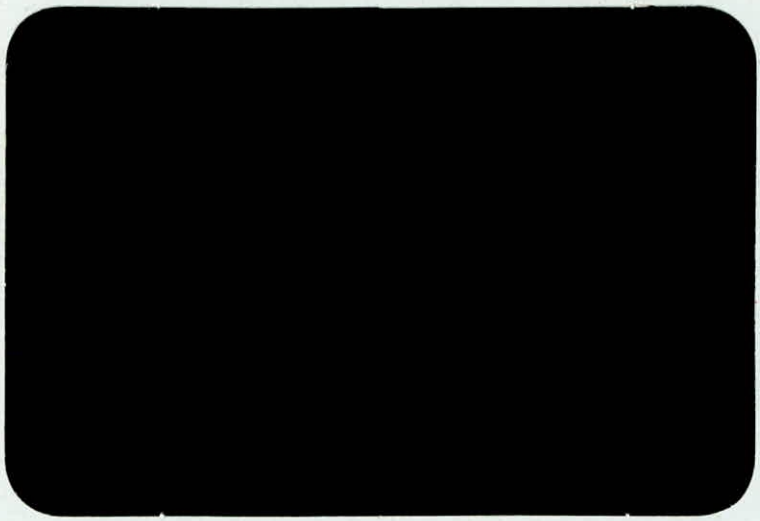

ENVIRONMENT AGENCY

RESEARCH AND DEVELOPMENT

TECHNICAL REPORT

Operational Mechanisms for the Protection and Enhancement of Headwaters

Scoping Study

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This report is provided for information only. It provides information in three areas: the number and length of headwaters in each Region, the awareness of headwater issues (within and outside the Agency) and areas for further research.

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EXECUTIVE SUMMARY

Information was used to derive estimates of the number of stream sources in England and Wales suggested that their true number is likely to be between 60, 000 - 70, 000. In total, headwater streams were estimated to represent approximately 70% of the total watercourse length in the two countries.

No definitive data-base exists which holds a full range of totally validated samples/sites from either the 1990 River Quality Survey (RQS) or the 1995 General Quality Assessment (GQA). A range of different statistics are presented, based on different versions of the data-base. During the 1995 GQA, the sampling density of headwater sites was close to one site for every 50 headwater segments; where a segment is a continuous length of first or second order streams within 2.5 km of the source. The exception was the Welsh Region, where the density was estimated at one site per 459 segments. Each Region was asked to supply information on additional headwater sampling that they undertook, other than the quinquennial national surveys. On the basis of their responses, there appeared to be strong inter-regional variation with highest density of sampling in the Welsh Region.

The overall quality of headwater sites, i.e. those within 2.5 km of source, included in the 1990 RQS was poorer than that for non-headwaters in the same survey. Direct comparisons between equivalent headwater and non-headwater sites is complicated by a number of factors, including the respective extent to which sampling is directed at known problem sites and the inappropriateness of using RIVPACS II to predict BMWP scores and number of scoring taxa for headwater samples.

The distribution of a set of sites from the 1990 RQS was examined by distance from source categories. Data were examined at three levels of spatial resolution. In general, the number of sites at different distances from source decreased in a downstream direction. The exception to this general pattern was headwater streams whose number of representative sites was fewer than sites in the > 2.5 km - 5 km from source category. The rate of decline in the number of sites with increasing distance from source, over the range > 2.5 km - 20 km from source, was used to calculate the number of headwater sites which need to be sampled to attain proportionality of representation with other downstream reaches. Based on regional estimates it was derived that future GQAs would need to include 1861 headwater sites, 579 more than in the 1995 GQA, to achieve this goal.

There was no indication in the 1990 data that sites between 2.5 - 5 km from source were systematically under-represented in the sampling network. However, this does not necessarily imply that each headwater site was complemented by a supporting site close downstream.

A headwaters perception questionnaire was circulated to NRA staff, chairpersons of NRA advisory committees and members of other Governmental and non-Governmental organisations.

Most respondents preferred to define headwaters as "the upper reaches of all watercourses" but used the supplied definition of streams within 2.5 km of their source for answering subsequent sections.

The most important "roles" of headwaters were identified as sources of biodiversity and spawning grounds for fish, but respondents were unclear about the proportion of macro-invertebrate biodiversity in river catchments which was exclusive to headwaters. Most respondents thought that the overall ecological quality of headwaters was "good" and that quality was better than reaches further downstream, this was in direct contrast to results obtained from previous headwater R&D studies. The five most important perceived threats to the ecological quality of headwaters were: acidification; land use change; organic pollution from farm waste disposal; organic pollution from agrochemicals; and channelization. Respondents were also clearly concerned about the impacts of low flow and over-abstraction, whilst there were also identifiable regional differences in the perceived threats to headwaters.

A large proportion of respondents thought that they would benefit from more information on the findings of the R&D study. The preferred methods of education were a headwaters factfile, talks to individual groups and a training video. Only a very low percentage of respondents had received outputs from, or were aware of, the related R&D project entitled "The Faunal Richness of Headwater Streams".

A broad variety of recommendations for future R&D studies or areas of greater operational activity were made by respondents. These fell into two broad categories of implementation and strategic research. Attention was drawn to the major areas of future implementation which included: greater awareness and education; more detailed monitoring; improved data storage and retrieval; and a wide variety of mechanisms for addressing specific environmental problems. Three areas of strategic research received support: the role of headwaters in the life cycle of fish and the implications for fisheries management; the impact of loss of ecological and chemical quality in headwaters on the larger watercourses they feed; and the ecological requirements of characteristic headwaters taxa and the factors which promote or threaten biodiversity and sustainability in the headwater environment.

A headwaters factfile has been produced to increase awareness of headwaters within the Environment Agency and externally and stimulate work and collaboration between the Agency, government departments, conservation agencies, agricultural and environmental advisors, farmers and landowners to help them value, protect and improve headwaters.

A variety of recommendations on how to improve headwaters and sampling programmes, communicate research findings and instigate future headwaters R&D within the Agency were made and these are detailed within the report.

KEYWORDS

Headwaters; Streams (in natural channels); Tributaries; Sampling; Watercourse Length; Water Quality (natural waters); Biological Analysis; Ecology; Questionnaire Analysis; Research.

1 INTRODUCTION

1.1 Background Research

1.1.1 Countryside Survey 1990

During the summer of 1990 the Institute of Freshwater Ecology (IFE) collaborated in a multi-disciplinary survey of the state of the British countryside entitled Countryside Survey 1990 (Barr *et al.* 1993).

IFE's role was to sample the macro-invertebrate fauna of one running water site from each of the 508 randomly selected 1km squares surveyed as part of the wider study. The data were to be used to document the distribution of individual taxa and to assess the biological condition of each site using biotic score systems.

In practice only 361 of the squares contained an appropriate sampling site. Of the remaining 147 sites, 64 had no flowing watercourses marked on Ordnance Survey 1:10,000 scale maps but a further 66 had all their marked watercourses dry at the time of sampling. The remaining 17 squares had watercourses which were not sampled for a variety of operational reasons.

The majority of the dried up streams were small, near source, watercourses. These were termed *headwaters* and in subsequent research this category became formally defined as *those sections of a stream within 2.5km of their furthest source as marked with a blue line on Ordnance Survey (OS) Landranger maps with a scale of 1:50,000.*

The biological condition of the 361 stream sites was assessed using RIVPACS II (Wright *et al.* 1993). Assessments were based on the observed and predicted values of the Biological Monitoring Working Party (BMWP) index of Average Score per Taxon (ASPT) (Armitage *et al.* 1983).

Overall, 71% of all sites evaluated were shown to be in good biological condition but this value varied with landscape type. Thus, in predominantly pastural landscapes only 64% of all sites were "good" and this figure fell to 60% in predominantly arable landscapes (Barr *et al.* 1993).

Of the 361 sites, approximately 250 fell within the definition of headwaters. The proportions of these not in good biological condition was higher than that of larger, downstream watercourses (Furse unpublished).

The relatively poor condition of headwaters had not been anticipated. Subsequent literature searches, in preparation for reporting on the survey, revealed a paucity of published data on headwaters. Similarly, no co-ordinated monitoring and management strategy for headwaters appeared to be operating within the National River Authority (NRA).

The combination of the vulnerability of headwaters to both drought and loss of biological condition, lack of published information and the absence of a co-ordinated management strategy prompted the National Rivers Authority (NRA) to commission the IFE to undertake a special study of headwaters entitled "The Faunal Richness of Headwater Streams" (R&D Project 242).

1.1.2 The faunal richness of headwater streams

This project was initiated, as a five year study, in 1991.

The overall objectives of the study were to:-

- *assess the conservation value of headwater stream macro-invertebrates and their contribution to catchment macro-invertebrate richness*
- *determine agricultural impacts upon headwaters and their fauna*
- *propose a headwaters conservation strategy*

The project was divided into four successive stages of which the first three involved data collection and analysis.

The principal findings of these stages (Furse *et al.* 1991, 1993, 1995) were as follows:

- a wide range of macro-invertebrate species (>100) are confined to or significantly associated with headwaters and many of these have national conservation status
- approximately 20% of the macro-invertebrate biodiversity of total river catchments is derived from taxa only found in their headwaters
- a survey of 131 headwater sites from four disparate river catchments showed that only 40% were in "good" biological condition *(This figure was arrived at using a modified version of RIVPACS which included only headwater reference sites and was based on both ASPT values and BMWP scores. The equivalent values for the 123 Countryside Survey 1990 headwater sites were very similar when analyzed in the same manner)*
- headwaters whose biological condition was not good were frequent in catchments of all land cover types but the principal causes of environmental stress varied according to the principal land cover type in the site catchment
- an estimated 14.1% of national headwater channel length was channelized (straightened and/or realigned) but this figure rose to 41.4% in predominantly arable catchments
- 75% of headwater bank length had buffer zones less than 1m wide and a further 14% had buffer zones less than 2m wide

The fourth stage of the project concerned the development of a conservation strategy (Furse 1996a). The specific objectives of this stage were:-

- *to propose a conservation strategy to maximize faunal diversity and protect endangered species, taking into account other factors, e.g. flow regime, which may influence the fauna*
- *to make recommendations for any future development of this work for the benefit of the environmental quality of headwater streams*

The main recommendations of the conservation strategy are summarised by Furse (1996b) and are listed in order of perceived priority action. The first two priorities are to:

- produce and circulate a headwaters factfile
- disseminate information to raise awareness of NRA [*now part of the Environment Agency*] staff at Head Office, Region and Area levels and amongst Statutory Advisory Committees to the Authority [*now the Agency*]

The conservation strategy report also contains a recommendation that further headwater research should be undertaken. The five priority areas were seen to be:

- the implementation and evaluation of headwater restoration projects
- the development of an operational headwaters module for RIVPACS
- an evaluation of headwaters' as habitats, spawning grounds and recruitment areas for fish
- an evaluation of the role of soils and erosion in structuring the habitat quality and biological condition of headwaters
- sources of species richness in headwaters and the consequences for management and conservation

1.2 Objectives of the Scoping Study

The principal recommendations of the conservation strategy form the focus of the current scoping study.

1.2.1 Overall objective

The overall objective of the R&D Programme, as set out in the Terms of Reference of the Memorandum of Agreement for Research Contract between the Environment Agency and the Natural Environment Research Council is

- *to examine the scope of a project to produce a headwaters vulnerability model as an operational tool for their protection*

1.2.2 Specific objectives

The specific objectives of the study are to:

- *produce a regional breakdown of the number and lengths of headwaters and the proportions that are seriously impacted in each Region from the collated databases*
- *identify the gaps between headwaters, as defined for the R&D project, and main river as defined for the GQA survey*

- *carry out a perception questionnaire to NRA and other relevant organisation's key personnel to determine awareness of headwater issues*

- *produce a factfile which summarises the outputs of the R&D work on the "Faunal Richness of Headwater Streams"*

- *explore the links between this project and other relevant projects in progress or being planned by the NRA and external bodies and incorporate it into a PID (Project Initiation Document)*

- *produce a PID which draws together the requirements of the NRA and collaborating organisations to produce a ground truthed vulnerability model and operational decision making programme*

1.2.3 Programme of work

The programme of work set out in the Memorandum of Agreement is to:

- *compile regional databases and maps*

- *design questionnaire, undertake survey and interpret and report results*

- *produce a PID (on disk) for the next stage*

- *produce a headwater factfile*

2 THE NUMBER AND BIOLOGICAL CONDITION OF HEADWATERS

2.1 The Number and Length of Headwaters

2.1.1 Introduction

The definition of headwaters used in the "Faunal Richness of Headwater Streams" project and adopted here is novel to these studies. No consistent definition of the term previously existed in the scientific literature (Furse *et al.* 1995). Hence there have been no previous attempts to define the numbers and lengths of headwaters on a national or regional basis.

The nearest approach has been that of Smith and Lyle (1979) who estimated the total number of watercourse of different stream orders. Stream order is a measure of the tributary structure upstream of a given point on the river system. As defined by Strahler (1957) a first order stream is one with no tributaries. A second order stream is one formed by the merger of two first orders. The confluence of two second order streams leads to a third order watercourse and so on. Both merging streams must be of the same order for the next highest order to be created. Thus, the stream formed by the confluence of a first and a second order watercourse remains second order.

The order calculated for a given watercourse is also dependant on the scale of the maps used to determine it. The finer the scale the more watercourses are shown. Smith and Lyle (1979) used 1:625,000 scale maps to make total counts of the number of river systems and the total number of streams which comprise those systems in each of 105 Hydrometric Areas in Great Britain. In order to equate this figure with the number of systems and streams shown on 1:63,360 scale maps they examined thirteen lengths of coastline at the finer scale. This showed that there were approximately six times as many river systems on the 1:63,360 maps as on those at 1:625,000 scale.

Using the mathematical relationship between the numbers of river systems at the different scales in the thirteen areas they were able to estimate the total national number of streams of each order on the finer scale maps. Furthermore, they were able to estimate the total number of streams in each order shown on 1:63,360 maps by making use of the national mean stream bifurcation ratio. The bifurcation ratio is the slope of the regression between stream order number and the logarithm of the number of streams in each order (Leopald *et al.* 1964).

On this basis they estimated that there were 146,853 first order streams marked on the 1:63,360 scale maps of Britain. This is directly equivalent to saying that there are 146,853 stream sources marked on these maps. Since all stream sources must, by definition, give rise to a headwater this number is also an estimate of the minimum number of headwaters in Britain, as shown at this scale.

Whether there are any other sections of stream which qualify as additional headwaters depends on how a watercourse is defined. It could be argued that the section of stream formed by the merger of two first order tributaries is merely an extension of the larger of those two streams which is in receipt of a tributary. In this definition the stream formed by the merger is not defined as an extra watercourse. Alternatively, the strategy adopted by Smith and Lyle (1979) is that each continuous section of a river network which is of a given stream order is counted as a separate stream. Thus two first order streams (2) combining to give rise to a second order channel (1) counts as three streams (2+1=3).

For the purposes of this report the collective term *headwater segments* will be used to define continuous lengths of stream of the same order whose course is wholly or partially within 2.5km of its furthest source.

Most first order streams are very short and hence the upper reaches of second order channels are usually within 2.5km of their furthest source. Under Smith and Lyles's strategy (1979) these would be regarded as separate headwater segments for inclusion in the total count. They estimated that there were 36,534 second order streams. If these are each taken to be separate segments, within 2.5km of their furthest source at their point of creation, then the estimate of the number of headwaters in Britain rises to 183,387. Some third order streams may also start within 2.5km of their furthest source but, on the assumption that the number of these is approximately offset by the number of second order streams which are formed further than 2.5km from the source then 183,387 may be assumed to be a reasonable estimate of the maximum number of headwater segments in Britain.

Smith and Lyle (1979) provided absolute counts of the number of river systems and streams of each order in each Hydrometric Area based on those watercourses shown on the 1:625,000 scale maps. However, they made no attempt to estimate the average and total length of each stream in Britain. In order to get a feel for total lengths of headwaters Furse (1996a) devised estimates based on a set of simple assumptions:

- all second order streams started within 2.5km of their furthest source
- the average length of each first order stream was 0.5km
- the average length of each section of a second order stream which was within 2.5 km of source was 2.0km
- none of the 8,894 third order streams estimated by Smith and Lyle (1979) to be present in Britain started within 2.5km of their furthest source

On this basis, Furse (1996a) estimated the total length of British watercourses which were within 2.5km of their furthest source to be 146,495 km. Alternative estimates would have resulted from a different set of assumptions (Table 2.1).

Table 2.1 Estimates of the total length of headwaters in Britain using five different sets of assumptions

Estimated mean length of watercourse in the headwater zone (km)			Estimated total length (km)
First order streams	Second order streams	Third order streams	
0.5	2.0	0.0	146,495
0.5	1.5	0.5	132,675
1.0	1.5	0.0	201,654
1.0	1.0	0.5	187,834
1.5	1.0	0.0	256,813

2.1.2 Number of headwaters

Methods

The methods used to calculate the total number of headwaters in England and Wales were those most appropriate to the financial resources available.

The task was suited to a Geographic Information System (GIS) approach but the costs involved would have been too high. The "blueline" map of Britain's rivers, at the 1:50,000 scale, developed by the Institute of Hydrology, under license to the Ordnance Survey, would have been the best available electronic source. The main sources of expenditure would have been license fees and the development of macros in ARC Macro Language (AMLs) to link all arcs comprising the river network and to identify and quantify all sections of river arcs within 2.5km of source.

Similarly, the project budget precluded absolute counts of all headwaters.

The approach adopted was therefore to sub-sample 1km squares from 1:50,000 scale OS, Landranger series maps. The squares selected for headwater counts were those at the intersections of a 10x10km grid and bore the general numerical grid reference format XX5 XX4 (eg square 475 134 = SU 75 34).

In order to derive the regional distribution of headwaters, separate estimates were made for each of the counties in existence at the beginning of 1996. Estimates were based on number of stream sources in each square. To have included all headwater sections present in a square, irrespective of whether they had their origins in the square or not, would have meant that a headwater could be counted in more than one square and would greatly have over-estimated the number of headwaters present in the county/region/country.

Counts of stream sources were equivalent to counts of the number of first order watercourses. No direct counts of second order streams meeting the definition of headwaters were made.

Results

Stream source counts were made from 1731 1km squares distributed between 54 counties (Table 2.2). Of these squares, 1482 were in England and 249 in Wales. Estimates of the number of second order stream segments within each geographic region (county/country) were based on the published GB ratio (Smith and Lyle 1979) of 146853:36534 (approximately 4.02:1). Estimates of numbers of headwater segments are given in parentheses after estimates of the number of stream sources/first order streams.

The total number of whole or part 1km squares in England and Wales, as given in the Countryside Information System (Howard *et al.* 1994) is 155,235. Of these, 132,993 are in England and 21,584 in Wales. The estimate of the number of headwaters is therefore based on a sub-set of 1.12% of the 1km squares in the two countries (England = 1.11%.: Wales = 1.15%).

Numbers of sampled squares per county varied between three (Isle of Wight) and 88 (North Yorkshire). The proportion of squares sampled in each county varied between 0.67% (Isle of Wight) and 1.47% (Suffolk) (Table 2.2).

The total numbers of stream sources/first order streams and, in parentheses, headwater segments estimated to occur in England and Wales, as shown at the 1:50,000 scale were 58,223 (72708). Totals of 49,985 (62,420) were estimated to occur in England and 8,235 (10284) in Wales. Due to the mathematical effects of the disproportionate size of countries and counties the national estimate for England and Wales is not the sum of the individual estimates for the two countries and the estimate for a country is not the sum of the estimates of its component counties.

The overall density of stream sources was 0.376 km^{-2} and was consistent between England (0.376) and Wales (0.382). However there were considerable differences between individual counties, where the highest source density was often greatest amongst predominantly upland counties. Thus, high densities occurred in Durham (0.800 km^{-2}), East Sussex (0.750), Cumbria (0.744), North Yorkshire (0.716), West Glamorgan (0.700), and Cornwall (0.605). The high density in East Sussex (0.750) and Kent (0.644) result from the intricate stream networks on Weald Clay and Hastings Beds and in Cornwall (0.605) from the occurrence of the impermeable, igneous moorland rocks.

Discussion

The estimates provided here are for individual counties. These are not directly analogous with the new Environment Agency Regions because many counties extend across Environment Agency boundaries. Only very approximate estimates can be made for individual Environment Agency Regions (Table 2.3) but provide an informative "feel" of the relative number of headwaters in each Region.

The use of 1km squares as the sampling unit for estimating the number of stream sources, coupled with the low density of squares inevitably leads to wide variance terms in the estimates of the number of stream sources. Thus the standard deviation of estimate of the 58,223 stream sources in England and Wales is 108,504.

An approximate cross-check of the IFE estimates can be made from some of the more detailed information provided by Smith and Lyle (1979) who presented data on the estimated number of streams of each order in each Hydrometric Area in Great Britain.

Comparisons are complicated by the fact that their estimates are based on 1:625,000 scale maps. However a generalised conversion ratio can be calculated from the total number of first order streams they estimate to be present in Great Britain at each of the 1:625,000 and 1:63,360 scale. The respective numbers were 5,966 and146,853 and the ratio between them is 24.615:1.

Using this conversion factor comparisons can be made between the estimated numbers of streams made in this study and by Smith and Lyle (1979) in five Environment Agency Regions wholly comprised of complete Hydrometric Areas (Table 2.4).

Three of these Regions, Midlands, North West and North East, show very close similarity in the estimated number of stream sources calculated by the two methods. However, the discrepancies in the two other Regions, South West and Welsh were considerable suggesting that the generalised conversion ratio used to convert Smith and Lyle's counts from 1:625,000 maps to estimates from 1:63,360 may have differing degrees of applicability in different Regions with different geology.

Table 2.2 Estimates of the number of stream sources/first order streams (HWs) shown on the 1:50,000 scale OS Landranger maps of England and Wales (plus estimates of the number of headwater segments)

County/COUNTRY	No. squares sampled	No. squares in county	% of squares sampled	No HW in sample sqs	Mean no HWs/sq	HW (segs) in county
Avon	19	1389	1.368	10	0.526	731 (913)
Bedfordshire	18	1233	1.460	3	0.167	206 (257)
Berkshire	11	1255	0.876	6	0.545	685 (855)
Buckinghamshire	26	1879	1.384	7	0.269	506 (632)
Cambridgeshire	40	3416	1.171	12	0.300	1025 (1280)
Cheshire	23	2360	0.975	8	0.348	821 (1025)
Cleveland	7	637	1.099	4	0.571	364 (454)
Cornwall	38	3862	0.984	23	0.605	2338 (2920)
Cumbria	82	7011	1.170	61	0.744	5216 (6513)
Derbyshire	27	2629	1.027	9	0.333	876 (1094)
Devon	68	6945	0.979	29	0.426	2962 (3699)
Dorset	27	2793	0.967	6	0.222	621 (775)
Durham	25	2443	1.023	20	0.800	1954 (2440)
East Sussex	16	1855	0.863	12	0.750	1391 1737)
Essex	50	3839	1.302	6	0.120	461 (576)
Gloucestershire	31	2667	1.162	6	0.194	516 (644)
Greater London	14	1611	0.869	2	0.143	230 (287)
Greater Manchester	12	1285	0.934	2	0.167	214 (267)
Hampshire	35	3888	0.900	14	0.400	1555 (1942)
Hereford & Worcester	39	3923	0.994	14	0.359	1408 (1758)
Hertfordshire	16	1627	0.983	2	0.125	203 (254)
Humberside	36	3670	0.981	6	0.167	612 (764)
Isle of Wight	3	447	0.671	1	0.333	149 (186)
Kent	28	3921	0.714	18	0.643	2521 (3148)
Lancashire	39	3141	1.242	20	0.513	1611 (2012)
Leicestershire	36	2550	1.412	6	0.167	425 (531)
Lincolnshire	79	5999	1.317	19	0.241	1443 (1802)
Merseyside	8	719	1.113	2	0.250	180 (225)
Norfolk	77	5500	1.400	21	0.273	1500 (1873)
North Yorkshire	88	8360	1.053	63	0.716	5985 (7474)
Northamptonshire	30	2372	1.265	5	0.167	395 (493)
Northumberland	66	5142	1.284	32	0.485	2493 (3113)
Nottinghamshire	27	2173	1.243	7	0.259	563 (703)
Oxfordshire	34	2615	1.300	10	0.294	769 (9603)
Shropshire	42	3495	1.202	16	0.381	1331 (1662)
Somerset	29	3503	0.828	17	0.586	2053 (2563)
South Yorkshire	17	1553	1.095	2	0.118	183 (228)
Staffordshire	33	2720	1.213	8	0.242	659 (823)
Suffolk	57	3884	1.468	20	0.351	1363 (1702)
Surrey	17	1676	1.014	4	0.235	394 (492)
Tyne and Wear	6	583	1.029	1	0.167	97 (121)
Warwickshire	23	1976	1.164	2	0.087	172 (215)
West Midlands	10	900	1.111	1	0.100	90 (112)
West Sussex	22	2037	1.080	11	0.500	1019 (1273)
West Yorkshire	22	2037	1.080	2	0.091	185 (231)
Wiltshire	29	3473	0.835	7	0.241	838 (1046)
ENGLAND	1482	132993	1.114	557	0.376	49985 (62420)
Clwyd	31	2475	1.253	6	0.194	479 (598)
Dyfed	61	6070	1.005	22	0.361	2189 (2745)
Gwent	17	1412	1.204	9	0.529	748 (934)
Gwynedd	48	4195	1.144	19	0.396	1661 (2074)
Mid Glamorgan	10	1017	0.983	2	0.200	203 (254)
Powys	67	5064	1.323	28	0.418	2116 (2642)
South Glamorgan	5	456	1.096	2	0.400	182 (227)
West Glamorgan	10	895	1.117	7	0.700	627 (783)
WALES	249	21584	1.154	95	0.382	8235 (10284)
ENGLAND & WALES	1731	154577	1.120	652	0.377	58223 (72708)

Table 2.3 Estimates of the number of stream sources in each Environment Agency Region based on individual estimates of those counties wholly or partially (approximate % of county area) within each Region.

ENVIRONMENT AGENCY REGION	COMPONENT COUNTIES	ESTIMATED No. OF STREAM SOURCES (SEGMENTS)
SOUTH WEST	Cornwall, Devon, Dorset, Somerset, Wiltshire (80%), Avon, Gloucester (10%)	9427 (11772)
SOUTHERN	Wiltshire (5%), Hampshire (70%), West Sussex (95%), East Sussex, Kent (90%), Isle of Wight, Surrey (10%)	5947 (7426)
THAMES	Wiltshire (15%), Gloucestershire (35%), Oxfordshire, Buckinghamshire (70%), Bedfordshire (5%), Berkshire,Essex (20%), Hertfordshire, Hampshire (30%), West Sussex (5%), Surrey (90%), Kent (10%), Greater London,	3759 (4694)
WELSH	Gloucestershire (5%), Hereford & Worcester (50%), Gwent, West Glamorgan, Mid Glamorgan, South Glamorgan, Dyfed, Powys (75%), Gwynedd (98%), Clwyd (90%), Cheshire (15%),	8448 (10550)
MIDLANDS	Gloucestershire (50%), Hereford & Worcestershire (50%), Powys (25%), Gwynedd (2%), Clwyd (10%), Shropshire, Staffordshire, Warwickshire, West Midlands, Derbyshire (85%), Leicestershire (65%), Nottinghamshire (95%), Lincolnshire (5%), South Yorkshire (30%), Humberside (15%)	4990 (6231)
ANGLIAN	Buckinghamshire (30%), Bedfordshire (95%), Essex (80%), Northamptonshire, Cambridgeshire, Suffolk, Norfolk, Leicestershire (35%), Nottinghamshire (5%), Lincolnshire (95%), Humberside (25%)	6727 (8401)
NORTH WEST	Cheshire (85%), Derbyshire (5%), Greater Manchester, Merseyside, Lancashire, North Yorkshire (10%), Cumbria (95%)	8122 (10142)
NORTH EAST	Humberside (60%), Derbyshire (10%), South Yorkshire (70%), West Yorkshire, North Yorkshire (90%), Cumbria (5%), Durham, Cleveland, Tyne & Wear, Northumberland	11323 (14140)

Table 2.4 A comparison of the estimated numbers of stream sources/first order streams, in five Environment Agency Regions, made in this study and by Smith and Lyle (1979)

ENVIRONMENT AGENCY REGION	COMPONENT HYDROMETRIC AREAS	ESTIMATED NUMBER OF FIRST ORDER STREAMS	
		THIS STUDY	SMITH & LYLE
SOUTH WEST	43 - 53 inclusive	9427	16196
WELSH	55 -67 inclusive, 102	8448	14202
MIDLANDS	28, 54	4990	5612
NORTH WEST	68 - 76 incl., 103 (+ minor part of 77)	8122	7458 + part 866
NORTH EAST	22 - 26 inclusive (+ minor part of 21)	11323	11962 + part 2190
ENGLAND & WALES	22- 76 inclusive, 102, 103 (+ minor parts of 21, 77)	58223	71235 + parts of 866 and 2190

This overall conversion factor is based on Scottish as well as English and Welsh catchments and includes extensive Highland areas where the stream density and bifurcation ratios are much higher than in other parts of Britain. Thus, for example, the South West Region has an extensive belt of chalk in its eastern areas where the bifurcation ratio is characteristically low and the conversion ratio of 24.615:1 clearly an overestimate.

The variation in the applicability of the generalised conversion factor is illustrated by Smith and Lyle themselves (their Figure 7) in their regression plot of the number of systems on 1:625,000 maps against the additional number of systems on 1:63,360 maps for thirteen representative areas of Britain. Interpreting from their plot, for example, two Regions where the number of systems at 1:625,000 scale were both seven had contrasting additional numbers of systems at 1:63,360 scale of approximately 15 and 80. The regression coefficient, r, of their plot was 0.833 (Smith and Lyle 1979).

When comparisons are made for the whole of the Environment Agency Regions (Table 2.4), the estimates of number of stream sources derived from Smith and Lyle's data is slightly in excess of 71,235, a 22.3% higher estimate than the 58,223 obtained in the current study.

The whole of this discrepancy can be explained by the higher estimates for the South West and Welsh Regions derived from Smith and Lyle's counts. This suggests, but does not definitively prove, that the estimates for the remaining Environment Agency Regions, Southern, Thames and Anglian are each internally similar using the two different methods of derivation.

2.1.3 Length of headwaters

Methods

The only practicable method, within the budget of this study, for estimating the length of headwaters in England and Wales was to derive it from the published data of Smith and Lyle (1979).

The appropriate methodologies were outlined in section 2.1.1, as applied to the whole of Great Britain. The relative proportions of streams of each order in Scotland compared to the combined areas of England and Wales were derived from Smith and Lyle's (1979) counts for each Hydrometric Area at the 1:625,000 scale. These proportions were then applied to the estimated numbers of streams of each order at the 1:63,360 scale to determine separate estimates of each stream order in Scotland and in England and Wales combined.

For the convenience of these calculations Hydrometric Areas 21 and 77 were taken to lie entirely within Scotland. Errors associated with this course of action will be comparatively small compared with the others involved in the estimation process.

The estimated number of streams of each order in England and Wales was then used to derive a range of total headwater length estimates using the same set of alternative patterns of linkage/confluence used to create Table 2.1.

Results

Smith and Lyle (1979) estimated that there were 146,853 first, 36,534 second and 8,894 third order streams in Great Britain as a whole, as likely to be shown on 1:63,360 scale maps.

They also showed that, on 1:625,000 scale, 48.51% of first, 52.31% of second and 57.14% of third order streams lay in the Hydrometric Areas of England and Wales. Applying these proportions to the estimated British totals on 1:63,360 scale maps the estimated number of first order streams in England and Wales is 71,235 (cf Table 2.4), of second order is 19,111 and of third order is 5,082.

Based on these values, a range of estimated total headwater lengths have been calculated (Table 2.5) according to a set of alternative scenarios for the relative mean lengths of each stream order in each hypothetical headwater system. Estimates lie within the range 66,825 - 125,964 km.

Table 2.5 Estimates of the total length of headwaters in England and Wales using five different sets of assumptions.

Estimated mean length of watercourse in the headwater zone (m)			Estimated total length (km)
First order streams	Second order streams	Third order streams	
0.5	2.0	0.0	73,840
0.5	1.5	0.5	66,825
1.0	1.5	0.0	99,902
1.0	1.0	0.5	90,346
1.5	1.0	0.0	125,964

2.1.4 Discussion

Detailed Geographic Information System analyses would be necessary to determine the precise length of headwater streams shown on an OS map of a given scale. In contrast the values given here are a set of estimates based on an alternative mean lengths of each order of stream before they join to form or to supplement streams of higher orders.

Nonetheless, whichever estimate is taken as the most accurate, all the total lengths estimated emphasise what a substantial length of headwater streams exist within England and Wales.

The estimates can be put in context by comparison with the total length of 39,960km of watercourses monitored during the 1990 River Quality Survey (RQS) of England and Wales (National Rivers Authority 1991). This figure includes all main river reaches plus an unknown proportion of headwater reaches.

Even if the RQS reaches are taken to exclude any headwater sections and the lowest estimate of total headwater length from Table 2.5 is used then headwaters represent 62.5% of total English and Welsh watercourse length. Given that the RQS figure does include headwater sections and some of the higher estimates in Table 2.5 may be more accurate, the true proportion of total watercourse length which is headwaters is more likely to be in excess of 70%. For example, if 15% of the reach length monitored in the RQS was on headwaters and the total headwater length estimate of 90,346km (Table 2.5) was taken to be correct, then headwaters would represent 72.3% of total watercourse length.

These proportions will reduce slightly if the estimate of stream sources/first order streams, of 58,223 derived in this study is used instead of 71,235 and the number of other orders are reduced by the same proportion. The value range for the estimates will then become 54,619 - 10,295 and the minimum proportion that headwaters represent of the total watercourse length in England and Wales will become 57.7%. A more realistic value is still likely to be close to 70%.

2.2 The Biological Condition of Headwaters

2.2.1 Introduction

In Stage 4 of the R&D project, "The Faunal Richness of Headwater Streams" (Furse 1996a) preliminary analyses were made of the number and biological condition of headwater streams sampled during the 1990 River Quality Survey of England and Wales (National Rivers Authority 1991; Sweeting *et al.* 1992). The summary statistics presented were based on a data-set of sites supplied to the IFE by the National Rivers Authority and did not include the full set of sites known to be sampled during that survey.

Of the 7633 English and Welsh sites believed to have been sampled, IFE held information on 6,600 of them. This included data on 5109 of the 5,897 sites sampled in each of three seasons (Sweeting *et al.* 1992).

A total of 714 (10.8%) of the 6,600 sites held by IFE were recorded by the NRA as being within 2.5km of source and thus meeting the definition of headwaters used in the R&D project (Furse *et al.* 1993). When these figures are broken down by frequency of sampling, 409 (8.0%) of the 5,109 three season sites were on headwaters. In contrast, in the IFE-held data-set, 305 (20.5%) of the 1491 sites sampled in only one or two seasons were on headwaters.

These figures reflect the tendency to take only two, or more usually one biological sample from headwaters to obtain a quick snap-shot of the condition of small watercourses which are not sampled chemically.

Macro-invertebrate sampling in River Quality Surveys (RQSs) and the more recent General Quality Assessments (GQAs) is used to allocate sites to bands of biological condition. Banding is based upon the RIVPACS methodology, as applied to the Biological Monitoring Working Party (BMWP) score system, and the Ecological Quality Index values (EQIs) derived from it (Sweeting *et al.* 1992). For the 1990 survey four bands of biological condition were used ranging from A (the best) to D (the worst).

At the time of the Stage 4 analyses the only sites for which the bands of biological condition were held by IFE were those sampled in three seasons.

Of the 409 headwater sites sampled in three seasons only 25.9% were in band A (good condition), 30.1% were B (fair), 29.8% were C (poor) and 14.2% were D (bad). These values compare with the overall proportion of river lengths, of all sizes, for the same survey of 60.2% in band A, 20.8% in B, 11.2% in C and 7.8% in D (National Rivers Authority 1994).

Part of the reason for the disparity of the two sets of values may lie in the genuinely poorer condition of headwaters than in larger watercourses. However, it is also recognised that selection of headwater sites for RQS and GQA sampling is to target sites with known problems in order to identify the extent of these problems and to direct chemical monitoring and remedial measures towards them.

In the following sections consideration is given to:

- the location of 1990 RQS and 1995 GQA headwater sites in each Environment Agency Region
- the biological condition of all 1990 RQS headwater sites, including those sampled in less than three seasons
- other headwater programmes undertaken by each Region
- other information on headwaters provided by regional staff

2.2.2 Methods

Location and biological condition of RQS 1990 and GQA 1995 headwater sites

Two sources of information on the location of RQS 1990 headwater stream sites were used to produce regional distribution maps.

The first was the data-set provided to IFE by the NRA in 1991 and used to compile the statistics presented in a variety of RIVPACS reports (eg Clarke *et al.* 1992, Clarke *et al.* 1994) and the Stage 4 headwaters report cited in the preceding section (Furse 1996a).

The second was a version of the same data-set provided by the Environment Agency in April 1996. Although these data purported to be from the same source there were considerable differences in the apparent number of headwater sites within Regions in each of them. The differences were not consistent and in some cases the numbers of sites were fewer in the data-base provided in 1996 yet in others they were not.

Under the resources of a separate project (Walley 1996) both the 1990 and 1995 data-sets are being "cleaned up" to remove or correct erroneous information. This will greatly benefit the interpretation of the data collected by the NRA/Environment Agency and lead to a consistent and definitive data-base for use in future studies.

In the interim, two or more different maps of 1990 RQS headwater sites are produced for each Region based on the two sets of data supplied in 1991 and 1996.

The location map based on data supplied in 1991 provides colour-coded classes of biological condition for all headwater sites sampled in three seasons. Paired or single season sites are presented as black symbols indicating biological condition unknown. The classes of biological condition used are those originally supplied with the data-set.

The location map based on data supplied in 1996 provides colour-coded classes of biological condition for all headwater sites, irrespective of the number of seasons sampled. The classes of biological condition used are those supplied with the data-set.

The two data-sets supplied to IFE were each in ASCII format. Each was used to create two separate pairs of EXCEL files. Each pair comprised a point file and an attribute file. The point file contained a Point_ID (i.e. a sequential site number, 1 - n) fully numeric easting and for each site. The attribute file contained the same set of Point-IDs together with each site's NRA sample number (if known), distance from source (km), Region, number of seasons sampled (1 - 3) and band of biological condition (A - D) (if known). No banding information was available for the 1995 GQA.

EXCEL files were transferred to a UNIX work station and analyzed using ARC/INFO and used to create the site distribution maps described above.

The background river network shown in each headwater site distribution map (Figures 2.1 - 2.24) were derived from 1:253,440 scale digital "drainage" maps supplied by Bartholomews.

Other NRA/Environment Agency headwater sampling programmes and further information

Additional information on headwater sampling programmes was requested, by letter, to selected Environment Agency staff in each of the eight Regions in order to give a more balanced account of the work carried out on these watercourses.

Each letter contained preliminary distribution and biological condition maps for the 1990 RQS headwater sites for the respective Region with a request that these be checked for accuracy. The bands of biological condition of sites sampled fewer than three times were also requested although this information was subsequently provided by John Steel (Thames Region) from the central data-base.

2.2.3 Results

Results are presented on a Region by Region basis with each Region being considered in alphabetical order of their former NRA names.

Anglian

Distribution maps - A total of 122 headwater sites were identified from the 1990 RQS data-set supplied in 1991 (Figure 2.1). This fell to 103 sites in the data-set supplied in 1996 (Figure 2.2). In a separate data-set supplied by the Environment Agency, Anglian Region a total of 108 headwater sites were listed from the 1990 RQS. The latter data-set included eight sites whose distance from source was listed as zero whereas only one such site was included in the national data-set supplied to IFE, by the Environment Agency in 1996. Some of the sites in the Anglian data-set were also dry at the times of sampling and had no band of biological condition ascribed to them. Differences in numbers of sites were relatively trivial and too time-consuming to follow-up here. However, they do re-emphasise the need for a consistent national data-base for RQS and GQA surveys.

In all cases the sites were spread relatively evenly throughout the Region with no conspicuous clustering of sites in any particular area or catchment.

A total of 143 sites were sampled in the 1995 GQA (Figure 2.3) with a similar distribution to the 1990 survey.

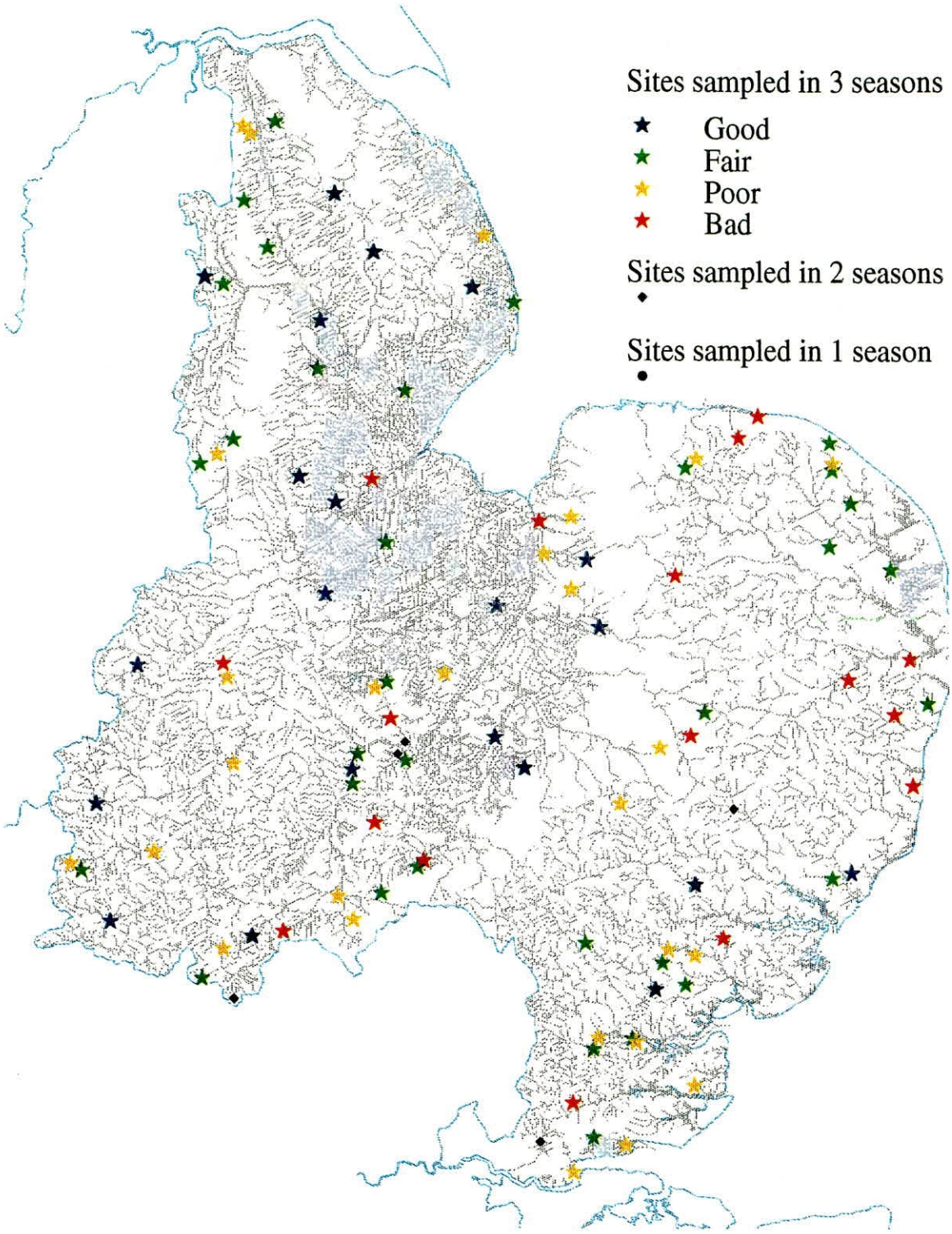

Figure 2.1 **Headwater sites sampled in the NRA Anglian Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1991.**

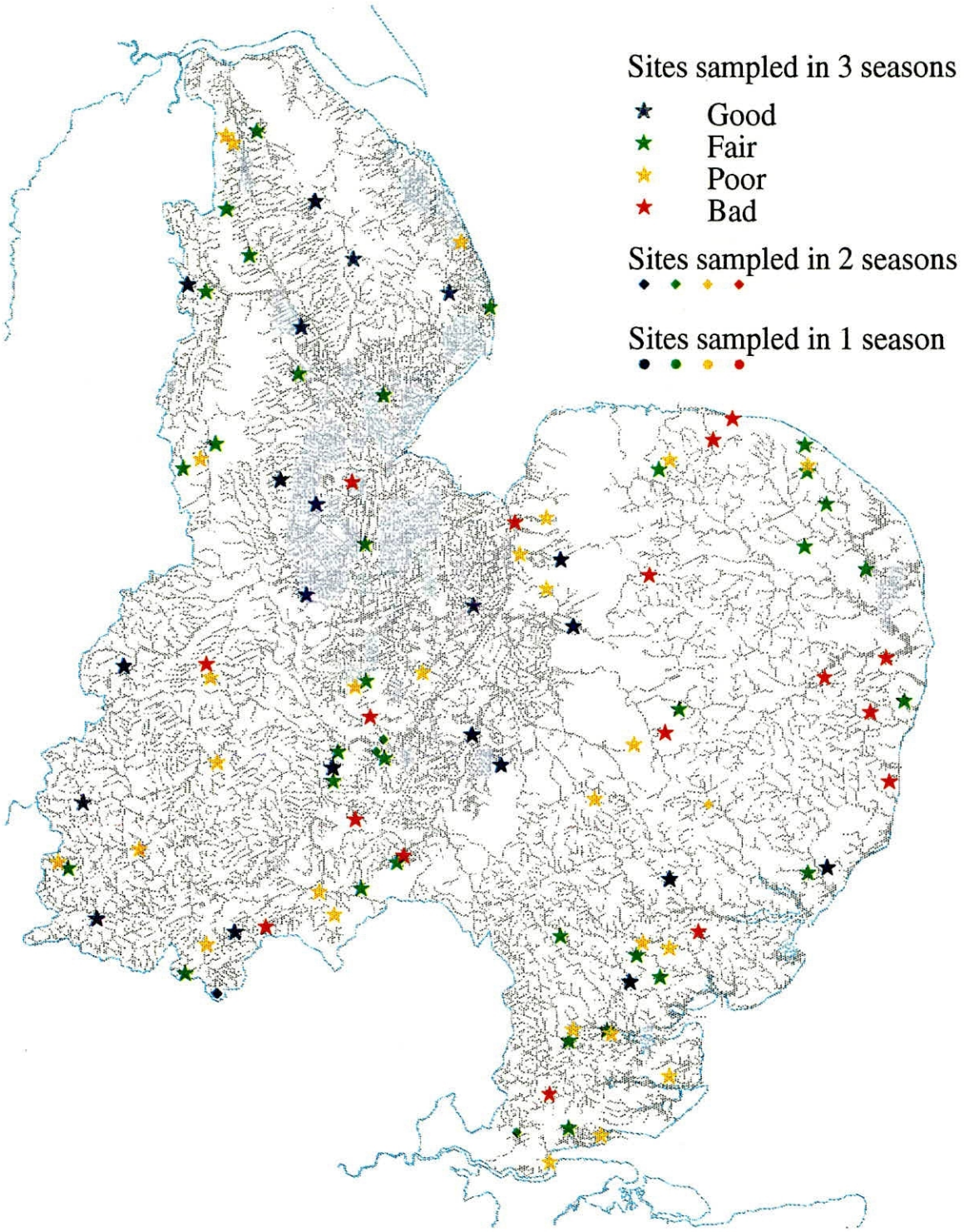

Figure 2.2 **Headwater sites sampled in the NRA Anglian Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1996.**

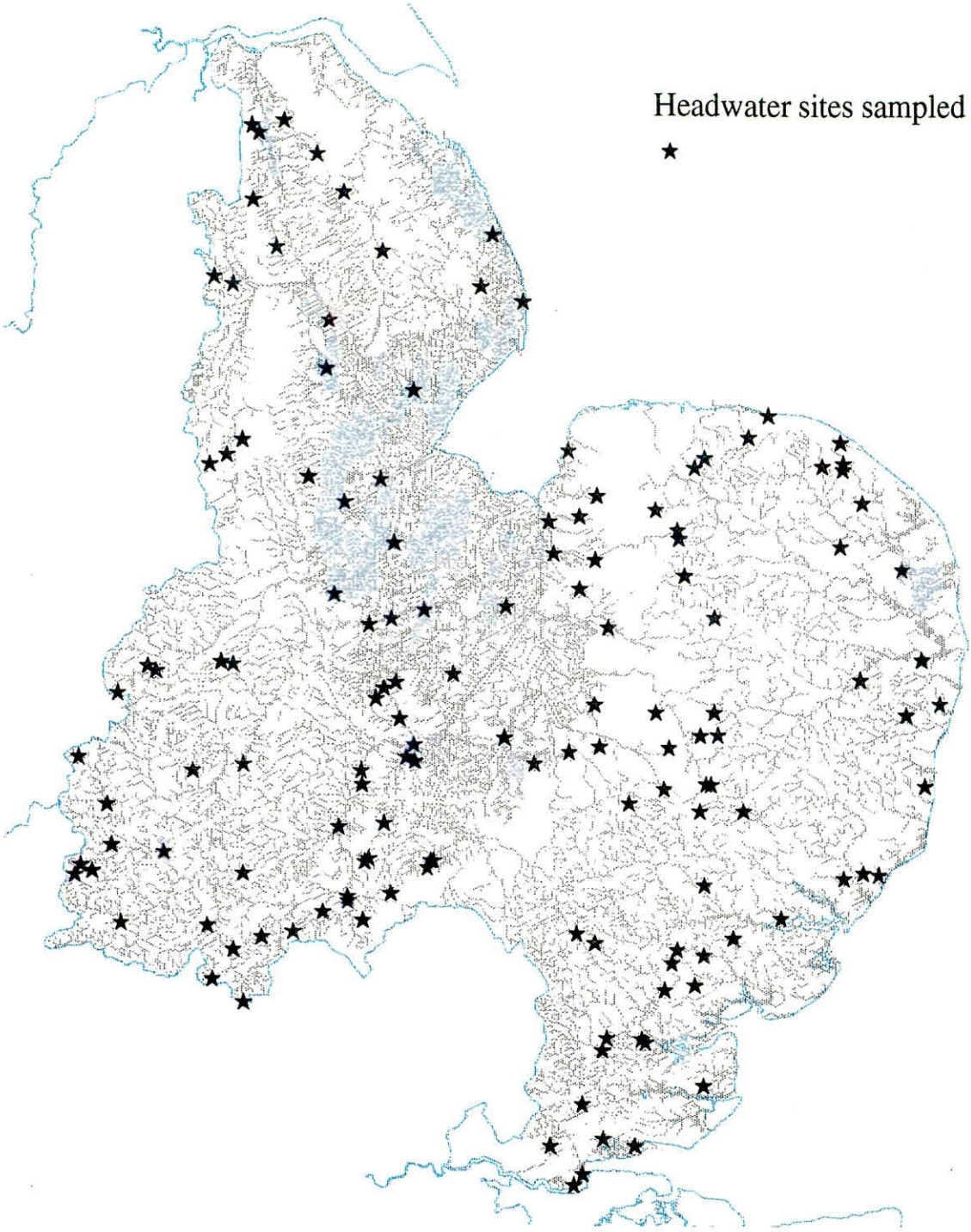

Figure 2.3 **Headwater sites sampled in the NRA Anglian Region during the 1995 General Quality Assessment.**

Sampling density - The 143 headwater sites sampled during the 1995 GQA represent an approximate density of sampling, as derived from Table 2.3, of one headwater site for every 44 headwater stream segments.

Biological condition - Based on the data supplied in 1996, the distribution of bands of biological quality for all headwater sites in the 1990 RQS was: A, 21.4%; B, 35.0%: C, 27.2% and D, 16.5%. Banding, here and throughout Section 2.2.3 is based on the 5M method (Wright *et al.* 1991) using the appropriate number of seasons' band ranges (Clarke *et al.*1992).

For the 98 sites sampled in three seasons the respective values were: A, 21.4%.; B, 33.7%: C, 27.6% and D, 17.3%.

For the five sites sampled in fewer than three seasons the respective values were: A, 20%.; B, 60%: C, 20% and D, 0%. Each of these five sites was sampled on two occasions.

There was no strong tendency for the distribution of quality bands to show regional variation although no band D sites were sampled in the northern part of the Region, including Lincolnshire.

Other headwater sampling programmes - Anglian Region provided a data-set of 31 sites sampled and biologically banded over the period 1991-95. These included only 10 new sites which did not occur on any of the 1990 RQS or 1995 GQA files held by IFE.

Of these sites, 11 were sampled and banded in a single year, six in two years, ten in three and four in four. The distribution of quality bands amongst the 69 banded samples was A, 20.3%; B, 42.0%: C, 30.4% and D, 7.2%.

The purpose of sampling these sites was not reported upon.

Other relevant information - None provided. However it is believed that eutrophication and pesticide accumulation in small streams in the Region is a cause for concern (Alastair Ferguson, personal communication).

In the report on the 1985 RQS (Department of the Environment and Welsh Office 1986) it is stated for Anglian Region that:

> *Many small streams, particularly in Norfolk and Suffolk, were affected by agricultural run-off, causing a general deterioration in the underlying water quality.*

Drought may be a particularly significant factor in eastern headwaters. Furse *et al.* (1995) showed that as many as 45% of 1km squares in lowland arable regions which were shown to have watercourses on 1:50,000 OS maps had all of them dry in the summer of 1990.

Northumbria & Yorkshire (Environment Agency North East Region)

Distribution maps - A total of 71 headwater sites were identified from the 1990 RQS data-set supplied in 1991 (Figure 2.4). These comprised 27 from the old Northumbrian NRA Region and 44 from the former Yorkshire NRA Region. The total number of headwater sites fell to 46 sites in the data-set supplied in 1996 (Figure 2.5), comprising 22 from Northumbria and 24 from Yorkshire.

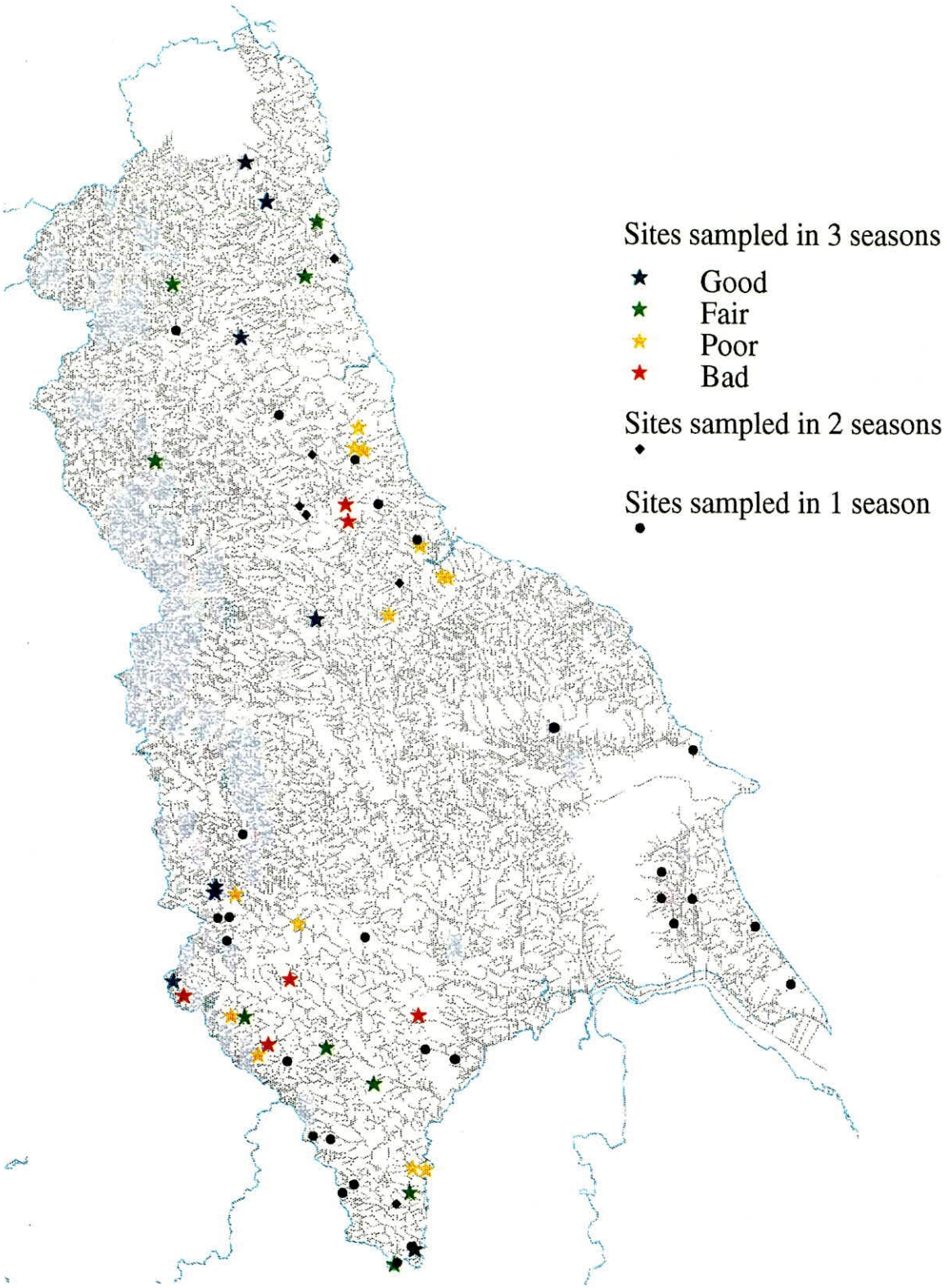

Figure 2.4 **Headwater sites sampled in the NRA Northumbrian and Yorkshire Regions during the 1990 River Quality Survey. Based on information supplied to IFE in 1991.**

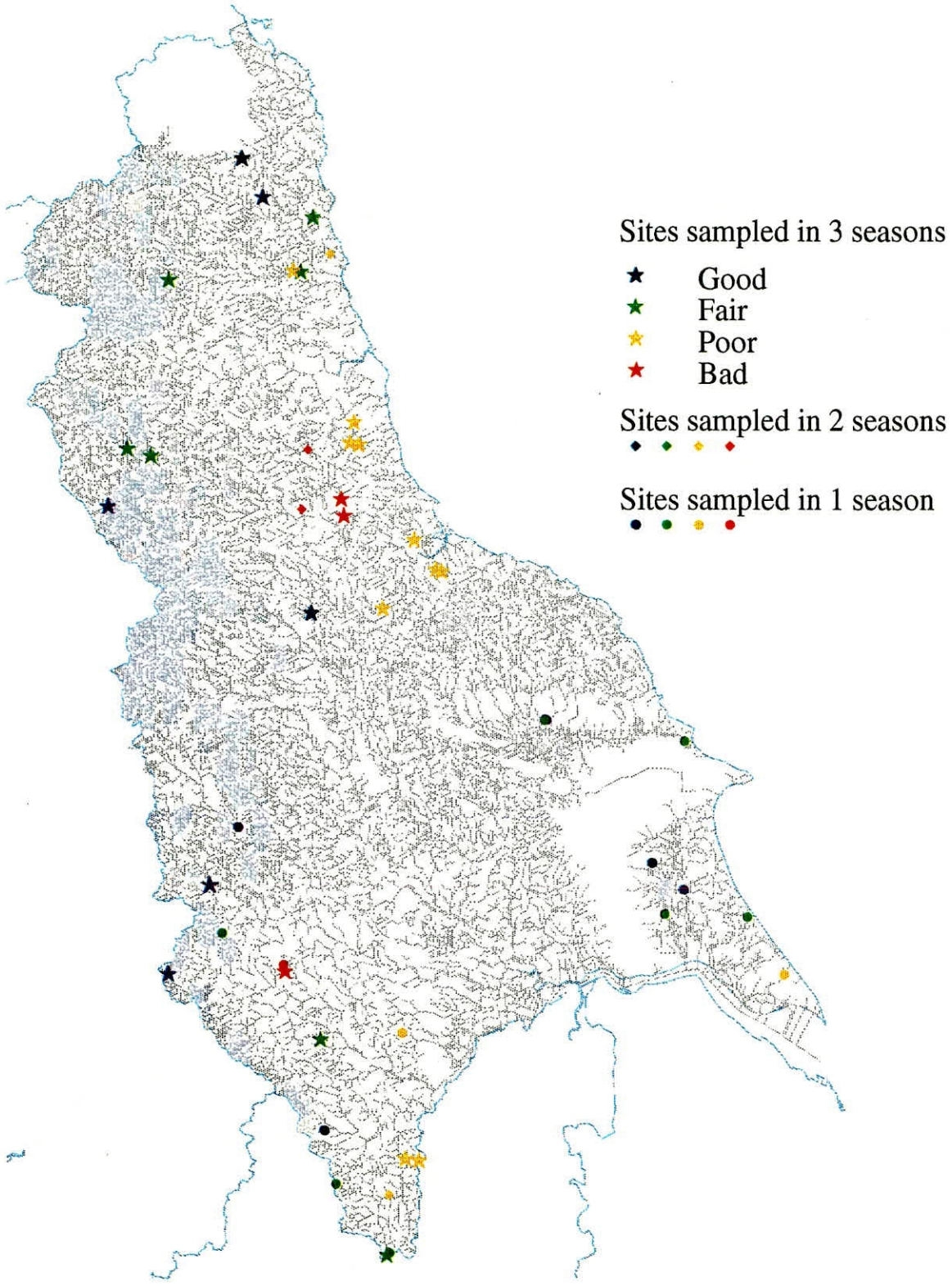

Figure 2.5 **Headwater sites sampled in the NRA Northumbrian and Yorkshire Regions during the 1990 River Quality Survey. Based on information supplied to IFE in 1996.**

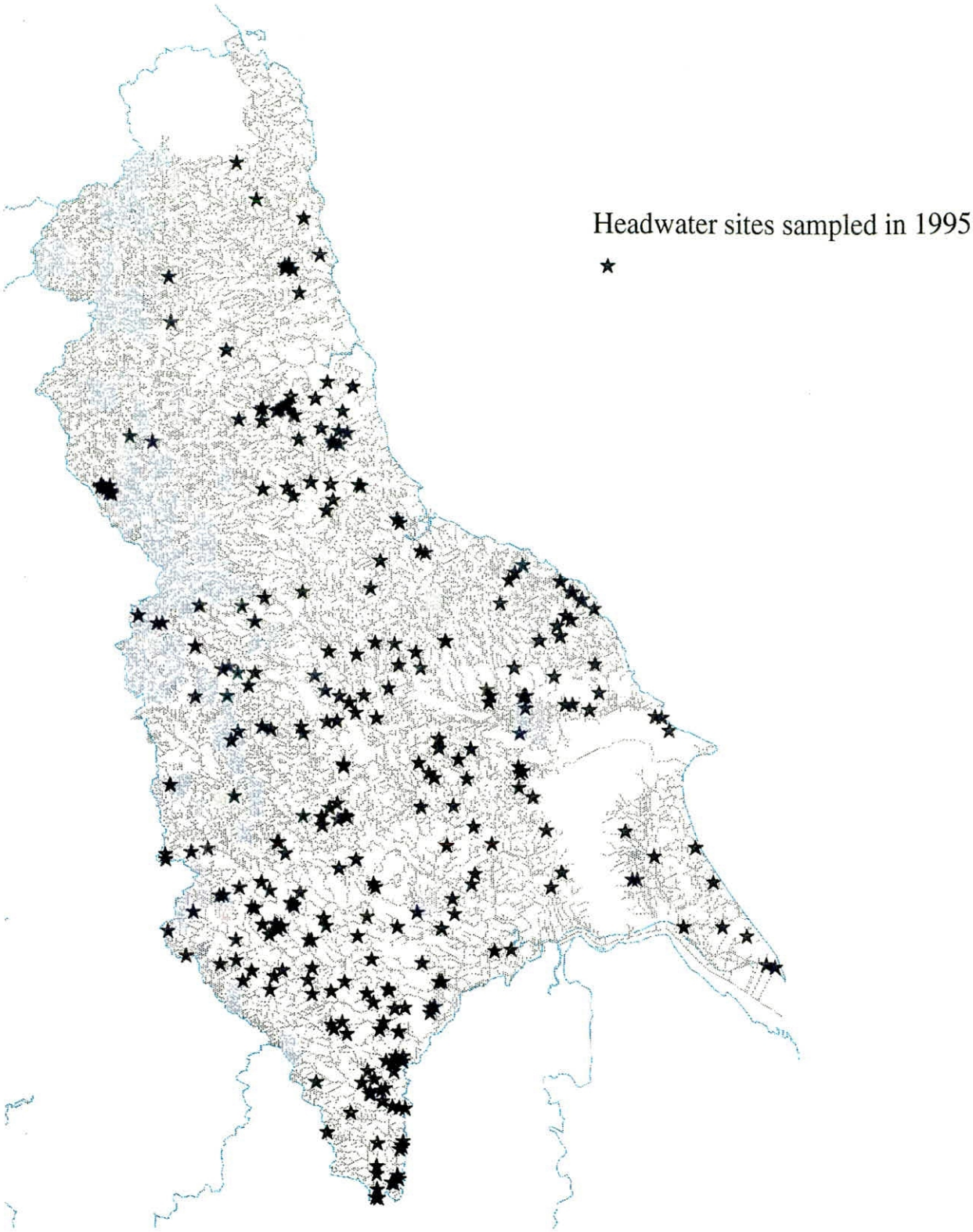

Figure 2.6 **Headwater sites sampled in the NRA Northumbria & Yorkshire Region during the 1995 General Quality Assessment.**

In each case concentrations of sites were apparent. In particular a relatively high density of sampling was conducted in the urban, often industrial south-west area of Yorkshire. Another, less dense, cluster of sites was sampled in and around the lower reaches of the Tyne, Tees and Wear.

Very few upland sites were sampled and there was virtually no headwater sampling of the Ouse and Derwent catchments.

The number of headwater sites sampled in the 1995 GQA increased considerably to 315 (Figure 2.6), comprising 68 in the former Northumbrian Region and an even greater increase of 247 in Yorkshire. Many of the gaps in the 1990 coverage were filled, particularly in the Ouse and Derwent catchments. The density of sampling in the most intensively covered areas in 1990 became even greater. The least intensively sampled type of headwaters were those in upland, often moorland, habitats.

Sampling density - The 315 headwater sites sampled during the 1995 GQA represent an approximate density of sampling of one headwater site for every 45 headwater stream segments.

Biological condition - Based on the data supplied in 1996, the distribution of bands of biological quality for all 1990 RQS headwater sites was: A, 26.1%; B, 30.4%: C, 30.4% and D, 13.0%.

For the 26 sites sampled in three seasons the respective values were: A, 23.1%.; B, 26.9%: C, 38.5% and D, 11.5%.

For the 20 sites sampled in fewer than three seasons the respective values were: A, 30%.; B, 35%: C, 20% and D, 15%. Of these sites, 16 were sampled on just one occasion.

There was a distinct tendency for the poorer quality sites to be those in the areas of greatest sampling density, as defined above.

Other headwater sampling programmes - Information was requested from each of the component Areas of the Region and replies were received from two of them, Dales Area and Ridings (formerly Southern Yorkshire) Area.

In the Dales Area a major headwater sampling campaign was undertaken in 1991. Samples were collected in single seasons, together with the necessary environmental data for making RIVPACS predictions.

A total of 94 sites were sampled during the campaign, of which 86 were banded for biological condition using the single season environmental data within RIVPACS. The proportional distribution of bands of biological condition amongst the sites, as determined by the Environment Agency, was: A, 58.1%.; B, 34.9%: C, 3.5% and D, 4.7%.

The reason for the additional sampling appears to be to extend the headwater data-base. None of the 94 sites had been previously sampled in the 1990 RQS.

In the Ridings Area major headwater sampling programmes were conducted in 1991 and 1992 and a smaller programme in 1994. In 1991, 84 headwater sites were sampled once and a further site was sampled twice. In 1992, 52 sites were sampled including several previously sampled in 1991. Of the 1992 sites, four were sampled once, 45 twice and three were sampled three times. No headwater sampling occurred in 1993 but in 1994 five of the poorer quality sites from earlier surveys were re-sampled, four of them twice and one once.

The main reason for the 1991-1994 headwater sampling programmes appears to have been to extend the database but some streams sampled in more than one place, or downstream of STWs, tips and other industrial locations, appear to be the subject of special pollution surveys.

Bands of biological condition were not supplied with the site data although the latter did include full family lists for each sample and their derived BMWP index values.

The sites sampled between 1991 and 1994 were mainly incorporated in the set of 1995 GQA sites for the Area.

No information was supplied for the Northumbria Area of the Region.

Other relevant information - None supplied by the Environment Agency.

Acidification of headwaters has been perceived as a potential problem by the Environment Agency and its forerunner, the NRA. A research programme at Huddersfield University has resulted in the development of a vulnerability model which demonstrates that large areas of the Region are susceptible to acidification of watercourses (McNish *et al.* 1994).

North West

Distribution maps - A total of 189 headwater sites were identified from the 1990 RQS data-set supplied in 1991 (Figure 2.7). Most of these, 174, were sampled just once, one twice and the remaining 14 three times. The same number of headwater sites, 189, was included in the data-set supplied in 1996 (Figure 2.8), although 6 of them appear to have been unsampled, presumably because they were dry. Of the sites actually sampled, 170 were sampled once, 2 twice and 11 three times.

The 1990 headwater sites were fairly evenly spread but with distinct clusters along and close to the northern Cumbria coast between Whitehaven and Maryport and also in the North East of the county, around Carlisle. The lowest intensity of sampling was in the southern and northern thirds of Lancashire.

The number of headwater sites sampled in the 1995 GQA increased to 246 (Figure 2.9), but with a similar overall spread to 1990.

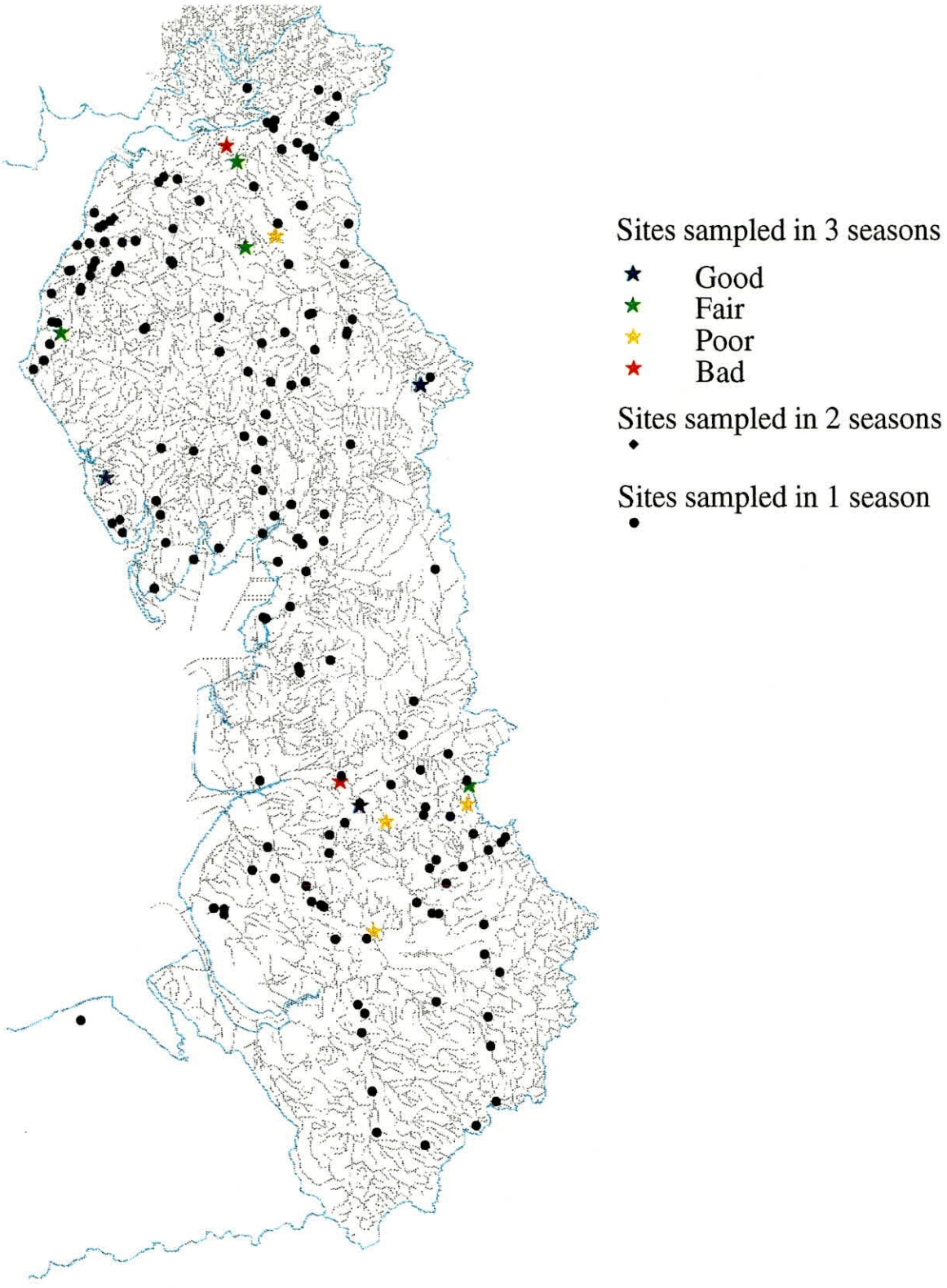

Figure 2.7 **Headwater sites sampled in the NRA North West Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1991.**

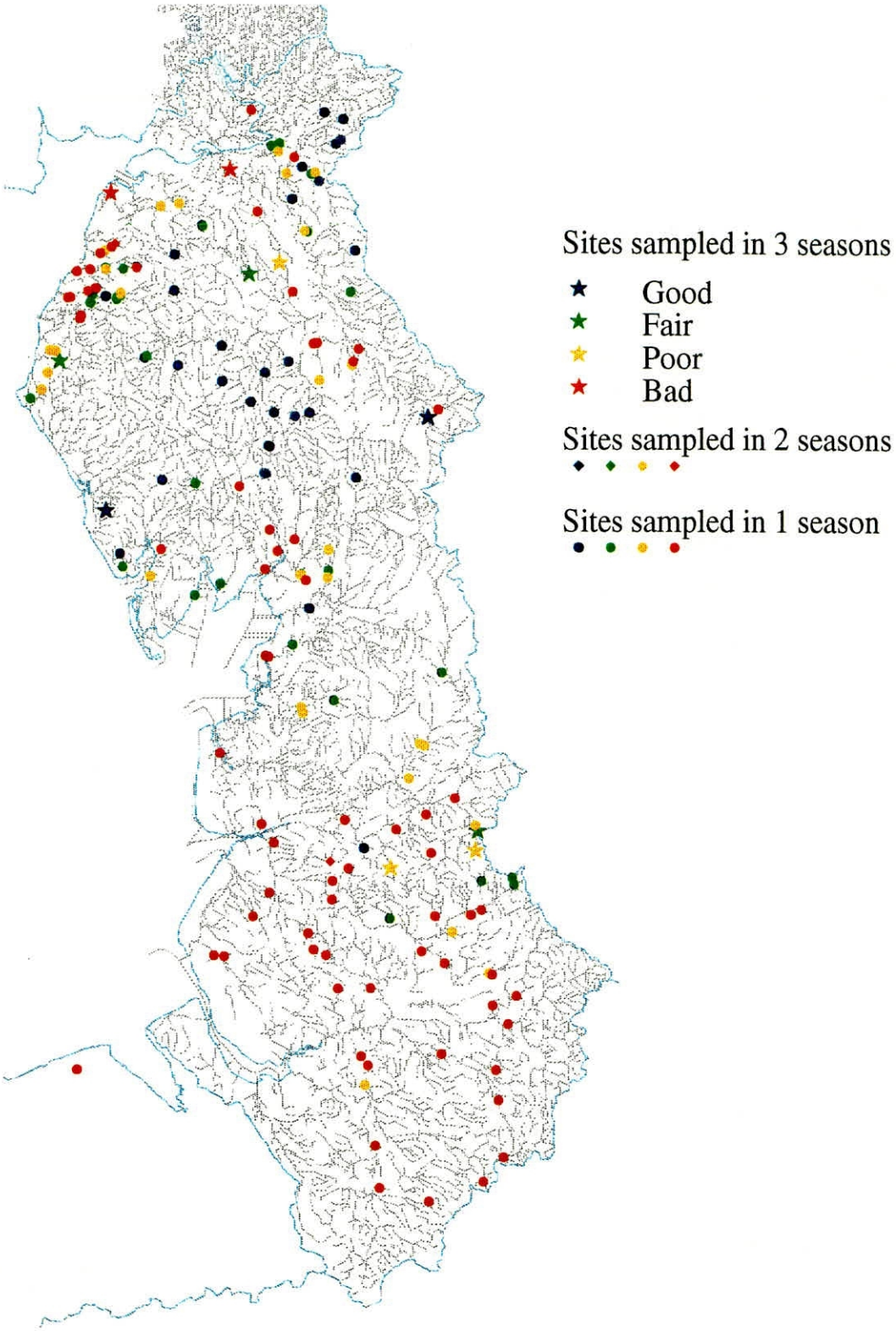

Figure 2.8 **Headwater sites sampled in the NRA North West Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1996.**

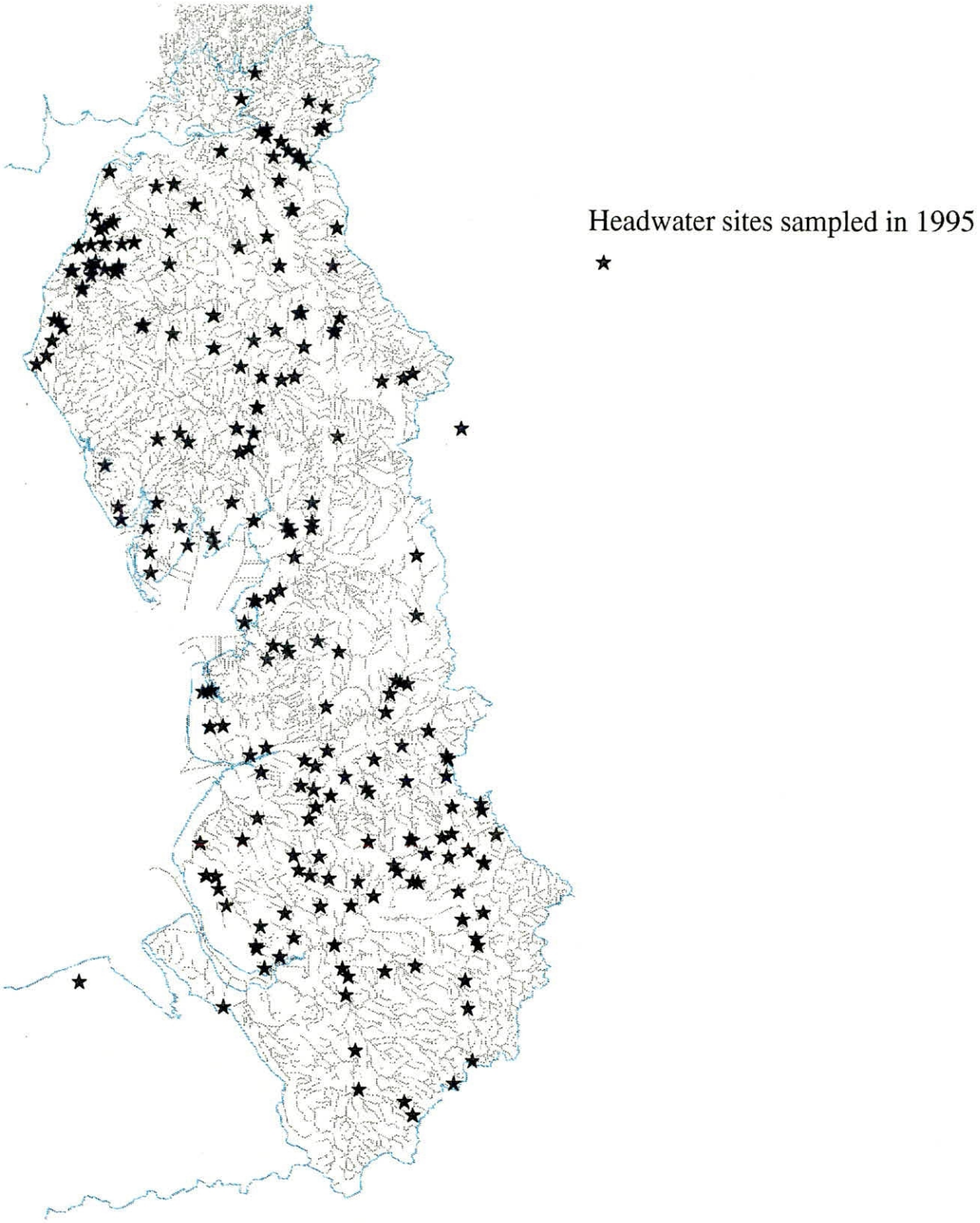

Figure 2.9 **Headwater sites sampled in the NRA North West Region during the 1995 General Quality Assessment.**

Sampling density - The 246 headwater sites sampled during the 1995 GQA represent an approximate density of sampling of one headwater site for every 41 headwater stream segments.

Biological condition - Based on the data supplied in 1996, the distribution of bands of biological quality for all 1990 RQS headwater sites, other than those banded as E and assumed dry, was: A, 18.0%; B, 18.6%: C, 19.7% and D, 43.7%.

For the 11 sites sampled in three seasons the respective values were: A, 18.2%.; B, 36.4%: C, 27.3% and D, 18.2%.

For the 172 sites sampled in fewer than three seasons the respective values were: A, 18.0%.; B, 17.4%: C, 19.2% and D, 45.3%.

Band D sites occurred commonly across the whole Region but the greatest concentrations were in the densely populated and industrialised regions of central and southern Lancashire and in the cluster of sites along the North Cumbria coast. Most of these sites were sampled once only and it is extremely probable that this sampling was targeted at sites most likely to be in poor biological condition.

Other headwater sampling programmes - No information supplied.

Other relevant information - None supplied by the Environment Agency.

In the report on the 1985 RQS (Department of the Environment and Welsh Office 1986), although not specifically writing about headwaters, it is stated for North West Region that:

> *Another source of decline in water quality is storm sewer overflow discharges which have a significant effect on river quality in urban areas. Urban areas are also affected by general urban run-off and drainage from industrial estates, with new industrial estates often located on the outskirts of towns at the head of sewerage systems which are inadequate to accept combined drainage.*

The impact of drainage overflow is likely to be in headwater streams with their low dilution capacities.

Severn-Trent (Environment Agency Midlands Region)

Distribution maps - A total of 105 headwater sites were identified from the 1990 RQS data-set supplied in 1991 (Figure 2.10). Of these, 88 were sampled three times, 12 twice and five once. The figure remained at 105 in the data-set supplied in 1996 (Figure 2.11) although the composition of the two lists showed slight changes as did the frequency with which some sites were listed as having been sampled. In this data-set 89 sites were sampled three times, 13 twice and 3 once.

The 1990 RQS sites were concentrated in the Trent Area alongside the middle and lower reaches of the Trent itself. A second concentration occurred in and around the Birmingham conurbation.

The number of headwater sites sampled in the 1995 GQA rose to 167 (Figure 2.12), with an increase in the number of sites in the lower Severn catchment and the Vale of Evesham. The sites otherwise showed a similar overall spread to 1990.

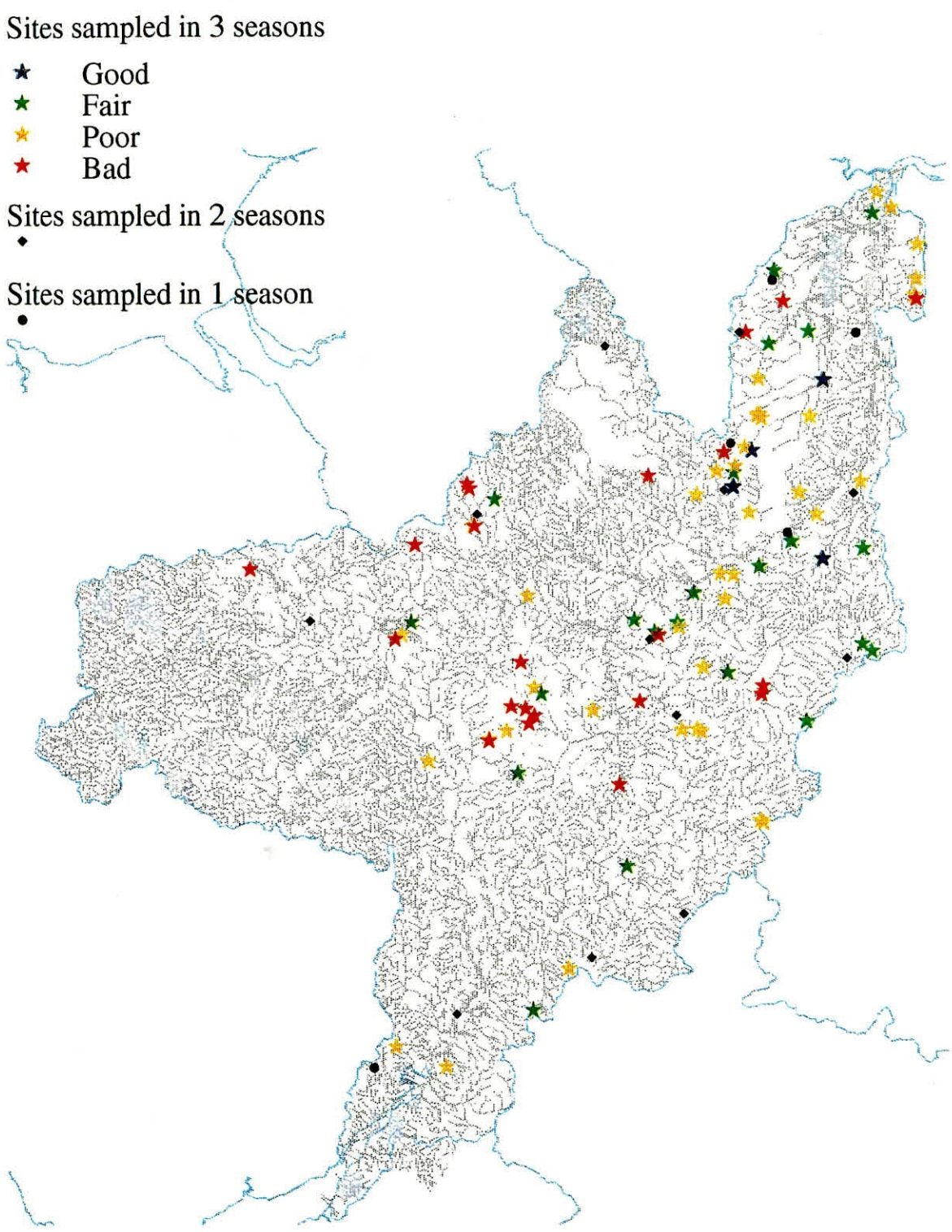

Figure 2.10 **Headwater sites sampled in the NRA Severn Trent Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1991.**

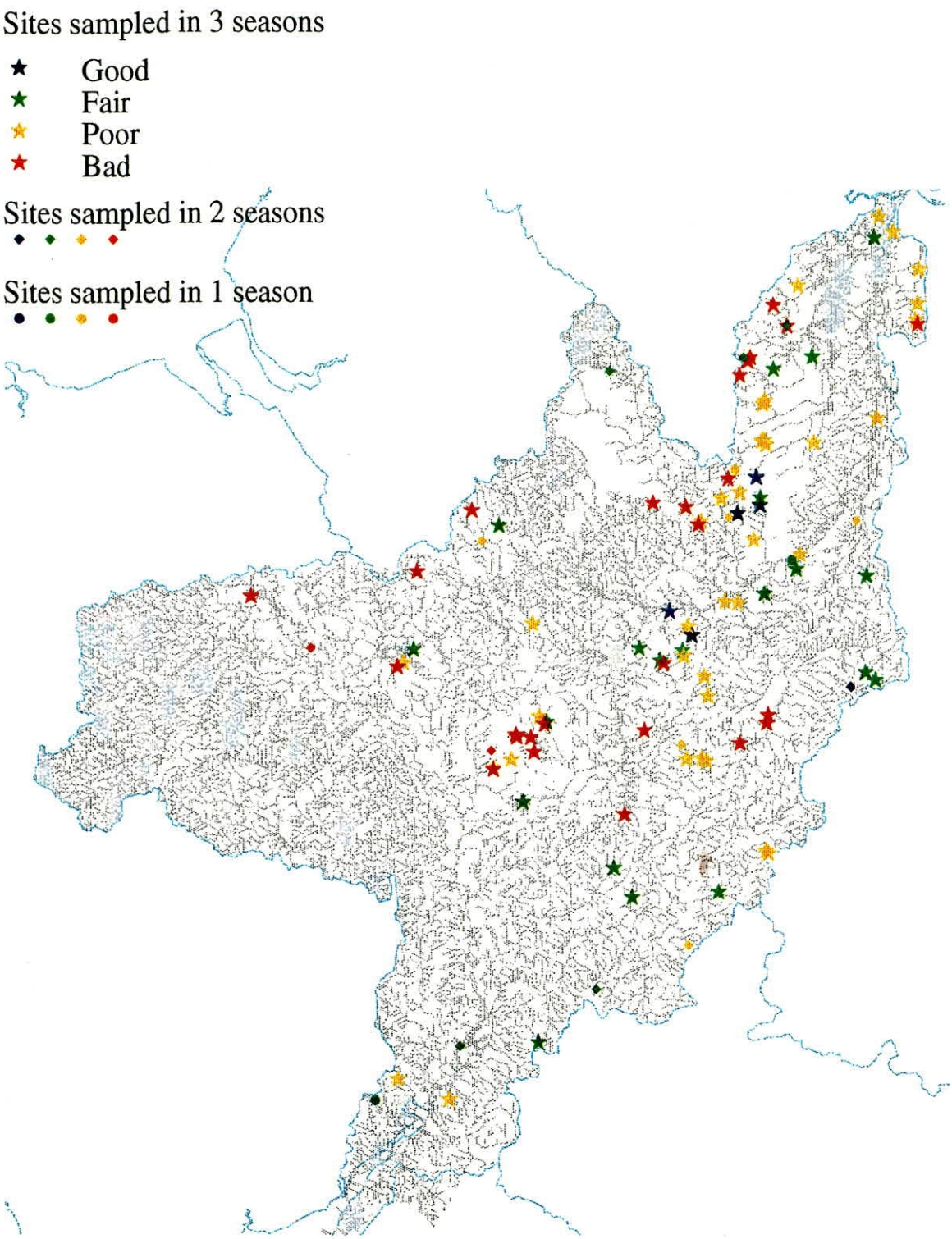

Figure 2.11 **Headwater sites sampled in the NRA Severn Trent Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1996.**

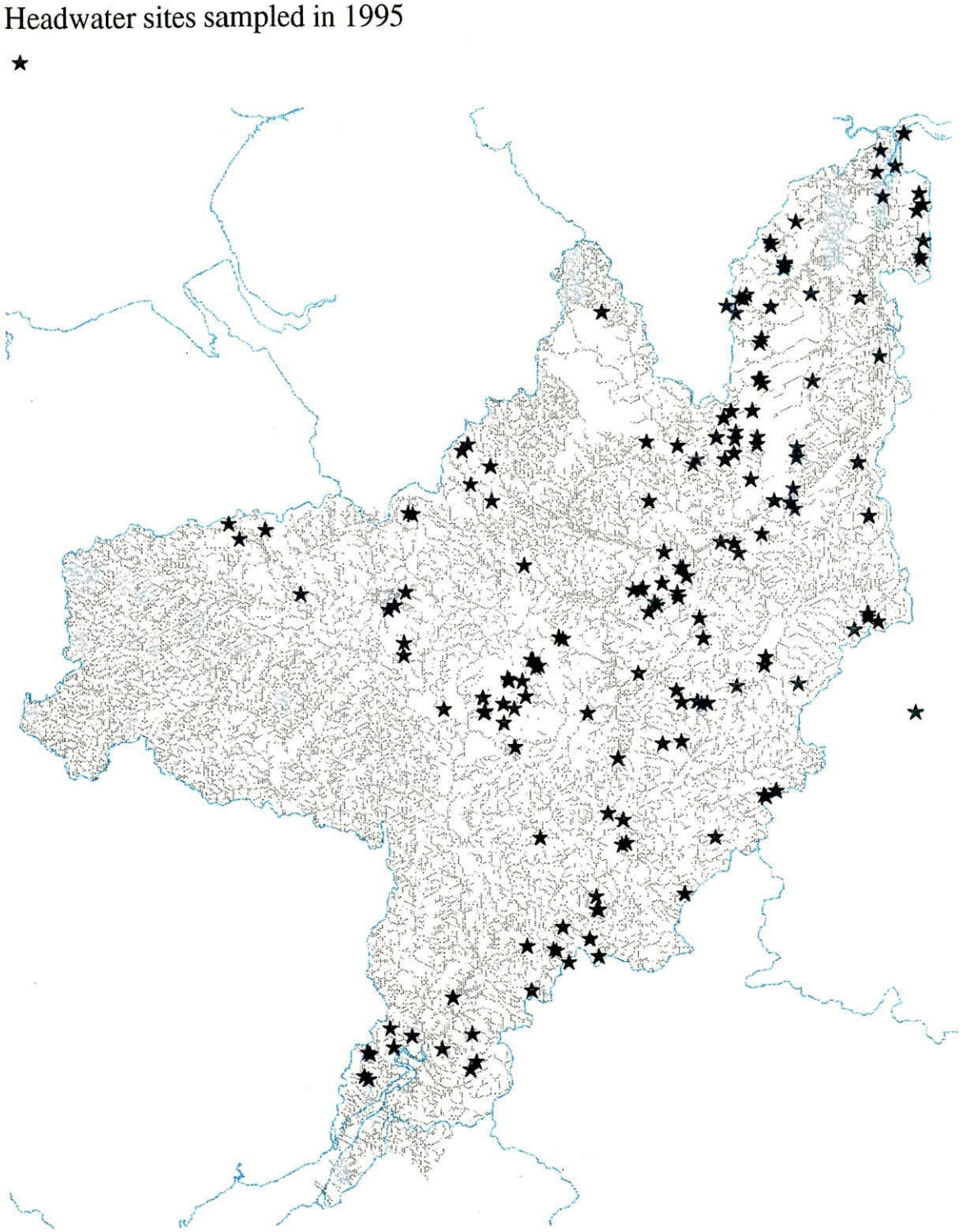

Figure 2.12 **Headwater sites sampled in the NRA Severn Trent Region during the 1995 General Quality Assessment.**

Sampling density - The 167 headwater sites sampled during the 1995 GQA represent an approximate density of sampling of one headwater site for every 37 headwater stream segments.

Biological condition - Based on the data supplied in 1996, the distribution of bands of biological quality for all 1990 RQS headwater sites was: A, 5.7%; B, 26.7%: C, 41.0% and D, 26.7%.

For the 89 sites sampled in three seasons the respective values were: A, 5.6%.; B, 23.6%: C, 41.6% and D, 29.2%.

For the 16 sites sampled in fewer than three seasons the respective values were: A, 6.3%.; B, 43.8%: C, 37.5% and D, 12.5%.

Although Band C and D sites occurred across the Trent Area, sites around Birmingham were in particularly poor condition. The sites in best condition tended to be those furthest from the course of the Trent, i.e those at greatest altitude.

In their response to the IFE letter of request, the Environment Agency (Shelley Howard *in litt*) writes:

> *The GQA programme for classified rivers will generally have headwater sites where a known effluent enters the stream at the top of the catchment, e.g. rural sewage works, minewater, due to the criteria imposed for classifying a stretch of river. The GQA programme will therefore not be representative of areas with little anthropogenic influence or diffuse inputs.*

Other headwater sampling programmes and relevant information - No specific information was provided on the number and biological condition of headwater sites sampled outwith RQS and GQA programmes.

The Environment Agency writes:

> [The] *region does not undertake surveys specifically to monitor headwaters and samples which are taken from headwater sites are not labelled as such*.....[sites other than RQS/GQA] *may be sampled for operational reasons in catchment surveys and pollution investigations but these are unlikely to be sampled regularly.*

The policy of restricting sampling to streams with known effluent input may underestimate the impact of agricultural activities on headwater streams. In the report on the 1985 RQS (Department of the Environment and Welsh Office 1986) it is stated for Severn Trent Region that:

> *Of particular concern is the impact of repeated pollution incidents in rural areas. Silage liquors and animal wastes are so polluting that even small quantities can be sufficient to affect water quality. Repeated minor entries of such wastes are having a chronic effect upon river quality.*

Southern

Distribution maps - Only two data-sets were available for this Region; the 1990 RQS set supplied to IFE in 1991 and the 1995 GQA set.

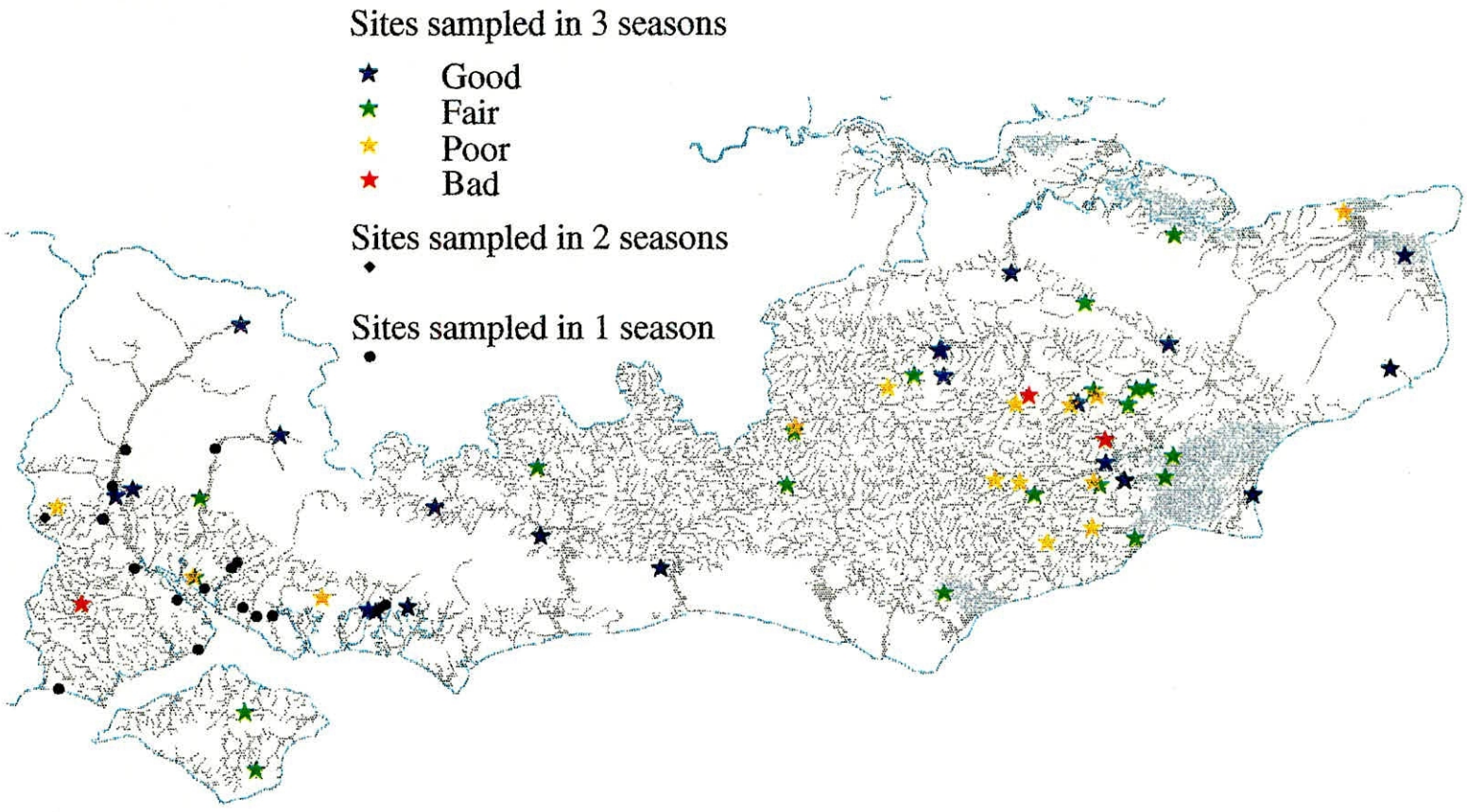

Figure 2.13 **Headwater sites sampled in the NRA Southern Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1991**

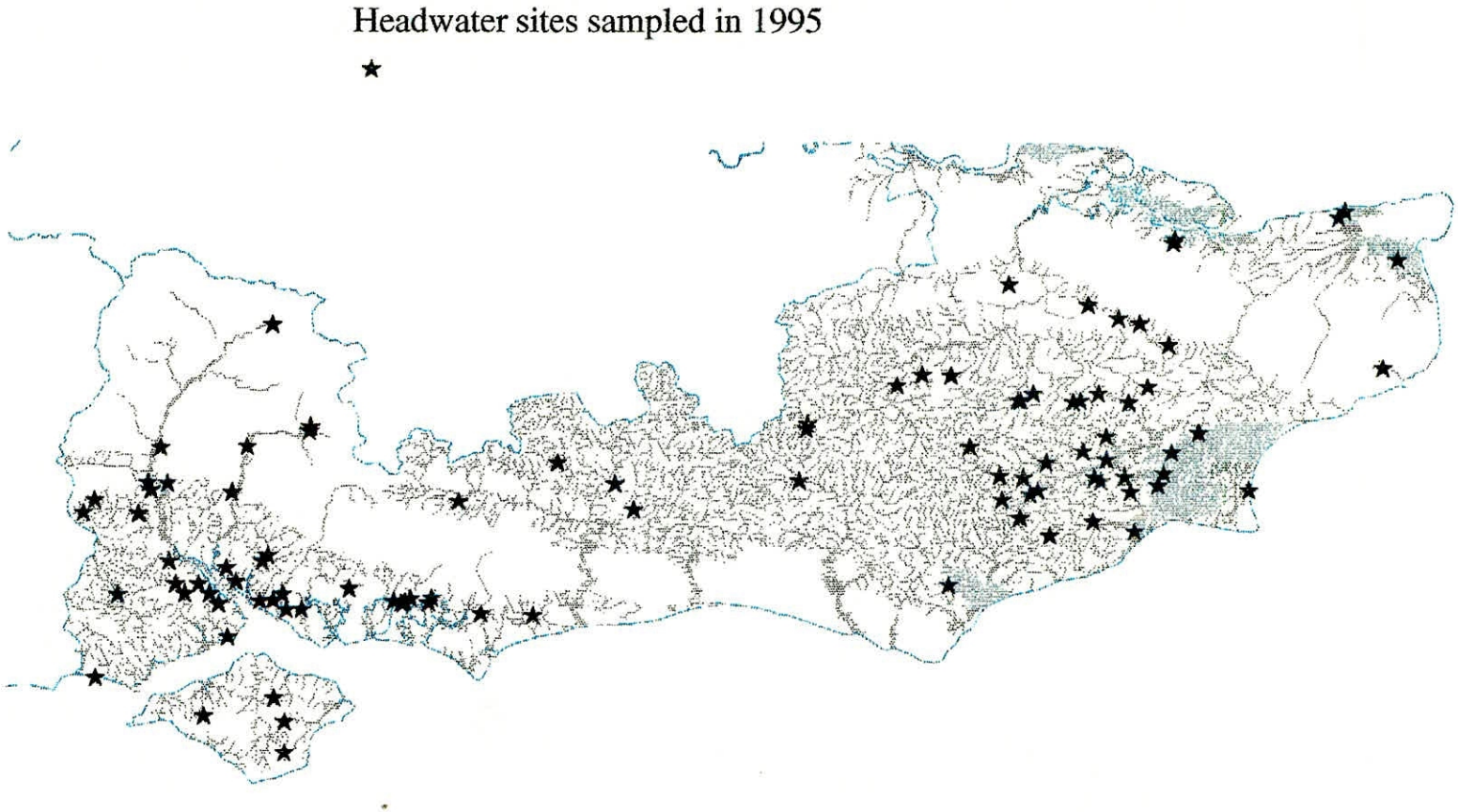

Figure 2.14 Headwater sites sampled in the NRA Southern Region during the 1995 General Quality Assessment.

A total of 78 headwater sites were identified from the 1990 RQS data-set supplied in 1991 (Figure 2.13). Of these, 59 were sampled three times, one twice and 18 once. This figure compares with Southern Region's own archives in which information on 82 sites is held for the 1990 RQS.

The 1990 RQS sites were concentrated in two areas, in south Hampshire and in East Sussex and western Kent. Two sites were sampled on the Isle of Wight.

The number of headwater sites sampled in the 1995 GQA rose to 103 (Figure 2.14), with a similar distribution and concentrations of sites to the 1990 RQS. This figure contrasts with Southern Region's own records of 90 headwater sites in this survey.

Sampling density - If 103 headwater sites were sampled during the 1995 GQA, this represents an approximate density of sampling of one headwater site for every 72 headwater stream segments.

Biological condition - Based on the data supplied in 1991, the distribution of bands of biological quality for the fifty-nine 1990 RQS headwater sites sampled in three seasons was: A, 35.6%; B, 35.6%: C, 23.7% and D, 5.1%.

There was no tendency for the sites with poorer biological condition to be concentrated in particular geographic locations. Nor did the selection of sites appear to be targeted at known problem streams. Indeed, information supplied by Southern Region (Bob Dines personal communication) suggests that some sites sampled in 1990 were not sampled in 1995 because of their proximity to a STW, fish farm or other disturbance.

Other headwater sampling programmes - Additional headwater sampling programmes, independent of national surveys, are related to special investigations, particularly around STW discharges.

Additional information on these sites is available from Southern Region on request.

Other relevant information - None supplied.

South Western (Environment Agency South West Region)

Distribution maps - Fifty-three headwater sites were identified from the 1990 RQS data-set supplied in 1991 (Figure 2.15). These comprised 28 from the former South West Region of the NRA and 25 from the former Wessex Region. All of these sites were sampled three times.

The 1990 RQS data-set supplied to IFE in 1996 from the central data-base contained the same number of sites, with the same numbers in each former Region, but some sites in this data-set were absent from the one supplied earlier and vice versa (Figure 2.16).

The issue is further complicated by separate information supplied by the Devon Area office of Environment Agency which list 33 headwater sites in Devon alone as having been sampled in the 1990 survey, of which eight were sampled in 1990 and 25 in 1991. Again, all of these sites are listed as having been sampled three times.

It appears that the data-sets provided centrally by the NRA/Environment Agency contain only those sites sampled in 1990 whereas the South West Region of the NRA conducted their 1990 RQS sampling over two years, 1990 and 1991. The number of 1990 RQS sites in Cornwall, as known to IFE, may also be underestimated in Figures 2.15 and 2.16.

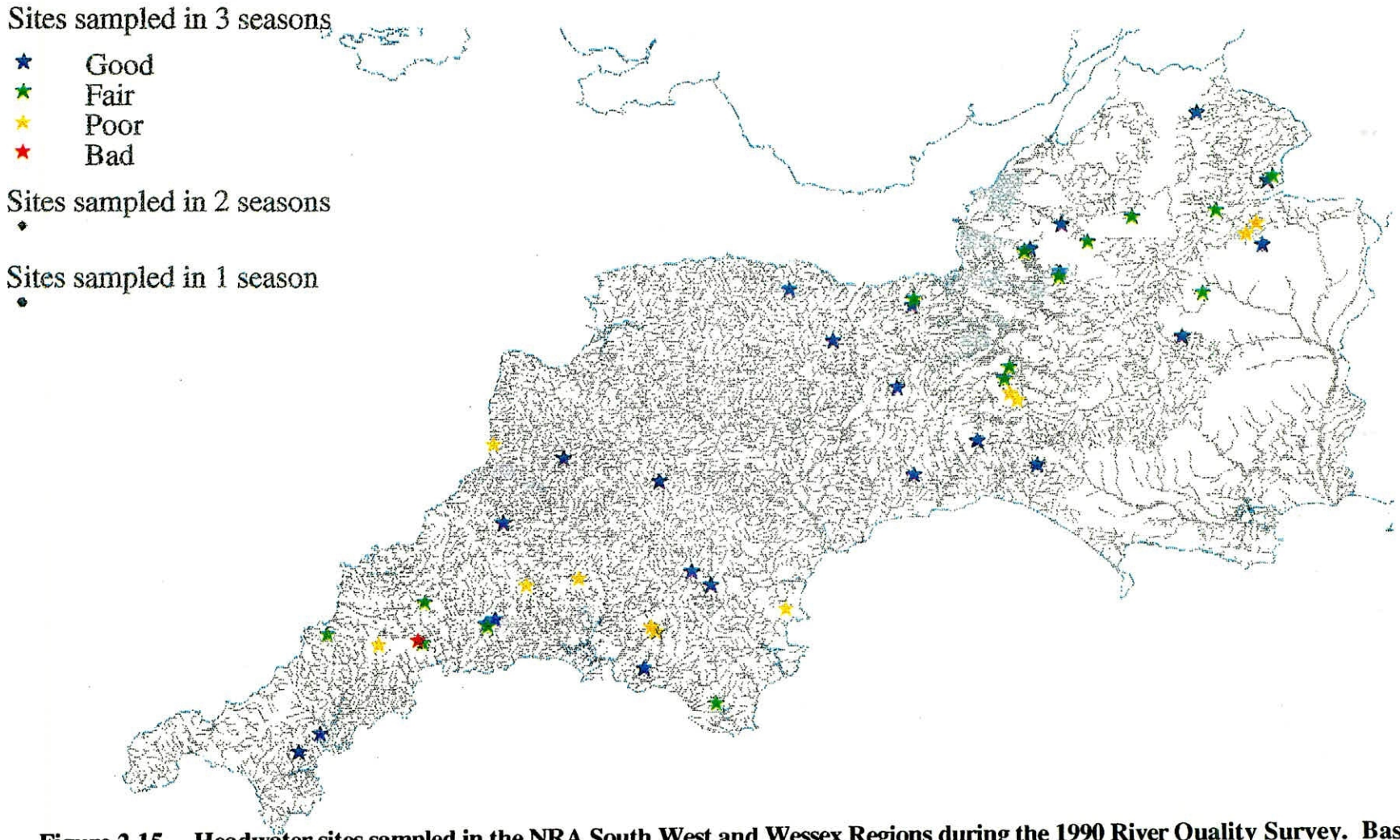

Figure 2.15 **Headwater sites sampled in the NRA South West and Wessex Regions during the 1990 River Quality Survey. Based on information supplied to IFE in 1991. South West samples exclude those collected in 1991.**

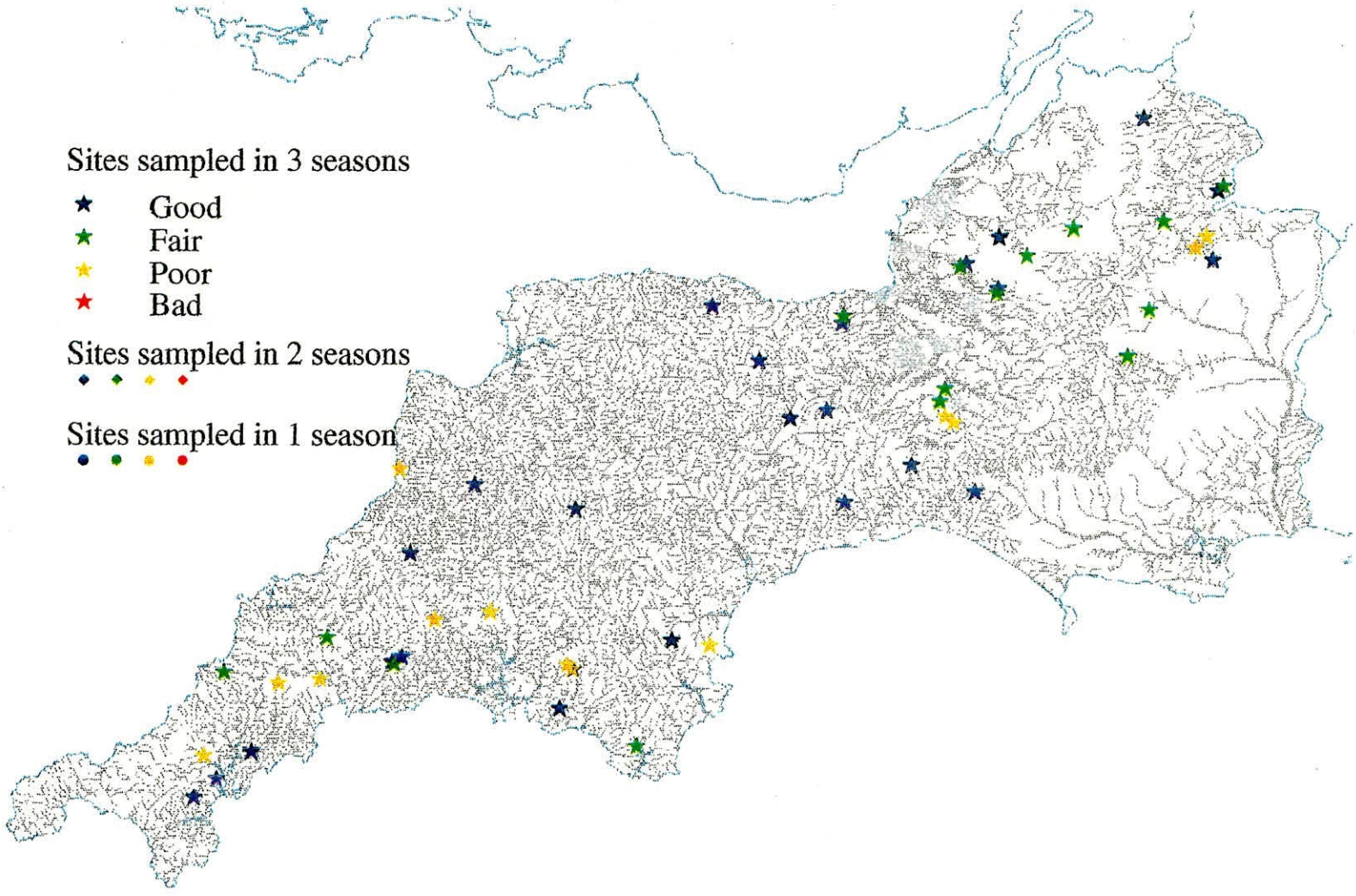

Figure 2.16 Headwater sites sampled in the NRA South West Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1996. South West samples exclude those collected in 1991.

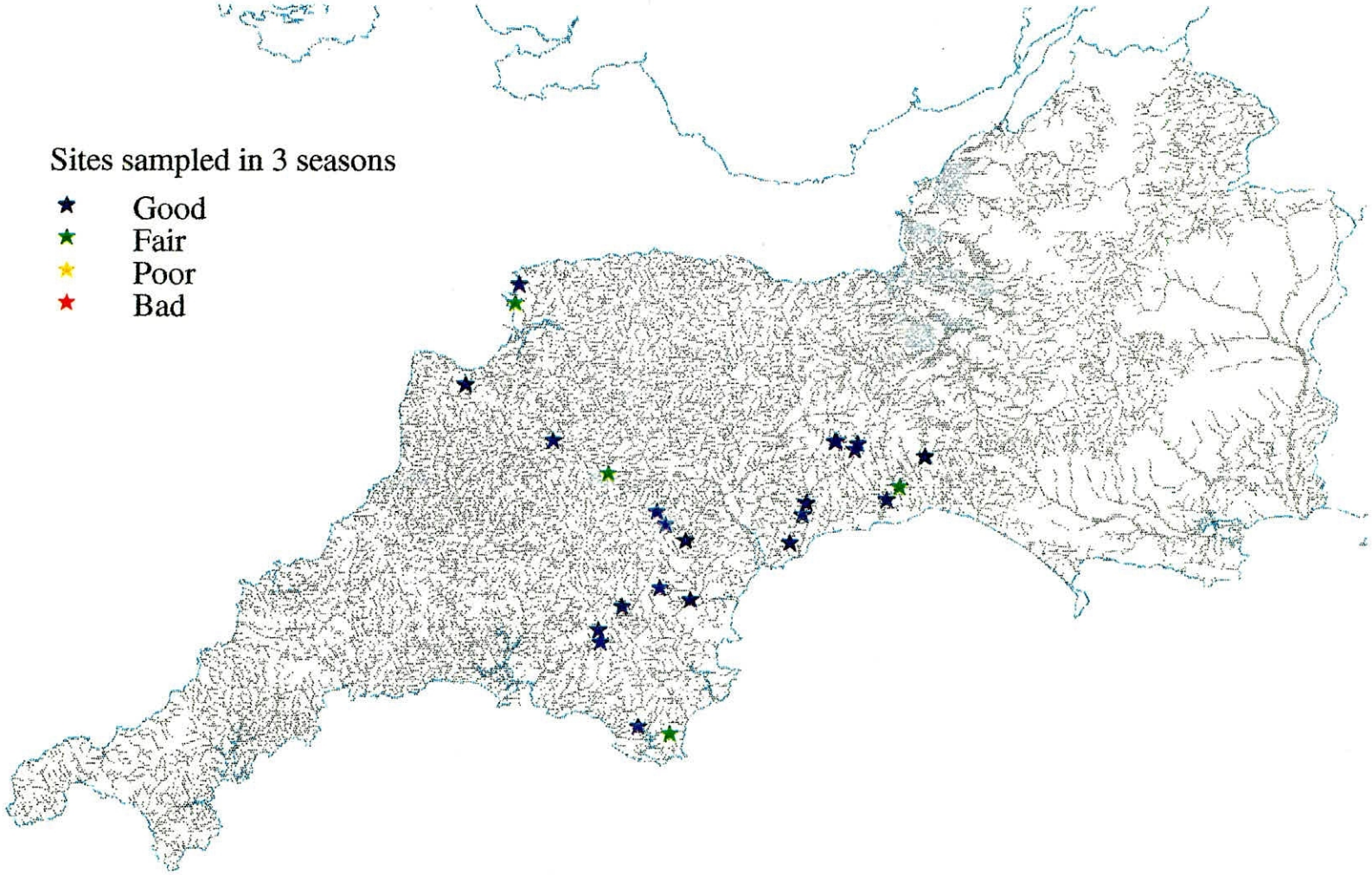

Figure 2.17 Headwater sites sampled in Devon in 1991 as part of the NRA South West Region 1990 River Quality Survey. Based on information supplied to IFE by the Environment Agency Devon Area Office.

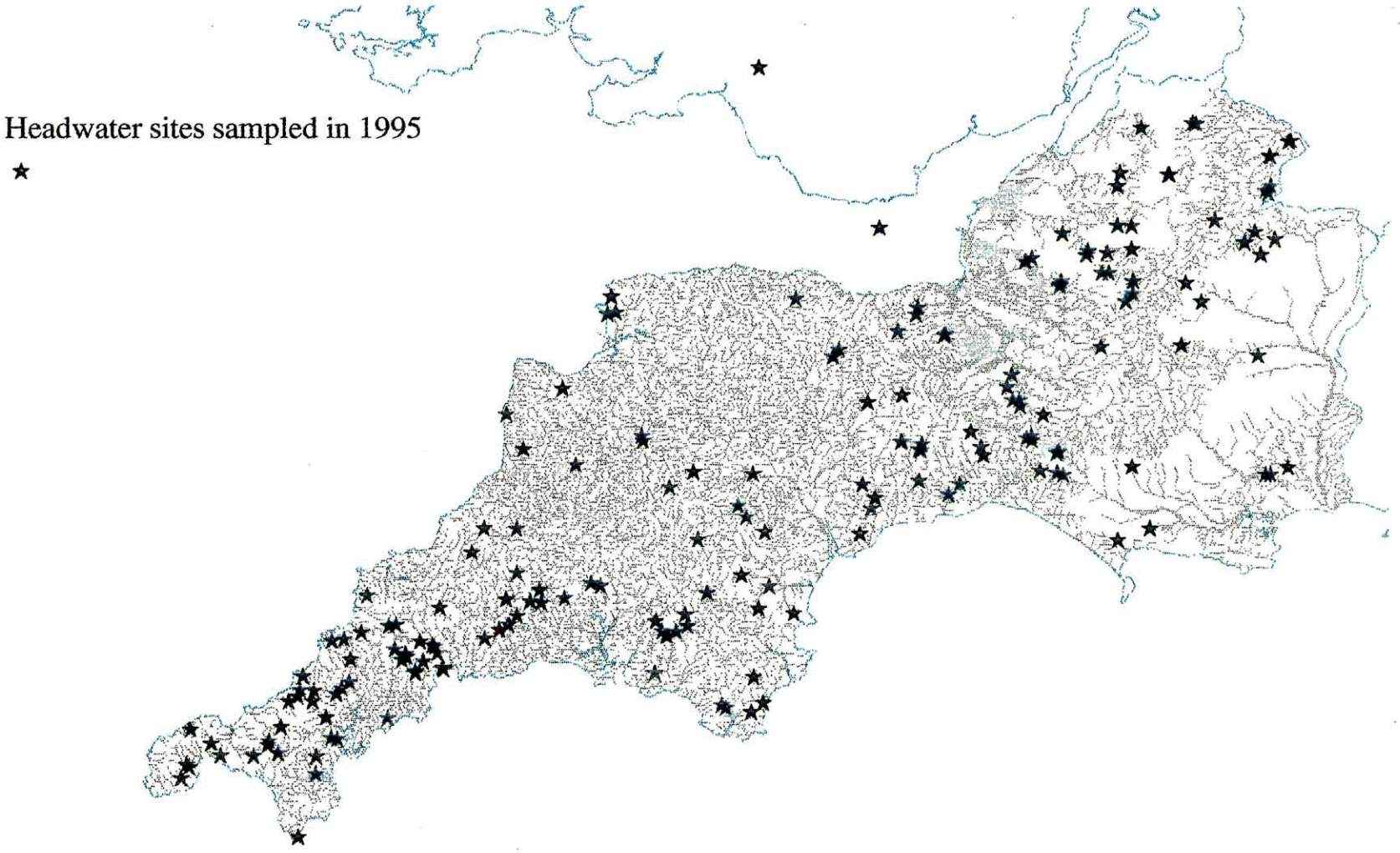

Figure 2.18 Headwater sites sampled in the NRA South Western Region during the 1995 River Quality Assessment.

The 1990 RQS sites known to have been sampled in that year were concentrated in two counties, Cornwall and Somerset The eight sites sampled in Devon in that were confined to the west of the county whilst the small number of Dorset sites were also almost all in its western edges. Dartmoor and Exmoor were largely unsampled for headwaters in 1990 as were the chalkstreams of Dorset.

However, the additional 1990 RQS headwater sites in Devon, sampled in 1991, extend the coverage in the south of the county in particular (Figure 2.17).

The number of headwater sites sampled in the 1995 GQA increased substantially to 197 (Figure 2.17) according to data supplied from the central data-base. This data-base is clearly in its early checking stage because two sites lie outside the regional boundaries.

The increase in headwaters sampled in the 1995 GQA compared to 1990 alone is spread across both Areas and each component county. Thus 119 sites were sampled in the former South West Region and 78 in the former Wessex Region. In the absence of full information on RQS sampling in the South West Region in 1991, it is not known to what extent the 119 headwater sites sampled in 1995 exceeded the number sampled in the previous survey.

In 1995, sites in central and eastern Dorset increased to a level commensurate with the low stream density in this part of the county. However, Northern Dartmoor and the whole of Exmoor remained relatively lightly sampled. An apparent increase in the number of sites in west Cornwall is complicated by lack of information on the number of Cornish sites sampled in 1991. Nonetheless, in 1995 at least, this was the most densely sampled part of the whole South Western Region.

Sampling density - The 197 headwater sites sampled during the 1995 GQA represent an approximate density of sampling of one headwater site for every 60 headwater stream segments, based on the estimates derived from 1km squares in this study (Table 2.3). If the larger estimate derived from Smith and Lyle's (1979) data is used (Table 2.4) then this density falls to one headwater site for every 103 segments.

Biological condition - Based on the data supplied in 1996, the distribution of bands of biological quality for the fifty-three 1990 RQS headwater sites sampled in three seasons was: A, 45.3%; B, 30.2%: C, 24.5% and D, 0.0%.

The distribution of bands for the former Wessex Region was: A, 40.0%; B, 44.0%: C, 16.0% and D, 0.0%. In the South West Region the equivalent figures were: A, 50.0%; B, 17.9%: C, 32.1% and D, 0.0%.

The separate band distribution, for 32 of the 33 sites supplied directly by the Devon Area (Jeanette Collett personal communication) was: A, 87.5%; B, 12.5%: C, 0.0% and D, 0.0%. The remaining site was a canal and was unclassified.

There was no major tendency for the 1990-sampled sites with poorer biological condition to be concentrated in particular geographic locations. Nor did the selection of sites appear to be targeted at known problem streams. The only Band D site in the data-set supplied in 1991 was not included in that supplied in 1996 or by the Agency's South West Region directly. Its location was central Cornwall. The overall condition of sites sampled in Devon in both 1990 and 1991 was better than that of the 1990-sampled sites in each of Cornwall and Somerset.

Other headwater sampling programmes - Additional headwater sampling in the Devon Area took place in each of 1992, 1993 and 1994. Most sites were sampled three times in their year of survey and almost all were sites listed by the Area as having been sampled in 1990 or 1991 for the 1990 RQS. In total 31 of the 33 survey sites were sampled again in either 1992, '93 or '94. Five RQS sites were sampled in two of the three following years and one, downstream of a dairy, was sampled in each of these years. Only three new, non-RQS headwater sites were surveyed during 1992-94, each in 1993.

No further information was provided for Cornwall or for any part of the former NRA Wessex Region.

Other relevant information - None supplied by the Environment Agency.

In the report on the 1985 RQS (Department of the Environment and Welsh Office 1986) it is stated for the, then, Wessex Region that:

> *Farm discharges and agricultural run-off continue to be the most significant sources of pollution.....mainly affecting smaller streams. Positive benefits in counter-acting this have been achieved through campaigns to reduce farm pollution in selected catchment areas and by giving increasing attention to the more polluted streams.*

Thames

Distribution maps - A total of 65 headwater sites were identified from the 1990 RQS data-set supplied in 1991. This data-set was stated to contain a series of errors according to biologists in both the Fobney and Waltham Cross laboratories. Eliminating known errors, eg canals, leats and sites whose distance from source was actually >2.5km left a residual of 53 sites (Figure 2.19). Of these, ten were sampled three times and 43 once only.

Few sites were situated in the most upland parts of the catchment, furthest from the main course of the Thames, and only four headwater sites were sampled within the geographic area of responsibility of the Waltham Cross Laboratory. None of the listed sites appeared to be in urban London.

No information on Thames sites was included in the 1990 RQS data-set supplied to IFE, from the national data-base, in 1996. Instead Thames Region supplied a list of all headwater sites held on their internal data-base which were considered routine 1990 sampling sites. It is not clear what the relationship between routine and RQS is. Some of the sites identified as routine by the Fobney Laboratory (Alan Tubb personal communication) were stated not to be RQS sites by the Waltham Cross Laboratory (Dave Leeming personal communication).

Eliminating the known non-RQS sites identified by Waltham Cross, together with canals and leats left a total of 57 headwater sites (Figure 2.21), some others of which may not have been part of the national survey.

The number of headwater sites sampled in the 1995 GQA increased to 86 (Figure 2.21), but with a similar overall spread to 1990, including very few sites sampled from the Waltham Cross Laboratory. Still no headwater sampling occurred in Greater London.

Relying on RQS and GQA samples alone gives a misleading impression of the attention paid to headwater sampling across the Region as a whole and from Waltham Cross in particular.

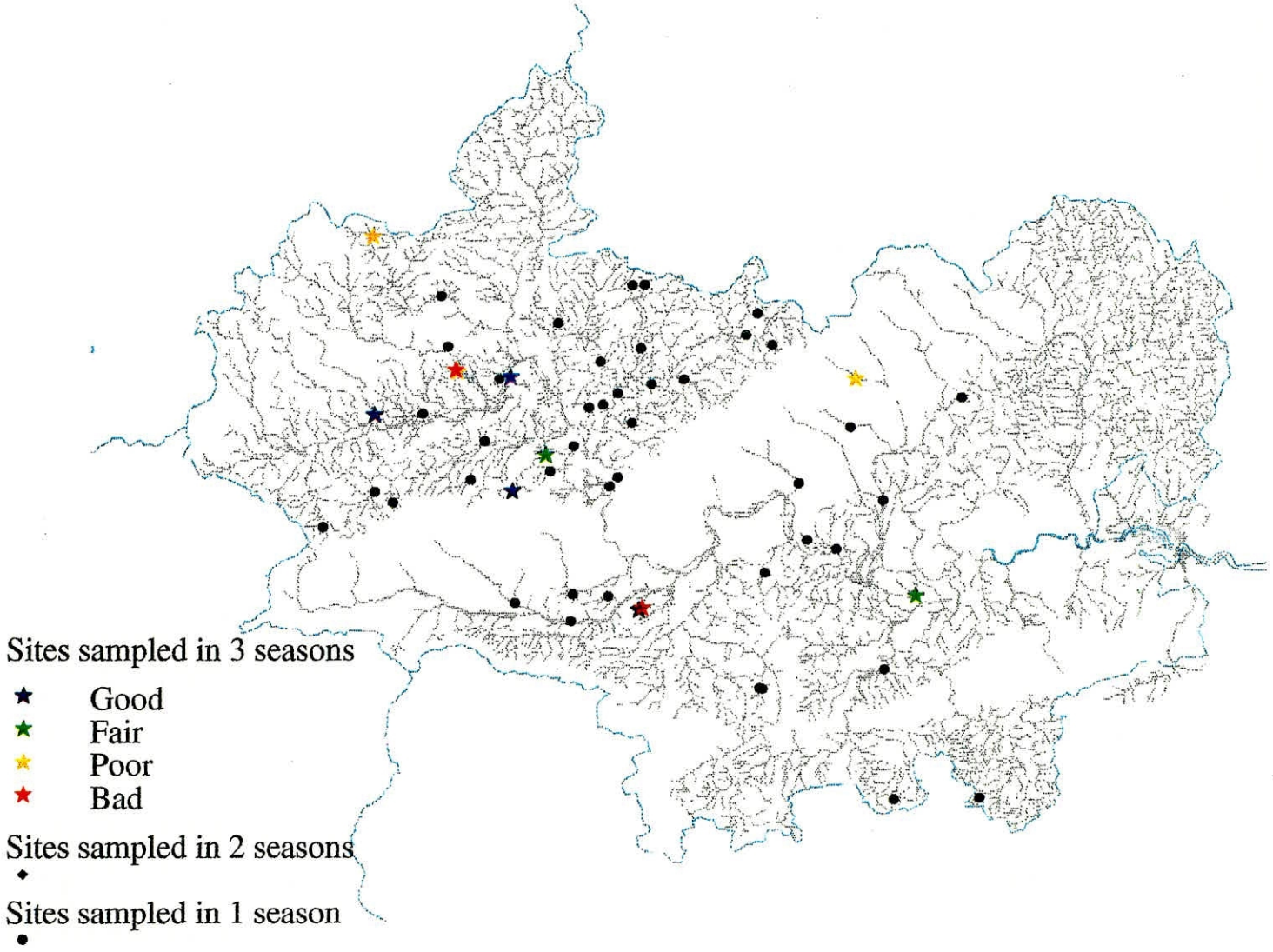

Figure 2.19 Headwater sites sampled in the NRA Thames Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1991.

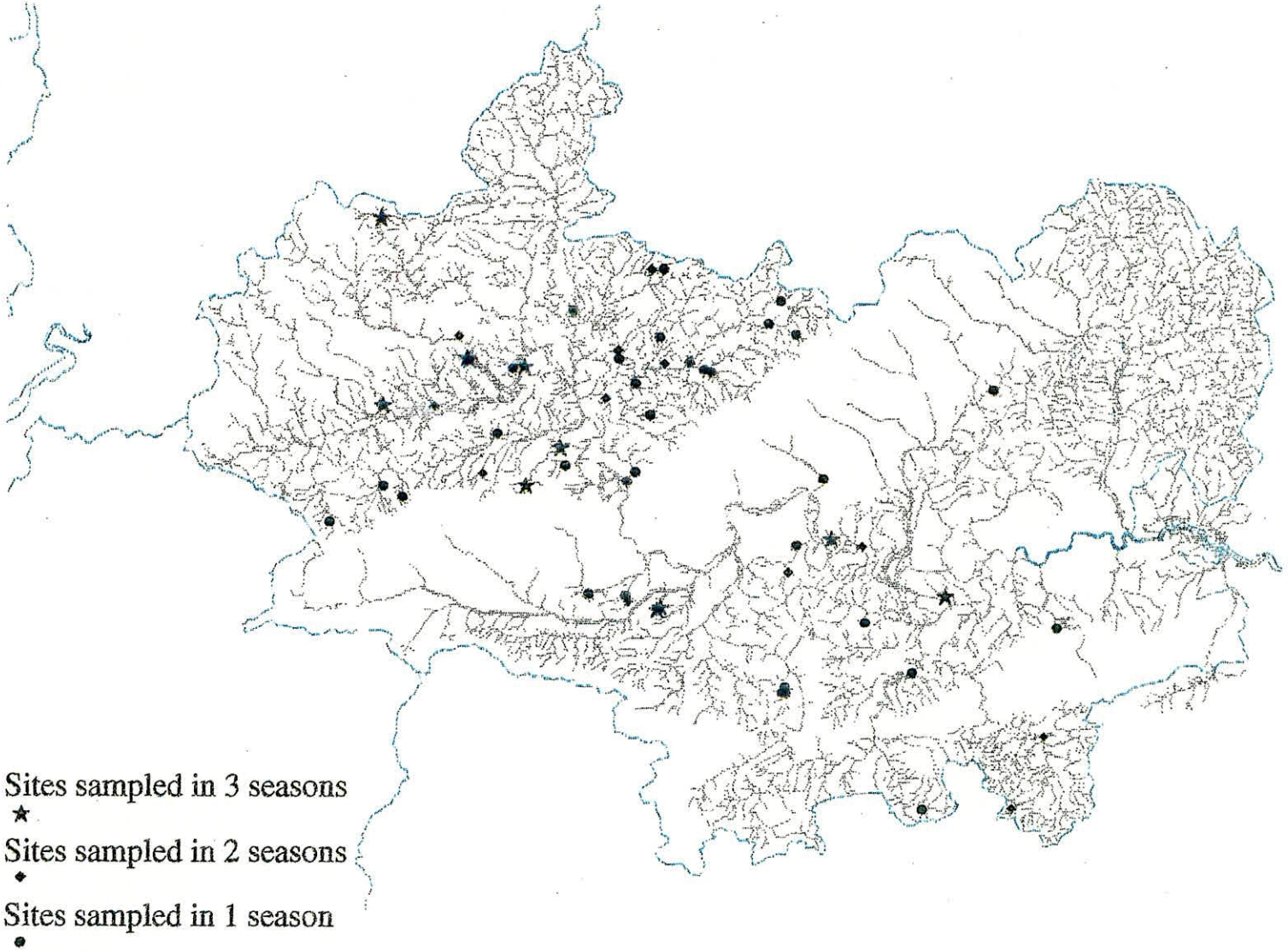

Figure 2.20 Routine headwater sites sampled in the NRA Thames Region during the 1990 River Quality Survey. Based on information supplied to IFE by the Environment Agency Thames Region.

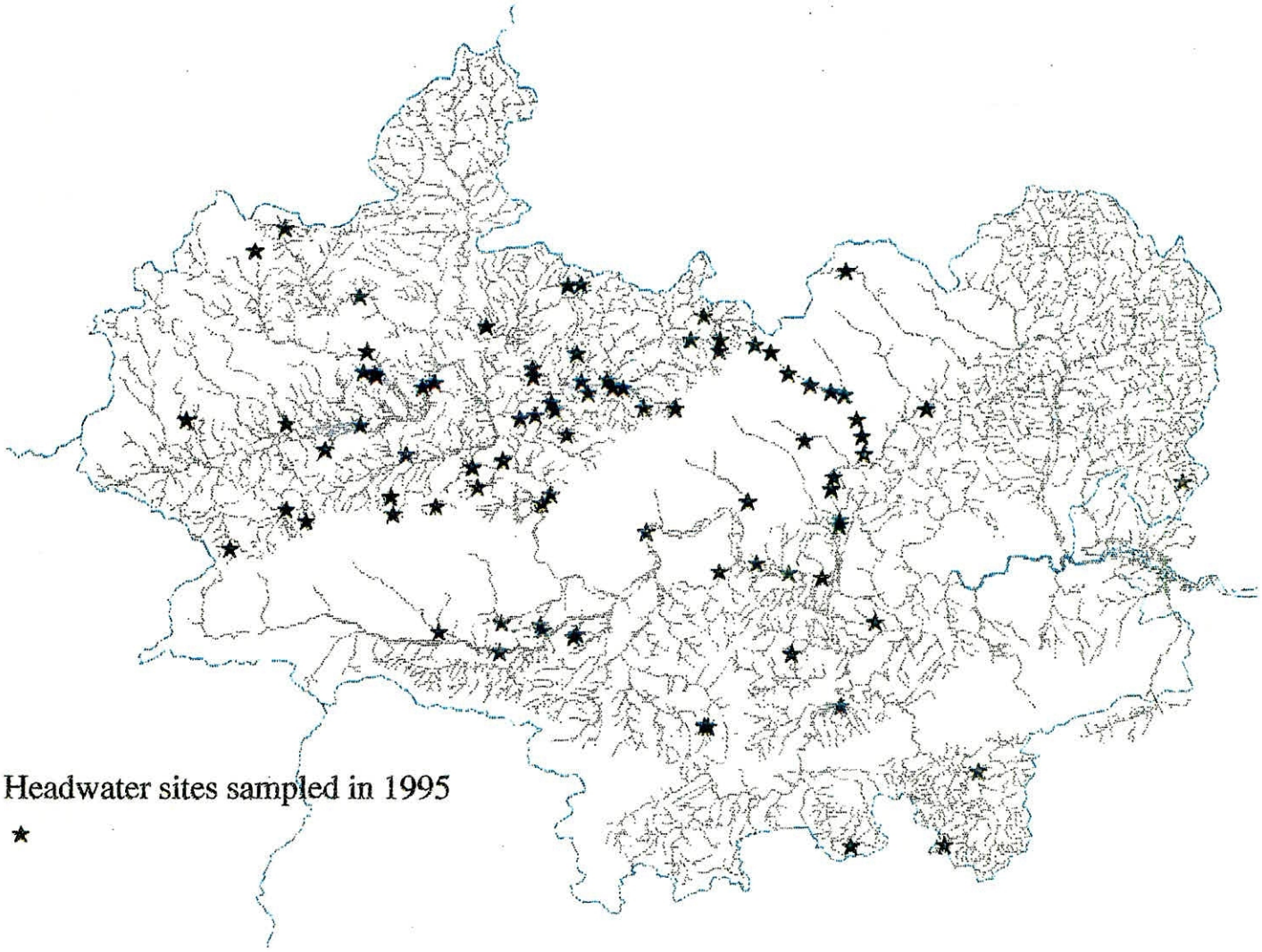

Figure 2.21 Headwater sites sampled in the NRA Thames Region during the 1995 General Quality Assessment.

Sampling density - The 86 headwater sites sampled during the 1995 GQA represent an approximate density of sampling of one headwater site for every 55 headwater stream segments. This density would be much greater if the additional samples collected between national surveys were taken into consideration (see *"Other headwater sampling programmes" below).*

Biological condition - Based on the corrected data supplied in 1991, the distribution of bands of biological quality of the 10 sites sampled in each of three seasons during the 1990 RQS headwater sites was: A, 40%; B, 20%: C, 20% and D, 20%.

No bandings were available for sites sampled in fewer than three seasons.

Insufficient sites were banded to draw any conclusions about differences in the distribution of the biological condition of sites throughout the Region. However Thames Region (Alan Tubb *in litt*) state that "routine" sites were chosen specifically to monitor pollution problems and will give a biased and false impression of poor quality headwaters in the Region.

Other headwater sampling programmes - Both the Fobney and Waltham Cross laboratories responded to the request for further information.

No specific additional headwater sampling programmes were identified at Fobney and the only additional sites supplied are those which may be "routine" sites not contributing to the RQSs/GQAs.

However, according to Dave Leeming (*in litt*) the 1990 RQS data-set gives a totally misleading impression of the effort put into headwater sampling into at Waltham Cross. In addition to "routine" annual or bi-annual sampling of a small number of sites not incorporated in the national surveys other forms of special sampling programmes are conducted which incorporate headwater studies. These are:

- detailed catchment studies
- MSc student projects
- additional strategic programmes

The areas subject to detailed studies ranged from highly urbanised, through mixed urban/suburban/green belt to rural catchments. Sites were sampled either once or twice and "the results were used to identify water quality and land use influences and locations of ecologically important watercourses".

MSc student projects were conducted in 1994 and 1995. The 1994 project was concerned with land use and water quality influences in the Colne, Rib and Roding catchments. The 1995 project included a survey of small watercourses in two highly urbanised catchments. Sites were sampled over one season. Extensive water quality problems were identified and attention was drawn to the role of headwaters in maintaining catchment biodiversity.

Strategic studies are undertaken in connection with developing Catchment Management Plans (CMPs) or Local Environment Agency Plans (LEAPS), reviewing planning applications and assessing the impact of pollution incidents.

In total, some 223 samples from an unstated number of sites have been collected from headwaters since 1st January 1990. These represent 9.3% of the samples collected within the Area over that period.

Other relevant information - The information received from the Fobney Laboratory seems to indicate that the biological condition of headwaters in their Area is of a high standard. Although sites are specifically selected because they are considered to be associated with pollution problems the general condition of these sites, as displayed in Figure 2.19, is high compared to many other Regions.

By way of contrast, a different picture emerges from Waltham Cross. Dave Leeming writes:

> *Our results confirm the poor condition of headwaters suggested by IFE's headwaters project. Whilst there has been a bias towards urban catchments even streams in relatively rural surroundings have been found to support particularly depauperate assemblages of pollution-tolerant taxa.*

Where headwater streams of high ecological value are noted then these and the interesting fauna they support are highlighted in catchment management plans. Dave Leeming continues:

> *Full species level surveys of target streams are a regular action arising from recent CMPs, and in one CMP (Wandle/Beverley/Hogsmill) there was a Specific Action to "Protect the Biological Status of Headwater Streams", which were seen to contribute significantly to the overall biodiversity of the catchment and provide a strategic species-pool for potential future recolonisation to currently degraded parts of the catchment.*

Both Areas draw attention to the fact that limiting the definition of headwaters to watercourses within 2.5km of source exclude valuable sites whose size characteristics are similar to "headwaters" *per se* and which function as important refugia for recolonisation. On this subject Dave Leeming writes:

> *If we ignore those streams between ... 2.5 and 4km* [from source] *we may create another gap in our understanding of equal significance to the one we are trying to fill. Experience suggests biological condition of this category includes significantly richer and equally important assemblages reflecting the less intermittent nature of these streams (at least in recent years). If we considered these it would enhance further our appreciation of headwaters/minor tributaries, without compromising the overall picture of ecological damage and sensitivity that is being presented.*

Welsh

Distribution maps - Very few headwater sites are sampled during RQS and GQA surveys. This is compensated for by extensive, targeted sampling as described below, under "Other headwater sampling programmes".

Just 23 headwater sites were identified from the 1990 RQS data-set supplied in 1991 (Figure 2.22). All but two were sampled on three occasions. The figure remained at 23 in the data-set supplied in 1996 (Figure 2.23) although the composition of the two lists showed a small number of changes. All the latter set of sites were listed as having been sampled three times.

The few 1990 RQS sites were concentrated in three parts of the country; the extreme north-east (Clwyd), the south-east (Hereford and Worcester) and the south (the Glamorgans). Only one other site was sampled in the rest of the Region.

The number of headwater sites sampled in the 1995 GQA increased slightly to 35 (Figure 2.24), with most of the 1990 RQS sites included in the list.

Sampling density - The 23 headwater sites sampled during the 1995 GQA represent an approximate density of sampling of one headwater site for every 459 headwater stream segments, as calculated from 1km square information. If the figures derived from Smith and Lyle (1979) are substituted the ration increases to 1:771.

Biological condition - Based on the data supplied in 1996, the distribution of bands of biological quality for all 1990 RQS headwater sites was: A, 30.4%; B, 13.0%: C, 43.5% and D, 13.0%.

There are insufficient sites to make any meaningful statements about differences in biological condition in different parts of the country or to identify any specific policy of targeting poor condition watercourses.

Other headwater sampling programmes - Extensive headwater sampling is undertaken in the Welsh Region as part of surveys targeted at particular problems. These surveys are not specifically directed at headwaters but the nature of the problems investigated result in headwater sites being highly represented in the sampling programmes.

A consequence of these programmes is that the density of headwater sampling in Wales is probably greater than in any other Region, despite the poor representation of these watercourses in GQAs and their predecessors.

Welsh Region (Graham Rutt *in litt*) provided very detailed information of the nature of the sampling programmes and the extent of headwater sampling each contained. Programmes are divided into four main categories, whose purposes are:

- to assess the extent of farm pollution, prioritise pollution prevention visits and assess the benefits of rapid pollution prevention activities
- to assess the extent of acidification in sensitive areas of Welsh Region
- to assess the impact of discharges into watercourses
- to investigate specific pollution problems, including *ad hoc* surveys

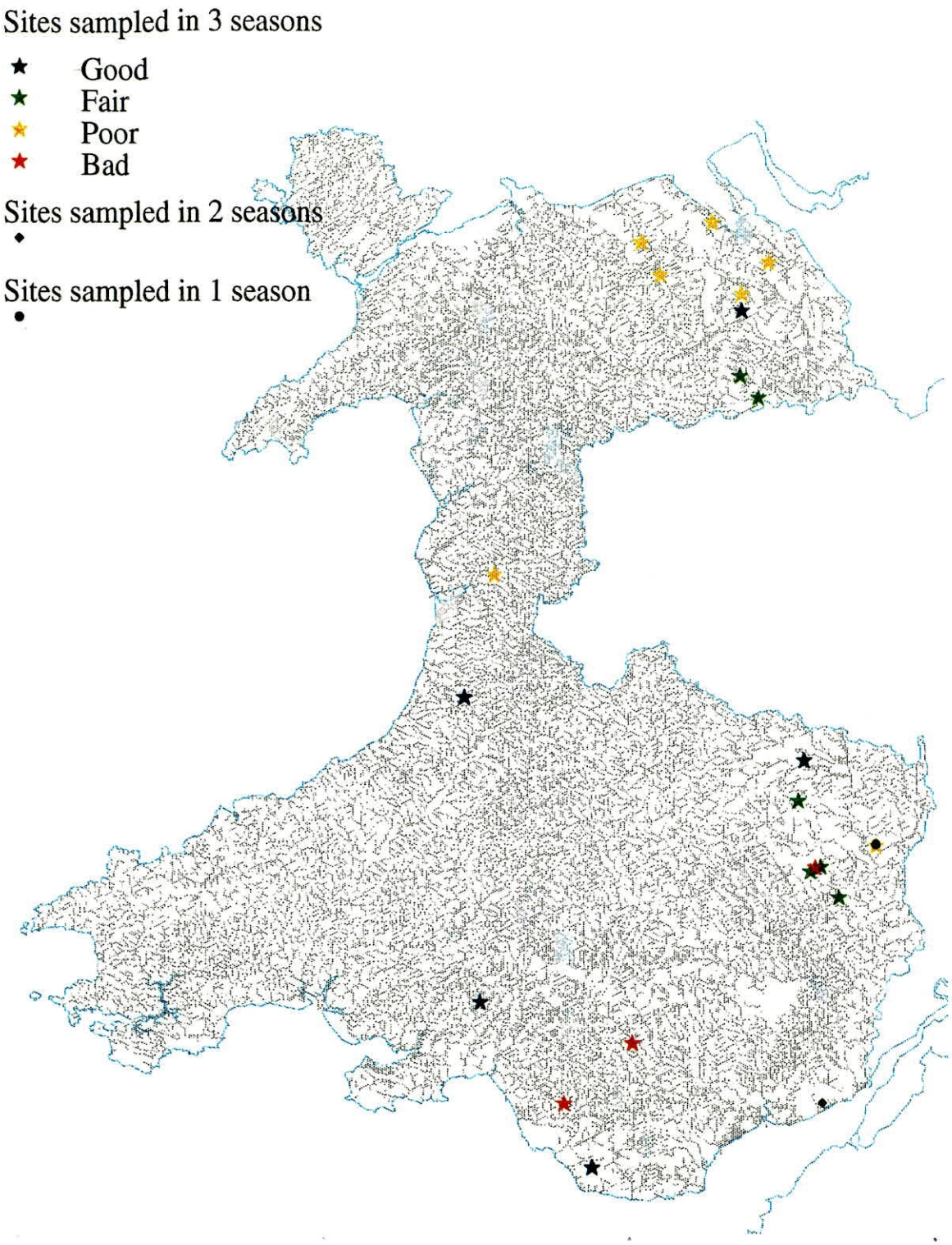

Figure 2.22 **Headwater sites sampled in the NRA Welsh Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1991.**

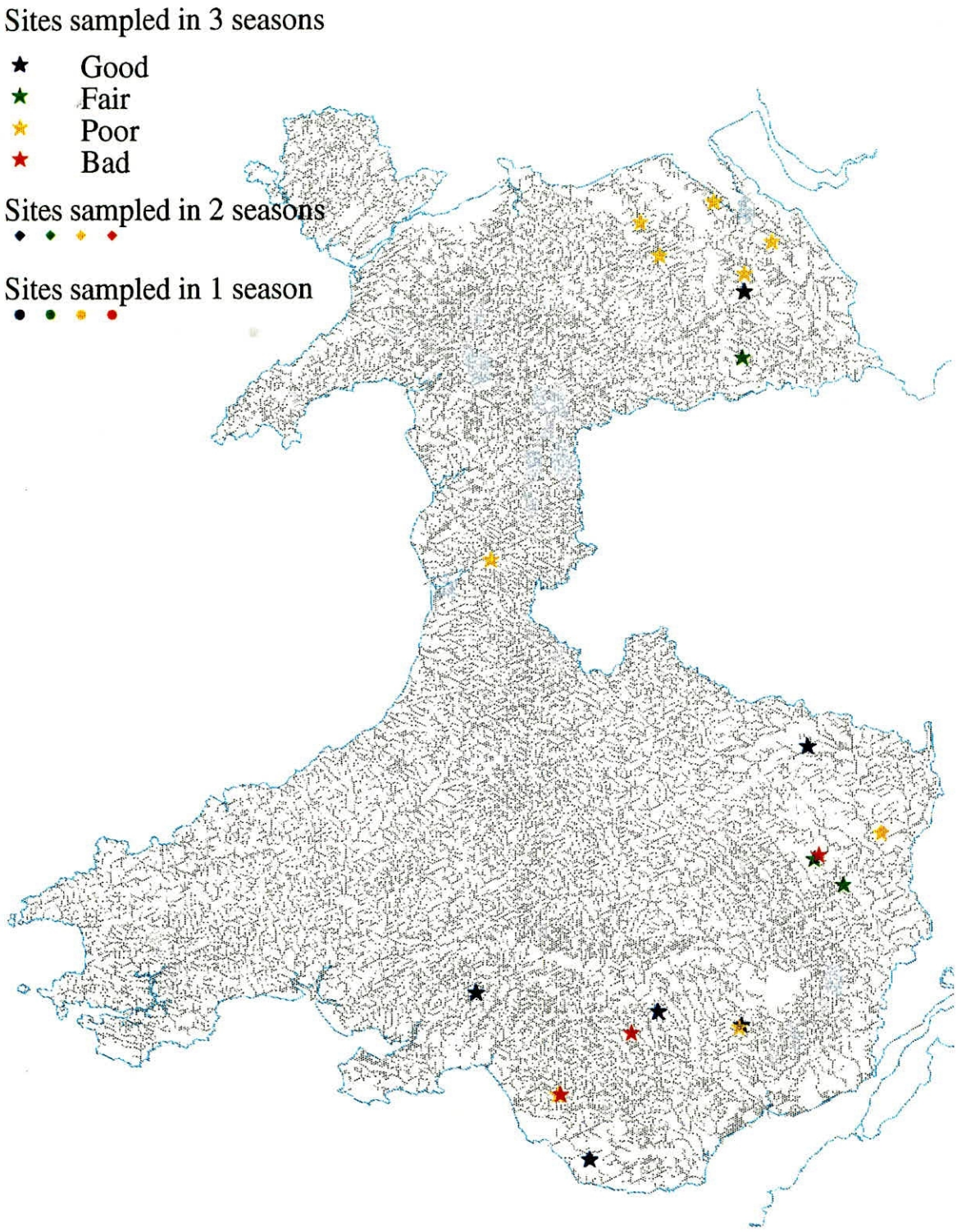

Figure 2.23 **Headwater sites sampled in the NRA Welsh Region during the 1990 River Quality Survey. Based on information supplied to IFE in 1996.**

Headwater sites sampled in 1995

★

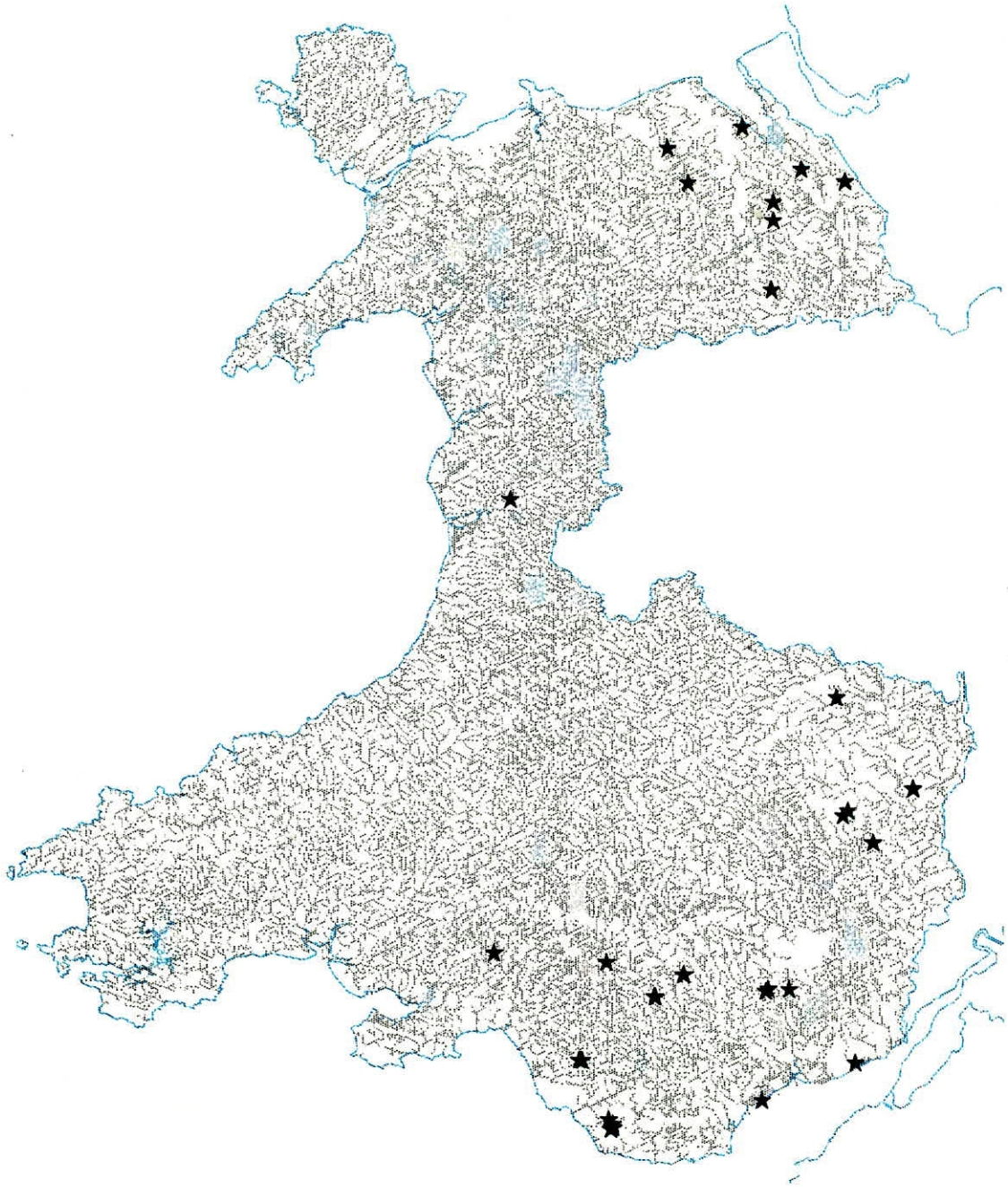

Figure 2.24 **Headwater sites sampled in the NRA Welsh Region during the 1995 General Quality Assessment.**

Over the period February 1991 to April 1996, a total of 707 sites from 52 sub-catchments in the South West Area of the Region alone have been sampled to assess the impact farm pollution. Almost 50% of these, (353), have been in headwaters. Similar work, but on a smaller scale, has been carried out in the other two Areas: South East and Northern. For example, (Rutt *in litt*), 113 sites were sampled in South East Region over a similar period, of which 52 sites were on headwaters.

Acidification studies have involved sampling over 70 sites in the South West Area, 85 in the South East Area and a similar number in the Northern Area. Full details of the proportion of these sites which are on headwaters is not available although the known value of 27% in the South East Area is likely to be fairly representative of the Region as a whole.

In farm and acidification studies assessments were based on a single one minute kick sample processed on the bankside (Rutt 1993; Davies 1994)..

With regard to impact assessment of specific discharges, Rutt (*in litt*) writes:

> *a number of regional strategies are in place which are designed to assess the impact of discharges and to prioritise expenditure by the dischargers. Examples of these are a STW strategy, an industrial discharge strategy and a WTW strategy. Biological surveys play a key role in determining impact ratings for the various types of discharge* [and] *a number of sites in headwaters will be sampled during the course of this work. Samples are collected using IFE methodology and processed to family level. All STW in Welsh Region discharging to freshwaters have been sampled in this way and* [it is estimated] *that ca 20% of these 787 works discharge to headwaters.*

A considerable number of headwater sites also get sampled during pollution incident surveys and *ad hoc* surveys. Numbers of these have not been estimated. By virtue of the rapid response required for this type of investigation, sample processing is often undertaken at the bankside.

On the basis of the information provided it is likely that, within the Welsh Region as a whole, as many as 750 headwater sites may have been sampled over the five year period from early 1991 to early 1996. If so, this represents a sampling density of one site for every 14 headwater stream segments, based on estimates obtained in this study, or 1:24 based on values derived from Smith and Lyle (1979).

No data were provided on the number of sampling occasions per site for discharge impact assessments, pollution incident investigations and *ad hoc* surveys but it is probable that each site was sampled only once, as is the norm for farm pollution and acidification assessments.

Other relevant information - The procedures used to assess the extent of farm pollution and acidification involved rapid assessment keys derived within the South West Area (Rutt *et al.* 1990, 1993; Wade et al. 1989). As stated by the authors, these sorts of techniques *"are designed for rapid investigations of catchments as a cost-effective means of prioritising effort"* (Rutt *et al.* 1993).

The portability of the procedures remains to be fully tested. Trials of the farm pollution key were encouraging when tested in Devon (Rutt *et al.* 1993) but are known not to be appropriate in other parts of Wales, such as the Vale of Glamorgan, where more traditional biological techniques are recommended (Rutt 1993). The need for new indicator keys in other Regions is more widely recognised by Rutt *et al.* (1993).

The headwater data collected during special surveys, including bands of biological condition are not routinely stored on the Agency's regional database. Plans for including the results of discharge impact assessment, pollution incident investigations and *ad hoc* surveys are now in hand and will lead to greater accessibility of headwater information.

Rutt (*in litt*) provides a summary of the Region's overall strategy for headwater sampling and the seriousness of the environmental stresses imposed on these small watercourses:

> *In Welsh Region headwaters are sampled as part of specific investigations either of point source discharges or more diffuse pollution issues such as acidification or farm pollution. A very pragmatic approach is taken to this work and the information produced from the surveys is at a level sufficient for the purposes of assessing pollution and targeting pollution-prevention resources rather than detailed assessment of the faunal composition at the sites surveyed.* ***Headwaters are often the worst affected parts of river systems in the region due to low dilution and the nature of two of the major pollution problems (farm pollution and acidification).***

Overall

Number of samples - A total of 694 headwater sites were identified from the 1990 RQS data-set supplied in 1991. Of these, 393 were sampled three times, 27 twice and 274 just once. This figure is undoubtedly an underestimate of the full number of headwater sites sampled since the total number of sites, of all sizes, supplied to IFE was 6,000 whereas Sweeting *et al.* (1992) cite 7633 sites as having been sampled.

The number of 1990 RQS headwater sites in the data-set supplied to IFE in 1996 excluded any from the Southern and Thames Region. This set contained 519 sites compared to 563 for the same six Regions from the data-set supplied five years earlier.

The number of headwater sites sampled in the 1995 GQA increased to 1292 according to the provisional national data-base which remains to be fully scrutinised for errors.

Sampling density - The 1292 headwater sites sampled during the 1995 GQA represent an approximate density of sampling of one headwater site for every 56 headwater stream segments (based on the estimated number of segments presented in Table 2.3).

This figure is close (± 20) to the individual values for most Regions (Table 2.6) except Welsh Region where the density in national surveys is much less. If Welsh Region is excluded the ratio becomes almost exactly 1:50 and all Regions contributing to this value lie in the range 1:37 to 1:72. As an overall estimate of the density of sampling of headwaters over the five year period represented by each RQS/GQA, the overall ratio of 1:57 fails to recognise the additional sampling other than these national surveys, particularly in Wales. Precise estimates of the number of these additional sites in each Region could not be readily accessed by Agency staff.

Table 2.6 Summary statistics for the headwater sampling programmes in the 1990 RQS and 1995 GQA for each current Environment Agency Region. (The proportion of sites in each band of biological condition for the 1990 RQS are based on data on all sites supplied in 1996 except for the Southern and Thames Regions which are based only on data from sites sampled in three seasons, as supplied in 1991. The data for South West Region for the 1990 RQS are based on only those samples collected in 1990).

	Anglian	North East	North West	Midlands	Southern	South West	Thames	Welsh
No. OF SITES								
1990 RQS (1991 supplied)	122	71	189	105	78	53	53	23
1990 RQS (1996 supplied)	103	46	189	105	N/A	53	N/A	23
1995 GQA	143	315	246	167	103	197	86	35
BAND OF BIOLOGICAL CONDITION (%)								
A	21.4	26.1	18.0	5.7	35.6	45.3	38.9	30.4
B	35.0	30.4	18.6	26.7	35.6	30.2	22.2	13.0
C	27.2	30.4	19.7	41.0	23.7	24.5	27.8	43.5
D	16.5	13.0	43.7	26.7	5.1	0.0	11.1	13.0
ESTIMATED No SOURCES	6,727	11,323	8,122	4,990	5,947	9,427	3,759	8,448
ESTIMATED No HEADWATER SEGMENTS	8,401	14,140	10,142	6,231	7,426	11,772	4,694	10,550
ESTIMATED SAMPLING DENSITY - 1995 GQA	1 : 44	1 : 45	1 : 41	1 : 37	1 : 72	1 : 60	1 : 55	1 : 459

In order to get a feel of the sampling density of headwater sites over the period 1991 - 1995, it has been assumed that 750 extra sites are surveyed in Wales and 500 in the remaining seven Regions. On this basis the sampling density would be one headwater site for every 29 headwater segments.

Biological condition - Based on the data supplied in 1996, the distribution of bands of biological quality for all 1990 RQS headwater sites, other than those banded as E, was: A, 20.3%; B, 25.5%: C, 28.1% and D, 26.1%.

This distribution excludes information on two Regions, Southern and Thames, which had no data supplied in 1996. The data-set supplied in 1991 includes these sites but has no bandings for sites sampled in fewer than three seasons. Using only three season sample sites the distribution of bands of biological condition in this data-set was A, 24.4%; B, 29.0%: C, 31.5% and D, 15.2%.

The comparison of these value ranges suggests that three season sites were of better overall quality than those sampled in fewer seasons. This is confirmed by more detailed analysis of the data-set supplied in 1996 (Table 2.7).

Table 2.7 The distribution of bands of biological condition in sites sampled in six current Environment Agency Regions during the 1990 RQS. Southern and Thames Region data unavailable.

BAND	NUMBER OF SEASONS SAMPLED		
	ONE	TWO	THREE
A	19.5	8.3	21.7
B	20.5	33.3	28.1
C	19.5	29.2	33.1
D	40.5	29.2	17.0

2.2.4 Discussion

Inconsistencies in the data-sets released to IFE make it difficult to provide accurate information on the number of headwater sites sampled in the 1990 RQS and the 1995 GQA. Errors in the national survey data-bases for each year, revealed by Walley (1996), emphasise the need to ensure the accuracy and consistency of these holdings for both operational purposes and for research and development. At present most comparisons, including those made in the following paragraphs must necessarily be qualified by uncertainties about the data available.

Within the limitations of the data provided, some clear factors emerge. The first of these is that the growing awareness of the relatively poor biological condition of headwaters (Furse *et al.* 1993, 1995; Furse 1996a) has stimulated an increase in the extent to which these have been sampled in national surveys. According to available data (Figure 2.6) all Regions increased the number of headwaters they sampled between the 1990 RQS (694 sites in the data supplied in 1991) and the 1995 GQA (1292 sites). This is a rise of 86.2%.

Even if a pro rata allowance is made for the apparent deficit of 6,600 English and Welsh sites in the data-set provided to IFE in 1991 compared with the 7,633 apparently sampled (Sweeting *et al.* 1992), which presumably included the former NRA South West Region sites sampled in 1991, these figures still represent an increase in sites, between surveys, of about 61%.

There is also evidence of increased sampling of headwater streams for special operational purposes. A good example is that of the Waltham Cross Laboratory, in Thames Region, where it has become routine to sample headwaters for purposes of developing catchment management plans. Headwater streams of high ecological value are then highlighted in these plans if they support a diverse fauna or one containing recognised indicator taxa, as defined by Thames Region, such as *Habrophlebia fusca*, Nemouridae, *Beraeodes minutus*, *Plectrocnemia conspersa* and others.

In addition to the Waltham Cross Area, special headwater sampling programmes, related to particular, defined problems are well developed in other Regions and were so before the current headwaters R&D programme. Notable amongst these are Welsh Region who sampled around 750 headwater sites for a variety of reasons between 1990 and 1995 and North West Region who use rapid, biological field survey techniques for assessment of ecological quality of watercourses in preference to chemical monitoring. Midlands Region also write of many headwaters being sampled in catchment surveys and pollution incidents whilst the Ridings Area of North East Region mounted a substantial, apparently non-pollution targeted, headwater survey programme in 1991.

Trends to include the results of operational sampling of headwaters in regional databases, such as noted in Welsh Region will further increase the accessibility of biological information on these watercourses. This process would be enhanced by the co-ordinated development of a national data-base, within the Environment Agency, which would facilitate the interchange and interpretation of headwater data and provide a valuable resource base for R&D studies.

In lieu of a national headwater data-base and of available banding data for the 1995 GQA, the 1990 RQS information provides the most recent national evaluation of the biological condition of headwaters in England and Wales. Interpretation of these data present clear difficulties in respect of the extent to which sites are selected in a random, or stratified random manner or in order to investigate specific, known pollution problems. Some Regions, Thames and Midlands, have identified a strategy of targeting problem streams within national as well as local surveys, whilst this policy clearly was adopted in North West Region. Other Regions, such as Welsh and Southern relied more heavily on regional, rather than national (RQSs/GQAs) sampling to investigate specific environmental stresses.

Within this framework a wide range of streams with distinct loss of biological condition were identified in the 1990 RQS. The overall results presented in this report (Table 2.8), based on all banded sites, of whatever sampling frequency, in the data-set supplied in 1996 and the three seasons Southern and Thames Region sites supplied in 1991, show that well over 50% of sites were banded as C ("poor" - 27.4%) or D ("bad" - 24.1%). Only 22.1% of sites were in the top band (Band A - "good") with the remaining 26.4% in Band B ("fair").

Even allowing for regional targeting, which cannot identify and sample all existing problem streams, the picture painted by these statistics is a disturbing one which is only re-enforced by the large number of additional problem watercourses identified by Regions adopting special operational sampling programmes with a high headwater component.

Comparative values for non-headwaters can be obtained from the data-sets on the 1990 RQS, as supplied to IFE. Using the data supplied in 1991, which is the only 1990 RQS data-set to contain Southern Region sites, direct comparisons can be made between three seasons headwaters and non-headwaters sites. Further comparisons can be made with the best available 1990 data, for all seasonal sampling regimes, as derived from each of the 1990 RQS data-sets supplied to IFE.

Table 2.8 The 1990 River Quality Survey. A comparison of the distribution of bands of biological condition in headwater and non-headwater sites.

SOURCE	BAND			
	A	B	C	D
Non-headwaters, 3 season samples, data supplied in 1991	53.9	24.3	13.9	7.8
Headwaters, 3 season samples, data supplied in 1991	24.4	39.0	31.5	15.2
Headwaters, all seasonal sampling regimes, mixed source	22.1	26.4	27.4	24.1

The distribution of bands of biological condition for 1990 RQS sites is distinctly better, whichever basis of comparison is used. In addition to selective targeting of poor quality headwaters the differences between the condition of headwater and non-headwater RQS sites is exaggerated by the tendency for RIVPACS to set unrealistically high targets for BMWP score and number of scoring taxa (Furse *et al.* 1995) which lead to poorer band allocations, under the 5M system than if more appropriate targets were set. Set against this is the unknown extent to which non-headwater sites are themselves selected in relation to known environmental stress. The greater the extent of targeting in the larger watercourses the more valid the comparisons with headwaters becomes.

Of the comparisons presented in Table 2.8, the more valid is likely to be that based exclusively on three seasons samples. Not only are the sampling regimes compatible and the full range of eight Regions included but it is also clear that single season sampling is more specifically targeted at known problems than multi-season sampling (Tables 2.7 & 2.8).

In order to obtain more realistic comparisons between headwater and non-headwater sites three specific recommendations are made:

- an operational headwaters module of RIVPACS is developed for assessing the biological condition of single season headwater samples (a non-operational version was used in Stage 3 of "The Faunal Richness of Headwater Streams" project, Furse *et al.* (1995)).

- the number of headwater sites sampled in future GQAs be increased by the inclusion of discrete suites of sites selected by randomised procedures not designed to selectively monitor known environmental stresses. This set of sites will better represent the overall condition of headwaters and provide a framework for better monitoring both gains and losses in condition. Selective monitoring of initially poor quality sites is likely to present a biased picture of gain in, rather than loss of, condition.

- all headwater monitoring in GQAs should involve single season sampling only at each site

The use of single season samples will offset the additional workload presented by increasing the number of headwater sites sampled. More extensive recommendations on headwater sampling programmes are made in Furse (1996a).

In order to make best use of headwater sampling in both RQSs/GQAs and regional/local operational sampling programmes it is further recommended that:

- a national headwaters data-base is developed which is fully compatible between the Regions and Areas of the Environment Agency

Further detailed recommendations on the data-holdings to be included in the national data-base are given by Furse (1996a).

2.3 The Relationship Between the Distribution of Headwater and Main River Sites in National Surveys

2.3.1 Introduction

The original intention of this item of the work programme was to quantify the distance between headwater sites and the next furthest site downstream on the same river system. In this way gaps in the sampling network could be shown and specific types of site or distance from source categories which were not being sampled could be drawn attention to.

It soon became clear that this was not a simple task. The nature of the coding of sites in the national data-base made it difficult to cross reference sites on the same river system. Similarly, the use of a GIS to obtain the data was impractical, within the resources available, for two reasons; firstly inexact spatial referencing of sites (ie their grid references rarely fell directly on a watercourse) would have required the true "blueline" watercourse of each site to be identified and linked to them: secondly tailor-made AMLs would be needed to link arcs on single river systems, so that each could be uniquely identified with that system, and then to measure distances between sites along the inter-connected arcs.

An alternative procedure was recommended to the Environment Agency, agreed by them and presented here. In this approach the distribution of sites as a whole is considered at a variety of scales and regional levels. Gaps in the overall distribution of sites are sought rather than those on individual river systems.

2.3.2 Methods

The longitudinal distribution of survey sites was derived from the 1990 RQS using the data supplied in 1991.

The full range of sites in the data-base were considered, irrespective of the number of seasons sampled. Data were manipulated within an EXCEL spreadsheet.

Results were presented as a series of diagrams (Figures 2.25 - 2.35) consisting of a set of three histograms. Separate diagrams were produced for the full data-set and for each of the ten former NRA Regions in existence during the 1990 RQS. Each separate histogram in each diagram presents the results at one of three different levels of spatial resolution.

The first histogram in each diagram shows the distribution of all headwater sites (i.e those within 2.5km of the nearest source). Sites were sub-divided into 500m distance from source categories. The second histogram displayed all "upper reaches" sites within 20km of source in 2.5km categories and the third showed "all sites" in nine 10km categories plus a tenth category of all sites >90km from source. Each column of each histogram was divided into three, two and one season sites by use of a shade set.

The "upper reaches" histogram is used to forecast the number of headwater sites which should be sampled to maintain the geometric trend in number of sites sampled in successive, decreasing distance from source categories from 20km to <2.5km. Predictions are based on the EXCEL 4.0 regression function, "FORECAST".

2.3.3 Results

Overall

Most headwater sites are shown to be located between >1.5 and 2.5km of source (Figure 2.25). The most frequent category is >1.5 - 2.0km and the number of sites decline progressively as the source is approached. Between 50 and 75% of sites in each category were sampled three times and most of the remainder once only.

"Upper reach" sites, within 10km of source, increased in frequency from the >17.5 - 20km category (fewest) to the >2.5 - 5km category (most). This replicated the increasing frequency of reaches of each category in the complete river network. On this basis it would be expected that the greatest number of sampling sites would be in the 0 - 2.5km (headwaters) category but this is not the case. The number of headwater sites is fewer than those in the next three distance from source categories: >2.5 - 5, >5 - 7.5 and >7.5 - 10km.

Regression analysis of the relationship between distance category and number of samples, over the range >2.5 - 20km suggests that proportional sampling of headwaters would require 1835 sites, compared with the minimum estimate of 706 sampled in 1990. This figure compares with the 1282 headwater sites currently listed for the 1990 GQA.

The proportion of sites sampled on fewer than three occasions fell consistently with increased distance from source.

The "all sites" distribution continued the pattern shown in the upper reaches with the number of sites sampled decreasing with increasing distance from source and the proportion which are sampled on three occasions increasing to the point of total exclusion of one and two season sites. The proportional shortfall in headwater sites is masked at this level of spatial resolution.

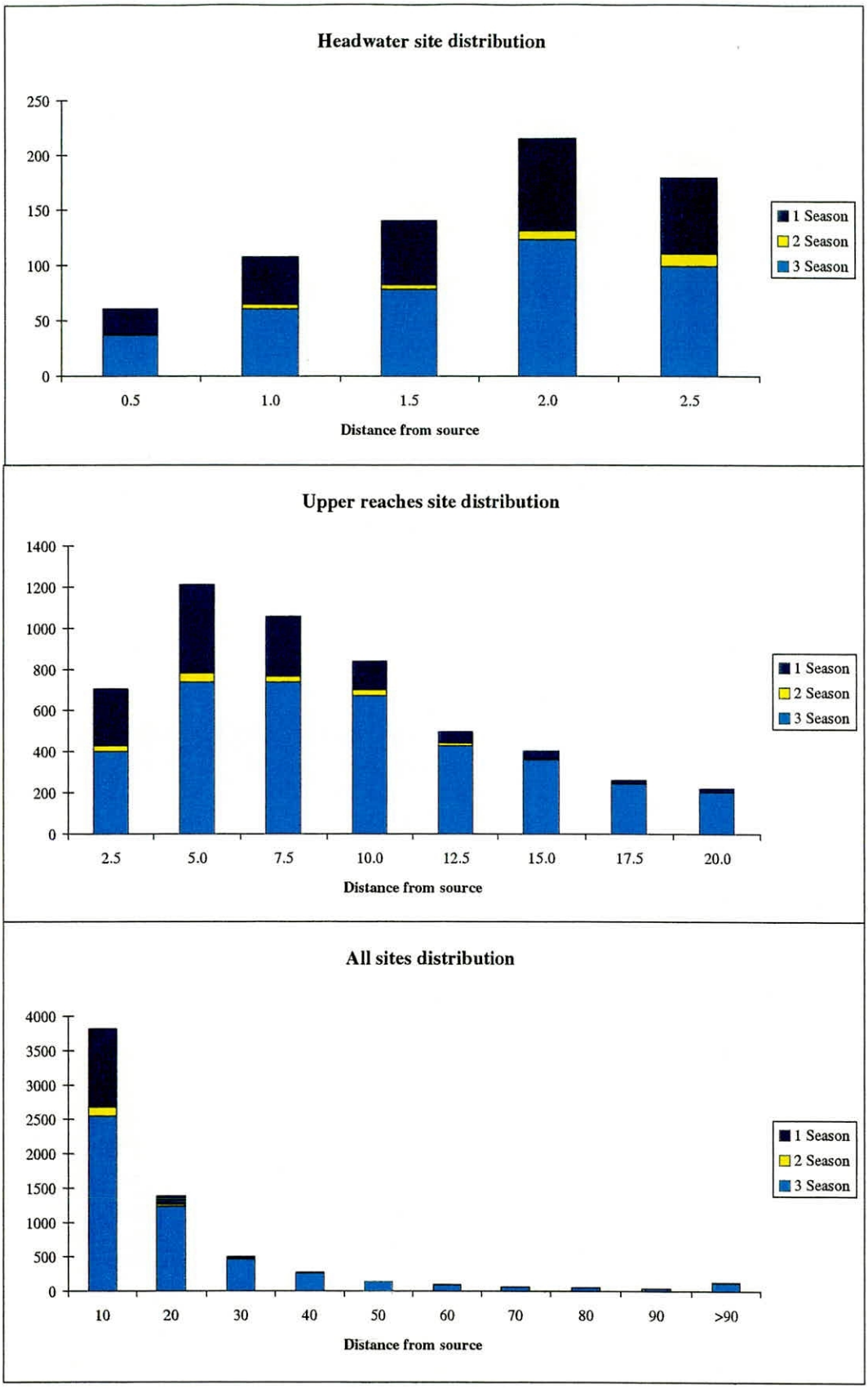

Figure 2.25 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Regions' sites supplied to IFE in 1991.**

Anglian

A smaller proportion of sites than the national average were sampled on less than three occasions but a higher proportion of headwater sites were in 0 - 1km category. There was also a tendency for a greater than average number of sites >90km from source to have been sampled (Figure 2.26). Otherwise distribution patterns are similar to the national picture.

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is 219 compared with 143 in the 1995 GQA.

Northumbrian

The number of headwater sites was few but, over the range >0.5 - 2.5 km the frequency of sites tended to increase with increased proximity to source (Figure 2.27). Only at 0 - 500m is this sequence reversed.

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is shown under Yorkshire.

North West

A large number of headwater sites were sampled, the vast majority of which were visited only once (Figure 2.28). The frequency of occurrence of headwater sites decreases with increasing proximity to source.

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is 447 compared with 246 in the 1995 GQA.

Severn Trent

Most sites, including those on headwaters, were sampled three times and very few only once (Figure 2.29). The frequency of occurrence of headwater sites decreased with increasing proximity to source.

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is 258 compared with 167 in the 1995 GQA.

Southern

Between 0 - 2km from source the number of headwater sites increased with increased distance from source (Figure 2.30). However, in comparison with nearer source categories and other former NRA Regions, relatively few sites were sampled in reaches >2 - 2.5km from source. Most sites were sampled three times.

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is 151 compared with 103 in the 1995 GQA.

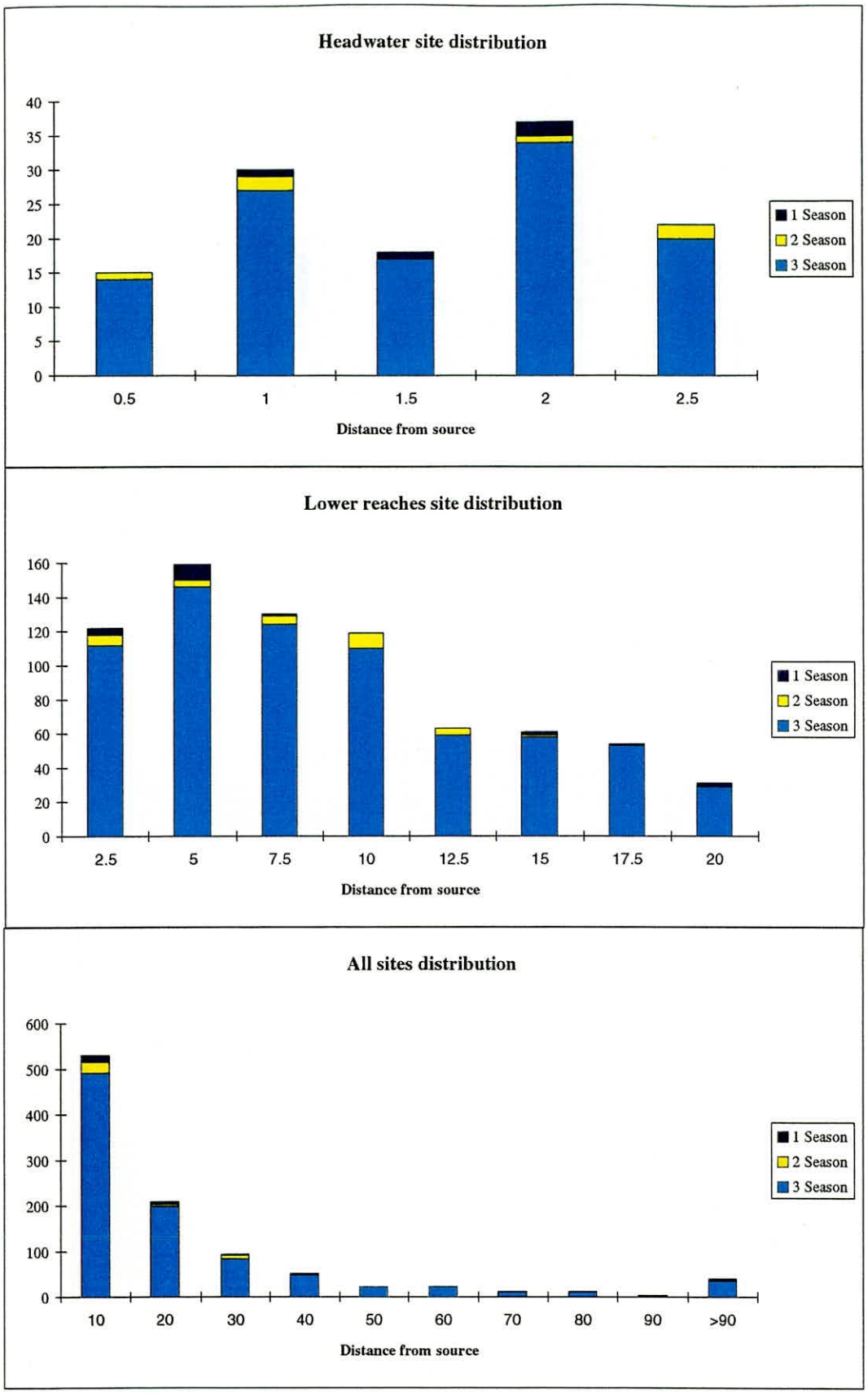

Figure 2.26 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Anglian Region sites supplied to IFE in 1991.**

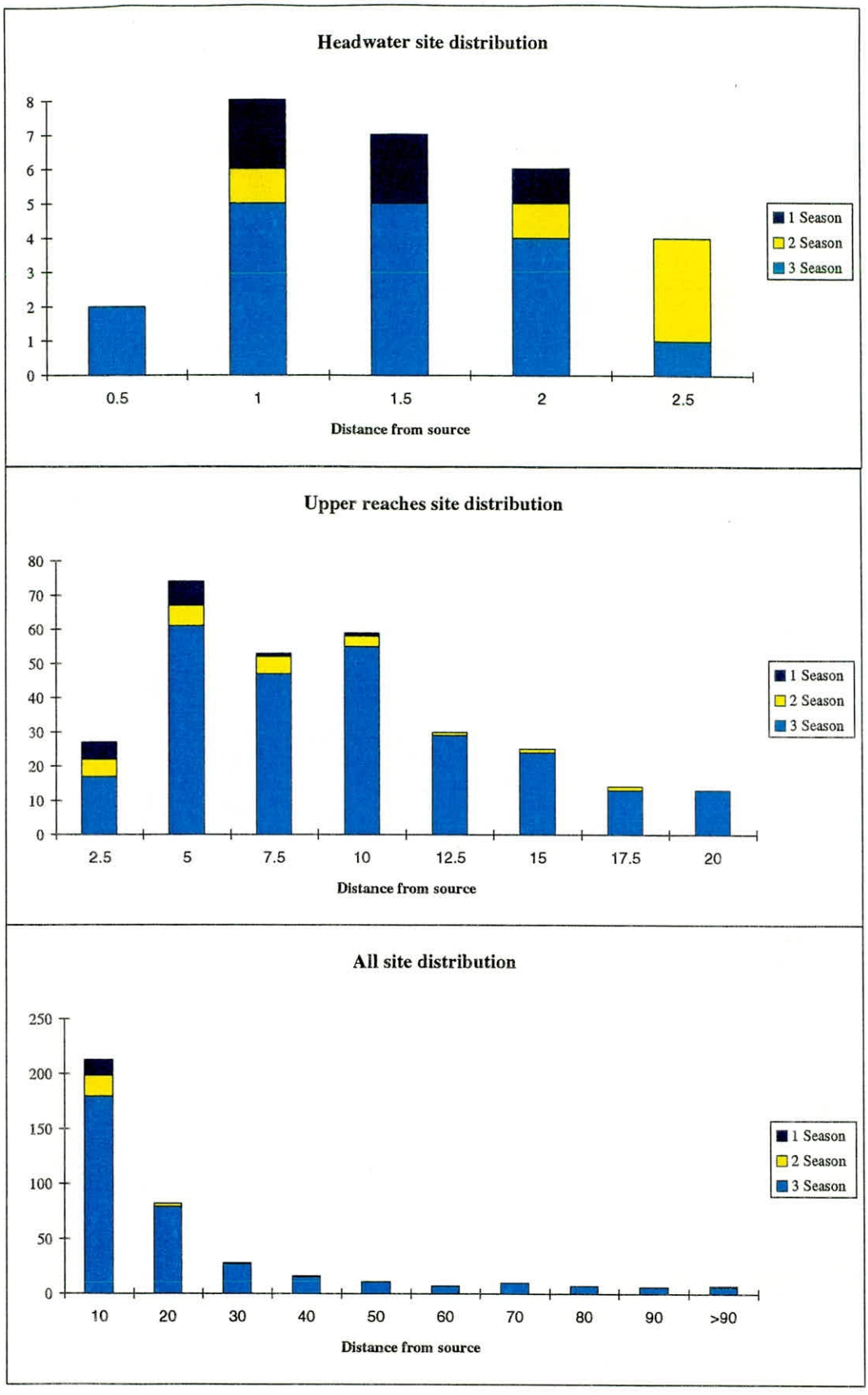

Figure 2.27 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Northumbrian Region sites supplied to IFE in 1991.**

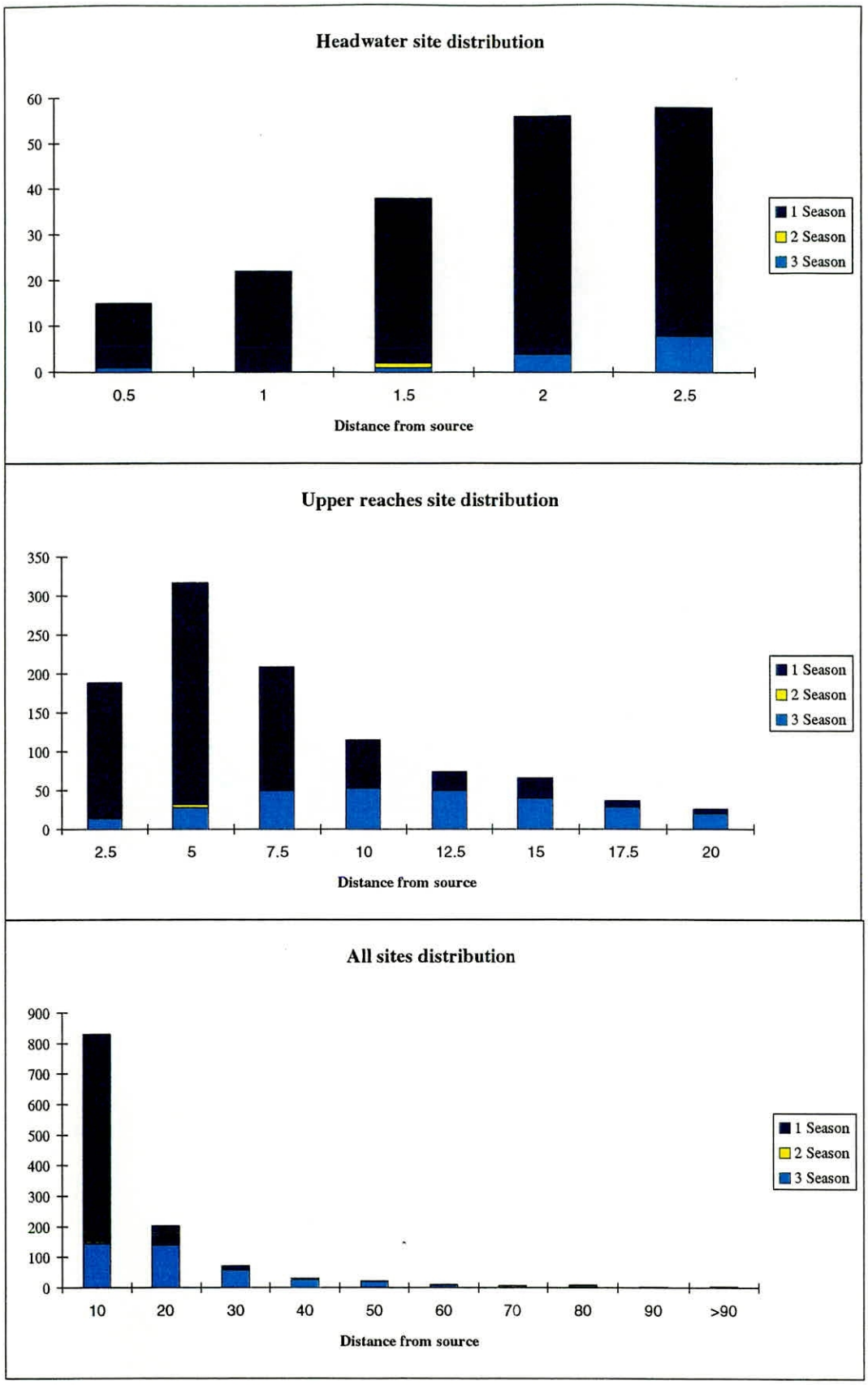

Figure 2.28 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All North West Region sites supplied to IFE in 1991.**

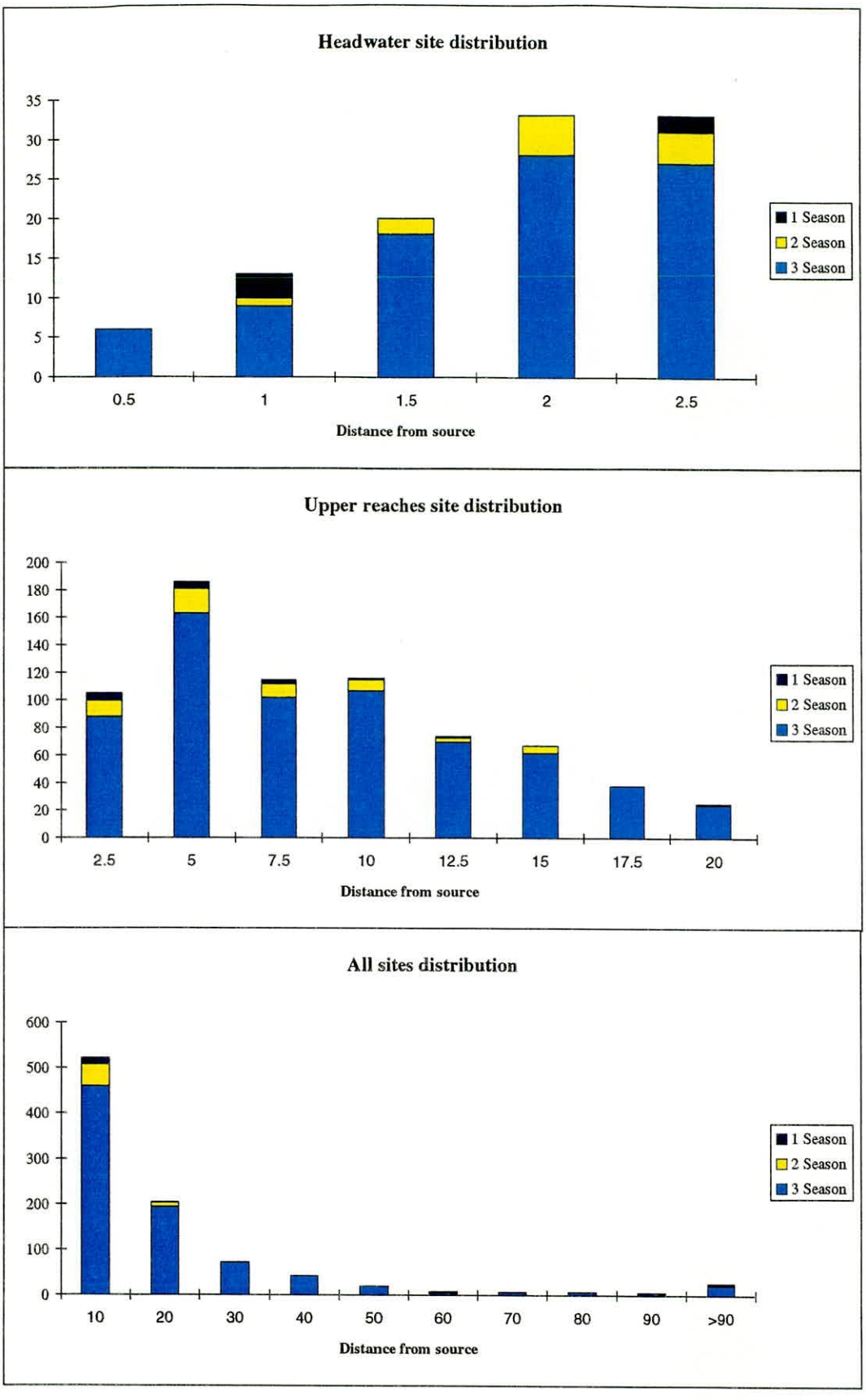

Figure 2.29 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Severn Trent Region sites supplied to IFE in 1991.**

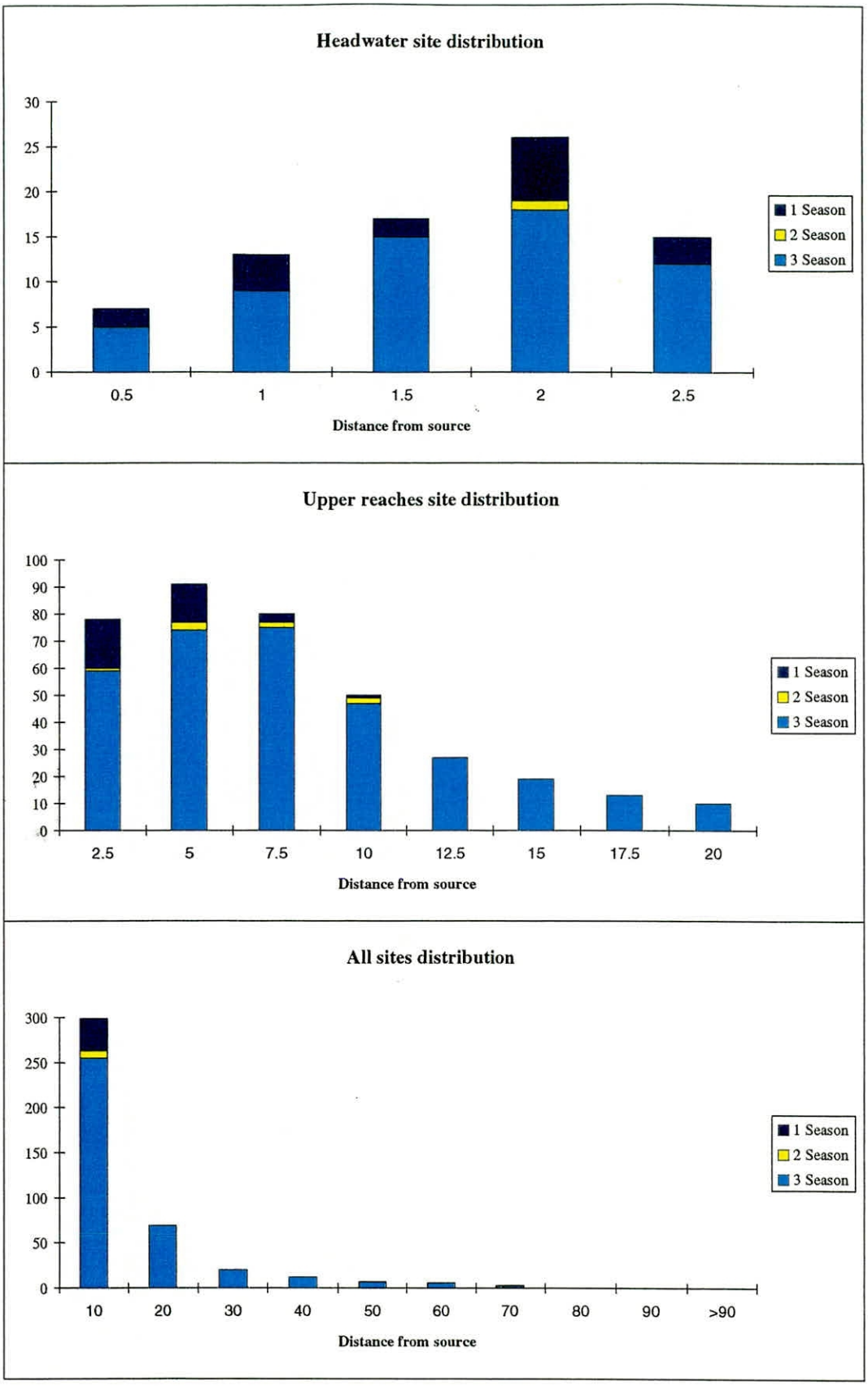

Figure 2.30 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Southern Region sites supplied to IFE in 1991.**

South West

Relatively few headwater sites were sampled in comparison with other Regions. The data-set excludes sites sampled for the 1990 survey in 1991 but this is only relevant to the proportional distribution of sites if the relative proportions of sites in each distance from source category differed between years.

Almost all sites were sampled three times and the frequency of occurrence of headwater sites tended to decrease with increasing proximity to source (Figure 2.31).

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is shown after Wessex.

Thames

Most headwater sites were sampled in a single season only. Numbers of headwater sites per distance from source category increased from 0 - 2km but declined for the >2 - 2.5km category (Figure 2.32). The "upper reaches" histogram showed headwater sites, 0 - 2.5km, to be the most frequently sampled category. This was the only Region where this occurred.

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is 84 compared with 86 in the 1995 GQA.

Welsh

Very few headwater sites were sampled in the 1990 RQS, as discussed in previous sections. The small number of sites sampled were predominantly >1.5km from source and most were sampled on three occasions (Figure 2.33).The tendency not to undertake near source sites was maintained in the <2.5 - 5km category. The most frequently sampled of the "upper reaches" categories was >7.5 - 10km. Unlike other Regions, single season sampling was commoner in the "upper reaches" than in headwaters.

The forecast number of headwaters which should be sampled to maintain the trend exhibited between >2.5km and 20km is 133 compared with 35 in the 1995 GQA. The predictive relationship is weaker than for other Regions because the frequency of occurrence of sites peaks in the category >7.5 - 10km, rather than >2.5 - 5km. Based on the trend between >7.5 - 20km the forecast number of headwater sites to be sampled increases to 254.

Wessex

Relatively few headwater sites were sampled and their distribution pattern was similar to that of the Thames and Welsh Regions, with fewer sites in the >2 - 2.5km category than expected from the trend of increasing frequency of headwater sampling with increased distance from source (Figure 2.34). Fewer sites were sampled in the >2.5 - 5km category than in reaches >5 - 7.5km from source.

The vast majority of sites sampled in this Region were visited in three seasons.

The forecast number of headwaters which should be sampled in the Environment Agency's South West Region to maintain the trend, for sites between >2.5km and 20km from source, exhibited in the former NRA's South West and Wessex Regions combined is 291 compared with 197 in the 1995 GQA.

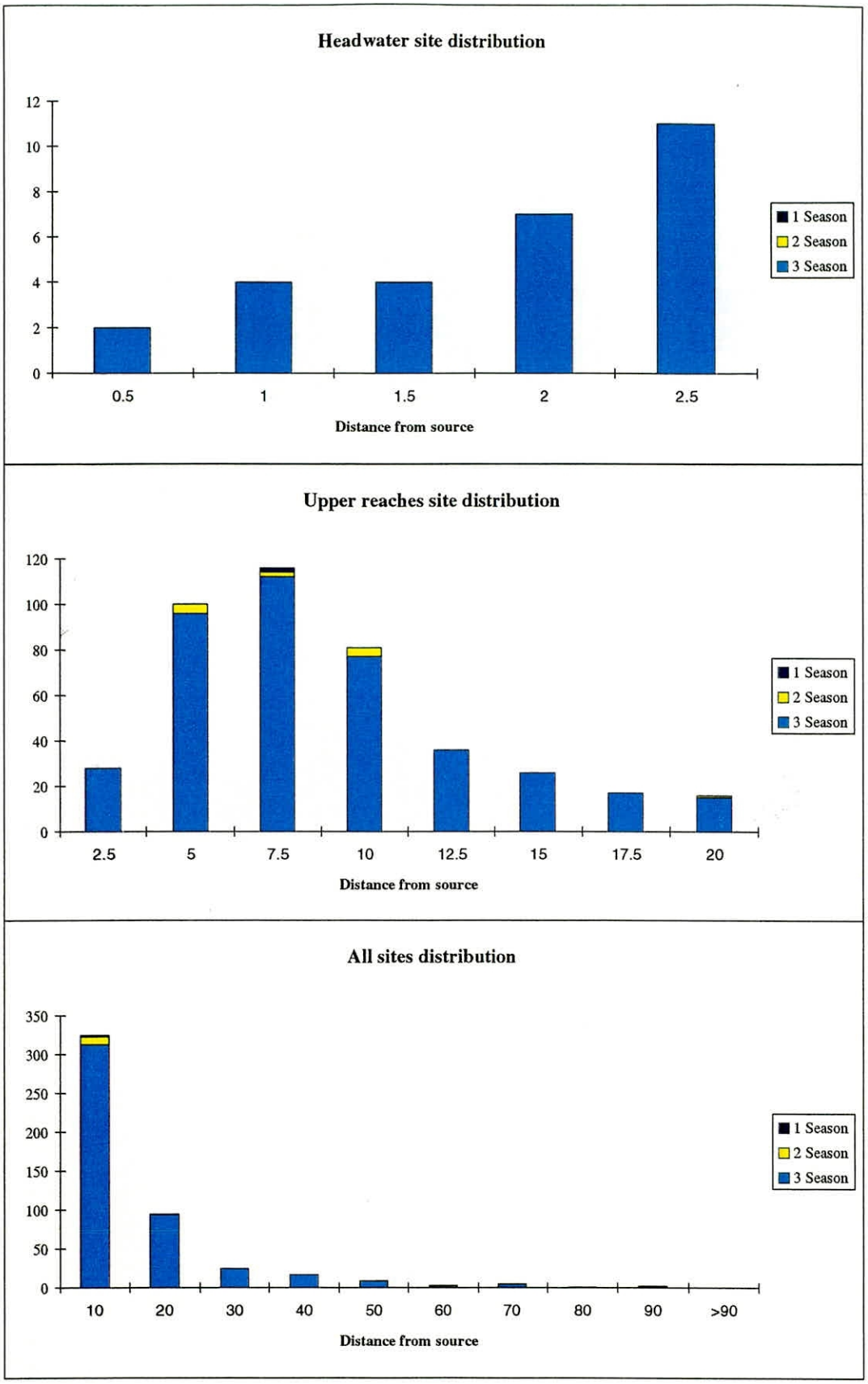

Figure 2.31 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All South West Region sites supplied to IFE in 1991.**

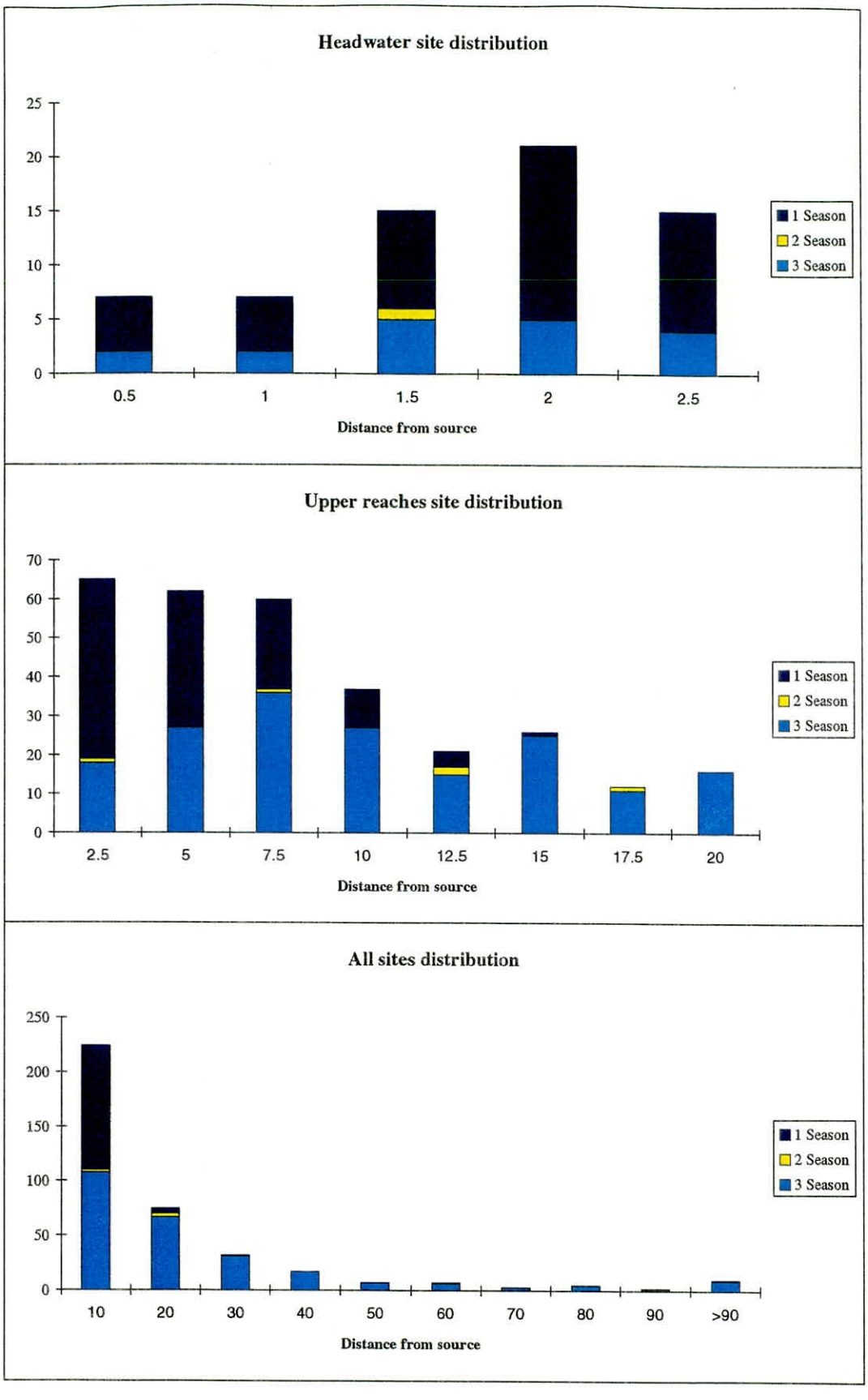

Figure 2.32 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Thames Region sites supplied to IFE in 1991.**

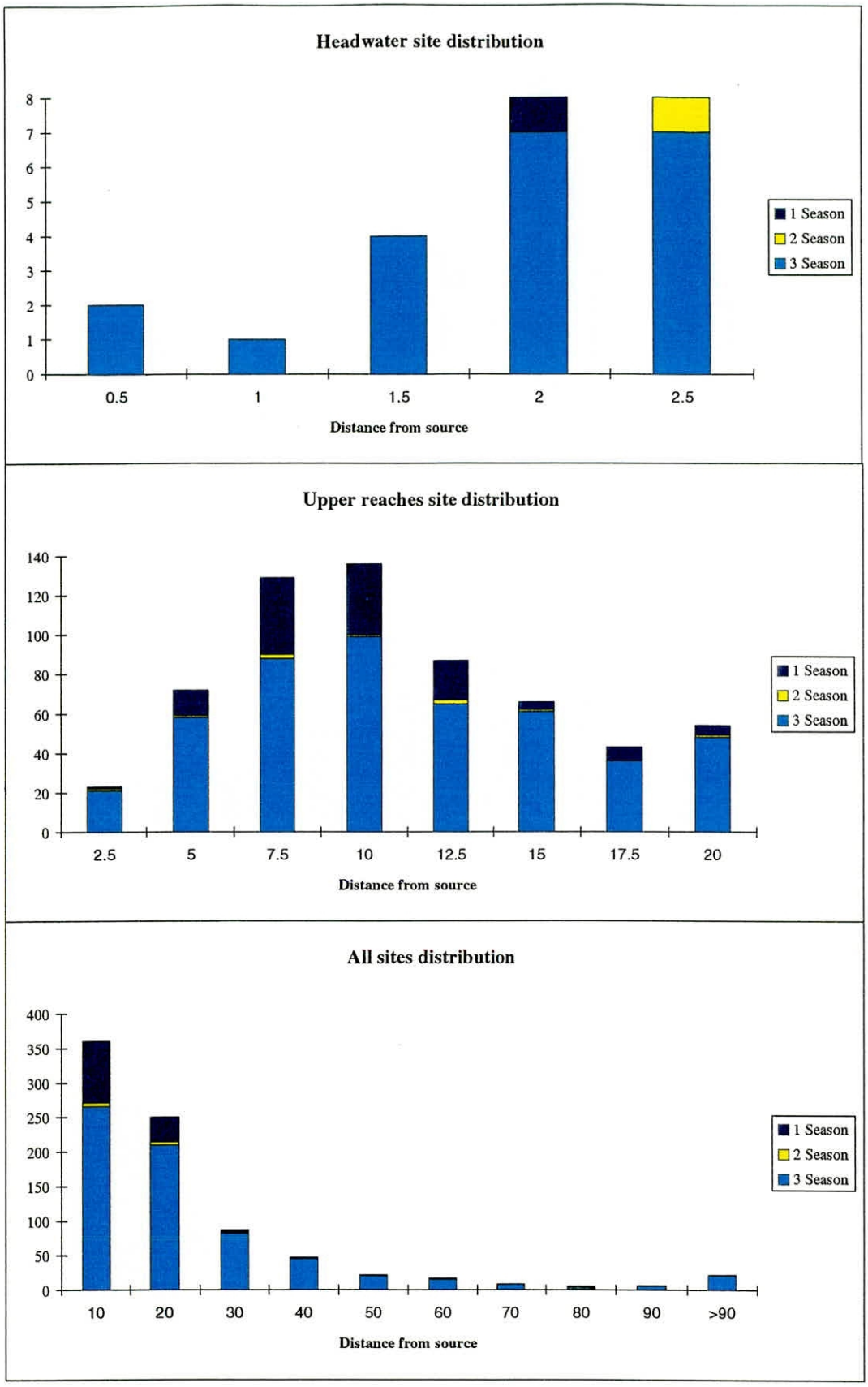

Figure 2.33 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Welsh Region sites supplied to IFE in 1991.**

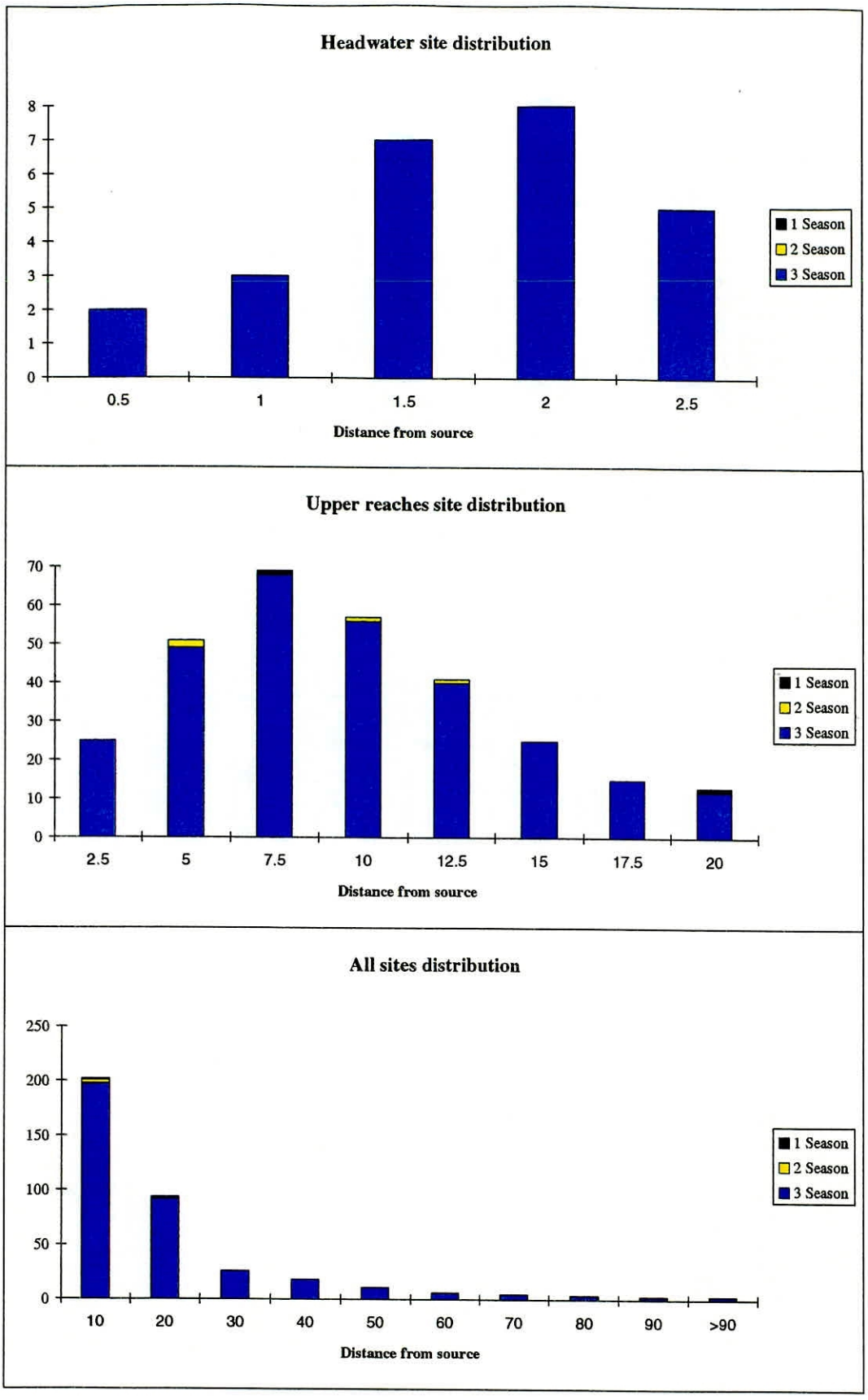

Figure 2.34 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Wessex Region sites supplied to IFE in 1991.**

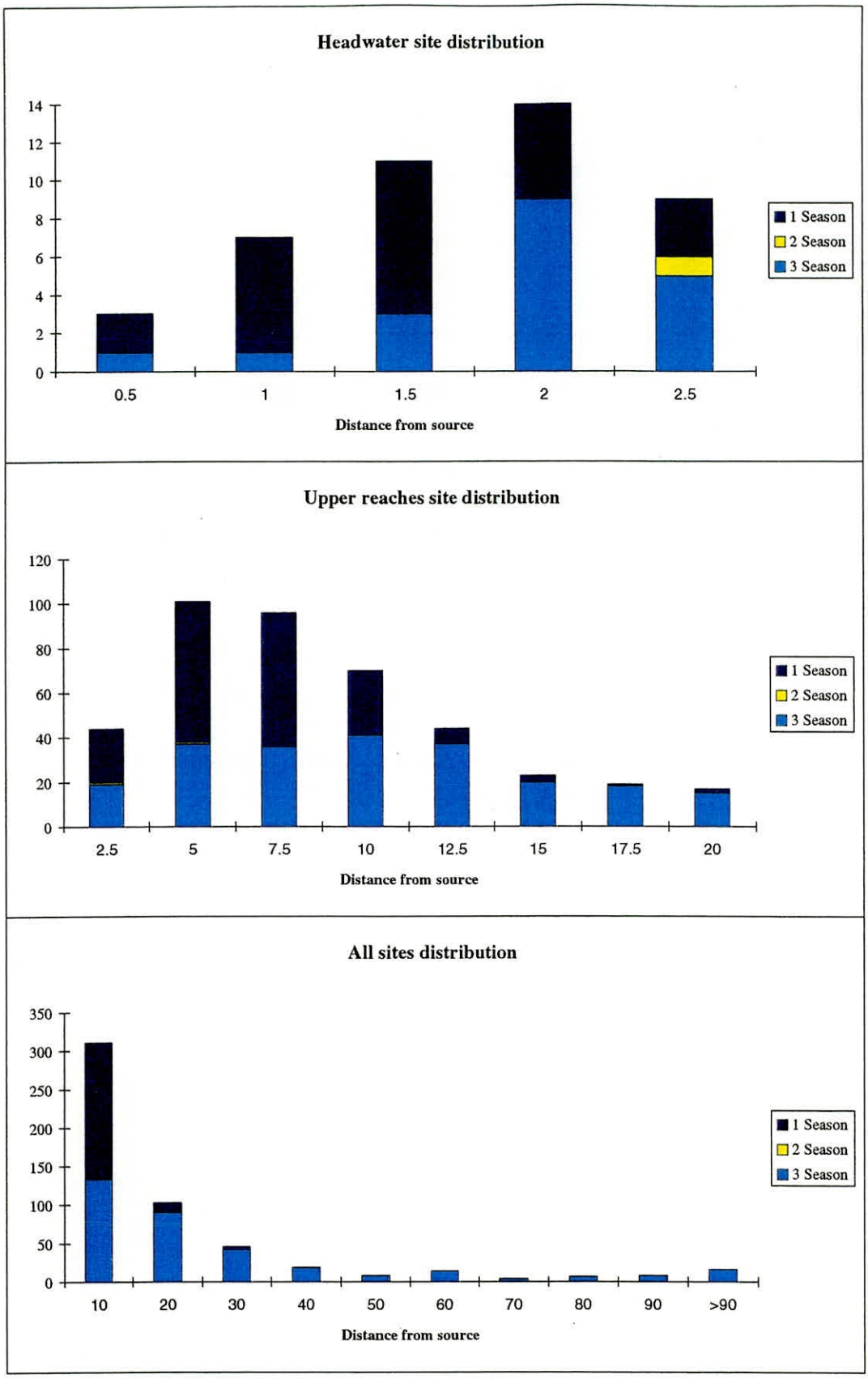

Figure 2.35 **The distribution of 1990 River Quality Survey biological sampling sites by distance from source categories. Three levels of resolution. All Yorkshire Region sites supplied to IFE in 1991.**

Yorkshire

The pattern of distribution of headwater sites was similar to Thames, Welsh and Wessex Regions. Approximately half of these sites were sampled in one season and about half in three (Figure 2.35). A small number were sampled in two seasons.

The "upper reaches" histogram shows that the number of headwater sites sampled was less than half of the next 2.5km category downstream.

The forecast number of headwaters which should be sampled in the Environment Agency's North East Region to maintain the trend, for sites between >2.5km and 20km from source, exhibited in the former NRA's Northumbrian and Yorkshire Regions combined is 278 compared with 315 in the 1995 GQA.

2.3.4 Discussion

In a river network there is an inevitable decrease in the number of reaches in progressive distance from source categories, as small streams merge to former larger ones. Within the 1990 RQS this pattern is largely mirrored by the distribution of sampling sites by distance from source category (Figure 2.25). The notable exception is headwater streams and, within this category, the reversal in the general trend becomes more pronounced with greater proximity to source. The national pattern is largely followed in individual Regions (Figures 2.25 - 2.35), with only Thames Region sampling more headwater sites than any other 2.5km reach category (Figure 2.32) in the 1990 RQS.

When the wider pattern of increasing numbers of sites with decreasing distance from source is used to examine the deficit in headwater sites, targets for the frequency of headwater sampling can be set which more closely mirror the relative abundance of these watercourses. In setting these theoretical targets a geometric progression is adopted, in line with the progression of the number of streams of different orders (Smith and Lyle 1979) and the distribution of "upper reach" and "all sites" in Figure 2.25.

The analyses of the entire data-set indicates that, given the same intensity of sampling of non-headwater sites, the number of headwater sites which should be sampled to attain proportionality is 1835. For mathematical reasons the sum of the indicative sampling levels for individual Regions, at 1861, is not identical to the combined value but is very close to it.

The 1292 headwater sites in the 1995 GQA data-set supplied to IFE greatly exceeds the number sampled in 1991 but is 569 fewer than the number suggested by the preceding analyses. Six Regions sampled fewer sites in the 1995 GQA than the analyses indicate to be appropriate (Table 2.9). Of the two Regions, Northumbria & Yorkshire and Thames, sampling above the indicative level, only Northumbria & Yorkshire greatly exceeded the recommended level.

Table 2.9 The number of headwater sites in the 1990 RQS and 1995 GQA data-sets supplied to IFE, together with the indicative level of sampling required to attain proportionality with downstream reaches. The 1990 values are derived from the data-set supplied in 1991. Regional names are as used in the 1995 General Quality Assessment.

REGION	NUMBER OF HEADWATER SITES		
	1990 RQS*	1995 GQA	INDICATIVE
ANGLIAN	122	143	219
NORTHUMBRIA & YORKSHIRE	71	315	278
NORTH WEST	189	246	447
SEVERN TRENT	105	167	258
SOUTHERN	78	103	151
SOUTH WESTERN	53	197	291
THAMES	53	86	84
WELSH	23	35	133

The preceding analyses are in line with the recommendation in section 2.2.4, namely that:

- **the number of headwater sites sampled in future GQAs be increased by the inclusion of discrete suites of sites selected by randomised procedures not designed to selectively monitor known environmental stresses.**

With the exception of headwater sites, there is no general pattern of the proportional under-representation of reaches in any other distance from source category in national surveys. Prior to analysis it was unclear whether overlong "gaps" existed in the coverage of reaches between headwaters and the next downstream sample (Roger Sweeting personal communication). This anxiety was re-iterated by Dave Leeming (*in litt*) when commenting on the headwater site distribution maps (see section 2.2.3, page 46).

With the exception of Welsh Region there is no indication from the distribution histograms that there is any systematic under-sampling of near-source sites in the >2.5 - 5km from source category. In Wales the apparent under-sampling of these near source sites is likely to be compensated for by their extensive representation in additional, operational sampling programmes (although these may be of selectively poor biological condition).

The proportional representation of >2.5 - 5km sites does not ensure that each headwater site is complemented by another near source site further downstream on the same river system. In an extreme scenario each river system sampled could have either a headwater site or a >2.5 - 5km site, but never both.

- **it is recommended that further attention is given to the relationship between the water quality of headwater sites and that of the larger watercourses into which they feed and the consequences of this for the biological condition of the feeder and receiver streams**

3 PERCEPTION QUESTIONNAIRE

3.1 Introduction

Prior to the NRA R&D project, "The Faunal Richness of Headwater Streams" there had been little scientific research or co-ordinated water industry attention to these small watercourses, defined as being within 2.5km from source.

Many significant findings arose from the project, emphasising the major role headwaters play in maintaining catchment biodiversity, supporting, as they do, many rare and specialised taxa. The study also illustrated the considerable extent to which the biological condition of so many of them has become degraded.

The findings of the study were published in the form of NRA R&D Notes (Furse *et al.* 1991, 1993, 1995; Furse 1996a). Information on the key findings was promulgated in talks by the NRA/Environment Agency Project Leader and the IFE Project Manager, a Water Guardian Article, a journalistic feature in the *"Geographical Magazine"*, R&D Digests for the last three of the four R&D Notes and by display boards. The project also involved direct contact between both the Project Manager and IFE researchers and NRA staff in each Region in order to acquire information for inclusion in the research programme.

The extent to which R&D Programmes translate into increased awareness of the subject area amongst the Environment Agency staff and Advisory Committees and how this affects their attitudes to the issue are rarely tested.

Given that the findings of the headwater research programme could have major implications for the prioritisation of core activities within the Agency it was decided to test the level of awareness of the, then, NRA staff and their Advisory Committees to headwater issues and how the acquired knowledge might modify the priority they placed upon these watercourses.

A limited number of questionnaires were also circulated to key personnel in government and non-governmental organisations with professional interests in the outcome of the research programme. These included representatives of the, then, Scottish River Purification Boards, the Department of the Environment, the Industrial Research and Technology Unit (Northern Ireland), the Ministry of Agriculture, Fisheries and Food (including the Agricultural Development Advisory Service), the Farming and Wildlife Advisory Group, English Nature, Scottish Natural Heritage and the Countryside Council for Wales.

3.2 Methods

Information was sought in the form of a perception questionnaire. Each question listed on the questionnaire is given in full and in bold font in Section 3.3 of this chapter.

A multiple choice, tick box approach was adopted as likely to give the greatest proportion of returns. The questionnaire was designed with the intention of providing clear guidance notes within its text and unambiguous questions and optional responses, each written in "plain English". The extent to which this approach succeeded can be judged from the level of response.

Questions fell into three broad categories: those to determine respondents basic knowledge or perceptions of what constituted a headwater, what their importance was in relation to faunal conservation and biodiversity and what their general biological condition was likely to be; those designed to illicit what importance the respondent felt they and their organisation had historically attached to headwaters and whether this was likely to change in future; and those exploring the extent to which their awareness of headwaters had been raised by the headwater research programme and how this awareness could be extended.

The final section of the questionnaire was open-ended and asked for the recipients brief comments on headwaters, if any, including views on the future strategic or operational research they thought the Environment Agency should be considering. Recipients were asked to give their name, position and organisation in order that replies could be analyzed in relation to Region, job areas and specialisations.

The circulation list for the questionnaire needed to be sufficiently wide to obtain a meaningful distribution of responses at national and regional level. It also needed to reflect the views of a broad range of disciplines within the NRA/Environment Agency. For example, attitudes to and awareness of headwater issues may well differ between conservationists and strategic planners who may attach different relative values to ecological and economic considerations. The circulation also needed to take account of the views of Advisory Committees to the NRA/Environment Agency and those other governmental and non-governmental organisations with a close working relationship with the Agency.

In total 388 questionnaires were circulated (Table 3.1), representing 359 NRA staff members, including Head Office personnel, Regional General Managers and a broad spectrum of staff with different professional specialisations, 20 Advisory Committee Chairmen and nine non-NRA personnel. Further indications of the spread of expertise covered can be determined from the job descriptions of the list of respondents (Tables 3.2 & 3.3).

Table 3.1 Summary of the circulation list of the perception questionnaire

Category of respondent	Number of people circulated
NRA staff - Head Office	11
NRA staff - Anglian Region	41
NRA staff - Northumbria & Yorkshire Region	41
NRA staff - North West Region	41
NRA staff - Severn Trent Region	51
NRA staff - Southern Region	41
NRA staff - South Western Region	51
NRA staff - Thames Region	41
NRA staff - Welsh Region	41
Regional Fisheries Advisory Committee Chairmen	10
Regional Rivers Advisory Committee Chairmen	10
Non-NRA staff	9
TOTAL	388

Selection and identification of the personnel to be circulated were made by the NRA.

Distribution of questionnaires within the NRA was undertaken via R&D Regional Co-ordinators. Advisory Committee Chairmen were circulated directly as were other non-NRA staff.

Each questionnaire was accompanied by a letter of explanation, a stamped addressed envelope for returning the questionnaire directly to the IFE Project Leader and a sealed envelope containing the definition of a headwater, *sensu* the headwaters R&D project. The latter envelope was to be opened after completion of Question 1 which sought the recipients view of the "correct" definition of a headwater. Upon opening the envelope, the responses to subsequent questions 2-15 were to be based on the definition of headwaters as being watercourses within 2.5km of their furthest source, irrespective of whether the respondent agreed with that definition or not .

Responses to the questionnaire were transferred to a specially devised ACCESS data-base for storage, retrieval and analysis.

3.3 Results and Interpretation

3.3.1 Level of response

A total of 294 questionnaires were returned. This represented an excellent return rate of 75.8%. Almost all returned questionnaires were totally or almost totally completed. A high level of returns were made from all categories of respondent (Table 3.2). The origins of 11 returned questionnaires are unknown because no affiliation was given.

Table 3.2 Summary of the response to the perception questionnaire

Category of respondent	Level of response (%)
NRA staff - Head Office	6/11 = 54.5%
NRA staff - Anglian Region	29/41 = 70.7%
NRA staff - Northumbria & Yorkshire Region	36/41 = 87.8%
NRA staff - North West Region	27/41 = 65.9%
NRA staff - Severn Trent Region	39/51 = 76.5%
NRA staff - Southern Region	25/41 = 61.0%
NRA staff - South Western Region	40/51 = 78.4%
NRA staff - Thames Region	36/41 = 87.8%
NRA staff - Welsh Region	25/41 = 61.0%
Regional Fisheries Advisory Committee chairmen	10/10 = 100.0%
Regional Rivers Advisory Committee chairmen	5/10 = 50.0%
Non-NRA staff	5/9 = 55.6%
TOTAL (including unknown origins)	294/388 = 75.8%

The range of replies covered a wide spectrum of NRA/Environment Agency disciplines from Regional General Managers to practising specialist scientists (Table 3.3)

Table 3.3 A breakdown of the job types of the 289 NRA respondents.

Job Group Description	No. of responses
Agricultural Liaison Officers	1
Appraisal Officers	4
Area Managers	10
Biologists & Ecologists	26
Catchment Planners and Managers	13
Conservation Officers & Managers	10
Corporate Planners	6
Engineers	6
Environmental Officers & Managers	8
Environmental Protection Officers & Managers	11
Fish Scientists and Fisheries Officers	21
Fisheries, Recreation & Conservation Officers & Managers	25
Flood Protection Officers	7
Hydrologists & Hydrogeologists	10
Landscape Architects	1
Licensing Officers	2
Operations Managers	1
Others	9
Planning Officers	12
Pollution Control Officers & Managers	29
Public Relations Officers	1
Regional Fisheries Advisory Committee Chairmen	10
Regional General Managers	4
Regional Rivers Advisory Committee Chairmen	5
Research & Development Co-ordinators	7
Resources & Navigation Managers	1
Scientists	4
Technical Officers	2
Water Quality Officers & Managers	30
Water Resources Officers & Managers	13
TOTAL	**289**

The high level of response provided justification for the style chosen for the layout of the questionnaire, which offered multiple choice responses in a series of large tick boxes. It also provided confidence that the distribution of replies gave a realistic impression of the perception of the issues involved. The level of response was also sufficiently high to allow for some soundly based comparisons of the different occupational groups who replied.

3.3.2 Replies to each question

The distribution of replies to each question on the questionnaire are considered in turn. The most significant features of the collective response to each question are drawn attention to.

Most questions required the participants to place a single tick in the box for the "best" reply to the question. These included questions 1, 3, 5, 6, 7, 8, 9, 10, 11 and 13. Question 12 required a single tick against one of the multiple choice options for each of four R&D Notes and three R&D Project Digests. Despite instructions, in some instances respondents ticked more than one box for these questions where they clearly felt it impossible to separate two "best" options. Hence the total number of responses to these questions may exceed the number of respondents.

Question 4 required three boxes to be ticked, Questions 2 and 14 required as many ticks as the recipients thought appropriate and question 15 was optional and allowed them to give a free-form text reply.

In the following summaries of response the distribution of replies to each question are listed in descending order of frequency of ticks. The numbers in bold font, to the left of each response, are the sequence numbers in which the options for that question were listed on the questionnaire.

Q.1 Which of the following definitions do you think best describes the term 'headwaters'?

6	The upper reaches of all watercourses	169
3	Watercourses within 2.5km of their source	49
4	Watercourses within 5km of their source	30
2	Watercourses with no tributaries, or only first order tributaries	22
1	Watercourses with no tributaries (known as first order streams)	11
5	Watercourses within 10km of their source	6
7	Small watercourses anywhere	4
9	Upland watercourses of any size	4
8	Small upland watercourses	3
	TOTAL	**298**

By far the most popular response (57%) was the loosely defined "upper reaches of all watercourses" in which no firm, quantitative criteria of distance from source, watercourse size or stream order were stated. This fits with the often ill-defined way the term "headwater" is used in many scientific papers (Furse *et al.* 1995). However, the response also demonstrates that there may be a need for flexibility in the use of the term according to the nature of the taxonomic groups being studied (eg the headwater zone for fish may need to be defined as longer than for macro-invertebrates) or the nature of the operational problems being addressed.

The definition of headwaters used in Stages 2 - 4 of the Faunal Richness of Headwater Streams" R&D project (Furse *et al.* 1993, 1995; Furse 1996a) was "watercourses within 2.5 km of their furthest source as marked by a blueline on the Ordnance Survey, 1:50,000 Landranger series maps". This was the second most popular response (17%) but will have included choices made by people familiar with the R&D project and the R&D Notes and talks emanating from it. Set against this, some respondents elected for option 6 even though, as they stated on their reply, they were aware of the definition used in the R&D project and felt it inappropriate.

The following are a selection of comments made by those people unhappy with headwaters being defined as watercourses within 2.5km of source:

> *I think there should be a stronger definition of what constitutes a headwater since no doubt various regions will have their own ideas which may not agree with the definition stated in the questionnaire. I, for one regard headwaters as the upland sources of watercourses, but for a longer length than 2.5km, and since I work in* [a northern district] *I could probably put forward many cases where this length should be extended for better representation of data recording and interpreting of results.* - Ecologist

> *The 2.5km limit of headwaters would mean that many of my headwaters would be dry for five months of the year.* - Conservation Officer

> *Not clear why you picked on a 2.5km definition- seems very subjective and not based on habitat conditions (e.g. morphology).* - Environmental Assessment Officer

> *The 2.5km definition is probably less appropriate for fisheries needs* - Fisheries Scientist

> *I think a definition of "within 2.5km from source is too limiting* .... [In a southern county] *such watercourses are always very small, and prone to drying out completely in drought conditions. I would rather take the wider view, to get far enough downstream for fish to be permanently present, and for drying up to be unlikely in any weather pattern.* - Fisheries Officer

> *I would disagree with the 2.5km definition, not appropriate for all watercourses. Lowland headwaters are very different in character and thus* [have few?] *species common to that expected within in upland watercourse.* - Conservation & Recreation Officer

> *Within 2.5km from source may be your definition but mine is still "upper reaches" - you cannot be precise to 0.1km - each watercourse will vary.* - Regional Fisheries Advisory Committee Chairman

> *2.5km from source is a ridiculously short length* - Water Quality Officer

> [In my Region] *most streams flow from chalk/limestone so if the source is the maximum winter source, no headwater exists for most of the summer! i.e. I do not think the definition is a good one.* - Senior Water Resources Officer

A minority of respondents (10%) preferred definition based on stream order, either just first order (Option 1) or first and second order (Option 2). The definition first or second order streams was initially used in Stage 1 of the R&D project (Furse *et al.* 1991).

Whatever the individual's understanding is of a headwater, in the view of the authors, it is important that everyone within the NRA/Environment Agency becomes more aware of the environmental issues relating to sites which are smaller and nearer to source than those which they are currently most intimately involved in.

However, the headwaters R&D programme was specifically tailored to investigate streams within 2.5km of source and it was the NRA and selected non-NRA staffs' perceptions of this research and issues related to these kind of watercourses which were being sought. Therefore the following questions were answered after the recipients had opened the envelope giving the definition of headwaters they were to use in deciding on their selection of options.

Q.2 Which of the following do you think is/are the most important role(s) of headwaters, if any?

2	As a source for floral and faunal diversity (species richness)	244
1	As a spawning ground for fish	216
3	As an aesthetically pleasing feature of the landscape	185
6	As a means of good land drainage	62
4	As a source of recreational activity	42
7	As a source of irrigation	9
8	None	8
5	As a means of effluent disposal	6
	TOTAL	772

The respondents seemed to be aware of the value of headwaters as a source of floral and faunal diversity. An encouraging 83% chose this, the most popular option. There was almost as strong a view (73%) that headwaters played an important role as a spawning ground for fish.

The aesthetic role of headwaters as a pleasing feature of the landscape was identified by 63% of respondents whilst others linked these small watercourses with good land drainage. Surprisingly few suggested that headwaters were used as a source of irrigation given the frequency with which signs of abstraction were noted during Stage 3 of the R&D programme.

Forty two respondents (14%) saw headwaters as offering opportunities for recreational activities but were not asked to define the type of activity involved. Angling, rambling and features of golf courses are likely candidates.

For purposes of comparison of replies, eight major categories of occupation/role type were recognised, each containing at least fifteen respondents. These were: Biologists/Ecologists (n = 26), Fish Scientists (21), Fisheries, Recreation and Conservation staff (35), Environmental Protection staff (19), Pollution Control Officers (29), Water Quality Officers (30), Corporate Planners/Catchment Planners/Planning Officers (31), Regional Fisheries/Rivers Advisory Committee Chairmen (15). The loosest aggregation were the "planners", a group which included Corporate and Catchment Planners and Planning Officers.

The breakdown of replies by these occupational groups showed little variation between them with each "job" category placing high emphasis on the importance of headwaters as a source of biodiversity, a spawning area for fish and as an aesthetically pleasing feature of the landscape. The latter "role" was most highly favoured by Environmental Protection Officers.

Q.3 What do you think is the overall ecological quality (biological condition) of headwaters in England and Wales?

2	Good	157
3	Fair	75
1	Very good	51
4	Poor	10
5	Bad	1
	TOTAL	**294**

The respondents' perceptions of the ecological quality of headwaters appeared higher than reality although this conclusion does presume a common understanding of the five quality classes offered.

In the Stage 3 R&D Note for the headwaters project (Furse *et al.* 1995) it was reported that less than half of the 131 sites studied could be classed as having good ecological quality. In approximate terms only 40% were in the top quality band (Band A = "good"), whereas 30% were Band B ("fair"), 24% were Band C (poor") and the remaining 6% were Band D ("bad"). A similar distribution pattern was obtained from a data-set of 125 headwater sites sampled throughout England and Wales, in 1990, as part of Countryside Survey 1990 (Barr *et al.* 1993; Furse *et al.* 1995)

The fact that 232 respondents (79%) considered the overall condition of headwaters was "either very good" or "good , however these terms are defined, creates a common wisdom that little attention needs to be directed at these watercourses. Evidence suggests that this perception is a false one (Furse *et al.* 1995) and one that needs to be disabused by a much higher level of awareness (Furse 1996a).

The breakdown of answers by percentage, by occupational group is as follows:

	V.Good	Good	Fair	Poor	Bad
Biologists	15	50	31	4	0
Fish Scientists	14	33	43	10	0
Conservation staff	9	49	34	6	3
Environmental Protection	37	47	16	0	0
Pollution Control	21	48	31	0	0
Water Quality	17	60	20	0	0
Planners	13	74	13	0	0
Advisory Chairmen	7	53	13	27	0

In the context of the findings of the Stage 3 headwater R&D report (Furse *et al.* 1995), the most "realistic" interpretation of the ecological quality of headwaters comes from the fish scientists, followed by the Fisheries, Recreation and Conservation Officers, biologists and Pollution Control Officers. The perceptions of the "planners", including Catchment Planners, Environmental Protection Officers and Water Quality Officers are at greatest variance with the findings of the research study. Advisory committee chairmen, the smallest and therefore least statistically reliable group of people in the analysis, perceive problems to exist but strike a more pessimistic balance between "poor" and "fair" quality than the research findings suggest.

Q.4 What do you think are the three most important threats to the ecological quality (biological condition) of headwaters in England and Wales?

1	Acidification	163
12	Land use change	134
2	Organic pollution from farm waste disposal	121
3	Organic pollution from agrochemicals	92
6	Channelization and re-alignment	63
9	Pesticide Pollution	59
8	Erosion	43
5	Climatic fluctuations	43
17	Other	35
16	Removal of riparian tree cover	33
10	Organic pollution from rural sewage treatment works	26
15	Poaching (mechanical damage by cattle)	24
7	Urban pollution	20
11	Highway run-off	13
4	Industrial effluents	5
13	Angling	3
14	Rubbish disposal and instream litter	3
	TOTAL	**880**

Seventeen alternative options were offered in the questionnaire and all were ticked by at least three respondents.

Although the questionnaire was aimed at an appraisal of the most important national issues response were clearly influenced by the particular problems faced in the respondents own Region. Thus 88% of respondents from the NRA Welsh Region listed acidification as a "most important" threat as opposed to 28% listing channelization and realignment. In contrast, acidification was only listed by 24% of respondents in Anglian Region whilst 28% again, thought channelization and re-alignment to be important.

Overall, the most frequently listed category (55% of respondents) was still acidification, reflecting the considerable international publicity directed at this issue. With this exception, the most commonly cited problems were those associated with agriculture. This is to be expected given the rural nature of most headwater catchments and the concomitant absence of intensive urbanisation and industrialisation.

Land-use change was a clear concern for many respondents (46%) and organic pollution from agricultural sources also prominent. Channel modification, which was listed as an important area of concern by Furse *et al.* (1995) and Furse (1996a), was cited in 21% of replies, a higher proportion than those citing pesticide pollution. Riparian issues such as removal of bankside tree cover and mechanical damage by cattle received a fairly strong response, given the other major issues offered as alternatives on the questionnaire.

Interestingly 83% of the small number of Head Office respondents listed organic pollution from agrochemicals as very important. In contrast the highest regional frequency for this option was Thames with 36% and the lowest was North West with 19%. The three highest returns from Head Office were:

Organic pollution from agrochemicals	83%
Land use change	67%
Acidification	50%

Many of the respondents' citing "Other" issues referred to abstraction, an option that might beneficially have been included on the questionnaire.

Analysis by occupational group is confined to the top five perceived threats by each category in order to highlight the principal differences and to limit the volume of output in the text.

Biologists/Ecologists

1	Acidification	61.5%
2	Organic pollution from farm waste disposal	61.5%
12	Land use change	38.5%
9	Pesticide pollution	26.9%
3	Organic pollution from agrochemicals	23.1%
6	Channelization and realignment	23.1%

Fish Scientists

12	Land use change	47.6%
1	Acidification	42.9%
3	Organic pollution from agrochemicals	33.3%
6	Channelization and realignment	33.3%
8	Erosion	23.8%

"Other" causes were listed by 28.6% of Fish Scientists who replied. These others varied but low flows were prominently listed.

Fisheries, Recreation and Conservation staff

12	Land use change	68.6%
1	Acidification	51.4%
2	Organic pollution from farm waste disposal	51.4%
6	Channelization and realignment	31.4%
8	Erosion	20.0%
16	Removal of riparian tree cover	20.0%

Environmental Protection staff

1	Acidification	63.2%
2	Organic pollution from farm waste disposal	52.6%
12	Land use change	47.4%
3	Organic pollution from agrochemicals	26.3%
8	Erosion	26.3%

Pollution Control Officers

1	Acidification	65.5%
2	Organic pollution from farm waste disposal	51.7%
12	Land use change	34.5%
3	Organic pollution from agrochemicals	31.0%
9	Pesticide pollution	27.6%

Water Quality Officers

2	Organic pollution from farm waste disposal	56.7%
1	Acidification	46.7%
12	Land use change	43.3%
3	Organic pollution from agrochemicals	36.7%
5	Climatic fluctuations	26.7%

Corporate Planners/Catchment Planners/Planning Officers

1	Acidification	51.6%
12	Land use change	35.5%
9	Pesticide pollution	35.5%
5	Climatic fluctuations	32.3%
4	Organic pollution from agrochemicals	29.0%

Regional Fisheries/Rivers Advisory Committee Chairmen

1	Acidification	80.0%
12	Land use change	40.0%
6	Channelization and realignment	40.0%
3	Organic pollution from agrochemicals	33.3%
2	Organic pollution from farm waste disposal	26.7%

There was considerable consensus between occupational groups as to the major threats to headwaters. Acidification and land use change appeared in each of the eight "top five" lists whilst organic pollution from agrochemicals and from farm waste disposal appeared in seven and six of the eight lists, respectively.

The Fish Scientists and the Fisheries, Recreation and Conservation Officers were the only groups to cite both channelization and erosion in their top five and this may be connected with a perception of loss of habitat quality and siltation impacting on spawning success.

The brevity of presentation of replies by occupational group masks one other interesting feature. A total of 20% of Water Quality Officers who replied cited pollution from small sewage works as a major threat, making it sixth on their list. The highest proportion of the other seven groups citing this threat was 12.9% of the planners who placed this source as only ninth on their list, which was also the second highest place amongst all the groups.

Q.5 Approximately what proportion of the total number of macro-invertebrates species (shrimps, snails, mayflies, midges etc.) in whole river catchments do you think are only found in headwaters?

6	About 20%	47
8	About 30%	41
9	About 50%	41
7	About 25%	40
4	About 10%	39
5	About 15%	36
3	About 5%	22
2	About 2%	19
1	None	4
TOTAL		**289**

The best estimate of the correct value, derived from Stage 2 of the R&D study is "About 20%" (Furse *et al.* 1993). Although this was the most popular response (16%) there was clearly a broad range of opinion with six different categories each occurring as ticked on between 12 and 16% of the returned questionnaires.

The distribution of replies in the six most popular categories was so equitable as to imply random selection. This is almost certain to be the reality of the situation because, prior to the headwaters R&D programme, no such practical evaluation of the true value (ca 20%) is known to have been undertaken.

If the Environment Agency is to fulfil its remit to "further conservation" and to is to maintain the sustainability of catchments and their intrinsic biodiversity, then an awareness of the sources of that diversity and the mechanisms which control it is vital to their strategic planning. The current level of awareness clearly needs raising.

Q.6 How do you think the overall ecological quality (biological condition) of headwaters compares with that of larger watercourses (i.e. all reaches between the downstream limit of the headwater zone and the tidal limit of the river)?

1	Better	217
3	Worse	38
2	The same	36
TOTAL		**291**

Again the response to this question illustrated a difference between perception and reality.

Comparisons made in the Stage 3 headwaters report showed headwaters to be of worse overall ecological quality than downstream reaches (Furse *et al.* 1995). In the questionnaire survey 74% thought headwaters were better and only 13% thought they were worse. This despite the fact that the very existence of the headwaters questionnaire might influence respondents to thinking that, unlikely as it might seem, "worse" was the correct answer.

Once again, there is a very strong need to raise awareness in this area.

The breakdown of answers to Question 6, by proportions, by occupational group is as follows:

	Better	Same	Worse
Biologists	62	19	19
Fish Scientists	67	19	14
Conservation staff	80	14	6
Environmental Protection	74	16	11
Pollution Control	69	10	17
Water Quality	77	7	17
Planners *	87	6	3
Advisory Chairmen	67	7	27

* includes one "no reply"

All groups included a majority who thought that headwaters were of better ecological quality than reaches further downstream. This was at variance with the findings of the headwaters study (Furse *et al.* 1995). The Advisory Committee Chairmen seemed more aware of the "true" situation than the NRA staff and particularly the planners, 87% of whom thought headwaters were of better quality.

Q.7 How often does your own work include any involvement with headwaters?

3	Occasionally	117
4	Rarely	69
2	Quite often	66
1	Very often	22
5	Never	18
	TOTAL	**292**

The vast majority of respondents, 93%, claim to have some contact with headwaters but 63% only occasionally or rarely. The relatively small total of 30% who have "often" or "quite often" have involvement with headwaters emphasises the comparatively low degree of attention these watercourses receive.

Two principal factors are presumed to be responsible for this situation:

- an historical lack of awareness of the poor ecological quality of these watercourses
- a belief that higher priority should be attached to "main rivers" and the problems they face

No headwater staff member's work very often or quite often involved headwaters and their commonest response (83%) was "rarely". The Regions listing highest involvement often or quite often were Thames and Southern (44%) and those listing the lowest involvement were Anglian (17%) and North West (19%).

The breakdown of answers by occupational group is as follows:

	V.Often	Q.Oft	Occas'n	Rarely	Never
Biologists	4	15	50	27	4
Fish Scientists	9	29	24	29	9
Conservation staff	17	23	40	17	3
Environmental Protection	16	37	37	11	0
Pollution Control	7	34	45	14	0
Water Quality	7	23	47	13	7
Planners	3	16	35	29	16
Advisory Chairmen	7	20	53	13	0

The occupational group which had least frequent involvement with headwaters was the planners but these were closely followed by three groups directly involved with the monitoring and assessment of the biological and chemical quality of watercourses, the Biologists and the Water Quality Officers, followed not far behind by the Fish Scientists. Greatest involvement was claimed by Environmental Protection Officers and, as a single group, the Fisheries, Recreation and Conservation Officers.

Q.8 In comparison with your answer to question 7 (above) how much of your activities do you think should be involved with headwaters in the future?

3	About the same	175
2	A little more	83
1	A lot more	22
4	A little less	6
5	A lot less	3
	TOTAL	**289**

Given the response to the preceding question, with most people having relatively little contact with headwaters it was inevitable that the majority of respondents would expect the same or more involvement in the future. However, **it is encouraging to note that as many as 36% expected to be more involved in headwater issues in the future,** including 67% of Head Office staff. From their already low base, 7% of North West staff expected less involvement in future, a higher figure than any other Region.

The proportional breakdown of replies to Question 8 by occupational groups was as follows:

	Lot more	Little more	About same	Little less	Lot less
Biologists	12	62	23	0	4
Fish Scientists	5	29	62	5	0
Conservation staff *	11	26	57	3	0
Environmental Protection	16	37	37	11	0
Pollution Control	0	24	72	3	0
Water Quality	10	30	60	0	0
Planners	3	26	71	0	0
Advisory Chairmen **	13	40	27	0	7

* includes one "no reply" ** includes two "no replies"

All occupational groups showed a skewed reply towards thinking their work should include more involvement with headwater streams. The most positive about this were the biologists, 74% of whom thought they should have more involvement. Despite the highest level of current involvement (see previous question), 53% of Environment Protection Officers they should be more involved in headwaters in the future. Conversely "planners", who collectively had least involvement with headwaters, tended to think their current level of involvement was adequate. Pollution Officers, too, tended to be content with the adequacy of their current involvement.

Q.9 What priority do you think the organisation you work for places on headwaters at the present?

2	Medium priority	109
3	Low priority	100
1	High priority	45
4	Don't know	35
TOTAL		**289**

The large majority of respondents expressing a positive selection (82%) felt that the NRA placed a low or medium priority on headwaters. Only a small minority of the total replies (15%) were that the organisation placed a high priority on these watercourses.

The breakdown of answers by occupational group is as follows:

	High	Medium	Low	Don't know
Biologists	4	23	65	7
Fish Scientists	19	38	38	5
Conservation staff	11	37	46	3
Environmental Protection	16	53	26	5
Pollution Control	21	55	14	10
Water Quality	6	40	37	13
Planners	16	23	29	29
Advisory Chairmen	27	60	13	0

The most pessimistic assessment of the priority placed on headwaters by the NRA came from the biologists, 65% of whom thought it to be low. This was also the occupational group with one of the lowest levels of direct involvement. The other was the "planners" and these appeared to be the most confused group with nearly 30% unsure what priority the organisation placed on these streams.

The two groups who perceived themselves to have the highest current level of involvement (see Question 7), the Environmental Protection and the Pollution Control Officers, were the two employed groups which most strongly felt that the NRA placed a high priority on headwaters. They were matched in this assessment by the Advisory Committee Chairmen.

Q.10 What priority should the Environment Agency place on headwaters in the future?

2	Medium priority	145
1	High priority	115
3	Low priority	16
4	Don't know	12
TOTAL		**288**

When asked what priority the Agency should place on headwaters in the future there was a strong shift towards an upgrading of attention from the current levels.

The proportion of the total respondents (34%) who felt that headwaters were assigned a low priority at present (Question 9) fell to 5% when considering the emphasis in future. In contrast the proportion (15%) who felt the NRA placed high priority on headwaters at present (Question 9) rose to 39% who thought the Agency should give high priority in future.

The breakdown of answers by occupational group is divided into the proportions giving each reply together with (in parentheses) the shift from the proportions giving the same reply to the previous question.

	High	Medium	Low	Don't know
Biologists	31 (+27)	58 (+35)	12 (-53)	0 (-8)
Fish Scientists	52 (+33)	33 (-5)	9 (-29)	5 (0)
Conservation staff	49 (+38)	43 (+6)	3 (-43)	3 (0)
Environmental Protection	47 (+32)	47 (-6)	5 (-21)	0 (-5)
Pollution Control *	38 (+17)	52 (-3)	7 (-7)	0 (-10)
Water Quality	27 (+20)	60 (+20)	37 (-34)	7 (-6)
Planners *	29 (+13)	45 (+23)	6 (-23)	16 (-13)
Advisory Chairmen	73 (+46)	27 (-33)	0 (-13)	0 (0)

* includes one "no reply"

All groups show a net upward shift in the priority they think should be accorded to headwaters in future. The net biggest shifts were by the Biologists (62%), the Advisory Committee Chairmen (46%), the various conservation staff (44%) and the Water Quality Officers (40%). The smallest shift was from Pollution Control Officers (17%).

Despite their upward evaluation, two of the three groups according headwaters the lowest proportions of high prioritisation for the future were those responsible for field sampling and laboratory analysis, the Water Quality Officers (27%) and the Biologists (31%). These were also the groups with the highest proportion of low priority ratings at 37% and 12% respectively. The relatively low priority given to headwaters by the "planners" was in line with their previous responses but only 6% felt headwaters should receive only low priority in future.

Excluding the chairmen, the greatest proportion of high priority ratings were accorded by the Fish Scientists, the conservation staff and the Environmental Protection Officers, approximately half of whom put headwaters in this category.

Q.11 Are you aware of (i.e. have you heard of) the R&D project "The Faunal Richness of Headwater Streams"?

2	No	186
1	Yes	106
TOTAL		**292**

It is clear that only a minority of NRA employees (36%) were aware of the research programme. Given that the study has been over five years, has involved input from all ten of the former NRA Regions, has resulted in four R&D Notes and three digests and has had a fairly high profile within the organisation, including coverage in the "Water Guardian", it is likely that the level of awareness of shorter and/or less prominent R&D programmes, particularly those in their early stages, will be even lower.

The breakdown of answers by occupational group is as follows:

	YES	NO
Biologists	88	12
Fish Scientists	19	81
Conservation staff	66	31
Environmental Protection	32	68
Pollution Control	21	79
Water Quality	33	67
Planners	16	84
Advisory Chairmen	13	87

Only the Biologists, many of whom had provided data, and the conservationists, many of whom had received one or more talks on the subject were more frequently aware of the project than not.

Q.12a Extent of awareness of "The Faunal Richness of Headwater Streams" reports.

		STAGE 1	STAGE 2	STAGE 3	STAGE 4
1	Not yet received	232	236	248	250
3	Rec'ved & skimmed	34	30	18	18
2	Received not read	13	14	14	14
4	Received and read	9	8	7	6
TOTALS		**288**	**288**	**287**	**288**

Very few respondents had actually received copies of the headwater reports. No report had been received by more than 19% of those replying to the questionnaire. This is perhaps not surprising given that each is a substantial document (ca 100pp +) and that the first two stages at least had a specialist biological slant. A higher uptake might have been expected for Stage 3 with its wider land use/agricultural interest and for Stage 4 which set out a broad conservation strategy with implications for all disciplines within the Agency. In the case of Stage 4, at least, the R&D Note had only just become available immediately prior to the questionnaire being circulated. Uptake of this document may have increased since.

Of those receiving each report, only between 15 and 18% had read any given document. This compared with a range of 23 and 37% who had neither read nor skimmed any part of any given report. Most documents received had been skimmed only. Proportions of replies in the latter category varied between 46 and 61% according to the document.

Analysis of the results by occupational group showed that the highest proportion of respondents having read any given report or digest were the Biologists but generally no more than 12% of even this group had read any one document. A very small number of respondents in all occupational groups, except the chairman, had read one or more document. Exceptionally, one "planner" had read almost all the reports and digests produced during the R&D study.

The indications from these replies are that the major outputs, such as R&D Notes, of the NRA/Environment Agency R&D programmes are not widely distributed or read. Even at Head Office, fewer than 35% of respondents had received copies of any given R&D Note.

Whilst the study programmes need to fully cover and discuss the results of the work programme there appears to be a need for more concise and accessible publications in order to raise awareness levels. These publications could include the R&D Digests produced to complement each R&D Note, as was the case with Stages 2-4 of the headwaters study.

Q.12b Extent of awareness of the digests of 'The Faunal Richness of Headwater Streams" reports.

		STAGE 2	STAGE 3	STAGE 4
1	Not yet received	245	248	252
3	Received and skimmed	19	18	16
4	Received and read	13	12	11
2	Received not read	11	8	7
TOTALS		**288**	**286**	**286**

The evidence from the replies to this question is that the R&D Digests are no more widely distributed than the R&D Notes they summarise.

In none of the three cases were more than 15% of the respondents in receipt of the summary document. Again ≥66.7% of Head Office staff had not received copies of any given Digest. This is clearly a disappointing situation which fails to maximise the value of the Digests, especially given that many people in receipt of the Digests were those who had already received the R&D Notes.

The replies do show that the Digests are more likely to be read or skimmed than the R&D Notes. The proportion fully read rose from an average of 16.2% for the R&D Notes to 31.3% for the Digests. However an average of 23% of those receiving Digests still had not read these very short documents at all.

The conclusion is that R&D Digests are not fulfilling the function of spreading awareness of R&D projects greatly beyond the range of personnel familiar with the project and its findings from other, more detailed, sources.

Q.13 Would your work benefit from more information on the results of R&D project 'The Faunal Richness of Headwater Streams'?

1	Yes	177
3	Don't know	63
2	No	49
TOTAL		**289**

The responses to this question showed that their is a genuine desire for a greater level of awareness of the headwater research, which is not being met by current methods of distribution.

A total of 60% of respondents replied that their work would benefit from greater awareness of the results of the R&D programme whilst only 17% envisaged that they would gain no benefit.

Of course these replies only deal in terms of a perceived benefit and respondents were not asked to quantify the extent of the benefit they anticipated. A more searching follow-up would be to scrutinise the benefits people felt they had gained and how this affected their work programmes once the information had been received and assimilated.

The breakdown of answers by occupational group is as follows:

	YES	NO	DON'T KNOW
Biologists	85	4	11
Fish Scientists	71	10	19
Conservation staff	74	14	11
Environmental Protection	42	26	32
Pollution Control	69	17	14
Water Quality	47	13	40
Planners	52	29	19
Advisory Chairmen	93	7	0

The most frequent reply for each occupational group was that they thought they would gain by receiving more information on the headwaters R&D study. The Advisory Committee Chairmen were the most positive in this respect, followed by the Biologists.

The Environmental Protection Officers, who claimed the greatest current involvement with headwaters (see Question 7) and the "planners", who claimed the least, were two of the three groups who felt they would gain least by further information on the R&D project. The other group was the Pollution Control Officers.

Not surprisingly, given the general lack of awareness of the work, a fairly high proportion of most groups were unsure whether the information contained in the reports would, or would not, be of benefit to them.

Q.14a How would you like to receive this information?

3	A headwater factfile	133
1	Talks/verbal presentations to individual work groups	89
8	A specially produced headwater video	58
2	General conferences/seminars	52
4	Articles in "Water Guardian"	50
6	Scientific papers	37
9	Via e-mail	29
7	Features on TV and radio programmes	24
5	Articles in popular journals	24
12	Other	14
11	Temporary displays and exhibitions	13
10	Via the Internet	7
TOTAL		**530**

By far the most favoured means of disseminating the results of this study was through the medium of a factfile. This approach was advocated by 45% of respondents. This was followed by 30% who were in favour of special talks to work groups, whilst 18% looked to conferences and seminars as a means of spreading awareness.

Some of the more "populist" approaches, such as press, radio and TV programmes, articles in popular journals and displays and exhibitions were not highly favoured by NRA staff. However there was a larger proportion of respondents who saw merit in the production of a special headwaters video.

Each option received some favour but relatively few promoted the use of electronic means of communication such as E-mail and the Internet.

Q.14b Would you like to receive information on how to obtain the H/W reports?

1	Yes	105
2	No	98
TOTAL		**203**

Of the multiple choice questions, this one received the fewest numbers of ticked responses. On the assumption that those not responding had no wish for the information offered, 36% of overall respondents wished to know how they could get more information on headwater reports. This response also indicates a greater desire for awareness than is currently being met.

This requested information will be circulated to all those requesting it.

Q.15 Comments?

1	Comments made	141
2	No comments made	153
TOTAL		**294**

Of the 294 respondents, a gratifying 48% took the trouble to append comments. The majority of the main points are presented here.

The majority of comments were positive about the importance of headwaters and the R&D carried out on them and/or made positive suggestions about the future direction of R&D and the implementation of results of the study to date. However there were also a number of respondents who did not attach priority to headwaters or were critical of the nature of the questionnaire.

Amongst those most convinced of **the importance of headwaters, and the need to pay greater attention to their welfare,** were the Regional Fisheries Advisory Committee Chairmen, all ten of whom completed and returned their questionnaires. One such chairman commented:

> *In* [my] *region....headwaters are probably most valuable for the diversity of habitat, flora and fauna they offer. They have often been neglected in the past - until they died or disappeared. Because of their sensitive position in the critical early life of a river, data collected on headwaters must be a valuable indicator of the well being of the river, its catchment and the sustainability of the supporting water resource. Continuing research and strategic planning for their well-being seems essential for successful sustainable management of the environment.*

A second chairman wrote:

> *Conservation and the ecology of the river is also of particular interest to me; in many cases the headwaters are situated in important rural areas and are subject to the effects of agricultural practices. It is essential that they continue to receive priority attention from the* [Environment Agency].

Another was equally enthusiastic but was concerned about the extent to which people in his position were informed of the results of R&D studies. He wrote:

> *R&D of this nature is a fundamental requirement of the successful management of most, if not all rivers. Whilst one may assume that those currently involved in management are acquainted with the results of such R&D it does not appear that sufficient action is taken to make aware those who can assist in promoting money being spent and action being taken on recommendations - i.e. RFAC's and RFAC's board members etc.*

This mixture of **perception of the value of the R&D research but lack of awareness of the detail** was reiterated by one of the two Regional General Managers to reply:

> *Valuable research. Regrettably R&D projects not generally read by RGM's who receive vast quantities of paperwork.*

Similarly from an Area Environmental Quality Officer:

> *I do believe quality of headwaters to be vital. The reason for my reply is that they do not presently attain a high profile and I receive more information on high profile items than I could possibly read in two lifetimes.*

Strong **support for the high priority that headwaters should receive** came from fisheries scientists and Fisheries, Recreation and Conservation (FRCN) Officers. Some of their comments are as follows:

> *I think that* [headwaters] *should be identified in a "transparent" manner as little ecological powerhouses in a wide variety of conflicting areas within the Agency.*
>
> *The importance of headwaters should not be overlooked. They can be important areas of recruitment (particularly in upland salmonid rivers).*
>
> *Clearly headwaters are very important.*

Support from the conservationist point of view came from the respondent from Scottish Natural Heritage:

> *Clearly I am interested in seeing information being built up on headwaters so that evaluation of rivers using SERCON can be made more comprehensive.*

Some Water Quality Officers and Managers were equally positive:

> *Great pressure, economically driven is being placed on the NRA to reduce its sampling programme. Sadly headwaters are the first to be dropped from programmes as they have little or no point source inputs, making it easier to justify dropping them. I feel this is very short-sighted as headwaters potentially offer a great deal of information regarding the health of the overall catchment.*
>
> *In general the "water industry" has paid scant attention to headwaters. For example, monitoring programmes for water quality or biology have not included them. I believe there is a need to educate more staff about both the intrinsic value of headwaters in the overall regime of the catchment.*

This theme of **greater awareness of headwater issues** was taken up by several respondents of which the responses from three biologists are typical:

> *I think it will be necessary to provide information to promote the importance of headwaters to water quality sections, so that there is more general awareness of the issues involved*
>
> *The threats to headwaters, both rural and urban, need to be given a much higher profile, but this is difficult to get across with so little information available.*
>
> *A definitive publication on the importance of headwater streams and the associated buffer zones would be extremely useful in helping the* [Environment Agency] *in protecting the headwaters from development..*

Many of the **cautionary comments about placing high priority on headwaters** came from those in planning and management posts. For example, a Corporate Manager wrote:

> *In entering the Environment Agency we are getting to grips with the wider air, land and water remit. The priority of* [awareness of headwater stream ecology] *will therefore be lower (inevitably) than it was in the NRA.*

A similar view was expressed by a senior member of Head Office staff

> *In the context of the pressures facing water management in the Agency headwater streams will struggle to gain high priority*

and also by an Area Manager

> *Headwater streams in the particular area I am based do not give rise to any particular problems other than in drought conditions affecting water resources, fisheries and conservation interests. This results in some short term damage but over a limited length of watercourse, therefore not regarded as a high priority.*

Some managers were **not convinced of the need to be more aware of or involved in headwater issues** which they considered were properly dealt with by the relevant professional officers. Three examples of this viewpoint are firstly from an Area Planning Liaison Officer, secondly from an Area Manager and thirdly, and most forcefully, from an Area Water Resources Manager:

> *Although I am not aware of the R&D project or the detail of headwater stream ecology I am aware of who to speak to about these issues. I do not consider that more than awareness is appropriate for my role as internal consultees can advise me accordingly*

> *I must say I am opposed to this "scatter gun" approach to this (or any other) detailed subject: as an Area Manager, I cannot possibly become personally involved in such detail; what is important is that I am advised of the results and issues, so that my team can take them into account in its decision making. I expect my Area Managers (Functional) to get themselves involved in the detail.*

> *If I am dealing with an issue related to headwaters I will TRUST the advice from my FRCN colleague as to whether I need to take certain matters into account. I don't need to know what R&D reports say myself. I think that by sending this questionnaire out to other than the specialists in FRCN ... you are abusing that trust.*

Another manager, this time an Area Water Quality Manager, thought that it *"would be poor value to carry out more operational research"* because of the *"perceived lack of appreciation by many of the value of headwaters"* which he assumed to be *"one of the main reasons for [the] questionnaire being distributed"*.

However it was not only managers who were **reluctant to prioritise staff and financial resources on headwater issues.** The next set of comments are from Fisheries, Conservation and Recreation Officers:

> *As our resources are fairly stretched, we could not make a large commitment to sampling headwaters.*
>
> *The aims and intentions of* [R&D Note 455 on headwater conservation strategies] *are very laudable but I am not yet convinced of their* [headwaters'] *priority in relation to other competing priorities - particular in relation to funding.*

Anxieties about assigning priority funding to headwaters also troubled three biologists:

> *In this region of NRA we do not manage to complete routine work. I am sure that headwaters are important for conservation but how can we justify sampling headwaters with respect to first comment.*
>
> *Whilst I recognise the importance of protecting headwaters in terms of biological quality it is very difficult to put good intentions into practice with the limited man power resources available to biology.*
>
> *Headwaters at 2.5km from source are so small & restricted in relation to the rest of the system & the amount of work required for the main system, that I cannot see us being able to put more effort into headwaters.*

Other respondents drew attention to what they considered to be **weaknesses in the questionnaire**. One Corporate Planner thought he detected a bias in the whole concept:

> *The design of your questionnaire, which will ultimately determine the results of your survey is worthy of comment. We cannot answer questions 8 & 10, 13, 15 without knowing the answers to Q2-6!. Too many questions are leading the respondent to conclude that s/he needs more information on headwaters.*

Others saw difficulty, as discussed earlier, in providing a national appraisal of the most important threats to the ecological quality of headwaters when there were such great regional differences. The difficulties are summed up by one Planning Liaison Officer who wrote:

> *Factors affecting headwaters are surely very specific to their location (e.g. Midlands agricultural area v welsh uplands) and the question is not framed to allow a response reflecting this.*

The same respondent also criticised Question 2 for being *"too broad to be useful"*.

Almost all the major arguments for not attaching priority to headwaters and all the criticisms of the questionnaire itself have been set out here as a measure of the value placed on all shades of opinion. However adopting this approach has given a disproportionate emphasis to these types of reply.

Of the respondents, who wished to see more attention directed at headwaters, many addressed the issue of the major causes of environmental stress in headwater streams. A total of 95 references to a source of stress were specifically mentioned under 37 specific categories. These were separated into six broad headings; predominantly upland issues, farming practices, channel/corridor modification, flow modification, urban influences and general pollution (Table 3.4). The specific categories largely mirrored the distribution of response to Question 4 but placed more emphasis on the effects of over-abstraction, low flows and loss of wetlands/water retaining sponges than that question permitted.

Table 3.4 The number of times environmental problems relating to headwaters were mentioned in reply to Question 15 of the questionnaire.

TYPE OF ENVIRONMENTAL PROBLEM/STRESS	NUMBER OF REFERENCES
Predominantly upland issues	*(14)*
Acidification	*7*
Minewater discharges	*3*
Forestry practices	*3*
Moorland gripping	*1*
Farming practices	*(34)*
Land-use change	*7*
Intensive agriculture	*1*
Agricultural practice	*1*
MAFF policies	*1*
Farm waste disposal	*4*
Agrochemicals	*1*
Fertilisers	*1*
Pesticides	*3*
Agricultural run-off	*4*
Sheep dip disposal	*1*
Upland sheep farming	*1*
Overgrazing	*3*
Erosion	*4*
Siltation	*2*

Table 3.4 continued

TYPE OF ENVIRONMENTAL PROBLEM/STRESS	NUMBER OF REFERENCES
Channel/corridor modification	**(9)**
Channelization	*3*
Channel clearance/dredging	*3*
Channel modification	*1*
Culverting	*1*
Loss of riparian cover	*1*
Flow modification	*(25)*
Low flows	*9*
Regulated flows	*1*
Drought	*1*
Over abstraction	*9*
Over drainage/loss of water holding capacity/wetlands	*5*
Urban influences	*(10)*
Urbanisation	*3*
Development	*2*
Industrial effluents	*1*
Road run-off	*1*
Wind farm siting	*1*
Sewage treatment works	*2*
General pollution	*(3)*
Eutrophication/nutrient enrichment	*1*
Toxic pollutants	*1*
Poor water quality	*1*

Many of the respondents stressed **the importance of not considering headwaters in isolation** and several were concerned about the impact of poor quality headwaters on watercourses further down the system. The following are typical examples:

> *The whole river catchment can often be affected by the situation in the headwaters.* - Regional Fisheries Advisory Committee Chairman

> *Because of their sensitive position in the critical early life of a river, data collected on headwaters must be a valuable indicator of the health of the river, its catchment and the sustainability of the supporting watercourse.* - Regional Fisheries Advisory Committee Chairman

> *I believe there is a need to educate more staff about both the intrinsic value of headwaters and their importance within the overall regime of the catchment.* - Regional Water Manager

> *We should not consider* [headwaters] *in isolation.* - Water Quality Officer

> *Headwaters of streams should be given a high priority with respect to biological condition because it is this stretch of the stream that defines the eventual overall quality of the river. If the headwater is polluted the chances of the rest of the river returning to a good quality are minimal.* - Water Quality Officer

> *I feel that protecting the water quality of headwaters is so important in maintaining good river quality for the whole length of systems.* - Biologist

> [Headwaters'] *contribution to the resource of the catchment overall is vital.* - FRCN Officer Fisheries

Therefore the need for **implementation of headwater management plans within the framework of the catchment as a whole** was one of the priority areas identified for operational R&D:

> *I would like to see more research on the functioning of catchments, particularly in the development of tools which would facilitate their appreciation by water managers across a wide spectrum of functions (e.g. modelling tools for catchment management).* - Regional Water Quality Manager

> *Future strategy and research needs to 1. Take an integrated approach & 2. Consider in the future an expansion of the project to "The faunal richness of: Headwaters, middle reaches, lowland rivers & reservoirs/lakes in the catchment system". This would allow the Agency/whoever to appreciate the whole systems and how different habitats/units interact.* - Catchment Planner

> *It is important that we do not ignore the actual and potential problems that beset headwaters but I think we should not consider them in isolation.* - Water Quality Officer

The quality/biodiversity of headwaters can be an issue that arises in Catchment Management Planning (CMP). Problems affecting headwaters .... can crop up in a number of CMPs and are not the sort of thing that can necessarily be resolved on an individual catchment basis (i.e.lack of resources for research etc). It would be of benefit if these issues could be addressed by a national R&D project and "fed" down to the areas so actions can be included in the appropriate CMPs. - Catchment Management Planning Officer

[The Environment Agency] *need*[s] *model policies for protection of headwaters, for use in catchment management plans.* - Conservation Officer.

Other aspects of implementation of a headwaters strategy were also prominent in the replies received. Despite the researching problems identified by some (see above), the following respondents were keen to see an **improved monitoring** programme:

We have been .... discussing the need for a more general survey of unclassified river stretches (which includes most headwaters) which would cover invertebrates, fish water quality etc. - Appraisal Officer

Many [headwaters] *are non-classified river reaches and as such are under-monitored and possibly neglected. I think these streams should receive more attention from the Agency.* - Appraisal Officer

Establish long term ecological monitoring networks in small streams (20yrs+). Include fish dynamics and link/integrate with any other relevant monitoring programmes (climate change or acid deposition for example. - Senior Environmental Appraisal Officer.

The biological monitoring of headwaters has sadly declined within the NRA. Headwaters do provide an important habitat for many rare invertebrate species and should therefore be regularly monitored. - Biologist.

EA (sic) *should take responsibility for all land drainage & flood defence matters from Local Planning Authorities. EA should have responsibility for monitoring headwaters under Biology or Conservation.* - Catchment Planner.

The condition of headwaters (in general terms) should be surveyed and evaluated in accordance with NRA methodology for landscape assessment, using mixed teams of landscape architects, ecologists & geomorphologists (and archaeologists) to provide an overview of the condition of headwaters (and the rest of the catchment). - Landscape Architect

The Senior Environmental Appraisal Officer cited above stressed the need to *"develop* [a] *National Inventory of small streams &* [their] *status".* He noted that *"RHS & certain fisheries projects may do this"* and stressed the need to co-ordinate the different sources of data. Others saw the need to **include headwater monitoring as part of quality objective schemes**:

Headwater streams should be included in the SWQO scheme - Area FRCN Manager

As many headwaters do not receive STW effluents, they have no water quality objectives and so remain relatively unprotected. Ecological quality objectives are more useful than water quality objectives, particularly for small streams. EQO's should be developed and implemented not only for existing classified watercourses, but also extended to headwater streams - Water Quality Officer.

With regard to implementation, a recurrent theme raised by respondents was the need to **promote awareness of headwater issues** as the following selected responses illustrate:

More emphasis on education: Schools, farmers, associations (fishing, ramblers, CPRE etc.). - Regional Rivers Advisory Committee Chairman

Means are needed of bringing [headwaters'] *importance to the attention of the public.* - Planning Liaison Officer

I have been working in planning liaison for some time, but I do not know how relevant the Headwaters R&D project is to my work (and vice versa), therefore, some idea of how relevant it is to particular Agency roles would be useful. - Planning Liaison Officer

We should have a clear view of the value, variety, and protection features required for headwaters. - Area Manager

I think it will be necessary to provide information on the importance of headwaters to water quality sections, so there is more general awareness of the issues involved. - Biologist

A definitive publication on the importance of headwater streams and the associated buffer zones would be extremely useful in helping the NRA/ENVAGE (sic) *in protecting the headwaters from development. It would also be very helpful in enabling us to assess the impact of our own flood defence works.* - Biologist

Clearly headwaters are very important. The problem for NRA staff on the ground is controlling changes in them which threaten their conservation value. We have no way of preventing the more damaging actions by farmers, e.g drainage, ditch straightening and cleaning out etc. as our responsibilities in headwaters are fairly weak. We are also working against MAFF and the drainage industry. The task is clearly beyond our reach. What is needed is a programme of education of landowners and MAFF officers. - Area Conservation and Recreation Officer.

The problems of **controlling drainage activity**, and the need for the Agency to have more effective powers in this respect were re-iterated by others:

Headwater streams are very often not main river - this means that on the whole they are not touched by flood defence maintenance works. However, this means that the landowner can put a machine in or plough across small streams without any consultation and we only find out some time after the event. - Area FRCN Manager

I currently have a problem where a headwater stream is being dredged by farmers. As this stream is not designated as "Main River" under Land Drainage legislation we seem to have little control over this activity. I strongly feel that this is an area that needs to be looked at in terms of changes to legislation. - Area FRCN Manager

Other respondents, including two cited above, saw the needed for **improved planning strategies and powers**:

From a strategic planning perspective the Agency should be seeking to avoid /divert pressures for development away from headwaters/top end of catchments, otherwise any adverse impacts such as pollution, poor water quality, low flows due to over abstraction will have an adverse effect on the whole length of watercourse. - Strategic Planner

[The Environment Agency] *receive quite a number of planning applications or pre-application enquiries for use of heads of rivers for recreation - e.g. golf courses, fishing lakes, amenity ponds - by "recent" purchasers who consider what they are doing is "good" for conservation and will enhance habitats. There needs to be more information for potential developers about the quality of heads of rivers and also for the knowledge of the planning officers of District and County Councils. This could influence Policies of Development Plans.* - Planning Liaison Officer

EA should produce a planning policy to protect headwaters. - Fisheries and Conservation Manager

[The] *information* [on headwaters] *would be very useful as a consultee for Local Planning Authorities and internal EA flood defence and navigation work. Often small watercourses, e.g. headwaters, are dismissed as not important because they are not "main river" so this information will help redress the balance!* - Biologist

One of the main issues addressed in the Stage 4 report of the "Faunal Richness of Headwater Streams" project was **the need for collaboration in the conservation and management of headwaters** (Furse *et al.* 1995). This theme was echoed in some of the questionnaire returns:

The role of headwaters is recognised as crucial by at least three interest groups - yours [i.e. those seen to be responsible for the headwaters R&D project], [the] *Rural Landuse Group and* [the] *wetland liaison group. These need to be integrated and produce inter-disciplinary information. Landuse/wetlands in headwater catchments should be a top priority for protection, conservation and restoration in the EA. This needs a pro-active approach to landowners and links with agri-environment schemes.* - Regional Conservation Officer

Research should involve the landowners/users of headwaters. - Corporate Planner

Need to link [headwater studies] *with RHS* [River Habitat Surveys] - Environmental Assessment Officer.

The CCW [Countryside Council for Wales] *is involved in a collaborative research project with the NRA relevant to headwater conservation.* - CCW Officer

Generate better liaison with MAFF to reduce agricultural impacts. - Unknown affiliation

Greater emphasis [is needed] *on liaison between the Environment Agency and MAFF re. grants - especially now that MAFF have responsibilities for Countryside Commission Grant Scheme.* - Fisheries and Recreation Manager

Establish strong working links with MAFF through Fisheries, Recreation and Conservation work. Objective: to influence all land-use policies to obtain funding for fisheries/conservation to rectify damage caused directly by MAFF policies. Clarify MAFF, English Nature, Environment Agency roles in post-designation work on SSSI/SAC's together with funding issue. - Regional Fisheries Advisory Committee Chairman

One respondent, a Regional Water Quality Planner, went even further and suggested that *"work on headwaters should be based on a business need and not the perceptions of the NRA". "In particular"*, s/he continued, *"any NRA policy should be based on what our customers want - e.g. the general public, conservation bodies, anglers, industry etc."*

The RFAC Chairman quoted just above raised the issue of costs of implementing headwater strategies. The problems of meeting staff and resource requirements for headwater monitoring and implementation have been addressed earlier in this section. A few respondents also referred to **the need to ascribe economic value to headwaters as part of the purpose of cost/benefit analysis of specific headwater conservation strategies**:

We should have a clear view of the value, variety and protection features required for headwaters. - Area Manager

I think the economic benefits of headwater streams to fisheries should be investigated. - Area FRCN Manager

Cost/benefit schemes for riparian owners in relation to production of juvenile salmonids in headwaters. - Fisheries and Recreation Manager

Environmental economics. Can we ascribe a value to headwaters? What is the value of a species or a biological community? Is one catchment worth more than another? These "values" would be useful in water resources planning. - Principal Water Resources Officer

Examine and define environmental costs resulting from loss or restoration of headwaters, i.e. C/B approach. - Senior Environmental Appraisal Officer

The idea of **pilot headwater restoration schemes** had previously been raised by Furse *et al.* (1995) and Furse (1996a) as a priority for operational research. The replies to the questionnaire included few other direct references to comprehensive restoration strategies. These were confined to the following comments:

> *We need to develop a strategy for collaborative improvement works with aggressive front-meetings to do more for this.* - Regional Fisheries Advisory Committee Chairman

> *Should river restoration work start in headwaters and work downstream?* - Area FRCN Manager

Instead, respondents tended to make suggestions for particular elements of an holistic headwater restoration programme. Prominent amongst these was to **restore the capacity for headwater catchments to act as a sponge** preventing too rapid loss of water through run-off and land drainage:

> *The network of headwaters and their naturally associated wetland habitats are vital in water storage. The draining of these areas has not only led to the loss of these habitats, but may also contribute to lack of water in the summer, and the flooding problems in winter.* [The Agency] *must look at ways that* [they] *can increase storage of water in the upper catchment.* - Conservation Assistant

> *A study of headwaters should include an assessment of the suitability for surface water run-off attenuation, particularly in relation to the effects of the hydrograph downstream.* - Engineer

> [A] *major threat* [to headwaters] *in the S*[outh] *E*[ast] *is urbanisation which also affects the "water holding" capacity of headwater streams.* - Fisheries and Conservation Manager

> *The flood defence value of headwaters in attenuating flooding and the impact of different associated land uses should be evaluated, together with the environmental benefits that accompany the various options.* - Flood Defence Manager

> *Many headwater catchments were drained (grant aided!) and our sponges lost. There should be a scheme for re-instating these sponges.* - Regional Fisheries Advisory Committee Chairman

> [As a priority R&D topic]: *The importance of the upper catchments, when in as natural a state as possible, in holding back flood waters, evening out seasonal variation, acting as a sponge etc.* - Regional Rivers Advisory Committee Chairman

> *Moorland gripping. Should investment be made to remove grips to make rivers less flashy?* - Ecologist (Fish Scientist)

Closely associated issues are those of **low flows and over abstraction**. These attracted the greatest level of response and one of the highest levels of concerns of the respondents (Table 3.4). The following abstracts are representative of the views expressed:

> *Further work* [needed] *on .... the impacts of drought (natural and man-made) and regulated flows.* - Area FRCN Manager

> *Even relatively small abstractions can reduce flow on headwater streams. We have little information on the effects upon flora/fauna.* - Hydrologist

> [As a priority R&D topic]: *Impacts of low flows* - Environment Agency staff member

> *The headwaters of rivers in my area tend to be largely supported by spring discharges. These are affected by winter rainfall and groundwater abstraction. The impact of the latter needs studying.* - Senior Water Quality Officer

> *I am involved in enforcing abstraction licenses - many of these affect headwaters. We know little at the moment of the source of even major streams (i.e. where water begins to flow at different times of the year - so we would be unsure of the relationship between flow (or lack of it) and e.g. biodiversity. Basic information is required.* - Senior Water Resources Officer

> *In* [my area], *the main water resource pressures on headwaters are over abstraction.* - Hydrogeologist

> *Abstraction on chalk rivers has produced winterbourne conditions in long downstream reaches.* - Conservation Officer

An issue which generated a similar level of interest amongst those surveyed was **the role and optimal design of buffer zones**. Many respondents stressed their importance and requested further guidance on how practical strategies and policies could be devised:

> *The principle of buffer strips alongside all watercourses needs to be given a greater priority in agricultural practice and urban management.* - Area Biologist

> *Agricultural run-off is ... a bigger problem than we are currently aware of from monitoring ... the use of buffer strips in heavy intensive arable farming areas is essential.* - Biologist

> *More extensive work on the benefits of buffer zones would ... be useful.* - Senior Biologist

> [I] *suggest work* [is carried out] *on the size and nature of buffer strips to protect headwaters.* - Senior Biologist

More information would be helpful on the requirements to be met by buffer zones to small watercourses in lowland and partly built up areas. - Planning Liaison Officer

The questionnaire does not appear to give much priority to riparian habitats which is an area of great importance. - Area Manager

Within the stream corridor respondents were also concerned about **the impacts of channel modification**. Some of these views were quoted above when considering the control of drainage activity. Other views were as follows:

Further work [is needed] ... *on the impacts of channel modification.* - Area FRCN Manager

There are particular pressures on headwaters from culverting for access, golf courses, and even in some cases to avoid the need for maintenance. ' - Planning Liaison Officer

[The Environment Agency] *need*[s] *to prevent channelization* [of headwaters] *and* [their] *use as drainage channels.* - FRE Manager

Canalization has damaged many headwaters. - Regional Fisheries Advisory Committee Chairman

The headwaters R&D project provided evidence that one of the effects of channelization is siltation (Furse *et al.* 1995) and that this substratum type supports a less diverse fauna than coarser stream beds, accumulation of detritus and large submerged particles such as sticks (Clarke 1994). The occurrence and **impact of siltation** is intimately linked, in some respondents view, with **changing land use and erosion:**

The most important factor we have identified [in headwaters in our Region] *is related to changing land use and siltation. This has caused blockage of spawning.* - FRCN Manager

We need to influence land use in these areas. We need to prevent ... erosion. - FRE Manager

I am particularly concerned about three issues [including] *impacts caused through land use change which has led to increased land run-off and soil erosion.* - Area Environmental Manager

Effects of erosion and diffuse pollution are probably the most significant [sources of environmental stress] *in headwaters. We need to focus advice on farmers to reduce their impact. May need some research to identify causes and pinpoint advice we should give and how it is delivered.* - Principal Pollution Officer

Others saw other sources of environmental stress arising from **land use and land-use change,** some of which were very general and others specific to a type of agricultural practice. General comments included these:

> *The Rural Landuse Group should be involved in applying operational elements to land use strategies to protect headwaters.* - Area Manager

> *Upland areas and headwaters have potential for large land use changes (e.g. changes in agricultural policies/subsidies, energy policies etc.), which can affect both the quantity and quality of the run-off to headwater streams.* - Catchment Management Planning Officer

> *I think we need more research on the effect of land use change on the water environment including analysis of historic changes in drainage, grazing regimes, forestry etc.* - Catchment Planning Officer

> *Headwaters face the continued threat of upland land drainage, afforestation and land use change.* - Appraisal Officer

More specific agricultural and land management practices which may influence the ecological quality of headwaters and their catchments include **sheep farming, grazing, waste disposal and pesticide contamination**:

> [As a priority R&D topic]: *Changes in land use, especially sheep farming on faunal/floral diversity and productivity of headwaters.* - Fisheries and Recreation Manager

> *There seems to be a lack of awareness of the damage done by upland sheep farming.* - Principal Fisheries, Conservation, Recreation and Biology Officer

> *Future research could be undertaken with the Rural Landuse Group ... to coordinate studies such as sheep dip disposal* [and] *farm effluent storage/disposal.* - Pollution Control Officer

> *I am particularly concerned about three issues* [including] *pollution from low rate irrigation of farm waste* [and] *pesticide contamination.* - Area Environmental Manager

The most frequently listed source of impact on headwaters was **acidification** (see **Q.4**). Seven respondents also commented on this issue and its relevance to headwaters in reply to Question 15, including the following views:

> [The] *main threat to headwaters in upland, base poor areas of England and Wales ... is acidification both from the atmosphere and from coniferous afforestation.* - Pollution Prevention Officer

> *In Wales, acidification of upland streams (including headwaters) is a serious issue, limiting the potential of river fisheries as well as affecting other invertebrate life.* - Regional Fisheries Advisory Committee Chairman

Much more needs to be done to establish acidification problems and the results. - Regional Rivers Advisory Committee Chairman

The remaining comments which fit within the framework of what might generally be termed the development and implementation of headwater conservation and management strategies and policies, including operational research, fall within the broad definition of **pollution control:**

The NRA have not funded projects or investigative work that really "gets to grip" with what is going on in headwaters with respect to farm waste disposal, pesticide disposal, agrochemical usage, use of inorganic fertilisers etc. The E.A. MUST recognise the importance of strategic pollution prevention campaigning to protect and enhance headwater quality, rather than rely on "reactive" firefighting work. In conclusion, greater researching is required (staff and funding) to instigate this important work. - Environmental Protection Principal

In our area there are enumerable sewage discharges on inappropriately small watercourses - with consequent damage to faunal diversity, public health hazards etc. ... I think many discharges to small streams should be prevented regardless of inappropriate licences to discharge which are outdated. - Biologist

I would support work which looks at the means of determining the impact of different classes/types of pollutant and on other aspects of the flora and fauna of these streams. - Regional Biologist

[Headwaters] *provide baseline quality data, if spring/other sources are uncontaminated and much information about diffuse sources of pollution such as agricultural run-off.* - Senior Water Quality Control Officer

Headwaters ... appear to be more susceptible to pollution. This is particularly evident in rivers [in our county] *which are adjacent to mining activities.* - Biologist

More continued research [needed] *on effective methods for treatment of minewaters.* - Environmental Protection Officer

Other respondents welcomed the prospect of more **fundamental research on the ecology of headwaters**

Stress and elaborate on the whole ecosystem role of headwaters. Their functional significance in nutrient/energy cycling, refuges etc. - Senior Environmental Appraisal Manager

I would like to see an evaluation of selected toxicity end points (in-stream) against stress measures. This has the potential to provide a means of direct assessment and control on impacts to the benefit of the biology. - Regional Scientist

Nutrient enrichment/eutrophication (is it a problem ... if so where and to what extent. - Environment Agency staff member

Further work on the relationship between headwater invertebrates and other fauna. - Area FRCN Manager

In particular many respondents made reference to the impacts of a variety of environmental stresses on the **biodiversity of headwater streams**. Some of their comments are quoted above in relation to the particular perceived stressors. Others made more specific suggestions about the strategic R&D needed to understand the causes of biodiversity, the way it may be promoted and its role in achieving a sustainable ecosystem:

Work should be undertaken on species diversity (flora and fauna) with a view to conservation. Where scarce species/communities are found habitat and water quality requirements should be researched and suitable conditions maintained/extended. - Biologist

The importance of headwaters as a source (reservoir) of flora [and] *fauna for downstream re-invasion (by drift etc.) after damage to downstream habitat* [is an] *idea* [which is] *gaining ground in the EA - but need*[s] *to be strengthened (i.e. quantifiable evidence gained) + spread to managers, board members, committee chairmen etc. ... protection o biodiversity (including that in headwaters) is a key element in sustainability.* - Regional Rivers Advisory Committee Chairman

In dealing with long term planning of water quality, e.g. SWQOs, WSPLCs, asset management plans and provision of new resources, the headwater streams tend to get forgotten. This should gradually change in the Environment Agency with the greater emphasis on biodiversity. - Regional Water Quality Manager.

[Through involvement with Surface Water Abstraction Licensing Policy R&D], *which aims to move to a licensing policy incorporating protection of in-river needs and flow variability, I am very interested in the interaction between surface flows and the communities they support ... I am intrigued by the possibility of establishing what their full ecological potential would be.* - Senior Water Resources Planner

As [the NRA] *move into a multi-media agency, the integrating effects on sensitive aquatic organisms (in sensitive headwaters) will provide biodiversity/sustainability indicators.* - Water Quality Planner

[As a priority R&D topic]: *Macrophyte richness.* - Environment Agency staff member

References to **the importance of headwaters in the ecology of fish populations** were commonplace and, once again, several have been previously cited in this review of replies. The perception seemed to be that headwaters were important spawning grounds but that breeding populations were not necessarily resident in these small watercourses. This viewpoint is encapsulated in two respondents' observations and recommendations:

> *Headwaters' importance tends to get forgotten from a fish breeding point of view, due to much larger downstream problems.* - Regional Rivers Advisory Committee Chairman

> *Develop R&D on coarse and game (trout) fish migrations into/out of headwaters.* - Unknown affiliation

With respect to the analyses of the responses to Question 15, only six replies were received in total from non-NRA staff and all their significant comments are quoted above.

3.4 Dissemination of the Results of R&D Programmes Within the Environment Agency

This information gained from the questionnaire, on the awareness of the headwaters R&D programme, raises serious issues about the manner in which the Agency educates it staff in the findings of their own research programmes. Clearly some of the research undertaken by the Agency has limited, specialist interest of direct concern to a relatively narrow range of occupational groups. Other programmes, and this is taken to include the headwaters study, are so fundamental in their conclusions that they will impact upon the objectives and interests of almost all occupational groups within the organisation.

If the results of this questionnaire provide a fair representation of the extent of penetration of the findings of R&D within the Agency then that organisation clearly needs to consider what steps need to be put into place to improve this situation. The evidence from the questionnaire replies is that a more effective mechanism would be welcome by the Agency staff. A total of 60% of respondents felt they would benefit from more information on the results headwaters R&D programme. The majority of the other respondents didn't know whether they would benefit or not through lack of adequate information about the project, i.e. they too might feel they would benefit if they only knew what advantages there were to be gained.

Given this desire for more information the respondents were given the opportunity to identify the most effective mechanisms for spreading information. The two most popular were two approaches that had already been adopted, a headwaters factfile and talks and verbal presentations to individual workgroups such as that provided for Conservation Officers in February 1995.

The factfile approach was favoured by 45% of the respondents. Even so, experience has shown that the production of a succinct document which represents the views, opinions and vested interests of all occupational groups and governmental and non-governmental organisations is not an easy matter to resolve, demonstrating again the need for an holistic and multi-functional approach, fuelled by a common knowledge base, to the issues raised by R&D Projects.

The production of a training video received a fair degree of support and this mechanism for communication is becoming an increasingly common mode of training within the Agency. There is less evidence that staff favour electronic means of communication such as E-mail or the Internet/World Wide Web.

Although the Agency staff perceived that they would benefit by further information transfer and nominated the ways they would best wish to learn there is no known objective study to prove that any of the preferred methods would be truly more effective than, say, the R&D Digests which are even shorter than the headwaters factfile which has now been completed.

In view of the findings of this survey and the uncertainty about the effectiveness of other modes of training:

> **It is recommended that the Agency undertake a comprehensive review of alternative means of communicating the findings of its own R&D projects to those of its staff with a need to know**

3.5 Comments and Recommendations for Research and Development

3.5.1 Introduction

The opportunity to comment on headwater issues and to recommend the direction of future R&D work proved to be one of the most valuable outputs of the questionnaire. A low level of response was anticipated for this, the only free-form question on the questionnaire. In fact almost half of all respondents took the opportunity to make comments of a generally constructive nature.

The majority of those commenting regarded on-going R&D studies of headwaters as important although this was not a universal response. A broad range of the more critical comments were provided in section 3.3 and fall into three main categories:

- a biased style of questionnaire design which leads the respondent to provide the desired answers
- a lack of resources for investing additional effort on headwaters
- not everyone need be aware of headwater issues as long as those with specialist knowledge are informed and can offer requisite professional advice

These comments are considered in the following sections.

Biased style of questionnaire design

The impact of an inbuilt bias in the questionnaire is difficult to quantify. The possibility that respondents have given the answers they thought the enquirers wished to receive cannot be discounted. However, if this were wholly true then it might be expected that people would judge that the document was aiming to draw attention to the problems faced by headwaters and lead many of them to reply that the overall ecological quality of headwaters was less than good (Question 3) and was worse than that of larger watercourse (Question 6). This was not overtly the case.

No attempt to account for inbuilt bias was incorporated in the analysis of the responses.

Lack of resources for investing additional effort on headwaters

It is true that the Environment Agency have a level of statutory responsibility in "main rivers" which is less rigorous for headwaters and often shared or devolved to others, including Internal Drainage Boards and Local Authorities. Furthermore, the headwaters rarely provide direct water supplies for domestic and industrial purposes, receive fewer consented effluent discharges from these sources or support active fisheries and other recreational activities. It is easy to see why this might lead to a level of apparent neglect that may be more realistically a considered balance of limited resources than a lack of concern.

The difficulties of juggling resources to meet the variety of responsibilities within the remit of the Agency, including the recognition that headwaters also present strong claims for priority attention is best summed up by the reply from one senior biologist, quoted in part earlier, who commented:

> *Headwaters at 2.5km from source are so small and restricted in relation to the rest of the system and the amount of work required for the main system,,,,, that I cannot see us being able to put more effort into headwaters. We do appreciate .... clean headwaters with a maximum of variety as [these] provide us with base-line experience of clean rivers.* ***However, many of our headwaters are actually of poor quality.***

What the headwater research programme has now achieved is to question some of the fundamental assumptions that contribute to decisions on resource allocation faced by this respondent. Firstly, it establishes the important role that these streams play in maintaining catchment biodiversity. This is of considerable significance, given the global concern over this issue, post-Rio, and also the driving role that the concept of sustainability now plays in determining Agency policies. Secondly, it alerts the Agency to the potential impact that poor headwater quality may have in determining that of the lower reaches that they feed. Thirdly, cartographic studies have shown the extent of headwaters in the United Kingdom and the fact that they represent an estimated 70% of total watercourse length, a figure that would be even greater if ditches and drains were included. Finally, whilst these streams may not provide direct angling opportunities, the headwater study (Furse 1996a) emphasises the importance of a greater understanding of headwaters in the breeding cycle and spawning success of fish.

The need for awareness of headwater issues in all occupational groups.

The view of "not needing to know" is more difficult to accept than the previous criticisms Whilst the authors of this report are well aware of the pressures of work faced by most professional officers we remain convinced that there is benefit in all policymakers having a basic awareness of the major issues that may affect their decision making. It is our view that at least some of the modes of communication offered in the questionnaire, e.g. R&D Digests, a factfile, a training and information video, a talk or articles in, say, the "Water Guardian" or other semi-populist journals offer informative but not necessarily greatly time-consuming introductions to the issue.

3.5.2 Research Priorities

The most constructive comments provided a solid framework for decisions on future developments of the headwaters study. The broad spectrum of replies makes categorisation difficult but two principal threads have been interpreted from the views expressed.

These two main categories can be defined as

- the need for a strategy for implementing the recommendations of the headwaters R&D study
- the value of further strategic research

The original objectives of this scoping study included the requirement to examine the possibility of producing a headwaters vulnerability model as an operational tool for their protection and a Project Initiation Document (PID) to the same effect.

The perception questionnaire, as a consultation exercise, gave no independent support for this approach amongst the many suggestions that were received. Following consultations with the NRA/Environment Agency Project Leader, it has been deemed more appropriate to proceed with an evaluation of those recommendations and suggestions put forward in this document as those best meeting the perceived priorities of the respondents and, hence, the business needs of the Agency.

The two principal categories of recommendations are considered in the following sections.

Implementation

The implementation category includes a demonstrable need for extending the current level of awareness of headwater issues. In its various guises this was a consistent theme of a large number of the replies and, even when not stated explicitly, the direct responses to specific questions made the same collective point. There is clearly a perceived lack of knowledge of headwater issues which is accompanied in the majority of cases by a desire to be better informed. This education process is seen to involve not only members of the Agency staff and their advisory committees but also a wider section of governmental and non-governmental organisations and the broader public at large.

The theme of implementation also included references to the need to extend and better organise the Agency's baseline monitoring programme and data storage and retrieval systems. Both this theme and the need for an education and awareness strategy were two of the major recommendations of the Stage 4 headwaters R&D Note (Furse 1996a).

> **It is recommended that the Environment Agency develop an R&D programme to implement the major findings of the headwaters research project and that this should include a strategy of training and awareness and the development of an integrated national monitoring network and data-base system.**

Other recommendations which fall under the loose banner of implementation address the need for policies and operational strategies to address specific practical problems. The most commonly expressed themes were the need for practical mechanisms for alleviating the following list of problems:

- loss of surface water attenuation in headwater catchments
- reductions in flow due to abstraction and climatic fluctuations
- pollution due to acute and chronic agricultural pollution including farm waste disposal and pesticides
- the impact of land-use change on ecological and water quality
- the loss of riparian vegetation and the effectiveness and optimal design of riparian buffer zones
- the reduction of habitat quality and diversity due to channelization and other stream modification practices
- erosion and siltation of watercourses
- the identification and remediation of acidification effects
- the impact of upland sheep-grazing
- the derivation of effective and specific planning policies for headwaters

Without exception these are major issues whose resolution has major resource implications. In many cases the Agency have active R&D programmes in progress which address these issues in full or in part.

Where findings of research provide solutions or where they indicate pathways to those solutions then it is essential that these are communicated more widely and effectively than the current headwater research has been shown to have been.

It is certainly not the case that current and past research will provide complete answers to all these problems and prioritisation of future research should take full account of the useful forum that the current perception questionnaire has provided to such a broad range of, now, Environment Agency staff. This prioritisation process has raised major issues of resourcing and the needs to meet both the public and political pressures and legitimate concerns. Furthermore these must operate within the framework of national legislation and European Union policies and directives.

It is beyond the scope of this study to prioritise the issues raised and therefore:

It is recommended that the operational issues of raised by respondents to the perception questionnaire are subject to broad, multi-disciplinary debate within the Environment Agency and with other interested parties and that additional headwater implementation strategies be developed to meet the prioritised needs of the Agency

The fulfilment of this recommendation could provide additional modules for inclusion in the R&D implementation programme proposed earlier in this section. In some cases the need for R&D of a more strategic nature may be required before the best operational practices can be identified and some of the recommendations made by respondents might just as appropriately lie under the heading of strategic research.

Strategic research

Three broad categories of research which can be more clearly identified as strategic in character were recommended by respondents to the questionnaire:

- the role of headwaters in the life cycle of fish and the implications for fisheries management
- the impact of loss of ecological and chemical quality in headwaters on the larger watercourses they feed
- the ecological requirements of characteristic headwaters taxa and the factors which promote or threaten biodiversity and sustainability in the headwater environment

A suitable fisheries research programme D02(95)2 has already been implemented and no further research is recommended until the outcomes of that programme become clearer.

The remaining recommendations each offer a route to understanding the role headwaters play in maintaining and promoting the biodiversity of river basins. Each recommendation has merit and each requires serious consideration for future research programmes.

Of the two, in the authors' view, the latter is more fundamental because it provides the basic understanding of the factors which promote a diverse and sustainable level of ecological quality and biotic diversity. It is an essential pre-requisite of an effective headwater management strategy that this understanding exists because only in this way can operational practices be most efficiently tailored to achieve these objectives. Failure to develop this understanding therefore runs the serious risk of the implementation of policies of unproven efficacy.

It is recommended that the Environment Agency instigates an R&D programme designed to elucidate the ecological requirements of characteristic headwaters taxa and the factors which promote or threaten biodiversity and sustainability in the headwater environment.

A Project Initiation Document (PID) detailing an appropriate research programme has been submitted to the Environment Agency. This proposal builds on the recommendations of the respondents to the perception questionnaire which is seen to meet a genuine business need within the Agency's corporate management aims and strategies.

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