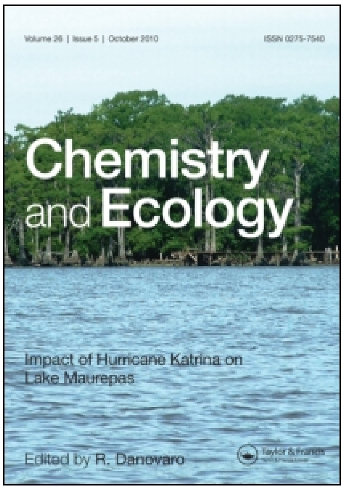

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

Increases in Nitrate Concentrations in the River Frome (Dorset) Catchment Related to Changes in Land Use, Fertiliser Applications and Sewage Input

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To cite this Article Casey, H. , Clarke, R. T. and Smith, S. M.(1993) 'Increases in Nitrate Concentrations in the River Frome (Dorset) Catchment Related to Changes in Land Use, Fertiliser Applications and Sewage Input', Chemistry and Ecology, 8: 2, 105 — 117
To link to this Article: DOI: 10.1080/02757549308035984
URL: http://dx.doi.org/10.1080/02757549308035984

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INCREASES IN NITRATE CONCENTRATIONS IN THE RIVER FROME (DORSET) CATCHMENT RELATED TO CHANGES IN LAND USE, FERTILISER APPLICATIONS AND SEWAGE INPUT

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(Received January 1993)

Nitrate concentrations and nitrate loads throughout the River Frome catchment (Dorset) are compared for the periods 1970–71 and 1984–86. Nitrate concentrations and loads have increased at every site, the increase in mean nitrate concentrations varying from 31% to 123%. These increases in nitrate concentrations are related to changes in land use and fertiliser applications and also to an increase in sewage effluent entering the river.

KEY WORDS Nitrate, R. Frome (UK), catchment, trends, seasonal variation, land use

INTRODUCTION

The River Frome is the westernmost major chalk stream in England. Previous papers have described the flow and chemical composition of the main river and its major tributaries (Casey 1969, 1975, 1976, 1977, Casey and Clarke, 1979, 1986, Casey, Clarke and Marker 1981, Casey and Newton 1972, 1973, Casey *et al.*, 1989).

Data on the suspended solid concentrations and variations, both weekly and daily, were published by Farr and Clarke (1979).

Information on nitrate concentrations and river flow has been measured at a single site on the River Frome (East Stoke) since 1965. Because of the widespread concern over increasing nitrate concentrations, a study was made to investigate seasonality, nitrate concentrations and river loads over the River Frome catchment in relation to land use. Data obtained in 1984–86 are compared with a previous survey made in 1970–71.

Study Area

The area of the River Frome catchment is 41,440 hectares. The source of the River Frome is at Evershot (ST 047576). It is joined at Maiden Newton by the River Hooke. The main tributaries upstream of Dorchester (the largest town in the catchment) are the River Cerne and Sydling Water. The South Winterbourne joins the River Frome before it passes from Cretaceous deposits on to the Tertiary sands and gravels at West Stafford. Tadnoll Brook and the River Win join the river downstream of West Stafford. Details of the major tributaries and the eight sampling sites are given in Figure 1 and Table 1.

Paolillo (1969) stated that the most important geological formation in the River Frome catchment is chalk, which outcrops over 46% of the whole catchment.

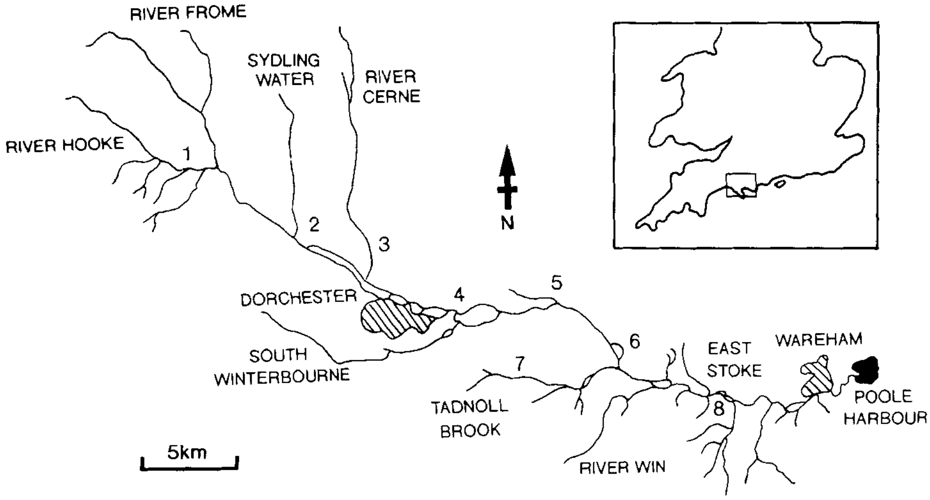

Figure 1 Details of the major tributaries and sampling sites.

Table 1 Details of the sampling points during the 1970–71 and 1984–86 catchment survey.

Sampling site and national grid reference	*Point number*	*Geological data of catchment*
River Hooke SY593976 at Maiden Newton	1	Upper Greensand (Cretaceous)
Sydling Water SY637947 at Viaduct	2	Chalk (Cretaceous)
River Cerne SY678935	3	Chalk (Cretaceous)
River Frome SY708903 at Dorchester Gauging Weir		
River Frome SY769909 at Woodsford	5	Chalk, sand and gravel (Cretaceous and Tertiary)
River Frome SY806893 at Moreton	6	Sand and gravel (Tertiary)
Tadnoll Brook SY770862 at Owermoigne	7	Lower Chalk and Greensand (Cretaceous)
River Frome SY867868 at East Stoke Gauging Weir	8	Sand and gravel (Tertiary)

METHODS

At each of the eight sampling sites, one water sample was taken at weekly intervals from October 1970 until December 1971 (the 1970–71 period) and then again from April 1984 until September 1986 (the 1984–86 period). Nitrate concentrations were measured using the diphenyl sulphonic acid method (APHA, 1960) until 1986 when the method was changed to a cadmium column reduction of nitrate to nitrite. A comparison using both methods was carried out for 6 months to see if there were any major differences between the methods. Over the six month period the comparison showed that, on average, the cadmium reduction method gave slightly higher results, usually in the range of 0.08 to 0.12 mg l^{-1}. This could be due to this method measuring both nitrate and nitrite; however, measurements of nitrite when the reduction column was removed were normally below 0.05 mg l^{-1}.

River Flow Measurements

The river discharge ($m^3 s^{-1}$) is termed river 'flow' throughout this paper to avoid any confusion with sewage discharges into the river system. The amount of nitrate passing a point site on the river per unit time is referred to as the nitrate load, measured in tonnes NO_3-N per week. There are gauging weirs at Dorchester (site 4) and East Stoke (site 8) which were originally operated by Avon & Dorset River Authority, then Wessex Water and now the National Rivers Authority. On tributaries without gauging weirs, 'spot' current velocities were measured at sampling points using an Ott current meter. The sites were chosen to avoid weed growth and where possible to have straight sides and uniform cross-sections. Velocity readings were taken across each river site at 60% of the total depth and then river flow at the site calculated as the sum of the product of the velocities and the cross sectional areas to which each applied.

Nitrate load for each week was estimated from the simple product of the weekly sample nitrate concentration and either the sampling day's average gauged weir river flow, or, if unavailable, the estimated spot flow at the time of sampling.

Rainfall

Precipitation occurs mainly as rainfall, snow normally being experienced for only a few days in a year in the lower catchment and up to 1–2 weeks in the upper catchment. The upper catchment had a 35 year average rainfall of 1016 mm, whereas the lower catchment had a 35 year average of 889 mm.

The amount of nitrogen entering the lower catchment due to rainfall was calculated by multiplying the rainfall for each year by the catchment area and by the average nitrate concentration of 0.31 mg l^{-1} found in the rain. The upper catchment, on average, received 15% more rain than the lower catchment, so the annual inputs of nitrogen per hectare from rainfall in the upper catchment were estimated by multiplying the lower catchment value by 1.15, assuming that the nitrogen content of rain is the same in both parts of the catchment.

Total atmospheric nitrogen deposition will also include an unknown additional amount due to dry deposition.

Land Use

The area of the River Frome catchment above the lowest sampling point (site 8, Figure 1) is 41,440 ha, with an estimated population of 327,000 giving a population density of 8 persons ha^{-1}. Dorchester is the largest centre of population, estimated at 13,736 in 1970 and 14,293 in 1985. Land use in the catchment was obtained from the parish summary records supplied by MAFF. Since 1973 some parishes have been combined and some boundaries altered, therefore any comparison of changes in land use has to take parish areas into account.

In 1983, MAFF farm survey returns indicate that 62% of all agricultural land in

Dorset was grassland and 25% was cereals. Thus the catchment is predominantly pastoral.

The generally increased use of nitrogen fertilisers in England and Wales has been reported elsewhere (The Royal Society Group Report, 1983; CAS Report 9, 1985; DOE Pollution paper No. 26, 1986).

RESULTS

Rainfall

Details of the nitrogen input from rainfall in the River Frome catchment are shown in Table 2. Nitrogen input from the rainfall was shown to be similar for both study periods.

Table 2 Rainfall (mm) and calculated nitrogen inputs (kg N ha^{-1}) for the years 1970–74 and 1980–85.

	Rainfall (mm) (lower catchment)	*Lower catchment kg N ha^{-1}*	*Upper catchment kg N ha^{-1}*
1970	911	2.72	3.13
1971	704	2.11	2.43
1972	984	2.94	3.38
1973	629	1.88	2.16
1974	1125	3.36	3.86
Average 1970–74	871	2.60	2.99
1980	540	1.61	1.85
1981	1006	3.00	3.45
1982	1009	3.02	3.47
1983	793	2.36	2.71
1984	884	2.64	3.04
1985	838	2.50	2.88
Average 1980–85	845	2.52	2.90

Livestock Numbers

Changes in livestock numbers between the two study periods 1970–71 and 1984–86 are suggested by MAFF data available for 1975 and 1982, as given in Table 3. Using information on nitrogen excretion given by MAFF (1976), the calculated changes in nitrogen content (as N) of livestock excrement in the Frome catchment are shown in Table 4.

Table 3 Changes in livestock numbers in the River Frome catchment between 1975 and 1982.

	1975	*1982*	*Percentage increase*
Total cattle and calves	24,580	22,779	–7
Total pigs	9,240	11,634	26
Total sheep	13,804	20,855	51
Total poultry	89,631	160,358	79

Table 4 Changes in nitrogen content of livestock excrement in the River Frome catchment between 1975 and 1982.

	1975		*1982*	
	Tonnes N	*kg N ha^{-1}*	*Tonnes*	*kg N ha^{-1}*
Cattle and calves	1839	44.4	1704	41.1
Pigs	61	1.5	64	1.6
Sheep	207	5.0	312	7.5
Poultry	80	1.9	144	3.5
Total	2187	51.8	2224	53.7
Increase			37	1.9

Over the seven year period 1975–82, there were increases in poultry (79%), pigs (26%) and sheep (51%), but a 7% reduction in cattle and calves resulting in a small increase of 1.9 kg N ha^{-1} due to animal excrement nitrogen.

Nitrogen Fertiliser Usage

Over 50% of the Frome catchment area is grassland. Figure 2 shows the overall annual rate of use of nitrogen fertilisers on 2–7 year leys in England and Wales for the period 1940–1985. In 1960 the average application of nitrogen fertilisers to grassland for the year was 26.3 kg N ha^{-1}. However, only 60% of temporary grass and 54% of permanent grass received any fertiliser at all. By 1971 the average application was 66.5 kg ha N and 84% of leys and 60% of permanent grassland were receiving fertiliser applications. In a written communication with MAFF (Dorset) the following applications were given as average local values:

1955	12.0 kg ha N
1965	33.2 kg ha N
1972	74.8 kg ha N

MAFF data from the "Surveys of Fertiliser Practice for Wales and England" for 1970 gave a national average of 83 kg N ha^{-1} per year, which is similar to the value given for Dorset.

Nationwide average annual fertiliser application rates for a variety of crops for 1982–83 and 1983–84 are given in Table 5 below.

Table 5 MAFF data for all England and Wales of the total areas (km^2) under major crops and grass, and their nitrogen fertiliser application rates (kg N ha^{-1} per annum).

	1982/83		*1983/84*	
	Area km^2	*Nitrogen kg N ha^{-1}*	*Area km^2*	*Nitrogen kg N ha^{-1}*
Wheat	16,910	180	19,650	188
Winter barley	9,120	152	10,270	155
Spring barley	12,400	101	9,400	94
Other cereals	1,220	88	1,210	94
Potatoes	1,940	188	1,990	199
Sugar beet	2,000	155	2,000	148
Oilseed rape	2,220	272	2,690	280
Other crops	5,570	66	4,850	60
Grass	69,560	105	69,300	114
All crops and grasses	120,940	122	121,360	131

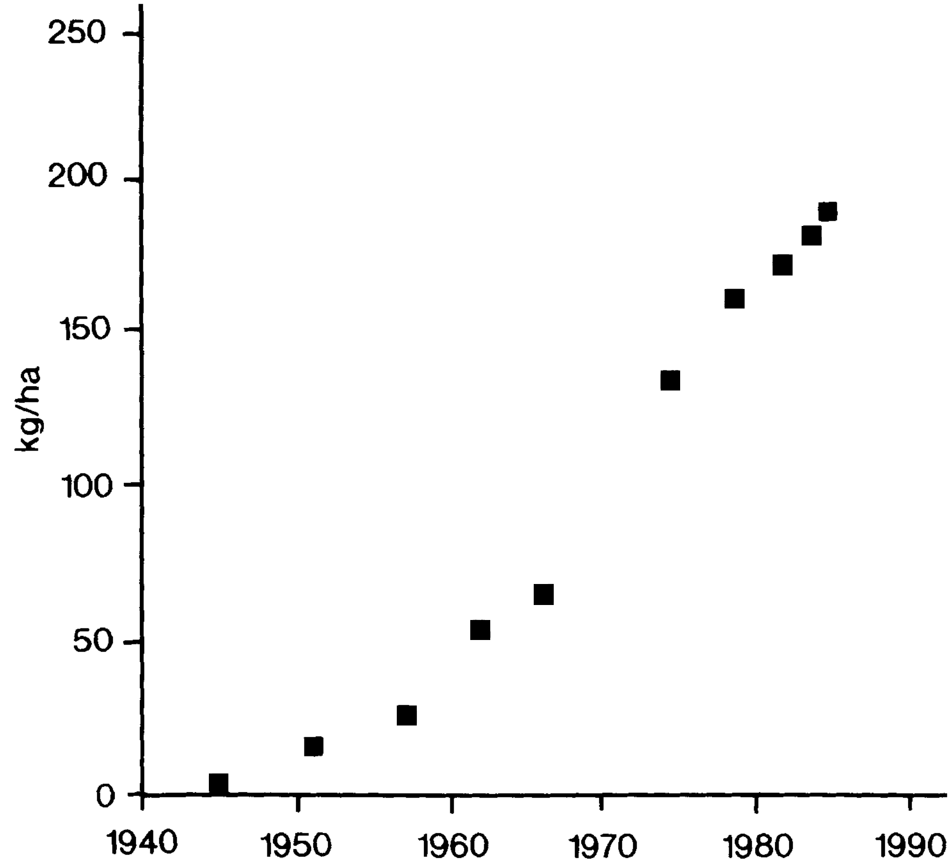

Figure 2 The national annual use of nitrogen fertilisers (kg N ha^{-1} per year) on 2–7 year grass leys for the period 1940–1985.

A survey of individual farmers in the catchment made in 1984–85 showed grassland application rates of nitrogen fertiliser ranging from 85 kg N ha^{-1} to 300 kg N ha^{-1} depending upon whether the grass was to be used for grazing or silage. In some cases extra nitrogen has been added earlier in the year to help provide an extra silage cut.

On dairy farms the rates of application depended upon the stocking rate of cows per hectare: with 0.94 cows per hectare foraged, fertiliser use was only 55 kg N ha^{-1}, but with 2.7 cows per hectare foraged, fertiliser use was 232 kg N ha^{-1} (CAS Report No. 9, 1985). Therefore, it is extremely difficult to get an overall average fertiliser application rate for the River Frome catchment area and application of the MAFF average figure for calculating increased fertiliser usage will provide only a very rough guide depending on land use.

Changes in land use have occurred in the River Frome catchment: what was rough pasture in the catchment in 1970 is now intensively farmed grassland. At that time, 7% of grassland was strip-grazed (where cattle graze a field in successive strips using a movable electric fence); this style of grassland management is now common practice.

Table 6 Sewage works effluents discharged into the River Frome and its tributaries in 1972 and 1983.

Works	*Grid Ref of Outfall*	*Approx dry weather flow* 1972 m^3d^{-1}	*Approx dry weather flow* 1983 m^3d^{-1}	*Total nitrate and ammonia concentrations in 1983* NH_4^+ $mg\,l^{-1}$ as N	*Total nitrate and ammonia concentrations in 1983* Inorganic and organic nitrogen (excluding NH_4^+) $mg\,l^{-1}$ as N	NO_2^- $mg\,l^{-1}$ as N	*Total nitrogen load tonnes/year*
Wool	SY825874	1135	1730	10	6	0.25	10.26
Warmwell	SY765874	N.A.	280	8	15	0.3	2.38
Broadmayne	SY734867	N.A.	300	0.1	18	0.25	1.98
Dorchester	SY712903	4010	6500	1.5	14	0.3	37.49
Bradford Peverell	SY666927	534	650	3	15	0.3	4.34
Cerne Abbas	SY668998	N.A.	145	2	18	0.25	1.02
Maiden Newton	SY602972	227	200	2	34	0.25	2.65
Sydling St Nicholas	SY633984	N.A.	65	0.1	25	0.1	0.60
Toller Porcorum	SY567979	N.A.	30	0.3	13	0.4	0.15
Evershot	SY579044	N.A.	35	0.5	20	0.5	0.27
Total		5906	9935				61.14

Sewage Effluent Input

Table 6 shows the sewage input discharged into the River Frome and its catchment in 1972 and 1983. It can be seen that approximate dry weather discharges from sewage effluent increased by 68% over this 11 year period. Calculations show that the percentage of the total River Frome nitrogen load passing East Stoke (site 8, in the lower catchment) due to sewage effluent had increased from 6.2% in 1972 to 7.0% in 1983.

Nitrate Concentrations in Rivers

Table 7 gives the mean, minimum and maximum nitrate-nitrogen concentrations for the sites sampled in both 1970–71 and 1984–86. To avoid any problems of bias due to seasonal variation, resulting from comparing means over periods involving unequal numbers of samples from each season, the 1970–71 period statistics for nitrate concentrations, river flows and nitrate loads are for the 12 month period October 1970 until September 1971 inclusive, and the 1984–1986 statistics are for the 24 month period October 1984 until September 1986 inclusive. The concentration increased at every site. The relative increase was notably greatest in the uppermost part of the catchment on the Hooke tributary (site 1) where concentrations were lowest in the early 1970s (average 1.36 mg l^{-1}) and then more than doubled to a mean of just over 3 mg l^{-1} by the mid-1980s. At the other seven sites the absolute increases were fairly consistent (range 1.10 – 1.49 mg l^{-1}), representing percentage increases of 33% – 62%. There were no other apparent relationships between the percentage or absolute increase and the initial concentration or the site river flow or distance from headwaters. The eight sites therefore showed average annual increases in nitrate concentrations over the 14 year period, 1971 to 1985, at a rate ranging between 0.079 and 0.124 mg l^{-1} per annum.

Figure 3 shows the nitrate concentrations from the Dorchester and East Stoke sites for both time periods. Concentrations were, and still are, higher during the November to May period, peaking in January or February, as initially modelled by Casey and Clarke (1979). At both sites, the increases in nitrate concentration since 1971 occurred for all seasons of the year. The increases and seasonal patterns of the concentrations were similar at all the other measured sites.

Relationship Between Nitrates and River Flow

The relationships between nitrate concentration and river flow were found to be roughly linear on a log-log scale, and on these scales the correlation coefficients varied between 0.32 to 0.87, indicating a consistent tendency for both river flow and nitrate concentration to be highest in winter and lowest in summer, indicating a general sinusoidal average seasonal pattern (Table 8).

Nitrate Loads

At the five sites where river flows were available or recorded throughout both periods, changes in nitrate load with time were also assessed (Table 7). Although there was a small 8% decrease in average weekly nitrate load for the River Cerne (site 3), the other four sites showed percentages increases ranging from 18%, up to 114% at Sydling Water in the upper catchment. However, average river flow was also higher in the 1984–86 period for three of the five sites, and there was a positive

Table 7 Summary and changes in nitrate concentration (mg l^{-1}), river flow ($m^3 s^{-1}$) and nitrate load (tonnes/week) at each of the catchment study sites for the periods 1970–71 and 1984–86. Site numbers as in Table 1 and Figure 1.

	Site		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
NO_3-N	1970–71	mean	1.36	2.13	2.71	2.32	3.02	3.14	3.67	2.79
		min	0.84	1.30	1.81	1.54	2.14	2.24	2.77	1.94
(mg l^{-1})		max	2.26	4.49	4.20	4.46	4.04	4.40	4.84	3.92
	1984–86	mean	3.09	3.46	3.81	3.67	4.51	4.44	4.89	4.22
		min	0.93	2.19	1.73	1.59	2.52	2.67	2.75	2.50
		max	5.32	7.02	5.81	5.33	6.76	6.07	9.56	6.40
	% increase	mean	127.00	62.00	41.00	58.00	49.00	41.00	33.00	51.00
		min	11.00	68.00	-4.00	3.00	18.00	19.00	-1.00	29.00
		max	135.00	56.00	38.00	20.00	67.00	38.00	98.00	63.00
Flow	1970–71	mean	–	0.29	0.39	1.93	–	–	0.59	4.87
		min	–	0.13	0.07	0.42	–	–	0.24	2.08
($m^3 s^{-1}$)		max	–	1.33	1.95	7.72	–	–	1.65	16.74
	1984–86	mean	–	0.46	0.31	3.14	–	–	0.59	6.50
		min	–	0.20	0.08	0.80	–	–	0.31	2.26
		max	–	1.10	2.00	11.76	–	–	1.15	22.53
	% increase	mean	–	59.00	-21.00	63.00	–		0	33.00
		min	–	63.00	14.00	90.00	–		79.00	9.00
		max	–	-17.00	3.00	52.00	–	–	-30.00	35.00
Nitrate Load	1970–71	mean	–	0.43	0.75	3.64	–	–	1.38	10.09
		min	–	0.14	0.11	0.90	–	–	0.43	3.11
		max	–	3.62	4.94	13.35	–	–	3.66	34.09
(tonnes /week)	1984–86	mean	–	1.02	0.78	7.23	–	–	1.72	17.54
		min	–	0.28	0.12	1.31	–	–	0.72	4.44
		max	–	3.36	4.72	25.30	–	–	4.34	54.25
	% increase	mean	–	137.00	4.00	97.00	–		25.00	74.00
		min	–	106.00	14.00	45.00	–	–	65.00	43.00
		max	–	-7.00	-5.00	90.00	–	–	19.00	59.00

relationship between change in river flow and change in nitrate load. This highlights the general observation that nitrate concentrations are likely to change more consistently than nitrate loads as the latter depend more on rainfall and hence river flow pattern of the period.

Irrespectively of this, the increased loads in the mid-1980s indicate that considerably more nitrogen is being input into the Frome catchment. The best river flow records and hence nitrate load estimates are available for the two gauging sites, namely Dorchester town (site 4) and East Stoke (site 8, the lowest in the catchment). The annual nitrate load at Dorchester in 1971 was 155 tonnes and at East Stoke 477 tonnes, indicating that 322 tonnes of nitrogen were added to the main Frome channel in the 15 km stretch between the two sites (Table 9). At both sites just over half the annual load was in the January–March winter quarter. In 1985, the annual nitrate load at Dorchester was 343 tonnes (an increase of 121% since 1971) and the annual load at East Stoke had increased to 864 tonnes (an increase of 81% since 1971) and at both sites, just under half the annual load passed during the winter quarter, as in 1971. Mean annual river flows in 1971 were 2.03 $m^3 s^1$ for Dorchester and 5.25 $m^3 s^{-1}$

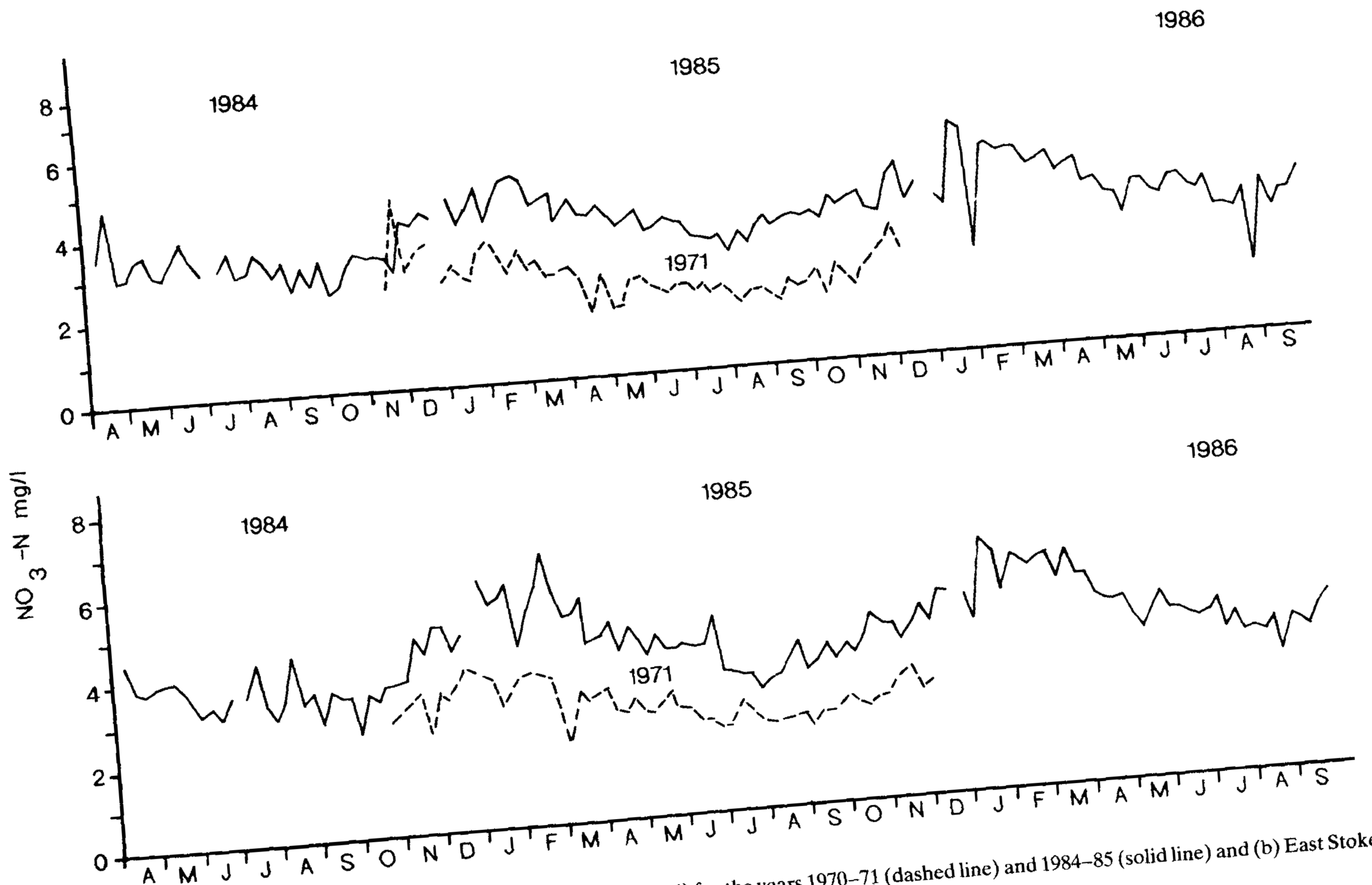

Figure 3 The nitrate concentrations at (a) Dorchester gauging weir (site 4) for the years 1970–71 (dashed line) and 1984–85 (solid line) and (b) East Stoke (site 8).

Table 8 The relationship between nitrate concentration and river flow values within each of the two study periods.

Site	*Correlation coefficient r* 1970–71	1984–86
2 Sydling Water	0.61	0.70
3 River Cerne	0.86	0.66
4 Dorchester	0.69	0.47
7 Tadnoll Brook	0.32	0.35
8 East Stoke	0.63	0.67

Table 9 Seasonal and annual nitrate loads (tonnes) at Dorchester (site 4) and East Stoke (site 8) gauging weir sites for 1971 and 1985.

	1971			*1985*		
	Site 4	*Site 8*	*Difference*	*Site 4*	*Site 8*	*Difference*
Jan–Mar	88	251	163	164	427	263
Apr–Jun	31	113	82	85	207	122
Jul-Sep	16	51	35	39	95	56
Oct–Dec	20	62	42	55	135	80
Total	155	477	322	343	864	521

for East Stoke, while in 1985, the flows were somewhat higher at 2.81 $m^3 s^{-1}$ and 6.10 $m^3 s^{-1}$, respectively.

Because of the problems caused by chance seasonal and annual variations of weather conditions and hence river flows influencing trends in nitrate loads, Table 10 has been prepared from a long term data set using two four-year periods, 1969–1972 and 1982–85, when the average flow of the R. Frome at East Stoke was very similar throughout (6.32 $m^3 s^{-1}$ for the 1969–72 period and 6.40 $m^3 s^{-1}$ for the 1982–85 period). The mean weekly nitrate load at East Stoke for these periods shows an increase of 47% from 11.7 tonnes/week in 1969–72 to 17.2 tonnes/week in 1982–85.

Table 10 Mean values of nitrate loads in tonnes/week for R. Frome (site 8) 1969–72 and 1982–85, based on weekly nitrate samples and daily river flows.

Year	*Mean flow* $m^3 s^{-1}$	*Mean tonnes /week*	*S.E.*	*Minimum tonnes /week*	*Maximum tonnes /week*	*Mean kg* ha^{-1} */annum*
1969	6.59	11.39	± 1.06	3.35	31.02	14.3
1970	6.64	12.36	± 1.21	3.69	38.55	15.5
1971	5.29	9.83	± 1.03	3.29	34.83	12.3
1972	6.78	13.13	± 1.23	3.78	35.72	16.5
Average	6.32	11.68	± 3.53	35.53	35.03	14.6
1982	7.49	19.59	± 1.89	4.19	57.03	24.6
1983	6.13	15.77	± 1.27	4.36	39.82	19.8
1984	5.82	16.64	± 1.85	3.27	57.26	20.9
1985	6.17	16.88	± 1.59	5.35	47.08	21.2
Average	6.40	17.22		4.29	50.30	21.6

The maximum weekly nitrate load at East Stoke during the 1969–72 period was 38.5 tonnes N during one week in 1970, but during the 1982–85 period, the estimated maximum weekly loads were over 57 tonnes/week, an increase of nearly 50%.

The mean annual loading of nitrogen in the River Frome at East Stoke per unit upstream area of the catchment has increased from 14.6 to 21.6 kg N ha^{-1} per annum, an increase of 48%.

CONCLUSIONS

Nitrogen inputs from rainfall have not increased from 1970–71 to 1984–86 and were approximately 3 kg N ha^{-1} per annum. Thus, rainfall contributed about 21% of the total catchment nitrogen load in 1971 and about 14% in 1985.

Because of changes in methodology and shifting of parish boundaries it is very difficult to obtain accurate estimates of land use changes over a long time scale. Because the values given by MAFF for nitrogen fertiliser applications are only averages, they provide only a very rough guide for calculating changes in fertiliser usage. Applications of nitrogen fertilisers to grassland in the River Frome catchment varied between 85 and 300 kg N ha^{-1} depending whether the grassland was to be used for grazing or silage. Application of nitrogen fertiliser was found also to vary with the stocking rate of cattle.

While the Royal Society Study Group Report (1983) concluded that only a small proportion of nitrogen fertiliser applied to grassland is leached, Ryden *et al.* (1984) found that leaching of nitrate from an intensively managed grazed grassland was five- or sixfold higher than comparable swards cut for hay or silage.

The amount of nitrate entering the River Frome and its tributaries from sewage effluent has increased by approximately 67% between 1971 and 1985. This has meant that the percentage of the total nitrogen load passing the lowest sampling site in the catchment due to sewage effluent has slightly increased from 6.2% to 7.0% between 1971 and 1985. Thus, by the mid-1980s, sewage effluent contributed roughly 7% of all the catchment nitrogen inputs.

Nitrate concentrations in the river have increased at every site, the increase ranging from 31% to 123% in mean values and at the River Hooke site in 1984–86 the mean and maximum values were more than twice those of 1970–71.

Increases in mean nitrate loading (tonnes per week) varied from −8% to 114%; the minimum nitrate weekly load increased at every site. At three sites, a reduction in the correlation coefficient of nitrate concentrations plotted against river flow was found, suggesting that possible changes in farming practices, such as more efficient timing of fertiliser application to avoid rain storms, were being effective.

Changes in nitrogen inputs to the River Frome catchment between the early 1970s and mid 1980s are summarised in Table 11, indicating a major change in inputs from farming.

Table 11 Nitrogen (N) inputs into the River Frome catchment.

	early 1970s		*mid 1980s*	
	kg ha^{-1}/annum	*% of Total*	*kg ha^{-1}/annum*	*% of Total*
Rainfall	3.0	21	3.0	14
Sewage effluent	0.9	6	1.5	7
Farming and other sources	10.7	73	17.1	79
Total	14.6	100	21.6	100

Changes in nitrogen inputs to the River Frome catchment between the early 1970s and mid 1980s are summarised in Table 11, indicating a major change in inputs from farming.

ACKNOWLEDGEMENTS

Financial support for this work was given by DoE under contract PEC.D7/7/136–93/84.

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