
1995	3603	1702	na
1996	1896	675	151
1997	2030	745	101
1998	2396	922	141
1999	1934	881	312
2000	1198	756	224
2001	1241	734	234

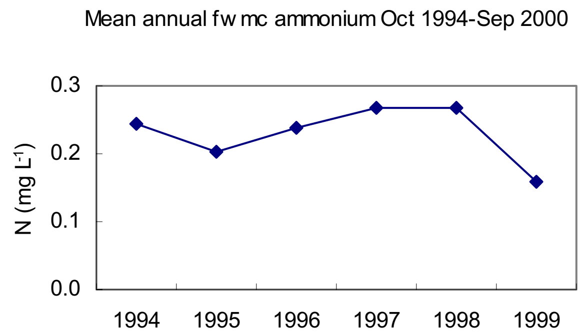
Fig 1. Nitrate and ammonium concentration in Lagan at Stranmillis.











Appendix A4 Nutrient loadings for Quoile Pondage and Strangford Lough.

The budgets for the Quoile Pondage and Strangford Lough are combined as the River Quoile is the largest river in both catchments. Its drainage area at Quoile Bridge represents 87% of the drainage area of the Quoile Pondage and 40% of the drainage are of Strangford Lough. The Quoile sampling point at Quoile Bridge also captures the inputs from all towns in the Quoile Basin, including Downpatrick.

There are only two further rivers that drain into Strangford: the Enler and Blackwater River. Both are small and in total drain only 19% of the Strangford drainage area. The direct drainage area for the Strangford catchment is therefore large representing 41% of the drainage basin. This area includes the largest WWTWs from Newtownards, Comber and Killyleagh. Comber. Both the Enler and Strangford Lough direct drainage area have unusually high for Northern Ireland proportions of arable. The analysis of loadings in Chapter 3 suggests that this does not result in a disproportionately high nitrate or DRP inputs in comparison to grassland.

Map A4 Map of Quoile and Strangford Lough catchments

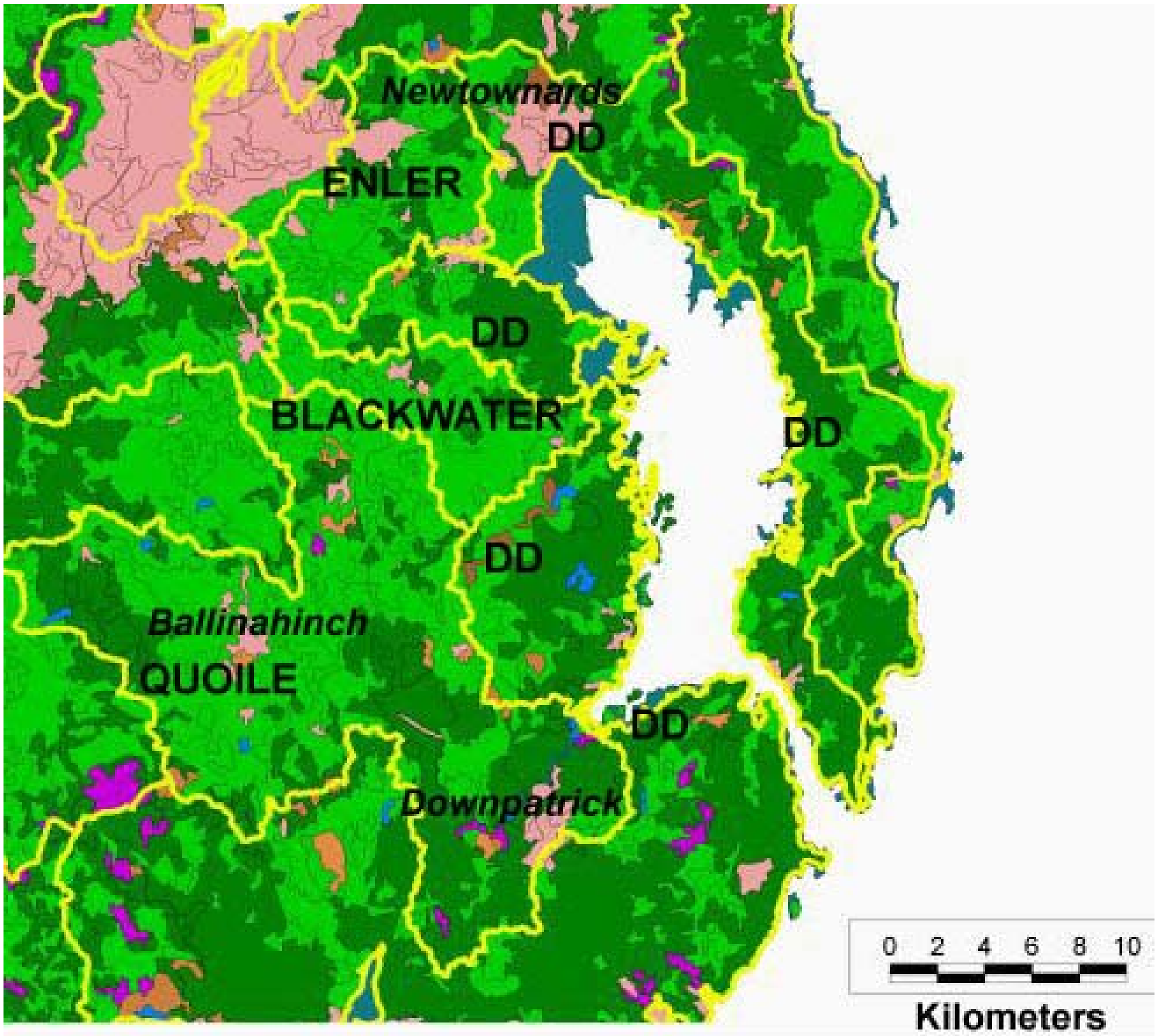


Table 1 River sampling locations, catchment areas, runoff and nitrate (NO3), ammonium (NH4) and dissolved reactive phosphorus (DRP) nutrient losses for rivers in Quoile and Strangford Lough catchments.

River	Sampling point	Grid ref	Area	Runoff	Loss rate[2]			Catchment loss[2]		
				mm	NO3	NH4	DRP	NO3	NH4	DRP
			km^2	yr^{-1}	tonnes km^{-2} yr^{-1}			tonnes yr^{-1}		
QUOILE										
Quoile	Quoile Bridge	J488465	233.8	0.592	1.78	0.11	0.130	415	24.5	30.5
STRANGFORD LOUGH										
Enler	Kennel Bridge	J456699	62.7	0.371	1.76	0.08	0.082	110	5.1	5.1
Blackwater	Ballymartin Rd. Bridge	J503624	50.1	0.592[1]	1.93	0.12	0.128	97	5.9	6.4

1) River not gauged flows and Quoile runoff rate assumed.

2) Nutrient losses for nitrate, ammonium and dissolved reactive P expressed as tonnes of N or P.

Table 2 Land use in sub-catchments of Quoile and Strangford Lough. Note Strangford total includes area of Quoile.

	Urban-industrial	Arable	Grass	Agric land	Rough grazing	Forest	Other land	Area Total km^2
			% area					
QUOILE								
Quoile at Quoile Bridge	4.2	1.8	90.9	92.7	0.0	1.7	1.4	233.8
Quoile Pondage remainder	0.0	1.9	94.8	96.7	0.0	1.8	1.4	33.7
Quoile Total	3.6	1.8	91.4	93.2	0.0	1.7	1.4	267.5
STRANGFORD								
Enler	11.7	25.2	63.0	88.2	0.0	0.0	0.0	62.7
Blackwater	3.0	1.5	95.5	97.0	0.0	0.0	0.0	50.1
Strangford Direct drainage	5.8	12.2	78.6	90.8	0.3	2.9	0.2	207.4
Strangford total	5.2	8.0	84.2	92.2	0.1	1.8	0.7	587.6

Table 3 Nitrate loading sources to Quoile and Strangford Lough. Note Strangford total includes loading from Quoile.

	Urban	Rough grazing	For-estry	Other land	Agric land	Nitrification	Total
			Nitrate tonnes N $year^{-1}$				
QUOILE							
Quoile at Quoile Bridge	26.3	0.0	0.8	2.6	385.2	0.0	415
Quoile Direct drainage	0.0	0.0	0.1	0.1	58.0	0.0	58
Quoile total	26.3	0.0	0.9	2.7	443.2	0.0	473
%	5.6	0.0	0.2	0.6	93.7	0.0	100
STRANGFORD LOUGH							
Enler	0.7	0.0	0.0	1.5	108.0	0.2	110
Blackwater	2.0	0.0	0.0	0.3	94.4	0.0	97
Strangford Direct drainage	77.7	0.1	1.2	2.5	355.9	0.0	437
Strangford Total	106.7	0.1	2.1	7.0	1001.5	0.2	1118
%	9.5	0.0	0.2	0.6	89.6	0.0	100

Table 4 Ammonium loading sources to Quoile and Strangford Lough. Note Strangford total includes loading from Quoile.

	Urban	Rough grazing	Forestry	Other land	Agric land	Other	Nitrification	Total
	Ammonium tonnes N $year^{-1}$							
QUOILE								
Quoile at Quoile Bridge	8.5	0.0	0.1	0.4	10.8	4.7	0.0	25
Quoile Direct Drainage	0.0	0.0	0.0	0.0	1.6	0.0	0.0	2
Quoile total	8.5	0.0	0.1	0.4	12.5	4.7	0.0	26
%	32.5	0.0	0.5	1.5	47.6	17.9	0.0	100
STRANGFORD LOUGH								
Enler	2.4	0.0	0.0	0.2	2.8	0.0	-0.2	5
Blackwater	3.1	0.0	0.0	0.0	2.4	0.3	0.0	6
Strangford Direct Drainage	85.8	0.0	0.2	0.4	9.4	0.0	0.0	96
Strangford Total	99.7	0.0	0.3	1.0	27.1	5.0	-0.2	133
%	75.0	0.0	0.2	0.8	20.4	3.8	-0.2	100

Table 5 Dissolved reactive phosphorus loading sources to Quoile and Strangford Lough. Note Strangford total includes loading from Quoile.

	Urban	Rough grazing	Forestry	Other land	Agric land	Total
	Dissolved reactive P tonnes P $year^{-1}$					
QUOILE						
Quoile at Quoile Bridge	11.3	0.0	0.1	0.3	18.7	30.5
Quoile Direct Drainage	0.0	0.0	0.0	0.0	2.8	2.8
Quoile total	11.3	0.0	0.1	0.3	21.6	33.3
%	34.0	0.0	0.2	1.0	64.7	100.0
STRANGFORD LOUGH						
Enler	0.8	0.0	0.0	0.2	3.2	4.2
Blackwater	2.1	0.0	0.0	0.0	10.3	12.4
Strangford Direct Drainage	64.3	0.0	0.1	0.3	15.9	80.6
Strangford Total	78.5	0.0	0.2	0.9	51.0	130.5
%	60.1	0.0	0.1	0.7	39.1	100.0

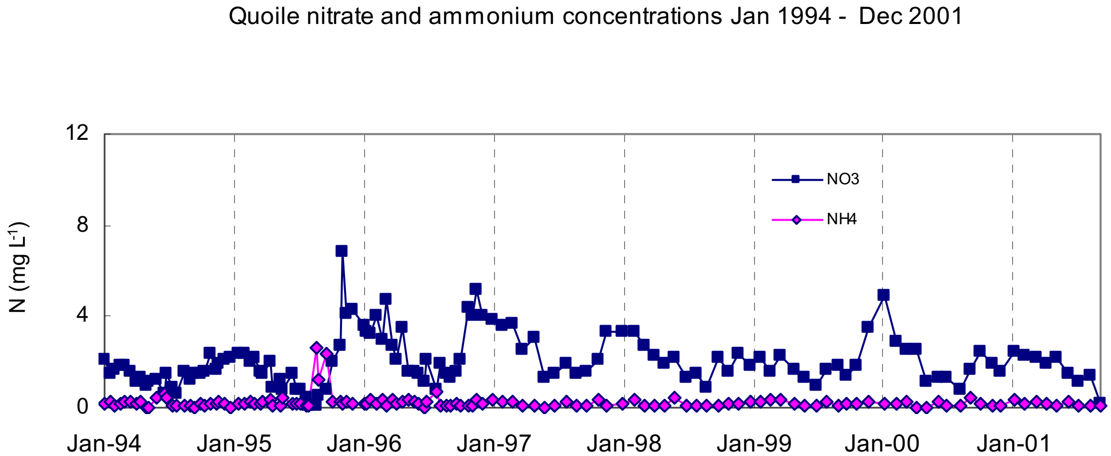
Table 6a Loadings from WWTWs in Quoile catchment. Loading 'ex Downpatrick refers to loading upstream of Quoile Pondage.

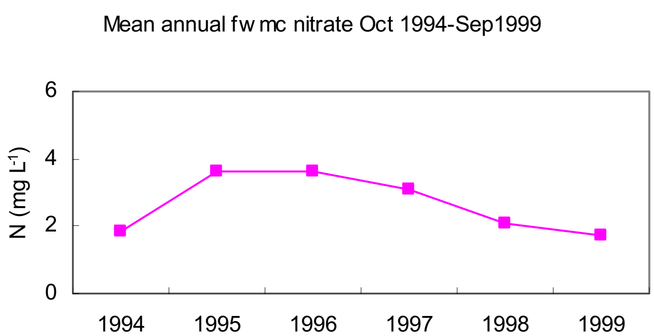
Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Total N	DRP
	nos.	$m^3\ d^{-1}$	mg L^{-1}			tonnes $year^{-1}$			kg $year^{-1}$	
DOWNPATRICK	8415	3019	0.7	11.7	4.5	0.73	12.84	5.00	1.6	0.59
B'NAHINCH	4490	1687	1.8	10.1	3.6	1.09	6.25	2.21	1.6	0.49
SAINTFIELD	2085	829	3.9	10.2	4.8	1.17	3.09	1.45	2.0	0.70
DRUMANESS	1419	580	7.2	11.7	5.9	1.53	2.48	1.25	2.8	0.88
CROSSGAR A.	1410	577	6.5	3.5	2.4	1.37	0.73	0.50	1.5	0.36
CROSSGAR F'R	940	396	9.4	4.7	3.6	1.36	0.68	0.53	2.2	0.56
SPA	540	237	9.8	2.1	3.4	0.85	0.18	0.30	1.9	0.55
ANNACLOY	240	112	9.3	1.5	2.5	0.38	0.06	0.10	1.8	0.43
G'DRUMMOND	20	11	6.1	5.2	2.2	0.03	0.02	0.01	2.3	0.45
Quoile R. ex. Downpatrick	11144	4430				7.78	13.49	6.34	1.9	0.57
Quoile total	19559	7449				8.51	26.33	11.34	1.8	0.58

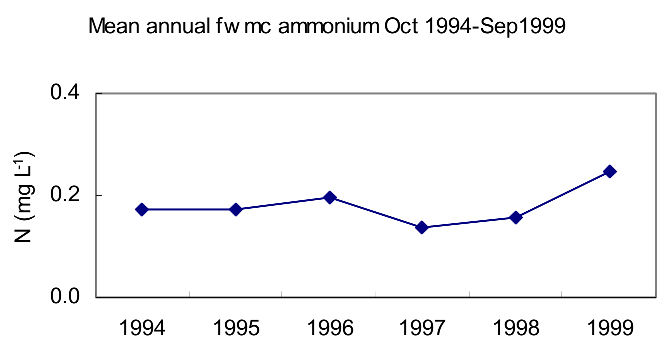
Table 6b Loadings from WWTWs in Strangford Lough catchment.

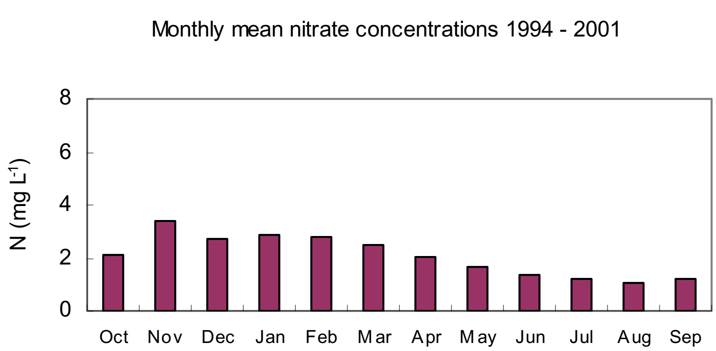
River/ Name	PE	Flow	Concentration			Loading			Per capita	
			NH4	NO3	DRP	NH4	NO3	DRP	Total N	DRP
	nos.	$m^3\ d^{-1}$	mg L^{-1}			tonnes $year^{-1}$			kg $year^{-1}$	
Blackwater River										
BALLYGOWAN	2675	1044	8.0	5.1	5.6	3.06	1.95	2.12	1.9	0.79
Comber River										
MONEYREAGH	1210	501	12.6	3.8	4.1	2.31	0.70	0.75	2.5	0.62
LESSANS	20	11	10.8	1.8	3.0	0.04	0.01	0.01	2.6	0.60
Strangford Direct Drainage										
B'RICKARD NEW	37125	11938	10.5	6.6	5.6	45.80	28.80	24.31	2.0	0.65
B'RICKARD OLD	22275	7437	7.9	7.4	5.4	21.47	19.97	14.66	1.9	0.66
KILLYLEAGH	13025	4524	1.7	13.8	3.5	2.81	22.86	5.82	2.0	0.45
KIRCUBBIN	1510	615	22.9	1.2	5.7	5.13	0.28	1.28	3.6	0.85
GREYABBEY	1500	611	13.9	5.4	5.1	3.09	1.21	1.14	2.9	0.76
STR'FORD 1	740	318	30.0	17.7	9.7	3.48	2.05	1.12	7.5	1.52
KILLINCHY	410	184	9.6	10.3	6.1	0.64	0.69	0.41	3.3	1.00
STR'FORD 2	370	167	19.3	3.5	5.9	1.18	0.21	0.36	3.8	0.97
WHITEROCK	341	155	11.3	4.7	3.9	0.64	0.27	0.22	2.7	0.64
LISBARNET	265	123	8.4	8.4	3.9	0.37	0.38	0.17	2.8	0.66
RAHOLP	265	123	10.9	6.5	6.4	0.49	0.29	0.29	2.9	1.09
LOUGHRIES	250	116	9.5	8.3	3.7	0.40	0.35	0.16	3.0	0.63
B'CRANBEG	150	72	5.4	9.9	3.5	0.14	0.26	0.09	2.7	0.62
KILMOOD	50	26	13.7	8.9	4.1	0.13	0.09	0.04	4.3	0.78
Quoile River	19559	7449				8.5	26.3	11.3	1.8	0.58
Blackwater R.	2675	1044				3.1	2.0	2.1	1.9	0.79
Comber R.	1230	512				2.4	0.7	0.8	2.5	0.62
Strangford DD	78276	26409				85.8	77.7	50.1	2.1	0.64
Strangford Total	101740	35414				99.7	106.7	64.3	2.0	0.63

Fig 1 Nitrate and ammonium concentration in Quoile River









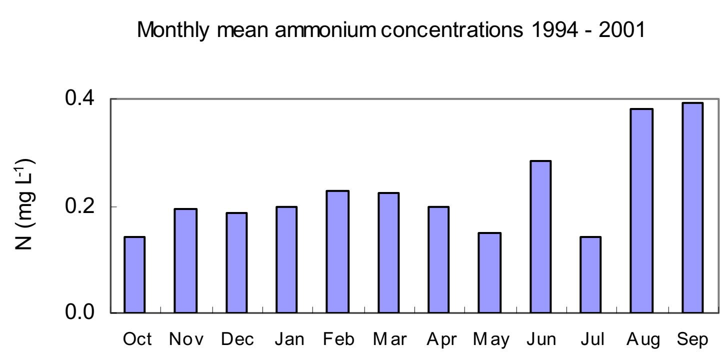


Fig 2 Nitrate and ammonium concentration in Enler River

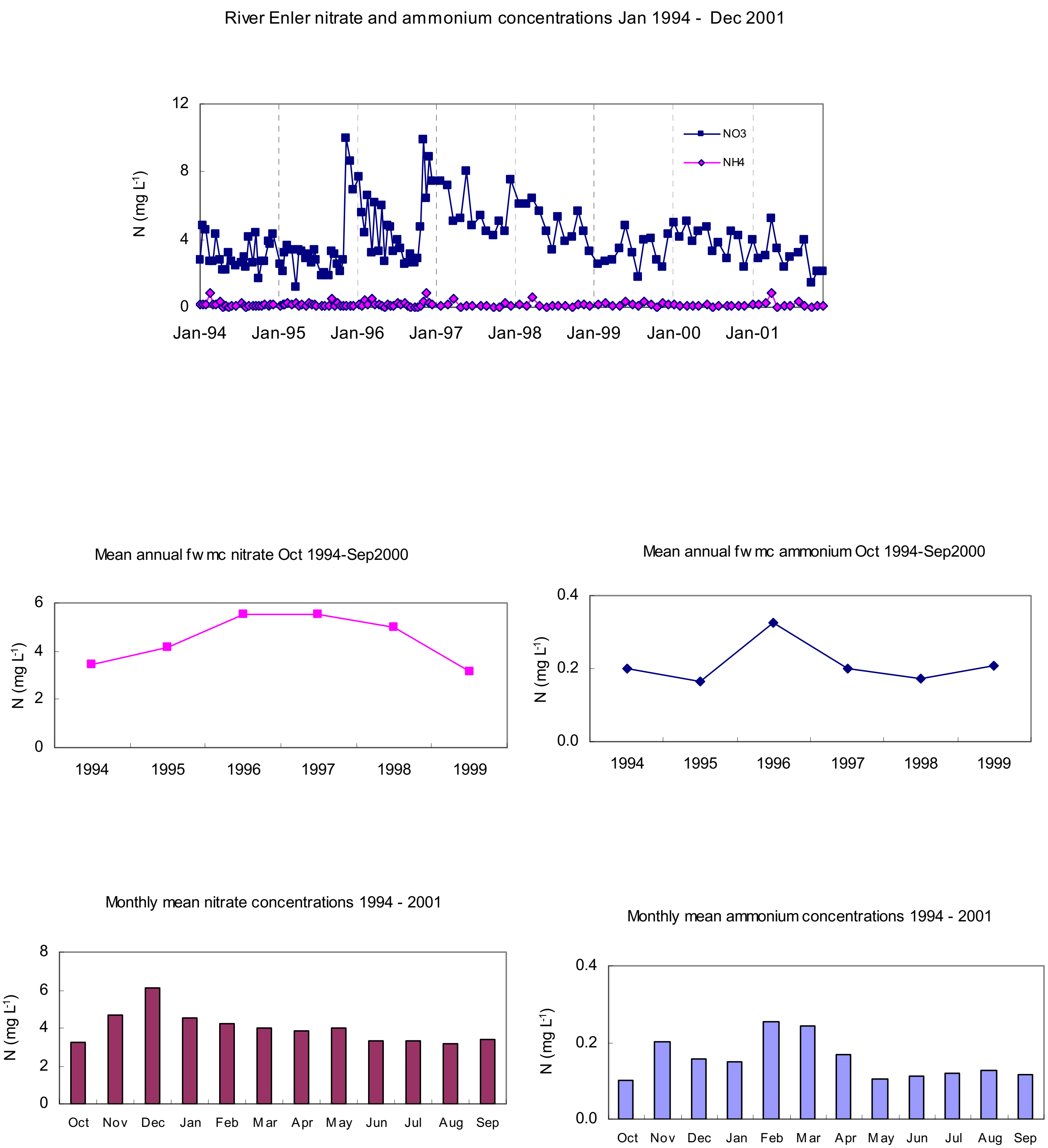
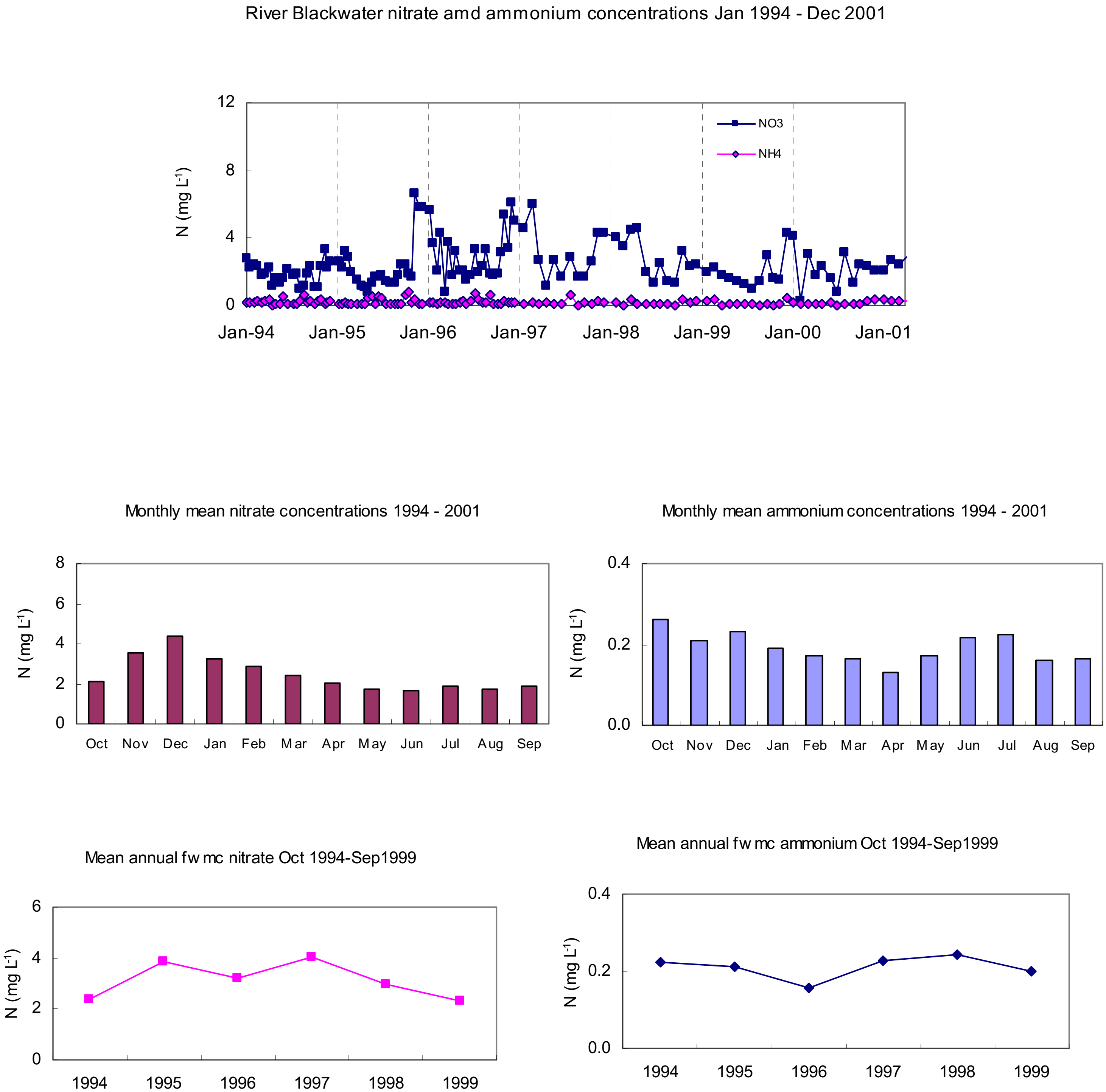


Fig 3 Nitrate and ammonium concentration in Blackwater River



Appendix A-5 Nutrient budgets for the Newry River.

The drainage basin the tidal portion of the River Newry is dominated by the Calorie (or Newry) River which is sampled at the freshwater limit. The catchment of the Clanrye is highly agricultural, with forms 94% of the drainage area leaving only small areas devoted other land classes. The arable component is small. It is noticeable that in 1995 and 1996, when summers were dry, winter nitrate concentrations in the Clanrye River ere high (Fig 1). The maximum of 9.8 mg N L^{-1}, which is equivalent to 43 mg NO_3 L^{-1} approached the 50 mg NO_3 L^{-1} limit for surface waters. It can also be seen from Figure 1 that this peak was not a random or isolated occurrence but formed part of a cycle of high winter concentrations that persisted over two winters.

The direct drainage area is small (10% of the drainage area) but contains the two largest towns, Newry and Warrenpoint. Their combined PE of 55k greatly exceeds the PE of 16K in the freshwater section of the catchment. The quality of the discharges from Newry and Warrenpoint is very poor and is dominated by ammonium. However as the catchment had the highest loss rates of nitrate, upgrading the quality of these WWTWs discharges so that ammonium was discharged as nitrate would not materially increase the nitrate load. It would however reduce direct pollution from these towns.

Map A5 Clanrye and Newry river catchment

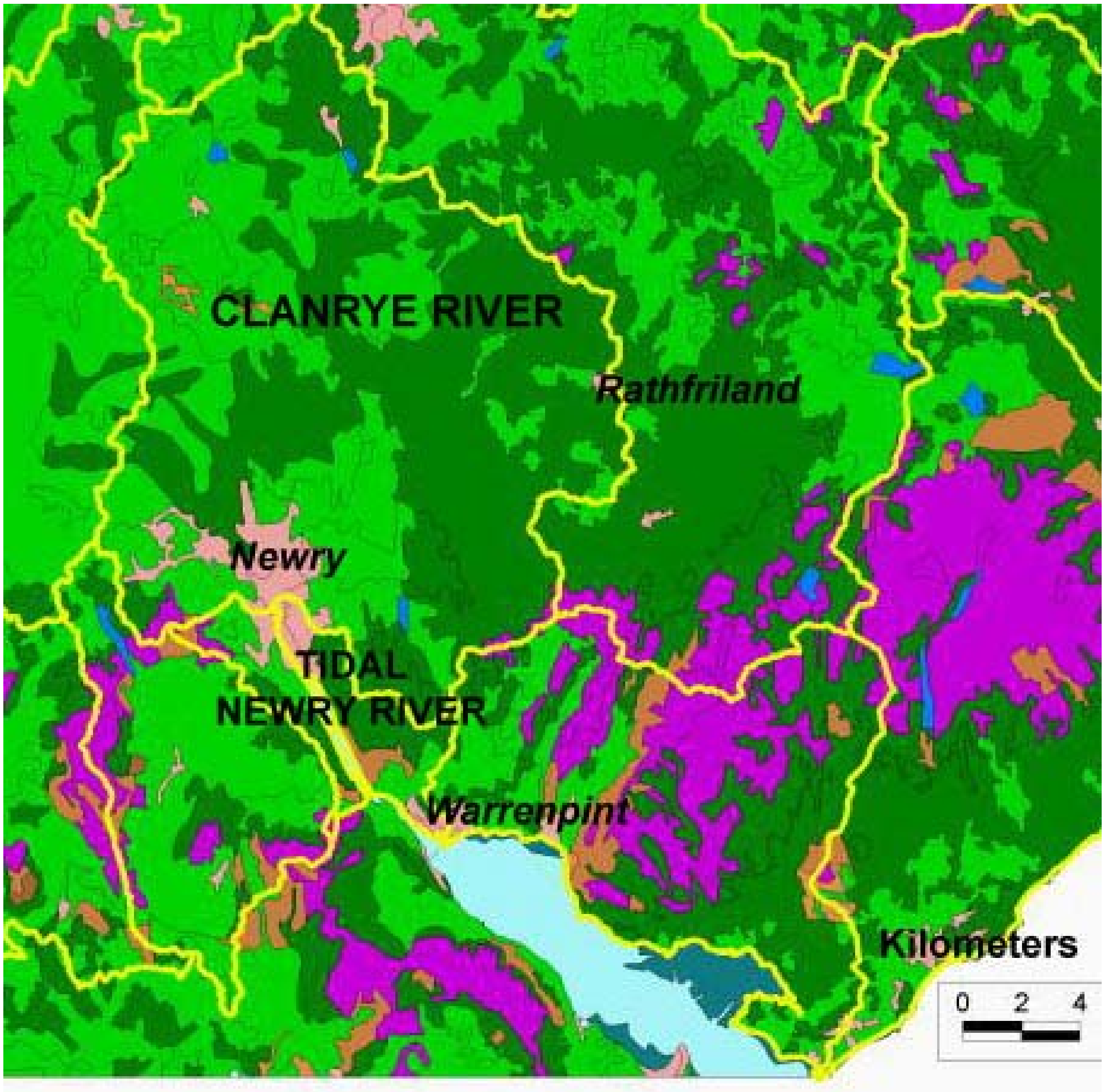


Table 1 River sampling location, catchment areas, runoff and nitrate (NO3), ammonium (NH4) and dissolved reactive phosphorus (DRP) nutrient losses for freshwater Newry River.

River	Sampling point	Grid ref	Area	Runoff	Loss rate[2]			Catchment loss[2]		
				mm	NO3	NH4	DRP	NO3	NH4	DRP
			km^2	yr^{-1}	tonnes km^{-2} yr^{-1}			tonnes yr^{-1}		
Newry River	Newry	J087267	274.9	0.503	2.37	0.04	0.086	653	11.1	23.6

Table 2 Land use in the Newry River catchments

	Urban-industrial	Arable	Grass	Agric land	Rough grazing	Forest	Other land	Area Total
				% area				km^2
Clanrye River	4.3	2.5	91.6	94.1	0.8	0.5	0.4	275
Newry River – tidal	17.8	0.8	68.5	69.3	3.9	9.0	0.0	29
Newry River Total	5.6	2.3	89.4	91.7	1.1	1.3	0.3	303

Table 3 Nitrate loadings to Newry River

	Urban	Rough grazing	For-estry	Other land	Agric land	Nitrif-ication	Total
			Nitrate tonnes N $year^{-1}$				
Clanrye River	12.8	0.5	0.3	2.5	631.1	5.8	653
Newry River Direct Inputs	6.2	0.2	0.5	1.0	48.3	0.0	56
Newry River Total	19.0	0.7	0.8	3.6	679.4	5.8	709
%	2.7	0.1	0.1	0.5	95.8	0.8	100

Table4 Ammonium loadings to Newry River

	Urban	Rough grazing	For-estry	Other land	Agric land	Nitrif-ication	Total
	Ammonium tonnes N $year^{-1}$						
Clanrye River	26.5	0.1	0.0	0.4	12.9	-5.8	34.2
Newry River Direct Inputs	102.3	0.0	0.1	0.2	1.0	0.0	103.5
Newry River Total	128.8	0.1	0.1	0.5	13.9	-5.8	137.7
%	93.5	0.1	0.1	0.4	10.1	-4.2	100.0

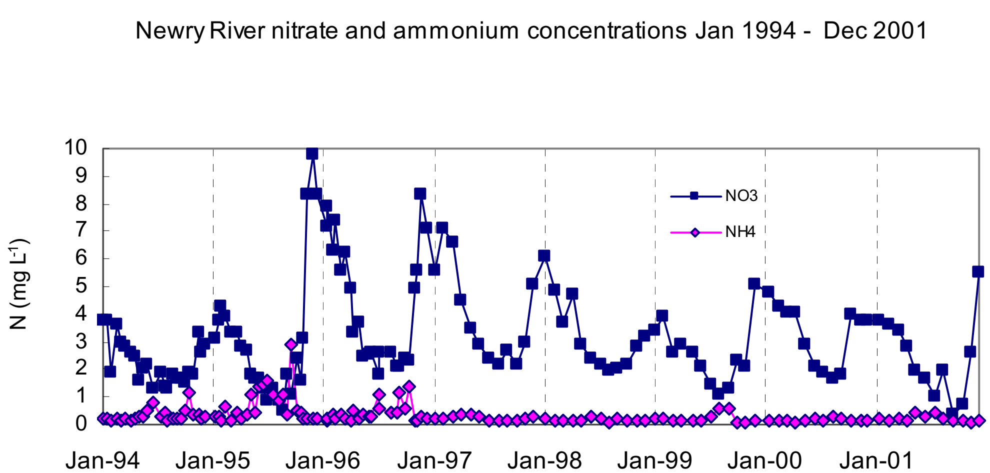
Table 5 Dissolved reactive phosphorus loadings to Newry River

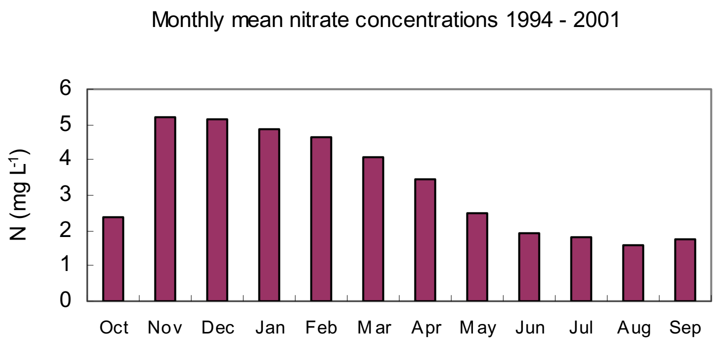
	Urban	Rough grazing	For-estry	Other land	Agric land	Total
	Dissolve reactive phosphorus tonnes P $year^{-1}$					
Clanrye River	8.7	0.0	0.0	0.0	14.9	23.6
Newry River Direct Inputs	23.1	0.0	0.0	0.0	1.1	24.3
Newry River Total	31.8	0.0	0.1	0.0	16.0	47.9
%	66.4	0.1	0.1	0.1	33.4	100.0

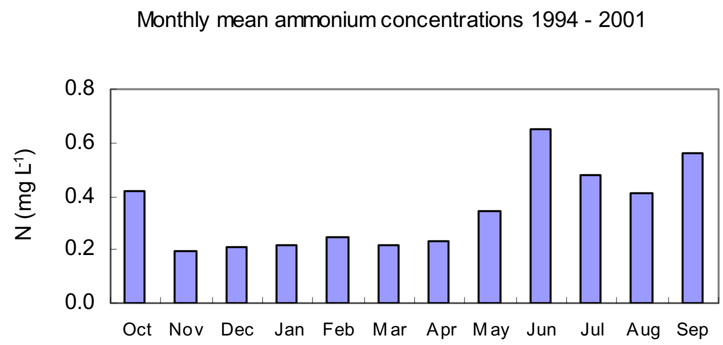
Table 6 Loadings from WWTWs in Newry River catchment.
Newry and Warrenpoint are downstream water quality sampling point on Newry-Clanrye River.

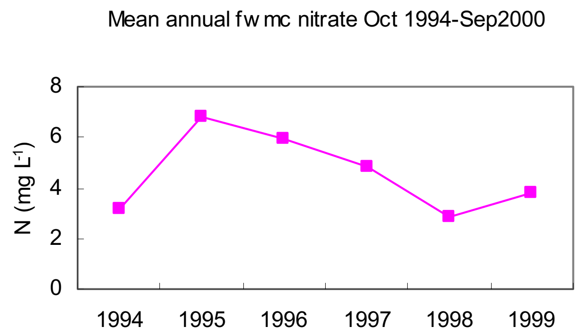
	PE	Flow	Concentration			Loading			Per capita	
Name			NH4	NO3	DRP	NH4	NO3	DRP	Total N	DRP
	nos.	$m^3\ d^{-1}$		$mg\ L^{-1}$			Tonnes $year^{-1}$		kg $year^{-1}$	
NEWRY	41569	13256	17.3	0.8	3.9	83.87	4.00	18.88	2.1	0.45
WARRENPOINT	13267	4602	10.9	1.3	2.5	18.39	2.16	4.21	1.5	0.32
BESSBROOK	8974	3204	10.1	5.2	3.1	11.77	6.08	3.57	2.0	0.40
RATHFRILAND	2321	916	6.5	7.5	4.0	2.18	2.51	1.32	2.0	0.57
DAMOLLY	1160	482	34.4	0.6	6.8	6.05	0.11	1.19	5.3	1.02
L'BRICKLAND	744	319	11.7	12.2	6.3	1.36	1.42	0.74	3.7	0.99
POYNTZPASS	550	241	4.0	12.8	3.5	0.36	1.13	0.31	2.7	0.56
MAYOBRIDGE	547	240	13.0	3.4	4.3	1.14	0.30	0.38	2.6	0.69
SCARVA	468	208	12.2	5.3	4.9	0.92	0.40	0.37	2.8	0.79
CARNBANE	250	116	25.5	0.3	5.8	1.08	0.01	0.25	4.4	0.99
SAVELBEG	219	103	6.9	15.1	3.5	0.26	0.57	0.13	3.8	0.60
LURGANARE	179	85	11.4	3.7	5.7	0.36	0.12	0.18	2.6	0.99
ACTON	127	62	34.3	1.5	5.7	0.78	0.03	0.13	6.4	1.02
CROWN CRT.	75	38	12.8	8.3	8.9	0.18	0.12	0.12	3.9	1.64
KENNEDY V'S.	35	19	12.1	0.5	5.6	0.08	0.00	0.04	2.5	1.10
Upstream	15649	6032				26.5	12.8	8.7	2.5	0.56
Downstream	54836	17858				102.3	6.2	23.1	2.0	0.42
Total	70485	23891				128.8	19.0	31.8	2.1	0.45

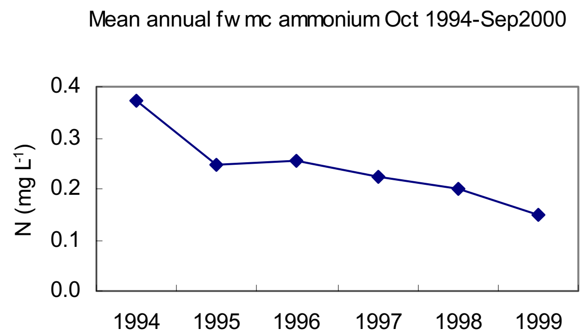
Fig 1 Nitrate and ammonium concentrations in the Newry River.



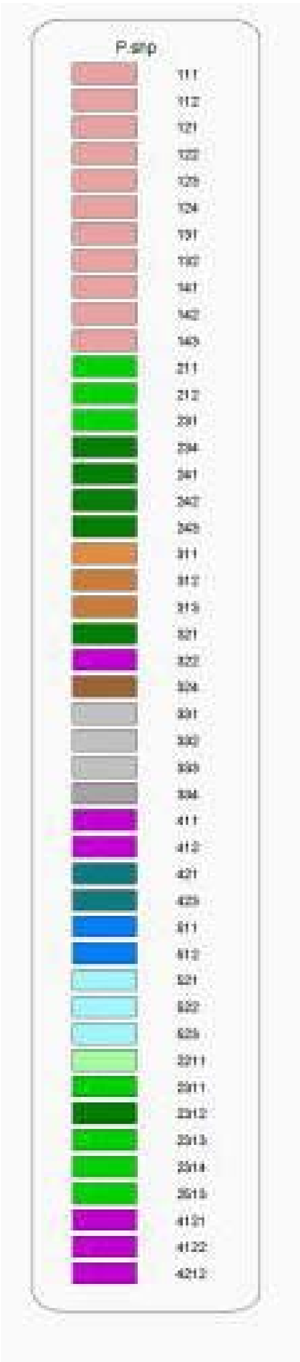

Monthly mean nitrate concentrations 1994 - 2001
N (mg L-1)
6
5
4
3
2
1
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


Monthly mean ammonium concentrations 1994 - 2001
N (mg L-1)
0.8
0.6
0.4
0.2
0.0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


Mean annual fwmc nitrate Oct 1994-Sep2000
N (mg L-1)
8
6
4
2
0
1994
1995
1996
1997
1998
1999


Mean annual fwmc ammonium Oct 1994-Sep2000
N (mg L-1)
0.4
0.3
0.2
0.1
0.0
1994
1995
1996
1997
1998
1999

Colour key



Appendix B Corrine land cover and colour key to maps

CORINE LAND COVER CLASSES
Urban/Industrial (3.1%)
1.1.1. Continuous urban fabric
1.1.2. Discontinuous urban fabric
1.2.1. Industrial or commercial units
1.2.2. Road & rail networks and associated land
1.2.3 & 1.2.4 Sea ports & Airports
1.3.1 & 1.3.2 Mineral extraction site & Dump
1.4.1. Green urban areas
1.4.2. Sport and leisure facilities
Arable land (2.6%)
2.1.1.& 2.1.2 Non irrigated and irrigated arable land
2.4.1. Annual crops associated with permanent crops
Agricultural grassland (72.9%)
2.3.1.1. Good pasture
2.3.1.2. Poor pasture
2.3.1.3. Mixed pasture
2.4.2. Complex cultivation patterns
2.4.3. Land principally occupied by agriculture
3.2.1. Natural grassland
Forest (5.6%)
3.1.1. Broad leaved forest
3.1.2. Coniferous forest
3.2.4. Transitional woodland-scrub
3.1.3. Mixed forest
Rough grazing (11.9%)
3.2.2. Moors and heathlands
4.1.2.1. Unexploited peat bogs
4.1.2.2. Exploited peat bogs
Other land and water bodies (4.0%)
3.3.1. Beaches, dunes, sand
3.3.3 & 3.3.4 Sparsely vegetated areas & Burnt areas
4.1.1. Inland marshes
4.2.1 & 4.2.3 Salt marshes & Intertidal flats
5.1.1 Stream courses
5.1.2. Water bodies