
**The effects of river restoration
on the R. Cole and R. Skerne
demonstration sites**

Final Report

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TECHNICAL SUMMARY

This report describes the initial effects of river restoration works on two demonstration sites established by the River Restoration Project on the River Cole, near Swindon, and the River Skerne in Darlington. Baseline information about the sites was obtained in 1994 and spring 1995. Physical restoration at both sites mainly took place in summer and autumn 1995 and post-works monitoring began in 1996.

Geomorphology

Historical baseline data indicated that the R. Cole was physically altered from its natural state in three main phases: pre-1650, in the late 18th century and by a recent 1970s land drainage scheme. The history of modification in the R. Skerne started in the 1850s and continued into the 20th century with progressive infilling of the floodplain and removal of meanders to create a highly channelised watercourse. Collectively these engineering works had left both sites with virtually straight, trapezoidal river channels.

Physical restoration of the rivers considerably increased their morphological diversity. Remeandering of the river channels increased channel length by about 30% on the R. Cole and about 13% on the R. Skerne. It was possible to re-establish some of the new sections of the R. Cole channel (about 25%) along the original, pre-straightened course. It was not possible to recreate the historic route of the R. Skerne owing to the location of services running close to the river (gas, electricity, sewerage).

Baseline studies indicated that the natural channel cross-sections of both the R. Cole and the R. Skerne were considerably smaller than those of the channelised rivers. On the R. Cole, for example, the natural cross-sectional area was estimated to be approximately 10 m². In the channelised river it was five times this, at about 50m². Similarly, river bed depths were typically 2.5 - 3.5 m below ground level in the channelised river whereas the natural bed depths were, on average, only 1.5 m below ground level. As a result of restoration, about 35% of the R. Cole's restored course was recreated with natural channel dimensions; elsewhere practical constraints required larger cross-sections to maintain flood conveyance. On the R. Skerne, flood defence considerations required that new channel cross-sections were maintained with similar proportions to the pre-restoration dimensions.

On the R. Cole, where more detailed geomorphological monitoring was undertaken, there was clear evidence that numbers of natural in-channel features (e.g. riffles, point-bars) increased after restoration. Both erosion and deposition-generated features increased in number. There was also evidence, on the R. Cole, of extensive sedimentation downstream of the restoration site which led to local raising of bed levels in the downstream area, and a small increase in numbers of berms.

Hydrological regime

Prior to restoration both the R. Cole and R. Skerne experienced infrequent flooding with significant overbank flows only likely to occur during floods with a return period of 1 in 2 years or more. Hydrological modelling was used to predict the likely increase in flood frequency after restoration.

On the R. Cole, the restored natural channel section upstream of Coleshill Bridge is currently expected to have out of bank flows for 17 days a year (i.e. 5% of the year), compared to 4 hours per year (0.05% of the year) prior to restoration. This extended, and more natural, flood regime currently affects about 10% of the floodplain on the

demonstration site. On the remaining 90% of the R. Cole demonstration site there was a smaller calculated increase in the frequency of out of bank flows; downstream of Coleshill Bridge out of bank flows are expected to occur for up to 24 hours per year (0.3% of the year). This reflected the need to ensure that the restoration did not (i) increase the risk of flooding the road that crosses the demonstration site or (ii) create severe constraints on agricultural activity on the floodplain.

During the study period (January 1994 to February 1998) significant out of bank flows occurred on the R. Cole once before restoration work started (in January 1994) and twice after restoration work was completed (in December 1995 and February 1998). As a result of a prolonged period of drought there were no out of bank flows in winter 1996/97.

On the R. Skerne, the need to maintain a high standard of flood defence for Darlington town centre (immediately downstream of the restoration site) placed constraints on the extent to which out of bank flows could be increased. Hydrological modelling indicated that the duration of out of bank flooding increased from less than 1 to 2 days per year to a maximum of 4.5 days per year in the demonstration site area. Lowering of the river banks in the restored area also increased storage within the demonstration site. Since restoration work has been completed there has been one out of bank flow, in February 1996.

Water quality: sediments and nutrients

Detailed studies of sediment and nutrient concentrations were made on the R. Cole. On the R. Skerne, samples were collected more infrequently (at monthly intervals) to give general background information about the effects of restoration on water quality.

During and shortly after the physical restoration work, suspended sediment concentrations in the R. Cole were often very high, with peak sediment concentrations up to ten times greater than in the upstream control reach (and maximum values up to 326 mg l⁻¹ in the first overbank floods after restoration). However, although sediment concentrations downstream of the restoration site were high from time to time, similar concentrations were also recorded elsewhere in the river. For example, upstream of the restoration site sediment concentration reached 246 mg l⁻¹ during the winter 1995/96 peak flood, as a result of resuspension of sediment stored in a ponded reach of the river. Overall, for the high flow month of December 1995, the monthly mean sediment concentrations above and below the works were very similar (71.08 and 71.73 mg l⁻¹, respectively).

After completion of the works on the R. Cole (i.e. from autumn 1995 to December 1997), suspended sediment concentrations downstream of the works were generally about double those of upstream sites (monthly mean value 45 mg l⁻¹ downstream of the works, compared to 23 mg l⁻¹ upstream).

The R. Cole is typical of many lowland rivers in showing anthropogenically elevated concentrations of both nitrogen and phosphorus compounds. Before restoration, annual mean total oxidised nitrogen (TON) concentrations were about 6 mg l⁻¹ (range 2-18 mg l⁻¹) and soluble reactive phosphorus concentrations were around 0.5 mg l⁻¹ (range <0.06-1.46 mg l⁻¹).

The post-restoration period has shown no evidence of systematic changes in nutrient concentrations, except for a period of elevated total oxidised nitrogen (TON) concentrations during summer 1996 (the year after the main period of works). These higher concentrations occurred from June to August 1996 when daily mean TON concentration were 16 mg l⁻¹ below the works, compared to 5 mg l⁻¹ upstream. The

cause of the elevation of TON concentrations is unknown. Inter-calibration between samples collected for this project and samples collected routinely by the Environment Agency suggest that it was not a sampling artefact. Likewise it did not seem to be due to effluent discharge from Coleshill STW as Environment Agency samples immediately downstream of the works showed no elevation of TON concentrations. Possible causes of elevated TON concentrations could include leaching of nutrients from bare ground, spillages from fertiliser bags or other undetected point source inputs unrelated to the restoration works.

Although it might be hoped that the restoration features (a meandering planform, increased channel buffering, installation of a reed bed filter etc.) introduced into the R. Cole, would act to reduce in-stream nutrient concentrations, the absence of any clear reduction to date is not unexpected. In particular: (i) a large proportion of the nutrient burden in the river is derived from sewage treatment works, especially for phosphate (ii) in-channel vegetation was little developed during the early stages of colonisation, providing few surfaces for biological uptake of nutrients (iii) there was little overbank flooding in the first 18 months after the scheme was completed, giving few opportunities for sediment bound nutrients to be translocated to the floodplain and (iv) any effective buffering and nutrient removal processes on the demonstration site, are likely to be outweighed by catchment-scale releases of nutrients.

On the R. Skerne, there were no significant or directional changes in any of the measured determinands that could be related to the restoration scheme.

River channel vegetation

On the R. Cole, plant species richness increased immediately after restoration as bare ground was colonised by wetland annuals. On the new channel downstream of Coleshill Bridge, for example, marginal-emergent plant species richness increased significantly from 27 species per 500 m length to 38 species. Restoration had a less immediate effect on the richness of submerged aquatic plants with an average of 7.5 species per 500 m length pre-restoration and 8.0 species per 500m length one year after restoration. The increase in wetland plant species richness seen at the 500m length scale on the Cole was even more marked at a small scale: quadrat monitoring in-channel indicated that there were about 4 times as many wetland species per 2m² quadrat after restoration compared to pre-restoration conditions.

Plant species rarity values on the River Cole recovered rapidly to pre-restoration levels. However, to date, there is no evidence that restoration has increased average plant species rarity above pre-restoration levels.

There was no evidence that the works on the R. Cole significantly affected the flora in the downstream 'impact' site in terms of species richness, rarity or abundance.

On the R. Skerne numbers of wetland plant species per 500 m section increased in all sections, including both upstream control and downstream impact sections. If species numbers in the restored reach are corrected for background increases in the controls, overall species richness in the restored channel section increased above pre-restoration levels by about 30% within a year of restoration. The average rarity value of aquatic, but not marginal, plants in the restored section increased slightly above the pre-restoration levels. Data describing the plant assemblages downstream of the restoration works are difficult to interpret. However there is no evidence of plant community damage resulting from downstream impacts of the restoration works.

Aquatic invertebrates

Detailed assessments of changes in invertebrate assemblage conservation value were made on the R. Cole. On the R. Skerne, invertebrate monitoring was undertaken as part of the Environment Agency's regional water quality monitoring programme.

Before restoration, the aquatic invertebrate fauna of the R. Cole was of moderate to high conservation value, equal in quality to some of the best rivers in the Thames catchment with at least 14 nationally local and notable species including White-legged Damselfly (*Platycnemis pennipes*). The R. Skerne supported a low conservation value invertebrate assemblage with a small number of common species.

In the R. Cole, invertebrate species richness reached about 50% of pre-restoration values one year after the new channel had been created, with colonists mainly comprising common species widely present in the pre-restoration river. Uncommon taxa present in the river before restoration was undertaken were slower to recolonise the new channel. This probably reflected the fact that most were species that are typically associated with habitats that take longer to establish, such as submerged tree roots and banks of mature aquatic vegetation.

Two invertebrate species were found in the restored R. Cole that had not been previously recorded from the local 'species pool' (i.e. in any of the sites surveyed in baseline survey work on, upstream or below the restoration site). This represented 1% of the total species pool, and included one stonefly, *Leuctra geniculata*, commonly associated with faster flowing well-oxygenated water and one generalist caddis fly, *Athripsodes albifrons*.

Downstream 'potentially impacted' sites showed evidence of a moderate decline in invertebrate species richness one to two months after the upstream restoration. However, nine months after restoration there was little evidence of any detrimental impacts on invertebrates. In terms of species rarity there was no downstream change in index values before and after restoration. Thus, whereas sedimentation of the 'impact' site may have affected species richness in the short term, it had no discernible effect on the quality of the fauna.

On the R. Skerne invertebrate assemblages following restoration showed similar BMWP family richness and ASPT scores to pre-restoration levels.

Birds

Prior to restoration the breeding bird assemblages of the two demonstration sites were typical of intensively managed rural and suburban landscapes. On the R. Cole, of 19 wetland species identified as potentially able to benefit from river restoration (mainly waders and waterfowl), baseline studies indicated that five were believed to be breeding on the site at the beginning of the project.

One year after restoration there was no change in the number of wetland species breeding on the R. Cole site. However, there was a significant increase in the abundance of Yellow Wagtails (*Motacilla flava*), one of the wetland species already using the restoration area. There was no evidence of waders breeding on the site, other than Lapwing, which were breeding prior to restoration. Casual inspection of the R. Cole site in 1997 suggested that there was little further change 2 years after restoration was completed.

On the R. Cole *control* site (downstream of the restored area), there were significant declines during the study in the abundance of four common farmland/woodland species

which were not matched by changes on the restoration site. These were: Blackbird (*Turdus merula*), Goldfinch (*Carduelis carduelis*), Woodpigeon (*Columba palumbus*) and Wren (*Troglodytes troglodytes*). Bird data for the R. Skerne have yet to be received.

Fish

Fish surveys were undertaken in spring 1995 (pre-restoration) and spring 1997, eighteen months after restoration was completed. On the R. Cole, the fish populations prior to restoration (spring 1995) were considered to be of high quality (with a biomass of 39 g m⁻²) in the gravelly riffle downstream of Coleshill Bridge but of lower quality in the more impounded sections in the upstream half of the site.

After restoration, fish biomass and density in the R. Cole quickly returned to pre-restoration levels. The highest biomasses and densities in the restored section were found in areas of gravelly eroding substrate (respectively, 35.6 g m⁻² and 1.035 individuals m⁻²). Perhaps surprisingly, however, the highest biomasses and densities of all were seen in the downstream impact reach just below the restoration site where biomass was 78.4 g m⁻² (at least double all other sites in the R. Cole) and fish density was 1.4 individuals m⁻² (also higher than all other sites). The high abundance of fish in this area may have been a reflection of the improved quality of habitat in the restored section, with fish resting in this area before moving into the faster flowing shallower water of the restored reach to spawn. The upstream control site on the R. Cole showed a slight decline in biomass, from 34.3 g m⁻² in 1995 to 28.7 g m⁻² in 1997, with a corresponding decline in density (0.994 to 0.255 individuals m⁻²). Fish species richness generally remained unchanged both in the restoration site and the control and impact reaches.

On the R. Skerne prior to restoration, the demonstration site supported mainly 'minor' species (e.g. Three-spined Stickleback (*Gasterosteus aculeatus*) and Stone Loach (*Neomachilus barbatus*)) and the only angling species present were stocked Brown Trout (*Salmo trutta*). Dace (*Leuciscus leuciscus*), which had also been stocked, were not recorded at any site in the study area prior to restoration. Brown Trout and 'minor' species also comprised the fauna in the upstream control section and the downstream impact reach.

After restoration on the R. Skerne, the first Roach (*Rutilus rutilus*) and Chub (*Leuciscus cephalus*) to be found in the river upstream of South Park Weir for some years, were recorded in the restored section. These fish, together with a small number of Dace (wild fish, not those stocked in the early 1990s), had probably swum up the river using the newly installed fish pass below Darlington. Two Brown Trout were also recorded in this area, remnants of earlier stocking. Although fish species richness clearly increased in the restored section, the number of individuals was small (the total catch of Brown Trout, Dace, Chub and Roach was only 16 fish) and biomasses of individual species were less than 1 g m⁻². Angling species were not found in either upstream control or downstream impact reaches confirming that the observed increases in the richness of the restored section were likely to be real. 'Minor' species remained abundant in the restored reach with little evidence of changes either in this area or in the upstream control and downstream 'impact' reaches.

Unfortunately, two severe pollution incidents in the R. Skerne in autumn 1997 may have largely eliminated recolonising fish populations.

Public perception

Assessment of public perception of the restoration schemes focused on the urban R. Skerne. A smaller-scale post-project assessment was also undertaken on the R. Cole. At both sites public opinion was assessed by structured questionnaire surveys undertaken by trained interviewers.

There was general approval for the restoration schemes with 52% of Darlington residents 'mostly', and 30% 'strongly', approving of the works. At Coleshill 53% 'mostly', and 17% 'strongly', approved.

The majority of Darlington residents (64%) felt that the R. Skerne scheme had partly or completely achieved its objectives. 70% of Darlington residents thought that more wildlife had been attracted to the area since the restoration scheme.

Economic benefits

Future widespread implementation of river restoration schemes will inevitably depend, to a large extent, on the ability of these schemes to provide economic benefits.

The potential economic benefits of the R. Cole and R. Skerne restorations were evaluated in six main categories over a 25 year period. These categories were: water quality, amenity, fisheries, agriculture, flood defence and recreation. For most categories, lower, middle and upper bounds were all calculated because of the inevitable uncertainties in willingness to pay values and other key variables.

The overall annual economic benefits of restoration on the R. Cole covered a range from £38,000 to £347,000. For the R. Skerne the equivalent values were £30,000 to £181,000 annually.

The largest benefits come from recreation and conservation benefits. If these benefits are excluded, the lower, mid and upper bound values for the R. Cole become £176, £20,000 and £29,000. If the mid bound values are taken then the restoration provides *annual benefits* of about £10,000 per kilometre restored. On the R. Skerne, the equivalent values (excluding recreation and non-use conservation benefits) were £6,000, £16,000 and £61,000 for lower, mid and upper bound estimates.

Overall, assuming the benefits from restoration lie between the lower and middle bound, and excluding (i) any water quality benefits (ii) all non-use recreational benefits (which are large but widely disputed), the economic benefits of restoration probably approach the cost per kilometre of undertaking the schemes.

Conclusions

Many of the changes expected following river restoration are likely to occur in the medium to long term. Despite this, the early results of the monitoring programme suggest that the restoration sites are recovering rapidly and showing some evidence of ecological and public perception benefits. There have been improvements to the structure of both the R. Cole and R. Skerne. Channel plant, invertebrate and fish assemblages have often reached or exceeded pre-restoration conditions on one or both sites. Changes on the floodplains are likely to be naturally slow and may have been slowed further by the recent drought. Despite this, increases in the abundance of at least one wetland bird, Yellow Wagtail, have been observed on the R. Cole. A high level of

public appreciation for the restoration work was evident at both sites, but particularly the urban R. Skerne.

Both newly restored rivers are still in a very active phase of their development and, with less than two years of year's post-project assessment data it is too early to draw general conclusions from the project. Future monitoring of the sites (now largely assured) will be critical in providing information on the real success of the restoration works in the medium and longer term.

1. INTRODUCTION

This report describes the initial effects of river restoration works on two national demonstration sites established by the River Restoration Project: the River Cole, near Swindon, and the River Skerne in Darlington. Work on this project was undertaken as part of the European Union LIFE funded project "*River restoration: benefits for integrated catchment management*".

1.1 Monitoring project aims

The overall aim of the monitoring programme was to assess the effects of restoration on the river environment. In particular, monitoring aimed to provide information which could be used to assess the value of river restoration for integrated catchment management, including its role in:

- (i) flood storage and flood alleviation
- (ii) control of diffuse nutrient pollution
- (iii) nature conservation and fisheries
- (iv) recreation and amenity.

To provide this information the monitoring programme gathered data describing 11 aspects of the ecology and management of the restoration demonstration sites (Table 1.1). Some aspects of the work were undertaken in considerable detail, employing funds from the EC LIFE grant.

Table 1.1 Demonstration site monitoring programme

	R. Cole	R. Skerne
Water quality	Special study	✓
Geomorphology	✓	✓
Hydrological regime	✓	✓
Aquatic invertebrate ecology	Special study	✓
Aquatic plant communities	Special study	✓
Floodplain plant communities	✓	✓
Birds	✓	✓
Fish	✓	✓
Landscape assessment	✓	✓
Public perception assessment	✓	Special study
Cost-benefit analysis	Special study	Special study

2. THE RESTORATION WORKS

2.1 Pre-restoration status of the sites

2.1.1 River Cole

The River Cole, a tributary of the River Thames, has a clay, chalk and sandy limestone catchment with an area of about 129 km² (Thames Water 1988). The catchment is flashy, a feature exacerbated by urbanisation in the headwaters around Swindon. The river is a low energy system with sediment transport mainly confined to fine silts and clays. This, combined with the effects of artificial deepening and widening, gives a largely depositional channel environment adjusting to the effects of dredging and overwidening. The river is generally not powerful enough to erode a new cross-section or planform.

The river restoration site lies on the Buscot and Coleshill Estate of the National Trust on the Oxfordshire/Wiltshire border, and consists of a 2 km reach of the river with approximately 50 ha of floodplain.

The former route of the river is shown by the old county boundary, and at the beginning of the project could be seen as a depression in the ground in some places. The modern river course before restoration was almost entirely artificial, and was probably created in three distinct stages: (i) pre-1650 straightening associated with creation of a mill leat above Coleshill Bridge (ii) a second major phase of straightening in the late 18th Century, and (iii) a 1970's land drainage scheme which deepened the river by about a metre between Coleshill and the Thames. The drainage scheme all but eliminated regular flooding on the lower half of the restoration demonstration site (downstream of Coleshill Bridge), and probably reduced flooding frequency above the bridge.

Prior to the restoration works, river vegetation was of moderate conservation value with no rare or Nationally Notable wetland plant species. About half of the floodplain was under arable agriculture, with most of the remainder intensively managed grassland. The exception was a small area of MG5¹ grassland, a nationally uncommon grassland type, which is traditionally managed by grazing. This grassland area supports a population of the Red Data Book plant snake's-head fritillary (*Fritillaria meleagris*).

Pre-restoration surveys of the R. Cole showed that the aquatic invertebrate fauna of the river was rich (equivalent in quality to some of the best rivers in the EA Thames Region) with at least 14 nationally local species including White-legged Damselfly (*Platycnemis pennipes*). Fish biomasses were assessed by the Environment Agency (then the NRA) as 'excellent' in the few areas where more rapid flow created shallow gravelly riffles but biomass was lower in the more impounded sections. Birds were fairly typical of intensively managed farmland areas and included relatively few wetland birds of conservation interest; of 19 wetland species of high conservation priority (mainly waders and waterfowl) only 5 were believed to be breeding on the site prior to the initiation of the restoration work.

2.1.2 River Skerne

The River Skerne, a tributary of the R. Tees, has a clay/alluvium lowland catchment, with an area of about 250 km². The channel of the R. Skerne throughout its length is almost entirely man-made. Although both coarse and fine sediments are

¹ The code MG5 refers to the National Vegetation Classification (NVC) type.

available (including gravels from glacial materials) the river is not sufficiently energetic to erode a new cross-section.

The 2 km river restoration site is located in an urban-fringe public open space, owned by Darlington Borough Council. The site has been greatly modified as a result of industrialisation and much of the original floodplain has been eliminated by spoil tipping. Modification of the river is documented from about 1850 onwards, culminating in modern flood defence schemes which protect Darlington from floods of up to 1 in 100 years frequency. At the beginning of the project, the river channel in the restoration area comprised a trapezoidal linear channel from which most instream features had been eliminated.

The R. Skerne has a long history of pollution, and although water quality is slowly improving, chemical water quality was only moderate to poor at the beginning of the project. Sediments were contaminated by heavy metals.

Surveys of the river channel prior to restoration indicated that river vegetation was of moderate conservation value. No Nationally Scarce or rare plant species were recorded. The floodplain vegetation largely comprised amenity grassland, except for the Rockwell Conservation Area, a small (1 ha) area at the western (downstream) end of the restoration site, which had more varied vegetation and a series of with ponds with Great Crested Newts (*Triturus cristatus*). Prior to restoration the aquatic invertebrate fauna of the river was impoverished, perhaps because of the high heavy metal content of the sediments, and of low conservation value. Until 1992 only 'minor' fish species (i.e. those of no interest to fishermen) were commonly found in the R. Skerne above Darlington. After 1992, however, Dace and Brown Trout were restocked at several sites above the demonstration area. Birds on the restoration site were those typical of the urban river environment (e.g. mallard *Anas platyrhynchos* and moorhen *Gallinula chloropus* etc.).

2.2 The physical restoration works

A brief summary of the main physical changes made on each site is given below. More detailed information is given in Vivash *et al.* (1997).

2.2.1 Restoration of the River Cole

Channel works

Channel reconstruction work on the R. Cole took place mainly between July and November 1995. Minor additional works were undertaken in July and August 1996.

In total, approximately 1300 m of new channel was constructed and 800 m of existing channel modified (mainly by reprofiling). Total channel length, compared to the pre-existing artificial channel, was increased by about 30%, from 1600 m to 2100 m. Approximately 1000 m of the restored channel follows the original channel course. For various practical reasons it was not possible to re-establish the river on an entirely natural course on the remaining 1100 m.

Dimensions for the new channel were established by investigating relict channel sections elsewhere in the catchment (Sear and White 1994). Prior to extensive land drainage, the natural channel of the R. Cole was very much smaller than the modern land-drainage channel, with a cross-sectional area about 20% of that of the modern channel. Practical constraints made it possible only to construct about 500 m of the most natural channel type.

Changes in floodplain land-use

On the eastern bank of the R. Cole, an 8.5 ha block of floodplain land downstream of Coleshill Bridge was taken out of arable agriculture and put into grass. This area was seeded with a standard Countryside Stewardship scheme mixture. Land on the western bank remained in arable agriculture.

There were no land use changes in the grassland areas above Coleshill Bridge. Existing grassland was, however, entered into Countryside Stewardship, with restrictions placed on fertiliser and agricultural chemical usage. A weir installed across the Waterloo Ditch raised water levels in the ditch by c.1 m and it is anticipated that this will raise water levels in part of the east bank grassland above Coleshill Bridge.

Planting up

The general principle of the R. Cole restoration was to allow natural colonisation of the restored river bank areas since new river side sites often colonise with very species-rich wetland plant assemblages (e.g. Biggs *et al.* 1998). However, some planting was undertaken on the R. Cole for practical purposes including:

- (i) *moving existing plants from one part of the site to another* (e.g. clumps of flowering-rush, *Butomus umbellatus*, and reed sweet-grass, *Glyceria maxima* moved from the old channel which was being filled-in),
- (ii) *planting at the point where a new gas pipeline crossed the river*. Immediately downstream of Coleshill Bridge a bank length of approximately 100 m was planted with various emergent species in Bestmann Pallets and Bestmann Fibre Rolls. Species planted are listed in Table 2.1,
- (iii) *shrub and tree-planting* (see Table 2.1),
- (iv) *planting of common reed (Phragmites australis)* in a reed bed for intercepting a drainage ditch running into the river,
- (v) *reseeding of arable land converted to grassland*. This land was reseeded as part of a Countryside Stewardship scheme with the mixes shown in Table 2.1. This scheme recommends, but does not absolutely require, that native seed is used.

2.2.2 Restoration of the River Skerne

Restoration of the R. Skerne involved modifications along a 2.0 km reach of the river, including remeandering of a 0.5 km reach. Channel dimensions remained similar to pre-restoration conditions due to urban flooding defence constraints. New waterside features, including a pond, have been created. Storm water drains entering the river were combined to reduce visual impact and, where possible, ensure that discharges were into backwaters.

Changes in floodplain landuse

There were no significant changes in floodplain landuse on the River Skerne, but floodplain areas that were lowered can be expected to be wetter. A new seasonal pond was also created.

Planting up

There was extensive planting-up on the R. Skerne (a) as part of a 'soft revetment' demonstration project and (b) to ensure that the site was rapidly re-vegetated. All wetland plants used in the planting scheme were species that are recorded in R.

Skerne catchment (although sourced from a variety of locations). Landscape planting included some ornamental species. A full list of the plants used is given in Table 2.2.

Table 2.1 Plant species used in planting-up on the R. Cole

Planting scheme downstream of Coleshill Bridge for British gas pipeline crossing

Bestmann Plant Pallets

<i>Phalaris arundinacea</i>	Reed Canary-grass
<i>Typha latifolia</i>	Bulrush
<i>Phragmites australis</i>	Common Reed
<i>Carex riparia</i>	Great Pond-sedge
<i>Butomus umbellatus</i>	Flowering-rush
<i>Veronica beccabunga</i>	Brooklime
<i>Mentha aquatic</i>	Water Mint
<i>Juncus effusus</i>	Soft Rush
<i>Juncus inflexus</i>	Hard Rush
<i>Lycopus europaeus</i>	Gypsywort
<i>Myosotis scorpioides</i>	Water Forget-me-not

Bestmann Fibre Rolls

<i>Butomus umbellatus</i> / <i>Filipendula ulmaria</i>	Flowering-rush/Meadowsweet
<i>Carex riparia</i> / <i>Phalaris arundinacea</i>	Great Pond-sedge/Reed Canary-grass

Tree planting scheme downstream of Coleshill Bridge

<i>Alnus glutinosa</i>	Alder
<i>Cornus sanguinea</i>	Dogwood
<i>Crataegus monogyna</i>	Hawthorn
<i>Fraxinus excelsior</i>	Ash
<i>Populus nigra</i> var <i>betulifolia</i>	Black Poplar
<i>Prunus spinosa</i>	Blackthorn
<i>Rhamnus cathartica</i>	Buckthorn
<i>Rosa canina</i>	Dog Rose
<i>Salix caprea</i>	Goat Willow
<i>Viburnum opulus</i>	Gelder-rose

Planting scheme for arable to grassland conversion downstream of Coleshill Bridge

<i>Agrostis capillaris</i>	Common Bent
<i>Alopecurus pratensis</i>	Meadow Foxtail
<i>Anthoxanthum odoratum</i>	Sweet Vernal Grass
<i>Cynosurus cristatus</i>	Crested Dog's-tail
<i>Festuca ovina</i>	Sheep's Fescue
<i>Festuca pratensis</i>	Meadow Fescue
<i>Bromus commutatus</i>	Meadow Brome
<i>Hordeum secalinum</i>	Meadow Barley
<i>Festuca arundinacea</i>	Tall Fescue
<i>Festuca rubra</i> (ssp. <i>commutata</i>)	Red Fescue
<i>Poa pratensis</i>	Smooth Meadow Grass
<i>Trisetum flavescens</i>	Yellow Oat Grass
<i>Phleum pratense</i> ssp. <i>bertolonii</i>	Small-leaved Timothy
<i>Dactylis glomerata</i>	Cocksfoot
<i>Deschampsia flexuosa</i>	Wavy-hair Grass

English names follow Stace (1997).

Table 2.2 Plant species used in planting-up on the R. SkerneLow maintenance grass mix (sown at 6-15 g m⁻²)

<i>Festuca ovina</i> (35%)	Common Bent
<i>Festuca rubra</i> (20%)	Red Fescue
<i>Agrostis capillaris</i> (15%)	Common Bent
<i>Poa pratensis</i> (15%)	Smooth Meadow-grass
<i>Cynosurus cristatus</i> (10%)	Crested Dogtail
<i>Lolium</i> sp. (5%)	Westerwolds annual ryegrass

<i>Alisma plantago-aquatica</i>	Water-plantain
<i>Butomus umbellatus</i>	Flowering-rush
<i>Carex riparia</i>	Great Pond-sedge
<i>Carex acutiformis</i>	Lesser Pond-sedge
<i>Fraxinus excelsior</i>	Ash
<i>Glyceria maxima</i>	Reed Sweet-grass
<i>Iris pseudacorus</i>	Yellow Iris
<i>Juncus effusus</i>	Soft Rush
<i>Juncus inflexus</i>	Hard Rush
<i>Lythrum salicaria</i>	Purple-loosestrife
<i>Mentha aquatica</i>	Water Mint
<i>Myosotis scorpioides</i>	Water Forget-me-not
<i>Phalaris arundinacea</i>	Reed Canary-grass
<i>Phragmites australis</i>	Common Reed
<i>Polygonum amphibium</i>	Amphibious Bistort
<i>Salix alba</i>	White Willow
<i>Salix caprea</i>	Goat Willow
<i>Salix cinerea</i>	Grey Willow
<i>Salix fragilis</i>	Crack Willow
<i>Salix viminalis</i>	Osier
<i>Sparganium erectum</i>	Branched Bur-reed
<i>Typha latifolia</i>	Bulrush
<i>Veronica beccabunga</i>	Brooklime

Species planted by schoolchildren in wetlands

<i>Lythrum salicaria</i>	Purple-loosestrife
<i>Lynchnis flos-cuculi</i>	Ragged-Robin
<i>Filipendula ulmaria</i>	Meadowsweet

Trees and shrubs used in the landscaping areas

<i>Alnus glutinosa</i>	Alder
<i>Betula pendula</i>	silver Birch
<i>Corylus avellana</i>	Hazel
<i>Crataegus monogyna</i>	Hawthorn
<i>Fraxinus excelsior</i>	Ash
<i>Ilex aquifolium</i>	Holly
<i>Ligustrum vulgare</i>	Wild Privet
<i>Pinus nigra</i> ssp. <i>nigra</i>	Austrian Pine
<i>Pinus sylvestris</i>	Scots Pine
<i>Populus trichocarpa</i>	Western Balsam-poplar
<i>Populus x canadensis</i> 'Robusta'	Hybrid Black-poplar var Robusta
<i>Prunus avium</i>	Wild Cherry
<i>Prunus padus</i>	Bird Cherry

Table 2.2 Plants used in planting-up on the R. Skerne (cont.)

Trees and shrubs used in the landscaping areas (continued)

<i>Prunus spinosa</i>	Blackthorn
<i>Quercus robur</i>	Pedunculate Oak
<i>Rosa arvensis</i>	Field Rose
<i>Rosa canina</i>	Dog Rose
<i>Rosa rugosa</i>	Japanese Rose
<i>Rosa rubiginosa</i>	Sweet-briar
<i>Salix alba</i>	White Willow
<i>Salix caprea</i>	Goat Willow
<i>Sorbus aucuparia</i>	Rowan
<i>Viburnum opulus</i>	Guelder-rose

Bulbs planted in landscaping area

<i>Narcissus minor</i>	
<i>Narcissus pseudonarcissus</i>	Wild Daffodil

Low maintenance grass mix with wild flowers (grass 80%, flowers 20%)

<i>Achillea millefolium</i>	Yarrow
<i>Centaurea nigra</i>	Black Knapweed
<i>Galium verum</i>	Lady'-bedstraw
<i>Leucanthemum vulgare</i>	Oxeye Daisy
<i>Lotus corniculatus</i>	Bird's-foot Trefoil
<i>Primula veris</i>	Cowslip
<i>Prunella vulgaris</i>	Self-heal
<i>Ranunculus acris</i>	Meadow Buttercup
<i>Festuca ovina</i> (20%)	Sheeps Fescue
<i>Festuca rubra</i> ssp. <i>pruinosa</i> (20%)	Bloomed Fescue
<i>Cynosurus cristatus</i> (15%)	Crested Dogstail
<i>Festuca rubra</i> ssp. <i>commutata</i>	Chewings Fescue
<i>Poa pratensis</i> (15%)	Smooth Meadow-grass
<i>Poa</i> sp. (10%)	Westerwolds Annual Ryegrass
<i>Agrostis capillaris</i> (5%)	Common Bent

English names follow Stace (1997).

3. GEOMORPHOLOGY

3.1 Assessing effects of restoration on channel geomorphology

A key objective of the R. Cole and R. Skerne restoration schemes was to re-establish the morphological diversity previously eliminated by channelisation. The monitoring programme assessed the extent to which restoration achieved this objective, with the most detailed work being undertaken on the R. Cole.

Two main aspects of morphology were considered:

- large-scale channel morphology (i.e. channel planform and cross-section),
- the frequency of small-scale morphological features (e.g. riffles and pools, point-bars, eroding cliffs).

3.2 Methods

Catchment audits were undertaken on the R. Cole and R. Skerne to identify the catchment and channel factors which had influenced the geomorphological evolution of the two rivers. The catchment audit methods are described by Sear and Newson (1994) and Newson and White (1994).

Morphological surveys, undertaken on the R. Cole as part of a more detailed research project, described in detail the individual reaches of the river (including reaches outside the restoration area). These surveys used a 'fluvial auditing' technique in which the number of channel and floodplain morphological features were assessed quantitatively over standard survey reaches.

3.3 River channel morphology before and after restoration

3.3.1 Basis for design

There are limited data available describing the natural form of lowland clay-alluvium channels since most of these river in these substrates have a very long history of modification. However, historical and field research provided information on the original planform of the rivers, and gave limited evidence of original channel dimensions (Sear and White 1994; Biggs 1995). Both rivers were overwidened and overdeepened on the demonstration sites.

The main objective of the restoration works was to increase channel sinuosity and reduce channel cross-sectional area. This was expected to (a) increase out of bank flow frequency (where this was practically feasible) and (b) create a more varied channel morphology. To increase sinuosity and reduce cross-sectional area, channels were, where possible, narrowed, raised and re-meandered. In general, there was greater freedom to reduced cross-sectional area on the R. Cole. On the R. Skerne, urban flood defence requirements required that channel capacity was only slightly reduced.

In addition to channel narrowing, bed-raising and channel re-meandering, other 'natural' features were incorporated into the designs including: gravel riffles (artificial and natural), in-channel pools, backwaters, vertical cliffs, a reed bed, artificial flow deflectors (R. Skerne only) and floodplain ponds (R. Skerne only).

Table 3.1 Morphological characteristics of the R. Cole and R. Skerne before and after restoration

	Length (m)		Sinuosity			Width (m) ³		Depth (m) ³	
	Before	After	Before	After		Before	After	Before	After
R. Cole ¹	1600	2100	1.06	1.34	u/s Coleshill Bridge	13.6	3.5	2.0	1.5
					d/s Coleshill Bridge	15.5	11.0	3.0	2.0
R. Skerne ²	750	850	1.01	1.13		11.0	12.5	2.5	2.4

¹Cole: channel length and sinuosity measured from beginning to end of restored section.

²R. Skerne: channel length measured from Hutton Avenue footbridge to 50m after last meander.

³Widths and depths measured at bankfull.

3.3.2 Effect of restoration on large scale channel morphology

Channel length on the restoration sites was increased by 13% on the R. Skerne (over the remeandered section) and 30% on the R. Cole (Table 3.1). On the R. Cole, sinuosity increased correspondingly, from around 1.05 before restoration to about 1.34 (average of both upstream and downstream of Coleshill Bridge). On the R. Skerne sinuosity of the remeandered section increased from 1.01 to 1.13.

Channel widths and depths on the R. Cole were reduced as a result of restoration (Table 3.1). On the R. Skerne, widths and depths have remained roughly the same because of urban flood defence constraints.

3.3.3 Channel features on new lengths of the R. Cole

Fluvial auditing on the R. Cole was undertaken to describe the development of channel features following restoration. Fluvial auditing has not been undertaken on the R. Skerne. As the two halves of the R. Cole site (upstream and downstream of Coleshill Bridge) showed different morphological characteristics they are described separately in the following section.

The 'control' site for the R. Cole (which was upstream of the restoration demonstration site area and is ponded and channelised) had no riffles, runs, point bars or mid-channel bars. Debris dams and berms did occur in small numbers. The control section showed little change over the course of the study (Table 3.2).

Compared to the control site, the newly restored channel upstream of Coleshill Bridge had increased numbers of riffles, pools, point-bars, actively eroding banks and overbank deposits. Note, however, that some of the pools, which were excavated rather than arising naturally, are now partially filling with sediments.

In the restored reach downstream of Coleshill Bridge, erosional channel features all increased following restoration, compared to pre-restoration conditions. Features which increased in abundance were riffles, pools, runs, point-bars, mid-channel bars and overbank deposits. Actively eroding banks were numerous immediately after restoration but had returned to pre-restoration levels by March 1998.

The downstream area below the restoration site could potentially have been positively or negatively impacted by the restoration works. In practice, the reaches below the restoration area showed a small increase in the number berms after restoration. This was probably the result of extensive sedimentation in the reach resulting from deposition of silt released during and after the restoration works. This deposition of sediment raised the bed of the river by 0.5-1.0 m in places but there were few other changes in the number of geomorphological features in the downstream section.

3.4 Summary

Restoration increased channel length and sinuosity on both demonstration sites and, on the R. Cole, raised bed levels and reduced channel cross-sectional area.

On the R. Cole, where more detailed geomorphological monitoring was undertaken, there was clear evidence that numbers of natural channel features increased (e.g. riffles, point-bars) after restoration. Both erosion and deposition generated features increased in number. There was also evidence on the R. Cole of extensive sedimentation downstream of the restoration site which led local raising of bed levels, and a small increase in numbers of berms.

Overall, the monitoring results indicate that the restoration works have increased channel morphological diversity.

Table 3.2 Numbers of geomorphological features in the R. Cole²**(a) Control site**

Geomorphological feature	Pre-restoration	Post-restoration			
		June 1996		March 1998	
		Total	No./100m	Total	No./100m
Riffle	Not surveyed	0	0	0	0
Pool	Not surveyed	1	0.28	3	0.84
Run	Not surveyed	0	0	0	0
Berm	Not surveyed	3	0.84	4	1.12
Point-bar	Not surveyed	0	0	0	0
Mid-channel bar	Not surveyed	0	0	0	0
Active eroding bank	Not surveyed	1	0.28	1	0.28
Debris dam	Not surveyed	2	0.56	3	0.84
Overbank deposit	Not surveyed	0	0	2	0.56

(b) Upstream restored site

Geomorphological feature	Pre-restoration	Post-restoration					
		June 1996		Jan. 1997		Mar. 1998	
		Total	No./100m	Total	No./100m	Total	No./100m
Riffle	Not present	4	0.7	4	0.7	5	0.87
Pool	Not present	4	0.7	10	1.74	8	1.39
Run	Not present	0	0	0	0	0	0
Berm	Not present	0	0	0	0	1	0.17
Point-bar	Not present	13	2.26	11	1.91	11	1.91
Mid-channel bar	Not present	0	0	0	0	0	0
Active eroding bank	Not present	13	2.26	13	2.26	9	1.57
Debris dam	Not present	0	0	1	0	0	0
Overbank deposit	Not present	13	2.26	13	2.26	13	2.26

² The data presented in Table 3.2 are based on unpublished information provided by Alison Briggs and should not be reproduced without her specific permission.

Table 3.2 Numbers of geomorphological features in the R. Cole (cont.)**(c) Downstream restored site**

Geomorphological feature	Pre-restoration		Post-restoration							
			Jan. 1996		June 1996		Jan. 1997		March 1998	
	Total	No./100m	Total	No./100m	Total	No./100m	Total	No./100m	Total	No./100m
Riffle	2	0.16	2	0.16	7	0.56	6	0.48	4	0.32
Pool	3	0.24	9	0.72	9	0.72	3	0.24	6	0.48
Run	0	0	3	0.24	4	0.32	1	0.08	2	0.16
Berm	9	0.72	1	0.08	0	0	1	0.08	2	0.16
Point-bar	0	0	2	0.16	3	0.24	9	0.72	9	0.72
Mid-channel bar	0	0	1	0.08	1	0.08	1	0.08	1	0.08
Active eroding bank	4	0.32	10	0.80	10	0.80	9	0.72	5	0.40
Debris dam	0	0	0	0	0	0	0	0	0	0
Overbank deposit	0	0	26	2.08	26	2.08	8	0.64	17	1.36

(d) Potentially impacted site

Geomorphological feature	Pre-restoration		Post-restoration			
			June 1996		March 1998	
	Total	No./100m	Total	No./100m	Total	No./100m
Riffle	1	0.19	2	0.37	1	0.5
Pool	3	0.56	4	0.93	3	1.5
Run	0	0	0	0	0	0
Berm	14	2.62	13	2.43	7	3.5
Point-bar	0	0	1	0.19	2	1
Mid-channel bar	0	0	0	0	0	0
Actively eroding bank	1	0.19	2	0.37	2	1
Debris dam	2	0.37	2	0.37	0	0
Overbank deposit	0	0	0	0	0	0

4. LANDSCAPE ASSESSMENT

4.1 Aims

River restoration is generally expected to lead to improvements in the quality of river landscapes. In order to provide the basis for long-term assessments of changes to the restored sections of the R. Cole and R. Skerne, standard landscape assessments were undertaken before the schemes started. It is anticipated that these will be repeated later, when the landscapes of the restored sites have matured.

This section summarises briefly the pre-restoration status of the landscapes.

4.2 Methods

The landscape assessment followed the standard NRA landscape methodology (NRA 1993).

4.3 Pre-restoration conditions

4.3.1 Macro landscape assessment

Prior to restoration, five landscape types were identified on the R. Cole, and three on the R. Skerne. Although the R. Cole had areas of higher landscape value than the R. Skerne, the majority of both sites were defined as Grade 2 - 3 (see Table 4.1). In the terminology of the NRA methodology, this is equivalent to areas in need of restoration (NRA 1993).

4.3.2 Micro landscape assessment

On the R. Skerne, micro landscape quality was predominantly Class 3, with small areas of Class 2 - 3 and 3 - 4. On the R. Cole, the pre-restoration micro landscape was Class 2 upstream of Coleshill Bridge, and Class 3 downstream of Coleshill Bridge (Table 4.2).

Table 4.1 Macro landscape types: R. Cole and R. Skerne

River	Landscape type	Value class
R. Cole	Coleshill Village	1
	Coleshill Parkland	1 - 2
	Clay Vale Farmland	2 - 3
	Alluvial Mixed farmland	2
	Wooded Limestone Valley	1 - 2
R. Skerne	Amenity Grassland	3 - 4
	Semi-natural grassland	2 - 3
	Degraded industrial space	4

Table 4.2 Micro landscape types: R. Cole and R. Skerne

River	Landscape type	Value class
R. Cole	Upstream of Coleshill Bridge	2
	Coleshill Mill - Coleshill Bridge	2 - 3
	Downstream of Coleshill Bridge	3
R. Skerne	Haughton Road Bridge to d/s Five Arches Bridge	3
	d/s Five Arches Bridge to Albert Bridge	2 - 3
	Albert Bridge to Skerne Bridge	3 - 4

5. HYDROLOGY AND CHANNEL HYDRAULICS

5.1 Aims

A general objective of the R. Cole and R. Skerne restorations was to raise water levels, lowered by channel overdeepening, and increase the frequency of overbank flows from the channel to the floodplain. In principle, these changes are generally expected to be beneficial in terms of:

- retaining water in the catchment and contributing to the alleviation of low flows,
- protecting floodplain wetlands or leading to floodplain wetland reinstatement,
- smoothing of the hydrograph during flood events and hence contributing to downstream flood protection.

A modelling approach was used to assess the extent to which the channel hydrological regime changed in the R. Cole and R. Skerne demonstration areas, and in particular to predict the frequency of overbank events before and after restoration.

Using the restoration changes made on the R. Cole as a model, general predictions were also made about the effect of restoration at a catchment scale using an existing hydrological model of the R. Cole catchment (Thames Water 1988). The model was used to assess the type of hydrological changes that would occur if restoration of the sort undertaken at the Coleshill was implemented widely throughout the R. Cole catchment.

5.2 Frequency of overbank flows

5.2.1 Changes in the frequency of overbank flows on the R. Cole

Modelling of the R. Cole restoration site showed that the frequency of overbank flows was predicted to vary markedly from one area of the site to another. Prior to restoration overbank flows were expected to occur for 1 to 8 hours per year on the straightened channel. This is roughly equivalent to stating that the 1 in 2 year flood was retained in channel. Table 5.1 summarises the frequency of overbank events before restoration.

After restoration, the duration of overbank flows was increased in all areas. However, except in the new channel upstream of Coleshill Bridge, the requirement to ensure that agricultural activity was not severely constrained meant that the duration of out of bank flows was increased only slightly (e.g. from 2 hrs to 24 hrs downstream of Coleshill Bridge).

In the new channel above Coleshill Bridge out of bank flows were predicted to occur for 400 hours per year (i.e. 16 days). This indicates that, in the most natural section of the R. Cole, for nearly 5% of the year water would be above bank level.

If the new channel upstream of Coleshill Bridge is taken as the standard (i.e. flood frequency here is considered to be 100% of the expected value), this indicates that the unrestored channel had about 0.5% of the normal overbank flows. The new restored channel *downstream* of Coleshill Bridge has overbank flows of about 5% of normal (Table 5.2).

Table 5.1 Modelled frequency of overbank flows on the R. Cole before and after restoration

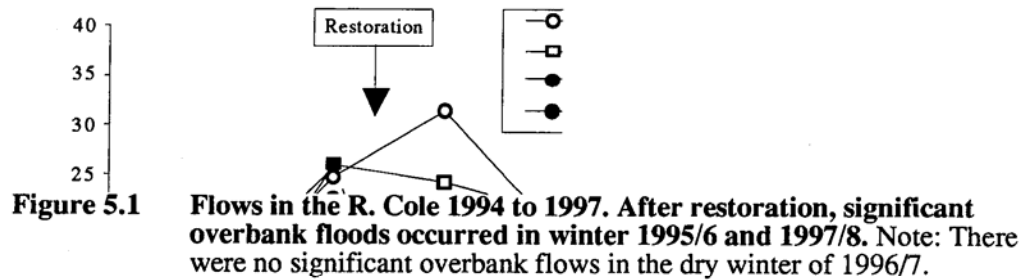
	Before restoration		After restoration	
	Flow when channel bankfull ($\text{m}^3 \text{s}^{-1}$)	Length of time overbank (hours per year)	Flow when channel bankfull ($\text{m}^3 \text{s}^{-1}$)	Length of time overbank (hours per year)
Straightened channel upstream of Coleshill Bridge	22	4	22	4
New natural channel upstream of Coleshill Bridge	Channel did not exist before restoration		1.5	408
Channel downstream of Coleshill Bridge	23	2	12	24

Table 5.2 Duration of overbank flows at various locations on R. Cole as a proportion of duration of overbank flows on new channel upstream of Coleshill Bridge

Section	Proportion of time overbank
Restored (upstream of Coleshill Bridge)	100%
Unrestored (upstream of Coleshill Bridge)	0.5%
Restored (downstream of Coleshill Bridge)	
• Adjacent to Fritillary Field	6%
• Immediately downstream of Coleshill Bridge	1%

5.2.2 Flood events on the R. Cole after restoration

Actual floods have occurred on the R. Cole in two of the three winters after restoration, in 1995/6 and 1997/98. In the second winter post-construction (1996/97) flows were low (the maximum daily mean flow was just under $6.0 \text{ m}^3 \text{s}^{-1}$) and there were no significant overbank flows (Figure 5.1).



5.2.3 Changes in the frequency of overbank flows on the R. Skerne

The frequency of overbank flows was increased on the R. Skerne through the restoration section by lowering the river bank. This had the effect of maintaining conveyance through the reach, and increasing frequency of overbank flows.

On the restored section, bankfull capacity in the channel was reduced by 23% from $12 \text{ m}^3 \text{ s}^{-1}$ to $8.5 \text{ m}^3 \text{ s}^{-1}$. Before restoration overbank flows occurred for less than 24 hours per year. After restoration, modelling predicted that overbank flows should occur between 79 and 108 hours per year in the restored area.

5.3 Catchment scale hydrological effects of river restoration

The restoration sites occupied a very small proportion of the total river lengths in their respective catchments. For example, the R. Cole catchment has at least 166 km of channels, so that the restoration section (2 km) represents only 1% of the total drainage network (Sear and White 1994). Consequently, the effects of restoration on the hydrology of the rivers was quite small.

To assess the potential effects of river restoration at the catchment scale, catchment-wide river restoration was simulated using a hydrological model of the R. Cole. The model was used to make an initial test of the effects of restoration, using the type of work undertaken at Coleshill as a model for simulated catchment-wide restoration. Four main options were tested:

- a 20% increase in channel length on all streams and rivers in the catchment,
- a 50% increase in channel length downstream of the confluence on the South Marston Brook and the R. Cole (roughly half way down the catchment),
- reducing channel depth by 50% on all streams and rivers in the catchment,
- reducing channel cross-sectional area to 20% of existing values (the equivalent to the changes made at Coleshill upstream of Coleshill Bridge).

Each of these options was then run at a variety of flood return periods, from 1 in 2 years to 1 in 100 year return periods. The results of this simulation suggested that the most effective option in reducing the flood peak at the bottom end of the catchment would be a catchment-wide reduction of channel cross sectional area to 20% of the existing values. This option had most effect because it allowed most water to move out onto the floodplain.

Table 5.3 Theoretical reduction in flood peak at the downstream end of the R. Cole catchment following simulated catchment-wide river restoration

Flood return period	Peak flow with no	Peak flow with channel	% change
---------------------	-------------------	------------------------	----------

(years)	restoration ($\text{m}^3 \text{s}^{-1}$)	cross-section 20% of original ($\text{m}^3 \text{s}^{-1}$)	
1 in 2	18	12	34%
1 in 5	23	16	30%
1 in 10	30	21	30%
1 in 25	40	34	15%
1 in 50	48	42	13%
1 in 100	57	51	10%

In terms of peak discharge, reductions in the flood peak varied from 34% for a 1 in 2 year event to about 10% for a 1 in 100 year event. In simulations of intermediate frequency flood events, flood peaks were reduced by intermediate amounts (Table 5.3). This reflects the fact that in the largest return period events flow occurs mostly on the floodplain, so that that channel alterations would have relatively less effect at the higher return period flows.

5.4 Summary

Restoration of the R. Cole created some channel sections in which overbank flow frequency probably approached the true pre-channelisation condition of the R. Cole catchment. These channels, simulating the small cross-sectional area that might be expected from a natural clay channel, were predicted to have overbank flows for about 5% of the year (i.e. about 2 weeks annually). On the unrestored channel, overbank flows occurred for less than half a day a year, on average.

On the R. Skerne flood defence requirements made it necessary to maintain flood conveyance through the restored section. However, out of bank frequency was predicted to increase from about 1 day year to about 4 days per year after restoration.

Modelling techniques were used to predict the effects of restoration at catchment scale on the R. Cole, using a previously constructed catchment model. This showed that catchment wide implementation of restoration techniques could have a significant effect on peak discharge. The most effective theoretical alteration to channel structure was to reduce channel cross-sectional area to 20% of the current value (simulating the changes made on the most natural channel upstream of Coleshill Bridge). This reduced the 1 in 100 year flood peak by about 10% at the bottom of the catchment. The more frequent return period floods were reduced by proportionately greater amounts, the 1 in 2 year flood peak being reduced by 35%.

6. WATER QUALITY: SEDIMENT AND NUTRIENT MONITORING

6.1 Overall aims of water quality monitoring

An important predicted benefit of river restoration is improvement of water quality, particularly through the reduction of in-channel concentrations of suspended sediments and nutrients. These changes are expected to result from a combination of (i) increased floodplain sediment deposition resulting from increased overbank flow and (ii) deintensification of river valley land-use and buffer zone creation.

In the restoration project, work on sediment and nutrient budgets focused on detailed data gathered for the R. Cole. However, additional data for the R. Skerne was derived from standard (approximately monthly) Environment Agency sampling.

The aims of sediment and nutrient monitoring were to:

- to assess the effect of river restoration on suspended sediment concentrations,
- to assess the effects of river restoration on nutrient concentrations.

6.2 Suspended sediments

6.2.1 R. Cole suspended sediments

On the R. Cole, the results show that after restoration, mean monthly suspended sediment concentrations were generally higher downstream of the restoration site than above it. Mean concentrations at the upstream control and the beginning of the restoration reach were 16.8 and 23.4 mg l⁻¹, respectively. Downstream of the restoration length, the mean suspended sediment concentration was 44.9 mg l⁻¹.

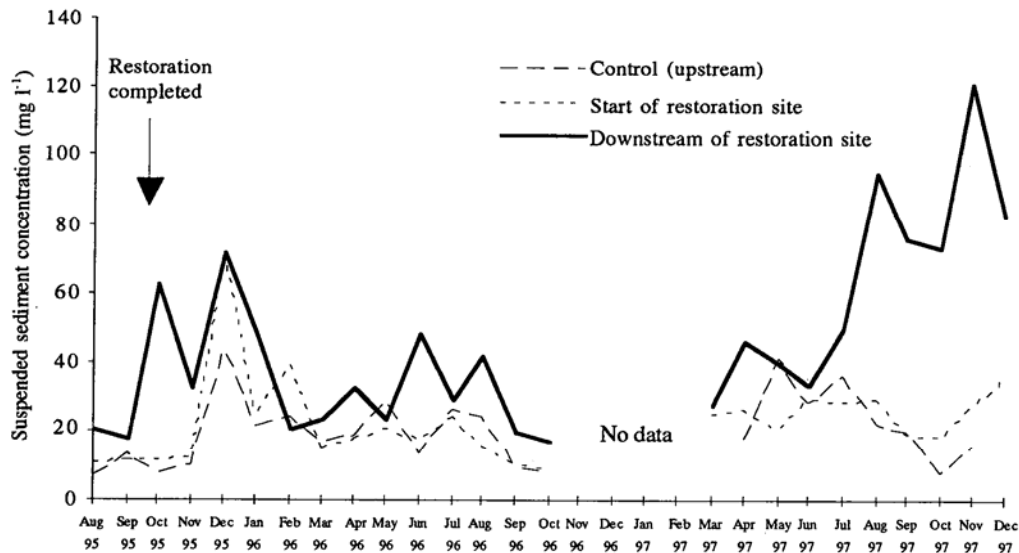


Figure 6.1 Suspended sediment concentrations (mean monthly values) in the R. Cole following restoration in 1995

These data were consistent through much of the survey period: sediment concentrations were higher downstream of the restored length on 80% of days when samples were collected at both sites (n=253).

Longer-term suspended sediment data for the R. Cole, collected by the Environment Agency, is available from immediately below Coleshill Bridge (mid-way through the restoration reach). These data suggest a slight, and statistically significant, increase in suspended sediment concentrations since 1990 (Figure 6.2). However, values are well below those seen at the downstream end of the restoration reach. Overall, therefore, the monitoring programme suggests that restoration has, to date, increased sediment concentrations downstream of the restoration site.

Possible explanations for the increased sediment concentrations observed are:

- the diversion of flow around the ponded mill leat (only 10% of the flow now is now routed through this channel) has eliminated a large area which previously trapped sediment,
- the bare substrates, especially downstream of Coleshill Bridge, are providing a large supply of sediment,
- sediments washed out of the restoration reach into the channel immediately downstream are being mobilised and gradually washed downstream.

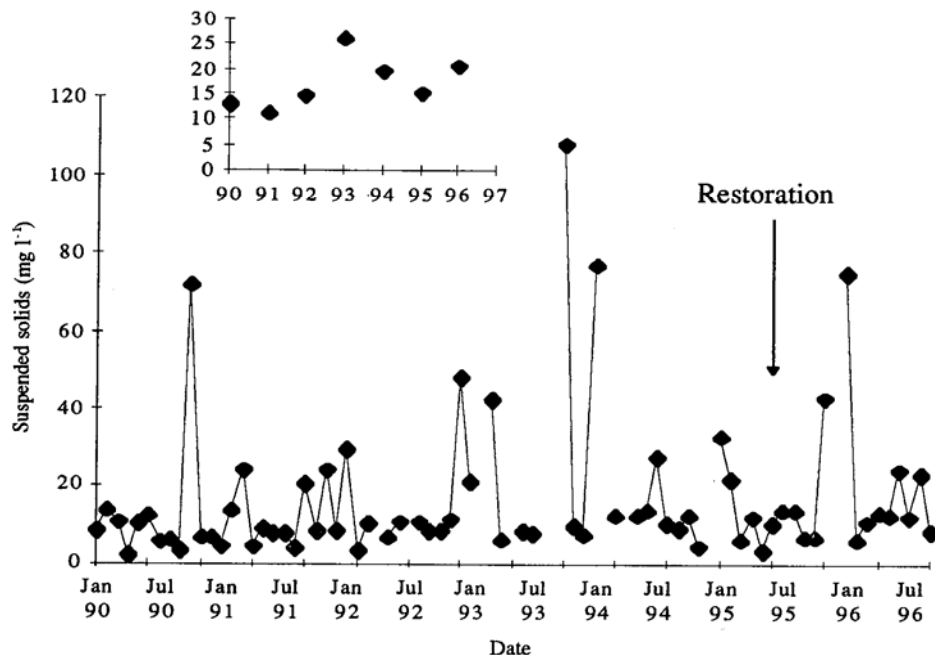


Figure 6.2. R. Cole monthly suspended sediment concentrations 1990-1996 (Environment Agency data) immediately downstream of Coleshill Bridge. Inset shows annual mean values.

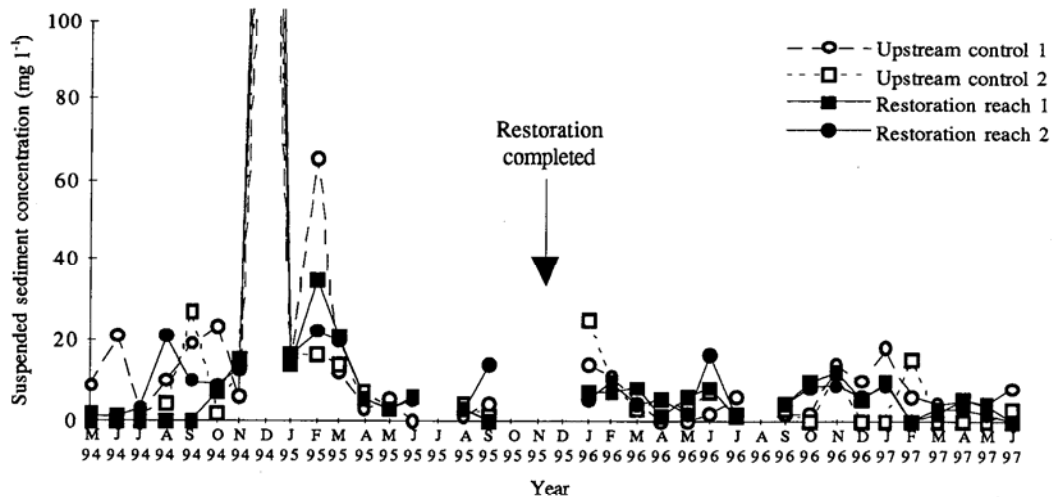


Figure 6.3 Suspended sediment concentrations in the R. Skerne, 1994-1997.

6.2.2 R. Skerne suspended sediments

On the R. Skerne, suspended sediment data were collected at Environment Agency monitoring stations at Ketton Bridge, Great Burdon (both upstream of the restoration site), Five Arches Bridge (at the downstream end of the restoration site), John Street and South Park Weir (both downstream in the area potentially impacted by downstream sediment release from the restoration works).

The Environment Agency data shows no evidence that suspended sediment concentrations changed significantly following restoration (Figure 6.3).

6.3 Nutrient concentrations

6.3.1 R. Cole nutrient concentrations

The R. Cole is typical of many lowland rivers in showing anthropogenically elevated concentrations of both nitrogen and phosphorus compounds. Before restoration, annual mean total oxidised nitrogen (TON) concentrations were about 6 mg l^{-1} (range $2\text{--}18 \text{ mg l}^{-1}$) and soluble reactive phosphorus concentrations were around 0.5 mg l^{-1} (range $<0.06\text{--}1.46 \text{ mg l}^{-1}$).

On the R. Cole there was little evidence that nutrient concentrations changed systematically following restoration, although there was a brief peak in nitrate nitrogen concentrations in spring and summer 1996 (the year after the main period of works). These higher concentrations reached a peak in June 1996 when daily mean TON concentration were 17 mg l^{-1} below the works, compared to 5 mg l^{-1} upstream.

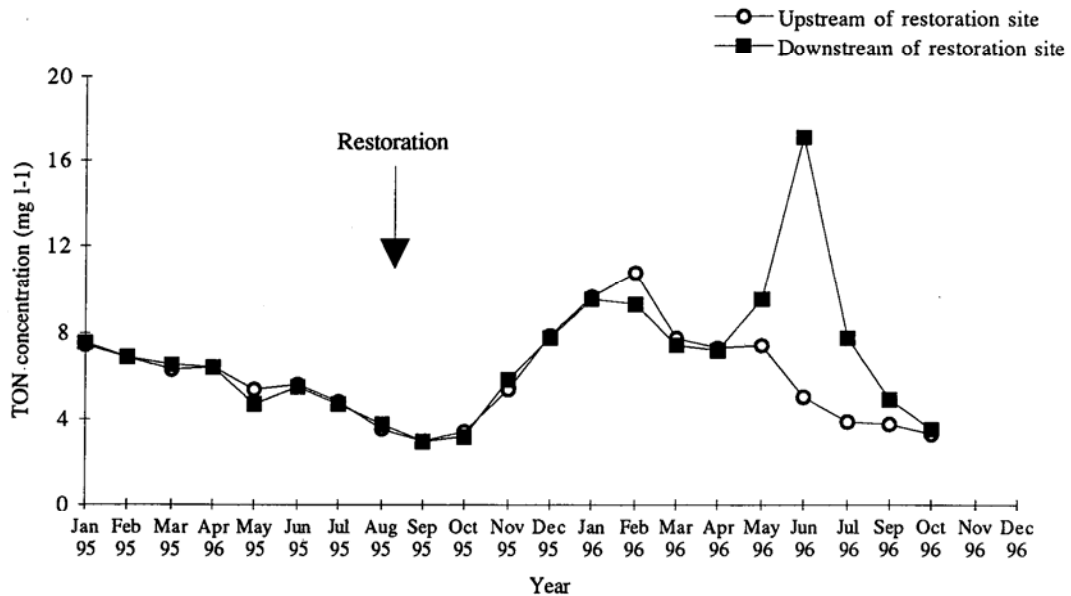


Figure 6.4 R. Cole total oxidised nitrogen (TON) concentrations above and below the restoration site. Values are mean monthly concentrations.

The cause of this short-term elevation in TON concentrations is unknown. Inter-calibration between samples collected for this project and samples collected routinely by the Environment Agency suggest that the peak was not a sampling artefact. Thus restoration project data from Site B (the beginning of the R. Cole restoration length) and Environment Agency data from immediately below Coleshill Bridge showed remarkably good correspondence allowing for the fact that not all samples were exactly coincident in terms of the days on which they collected (Figure 6.5).

Likewise, the elevated TON concentrations did not seem to be due to effluent discharge from Coleshill STW, since Environment Agency samples immediately downstream of the STW showed no elevated nitrogen concentrations. Possible alternative explanations could include leaching of nutrients from bare ground, spillages from fertiliser bags or other undetected point source inputs unrelated to the restoration works.

There was little evidence of systematic changes in phosphate phosphorus concentrations on the R. Cole following restoration. In general, trends at all sites were similar, largely reflecting the seasonal pattern of flow, and dilution of the phosphorus load in the river which is largely derived from sewage treatment works effluents (Figure 6.6).

6.3.2 R. Skerne nutrient concentrations

On the R. Skerne, there were no significant directional trends in nutrient concentrations over the duration of the restoration project (Figure 6.7).

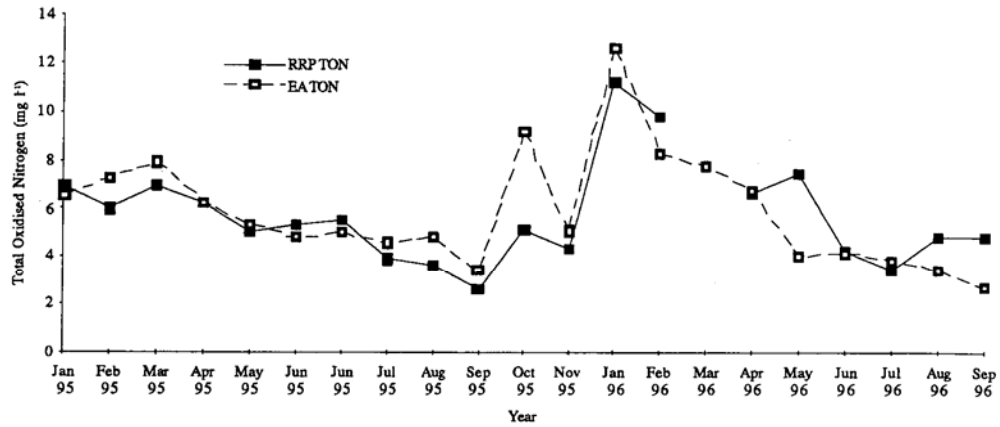


Figure 6.5 Comparison of RRP and Environment Agency total oxidised nitrogen concentrations in the R. Cole.

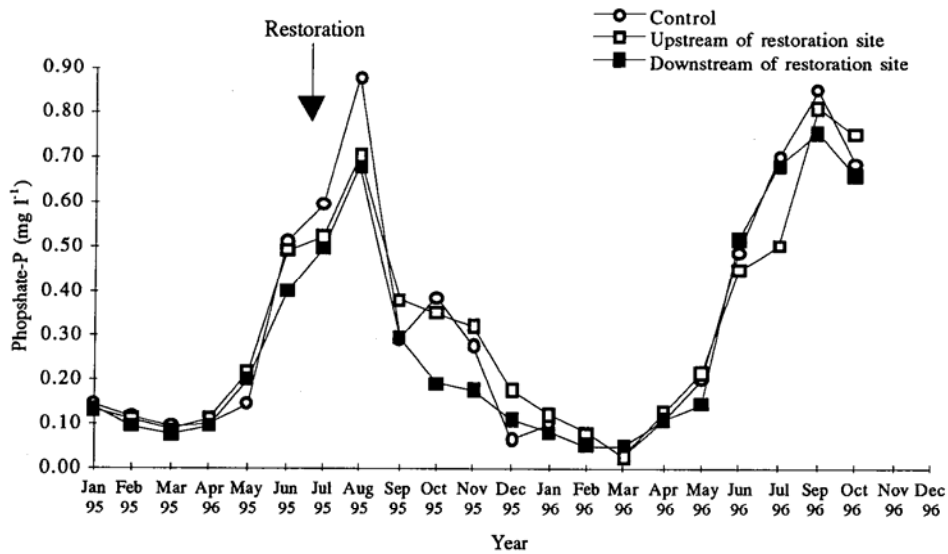


Figure 6.6 R. Cole phosphate phosphorus concentrations: Jan 1995 to October 1996.

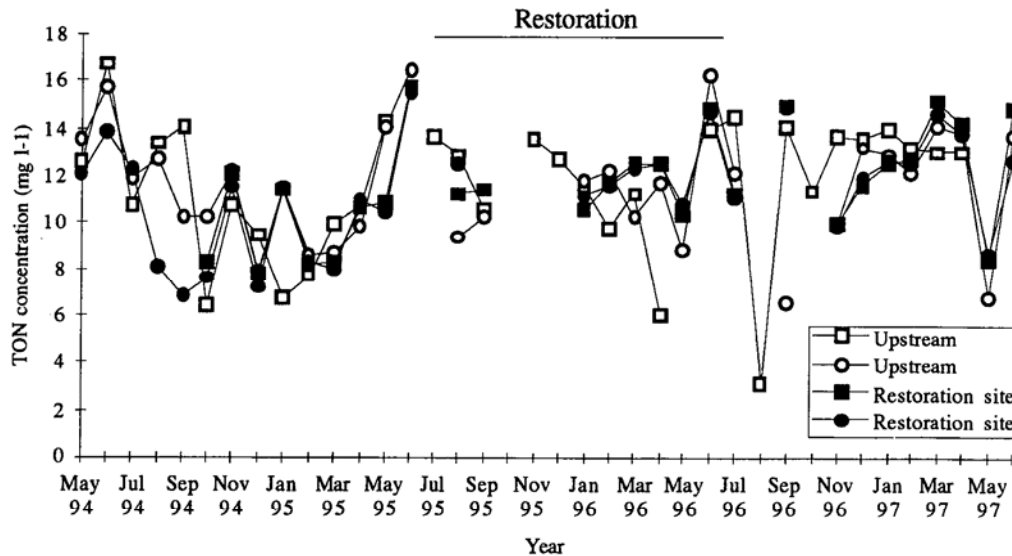


Figure 6.7 R. Skerne total oxidised nitrogen concentration (Environment Agency data): 1995 to 1997.

6.4 Summary

Although it might be hoped that the restoration features (a meandering planform, increased channel buffering, installation of a reed bed etc.) introduced into the R. Cole, would act to reduce in-stream nutrient concentrations, the absence of any clear reduction to date is not unexpected.

In particular: (i) a large proportion of the nutrient burden in the river is derived from sewage treatment works, especially for phosphate (ii) in-channel vegetation was little developed during the early stages of colonisation, providing few surfaces for biological uptake of nutrients (iii) there was little overbank flooding in the first 2 years after the scheme was completed, giving few opportunities for sediment bound nutrients to be translocated to the floodplain.

Overall, it is early days in terms of the potential for the restored river to show nutrient reduction effects. In the medium and long term, however, it is possible that effective buffering and nutrient removal processes which occurs on the demonstration site may be 'swamped' by catchment-scale releases of nutrients.

7. VEGETATION ECOLOGY

7.1 Aims

Vegetation monitoring involved surveys of the river channel within:

- The *restoration* area,
- An *upstream length* of channel/floodplain to act as a control,
- A *downstream* area to ensure that the restoration works did not have adverse downstream impacts (e.g. excess sediment deposition).

7.2 Survey methods

7.2.1 Surveys of 500 m river channel lengths

In both the R. Cole and R. Skerne semi-quantitative surveys were undertaken to provide information about changes in the conservation value of the riparian plant community after restoration. These surveys were based on wetland species lists compiled for each 500 m length of the river channel (including sections upstream and downstream of the restored section). Conservation value was measured principally in terms of wetland plant species richness and rarity (see below).

7.2.2 Quadrat surveys of the R. Cole channel

In addition to the semi-quantitative data collected from both rivers, on the R. Cole, quantitative data were collected from the river channel and banks using 2 m² quadrats. These data provided more detailed information about changes in the number and abundance of wetland plant species in the survey area after restoration.

The quantitative quadrat monitoring involved establishment of a total of 36 permanent 2m² quadrats. The quadrats were grouped together so as to provide transects along nine sections of the R. Cole. Four of these transects were located within the restoration area, with two control transects upstream and three downstream of the restoration area. Transects were located to typify areas of the river, and quadrats were more precisely located to include plant stand edges so that changes in stand size as well as composition could be evaluated. At each of the nine transects, the quadrats were established in four areas of the river channel: (i) mid bank, (ii) lower bank, (iii) shallow river/river edge and (iv) central channel. The position of quadrats was marked using either permanent ground markers or by taking accurate measurements from permanent landscape features. The 2m² quadrats each comprised an 8m x 0.5m rectangle, which was positioned along the river with the long axis of the quadrat oriented parallel to the hydrosere. Each of these quadrats was subdivided into four 0.5m x 1m sub-quadrats ('replicates') to facilitate statistical comparisons within and between monitoring sections.

7.2.3 Surveyors

The 500 m semi-quantitative river channel plant surveys the on the R. Cole were undertaken by R. Lansdown and P. Williams in 1994, and by P. Williams in 1996. Surveys of the R. Skerne were undertaken by D. Cowen in 1994 and P. Williams in 1996. All channel quadrat surveys were undertaken by P. Williams. All river channel surveys were undertaken in late summer (August to September). Additional surveys were also undertaken by N. Holmes.

7.2.4 Assessing the conservation value of the plant community

The conservation value of the R. Cole plant community was assessed on the basis of the presence of the number of wetland species and the number of nationally uncommon (i.e. local, nationally scarce or Red Data Book) wetland plants in the river corridor.

A Species Rarity Index (SRI) was used to provide a relatively objective comparison of the reaches surveyed with sites in other areas (Biggs *et al.* 1998). The SRI is a measure of the 'average rarity' of the species in a community and is derived in the following way:

- All species present are given a numerical value from 1 to 64 depending on their rarity (i.e. Common species = 1, Local species³ = 2, Nationally Scarce B = 4, Nationally Scarce A = 8, Red Data Book 3 (rare) = 16, RDB 2 (vulnerable) = 32, RDB1 (endangered), = 64),
- The values of all the species present are totalled to give a Species Rarity Score (SRS),
- The SRS is divided by the number of species present to give the SRI.

7.3 Results: R. Cole

7.3.1 Wetland plant species richness and rarity

Numbers of species recorded

The number of wetland macrophyte species (aquatic and emergent plants combined) in the new channels of the R. Cole quickly reached pre-restoration levels (Appendix Tables 1&2, Figure 7.1). However there were differences in the responses of the emergent and aquatic plants to the restoration work.

Emergent plant species richness showed a rapid recovery after channel reconstruction, so for example, the numbers of emergent species in 500 m survey lengths below Coleshill bridge a month after restoration (in autumn 1995) were virtually identical to the number recorded before channel restoration (autumn 1994) (Figure 7.1). One year later (autumn 1996), the emergent plant species richness in the restored R. Cole reaches had increased from an average of 27 to 38 species per 500 m survey length.

Within the current survey period, the number of aquatic plant species recorded from the R. Cole downstream of Coleshill Bridge appears to have been little affected by restoration (mean number of species/500 m length: 7.5 species pre-restoration, 7.0 species within a month of restoration, 8.0 species one year after restoration) (Figure 7.1).

Wetland plant Species Rarity Indices indicated similar average rarity values for the plant assemblages in the restored reaches before, during and after restoration.

³ 'Locally uncommon' plants here refers to plant species recorded from between 100 and 600 km squares in Britain.

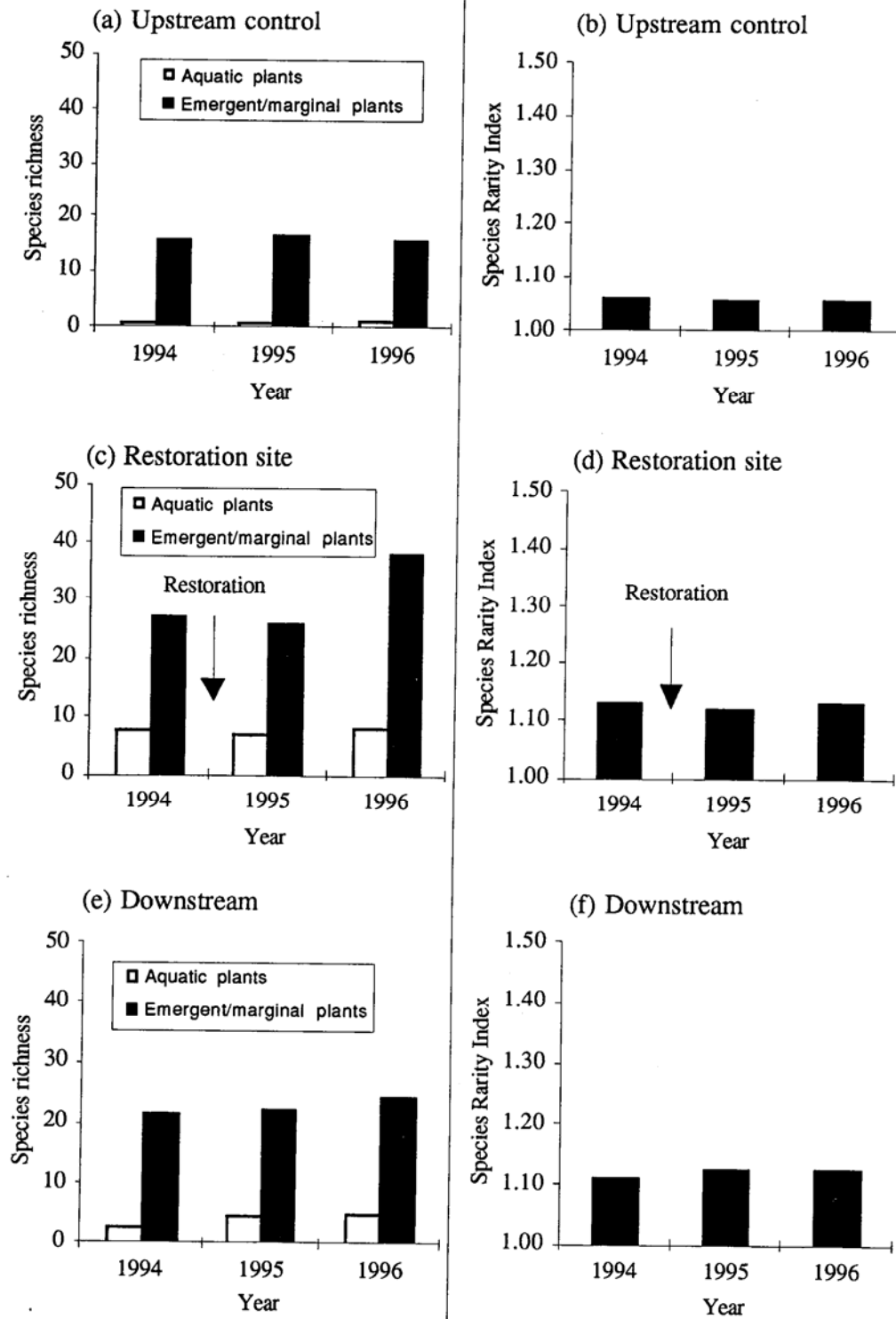


Figure 7.1 Average number of plant species recorded from 500 m lengths of the R. Cole channel before, during and after restoration

7.3.2 Quantitative quadrat monitoring

Species richness

The increase in wetland plant species richness seen at the 500m length scale on the R. Cole was even more marked at a small scale. Quadrat monitoring in-channel indicated that, on average, there were about four times as many wetland species per 2m² quadrat after restoration as there were before restoration.

Vegetation abundance

In contrast to species richness, the abundance (cover) of vegetation appeared to increase relatively gradually after restoration. Thus, on average, vegetation cover in the R. Cole quadrats in the restored river sections was only 6.5% (marginal and aquatic cover combined) one year after channel construction (Figure 7.2). This was roughly one third the pre-restoration cover values.

Proportion of wetland and terrestrial plant species

Quadrat data from the R. Cole were also used to assess whether the relative proportion of wetland and terrestrial plant cover changed on the newly reprofiled banks. Early indications a year after the completion of the works provide limited evidence that wetland plant cover had increased, relative to terrestrial vegetation, after restoration⁴.

7.3.3 The impact of the restoration works on the vegetation of downstream reaches

Overall, results from both quadrat and river corridor surveys indicate that there was no evidence that sediment released during active construction of the new channel adversely affected plant communities downstream of Coleshill restoration site in terms of species richness, rarity or abundance.

There was particular concern that sediments released from the works could shade-out submerged aquatic plant assemblages downstream but, in practice, there was no evidence of such damage.

⁴ In 1998 large quantities of *Ranunculus* sp. were present in the downstream section of the R. Cole.

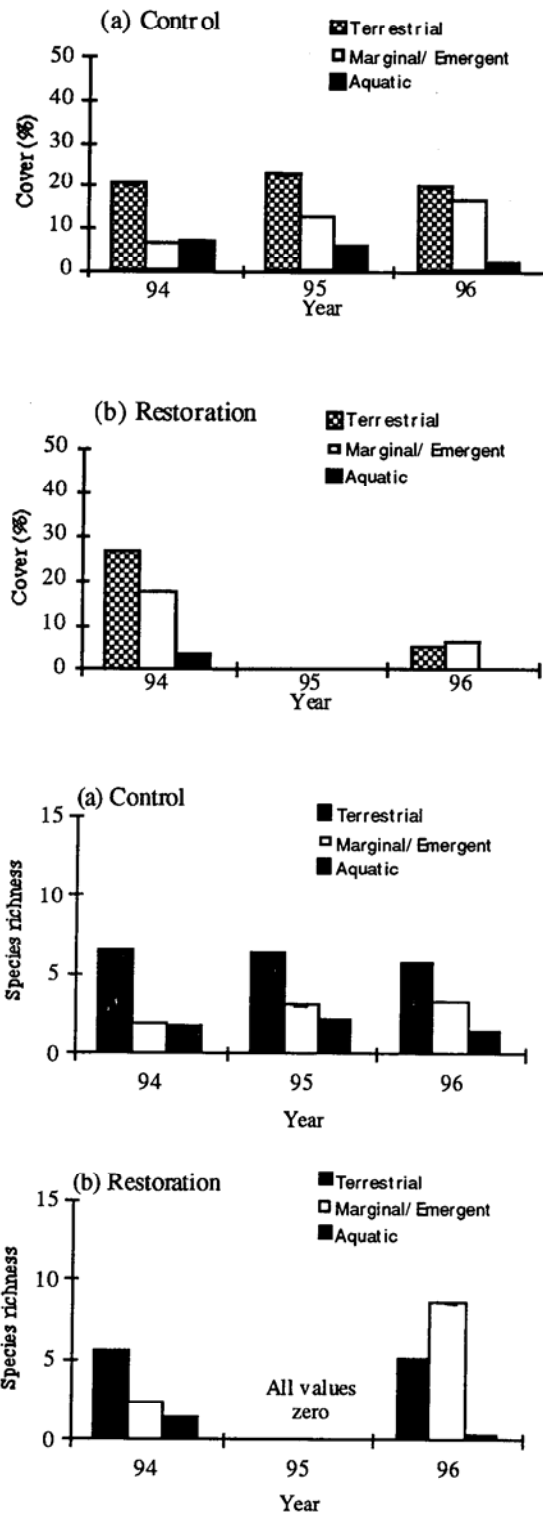


Figure 7.2 Wetland plant quadrat monitoring results from the R. Cole before, during and after restoration

7.4 Results: River Skerne

7.4.1 Wetland plant species richness and rarity

Numbers of species recorded

On the R. Skerne numbers of wetland plant species per 500 m section increased in all sections between 1994 and 1996. This included both upstream control and downstream impact sections (Table 7.1). The most likely reason for this consistent increase was differences between the field surveyor (see Section 7.2.3). However, if species numbers in the restored reach are corrected for background increases in the upstream control reach, overall species richness in the restored section as a whole rose by 29% after one year and individual 500 m reaches increased by an average of 27%. This total does not include records for an additional nine plant species which were present only as new plants introduced into the restored section in 1995 (using plant palettes). If these introduced species are included, the plant richness in the 2 km restored section as a whole rose by 43% after one year. Individual 500 m reaches increased in richness by an average of 39%.

Overall, therefore, the plant richness in the R. Skerne showed very rapid recovery, and the number of plant species present exceeded pre-restoration levels within a year of the restoration work through natural colonisation processes alone. Planting-up of the river margins with additional emergent species enhanced this trend.

The increased species richness of the restored reach was due to greater numbers of both aquatic and emergent plants. However, as with the R. Cole, emergent plant richness increased at a greater rate than the aquatic plants. Thus, whereas the average number of an aquatic plants recorded from the 2 km restoration reach increased by average of 20%, marginal plant richness increased by 32% (both figures corrected for the controls).

Five aquatic species, *Elodea nuttallii* (Nuttall's waterweed), *Potamogeton pectinatus* (fennel pondweed), *Sparganium emersum* (unbranched bur-reed) *Callitriche* species (water starwort) and *Lemna minor* (common duckweed) all colonised the restored reach rapidly and were recorded from most or all of the 500 m restored survey lengths. Three completely new aquatic species to the area were also recorded from the restored reach. These were: *Potamogeton crispus* (curled pondweed), *Ranunculus* sp. (a water crowfoot species) and *Zanichellia palustris* (horned pondweed). None of these three aquatics had been recorded either from the restored area before restoration, or from the control and downstream sections before or after the restoration works.

Twelve species of emergent plant were recorded for the first time in the restoration reach in 1996, excluding deliberately introduced plants (see Table 7.2). Amongst these were five new species which had not previously been recorded from any of the survey sections. These were: *Deschampsia caespitosa* (wavy-hair grass), *Glyceria notata* (plicate sweet-grass), *Rorripa palustris* (marsh yellow-cress), *Typha latifolia* (bulrush) and *Veronica catenata* (pink water-speedwell).

Uncommon plant species

No naturally occurring nationally scarce or rare plant species were recorded from the R. Skerne survey sections in 1994 or 1996. However, the number of 'locally uncommon'

plants'⁵ increased from one to four. All three new locally uncommon plants occurred in the restored section of the river. They were: *Potamogeton crispus* (curled pondweed), *Zanichellia palustris* (horned pondweed) and *Veronica catenata* (pink water-speedwell). The occurrence of these species increased the average aquatic plant species rarity value in the R. Skerne's restored sections by approximately 70% (corrected for control data). The average rarity value of the marginal plant community in the restored sections remained very similar to the pre-restoration values (corrected for controls).

7.3.2 Impact on vegetation of sediment releases on the R. Skerne

Species data describing the impact of the restoration works on downstream reaches of the R. Skerne are difficult to interpret. The raw data suggests considerable increases in the species richness of both 500m lengths downstream of the restoration works, even after corrections have been made using control reach data (see Figure 7.2). It is possible that these increases resulted from changes brought about by the works. In practice, however, the increase was probably due to surveyor differences: most areas of the impact reaches were exceptionally difficult to access and survey, and were probably not fully accessed during the 1994 baseline survey.

7.5 Conclusions

In both the R. Cole and R. Skerne, wetland macrophyte species richness recovered rapidly in the restored channels, and within one to two years the number of species recorded exceeded pre-restoration levels. In both rivers the rich macrophyte assemblage was largely achieved through rapid colonisation of new muddy banks by marginal wetland ruderals such as *Veronica catenata* (pink water-speedwell) and *Ranunculus sceleratus* (celery-leaved buttercup). In addition, field observations showed that, particularly on the R. Cole, species totals were increased by the retention of a number of more slowly colonising competitor species in backwaters which functioned as refuges. Plants retained in this way included *Carex riparia* (great pond sedge), *Solanum dulcamara* (bittersweet) and *Nuphar lutea* (yellow water-lily).

The average rarity value of species remained approximately similar to the control reaches in the R. Cole. However, in the R. Skerne the aquatic plant community increased in rarity value due to the colonisation of 'locally common' species such as *Zanichellia palustris* (horned pondweed) and *Potamogeton crispus* (curled pondweed).

In both the R. Cole and the R. Skerne there was no evidence that released sediment or other potentially damaging impacts of the restoration work had any adverse impact on the downstream plant communities.

⁵ 'Locally uncommon' plants here refers to plant species recorded from between 100 and 600 km squares in Britain.

Table 7.1 Wetland plant species recorded from the River Skerne before restoration (1994) and after restoration (1996)

	Upstream 'control' sections				Restoration sections								Downstream 'Impact' sections			
	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8
	94	96	94	96	94	96	94	96	94	96	94	96	94	96	94	96
Aquatic plants																
<i>Callitriche stagnalis</i>	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>Callitriche</i> sp.	-	+	-	-	-	-	-	+	-	+	-	+	-	+	-	-
<i>Elodea canadensis</i>	-	-	-	+	-	-	-	+	-	-	+	-	-	-	-	-
<i>Elodea nuttallii</i>	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+
<i>Fontinalis antipyretica</i>	-	-	-	-	-	+	-	-	-	-	-	+	-	+	-	+
<i>Lemna minor</i>	-	+	-	+	-	+	-	+	+	+	+	+	-	+	-	+
<i>Potamogeton crispus</i> *	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Potamogeton pectinatus</i> *	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Ranunculus</i> sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
<i>Sparganium emersum</i> *	-	+	+	+	-	+	-	+	-	+	-	+	-	+	-	+
<i>Zannichellia palustris</i> *	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-
Aquatic plant total	1	5	2	5	1	7	2	8	2	5	3	6	1	6	1	5
Emergent plants																
<i>Agrostis stolonifera</i>	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Alisma plantago-aquatica</i>	-	-	-	-	-	-	-	+	+	-	+	-	-	+	-	-
<i>Angelica sylvestris</i>	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-
<i>Apium nodiflorum</i>	-	+	-	-	-	-	-	+	-	+	-	-	-	+	-	+
<i>Barbarea vulgaris</i>	-	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+
<i>Carex otrubae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
<i>Cirsium palustre</i>	+	+	+	+	+	+	+	-	-	-	+	-	-	-	-	-
<i>Deschampsia caespitosa</i>	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
<i>Epilobium hirsutum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Eupatorium cannabinum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
<i>Filipendula ulmaria</i>	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
<i>Glyceria notata</i>	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-
<i>Glyceria maxima</i>	+	-	+	-	+	+	+	-	+	-	+	+	+	+	+	-
<i>Impatiens glandulifera</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Juncus articulatus</i>	-	-	-	-	-	+	-	+	+	+	-	-	-	-	-	-
<i>Juncus buffonis</i> agg.	-	-	-	-	-	+	-	+	-	-	-	-	-	+	-	-
<i>Juncus effusus</i>	-	-	-	-	-	+	-	+	-	+	-	-	-	+	-	-
<i>Juncus inflexus</i>	-	-	-	-	-	+	-	+	+	+	+	-	-	+	-	-
<i>Lycopus europaeus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
<i>Nasturtium</i> sp.	-	-	-	-	-	+	-	+	-	+	-	-	-	+	-	+
<i>Petasites hybridus</i>	+	+	+	+	-	-	-	-	-	-	-	+	-	-	-	-
<i>Phalaris arundinacea</i>	-	+	+	+	+	+	+	+	-	+	-	+	+	+	-	+
<i>Persicaria amphibi</i>	-	-	+	+	-	+	-	-	-	-	-	+	-	+	-	-
<i>Persicaria maculosa</i>	+	-	+	+	+	+	-	+	-	+	-	-	+	+	-	-
<i>Ranunculus sceleratus</i>	-	-	-	-	-	+	-	+	-	+	-	-	-	+	-	+
<i>Rorripa palustris</i>	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Schoenoplectus lacustris</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
<i>Scrophulara auriculata</i>	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+
<i>Solanum dulcamara</i>	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	+
<i>Sparganium erectum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Symphytum officinale</i>	-	-	-	+	-	-	-	-	-	-	+	+	-	+	-	-
<i>Typha latifolia</i>	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Veronica beccabunda</i>	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+
<i>Veronica catenata</i> *	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Emergents total	9	14	12	14	10	20	9	22	11	17	10	15	9	24	5	13
All plants total	10	19	14	19	11	27	11	30	13	22	13	21	10	30	6	18

* = Local species

Table 7.2 Wetland plant species only present as introduced plants in the River Skerne before (1994) and after restoration (1996)

	Upstream 'control' sections				Restoration sections								Downstream 'Impact' sections			
	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8
	94	96	94	96	94	96	94	96	94	96	94	96	94	96	94	96
<i>Acorus calamus</i>	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Carex acutiformis</i>	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
<i>Carex riparia</i>	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-
<i>Carex</i> spp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Cyperus longus</i>	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Iris pseudacorus</i>	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-
<i>Lythrum salicaria</i>	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-
<i>Mentha aquatica</i>	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
<i>Myosotis scorpioides</i>	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Number of introduced species	0	0	0	0	0	3	0	9	0	4	0	0	0	0	0	0

8. AQUATIC INVERTEBRATES

8.1 Aims

The two main aims of the invertebrate monitoring programme were:

- to estimate the change in the species-richness and conservation value of the aquatic macroinvertebrate fauna in the years following restoration.
- to monitor the areas downstream of the restoration sites to assess impacts from the works.

8.2 Methods

The invertebrate monitoring on the R. Cole was based on detailed semi-quantitative sampling of nine survey stations (two upstream controls; four restoration sites; three downstream potentially impacted sites). Surveys were undertaken in two seasons (summer and autumn). On the R. Skerne, a less detailed semi-quantitative sampling programme was undertaken by Environment Agency North East Region at four survey sites (one upstream Control, two on the restoration site and one downstream).

8.3 R. Cole: Species richness and rarity of aquatic macro-invertebrate communities

In the restored sections of the R. Cole, the process of remeandering eliminated most of the original river channel (which was backfilled with spoil from the newly created sinuous channels). Colonisation therefore began in channels with no pre-existing invertebrate assemblages.

Species richness

Aquatic macroinvertebrates recolonisation was rapid in the R. Cole and by 1996, one after year restoration, species richness was only slightly below pre-restoration values (Figure 8.1). Statistically, there was a significant interaction between time (before vs. after) and location (control vs restored). This indicated that species richness in the restored channel had not fully recovered to pre-restoration levels (Figure 8.1; three-way ANOVA, $p=0.001$, $F = 49.93$, $df = 1, 8$). The two upstream control sites showed similar species richness values to each other throughout the project.

Species rarity

The average species rarity of macroinvertebrates colonising the restored R. Cole section was significantly lower than in the pre-existing channel (Figure 8.2; Mann-Witney U -test, $p<0.05$ for both restored sites), although by November 1996 four local or Nationally Scarce species had colonised the new channel (Table 8.1). Before the creation of the new channel began, thirteen local or Nationally Scarce species had been recorded in the restoration section, with a mean Species Rarity Index⁶ of 1.05 ('moderate' conservation value). After restoration mean SRI dropped slightly to 1.01. There were no significant changes before and after restoration in either the control or downstream section SRIs.

⁶ The derivation of Species Rarity Indices is explained in Section 7.2.4

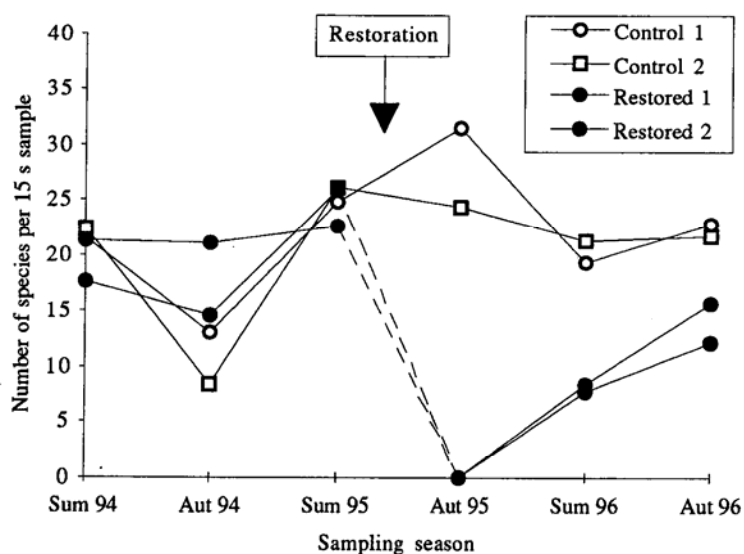


Figure 8.1 Aquatic invertebrate species richness on the R. Cole before and after restoration.

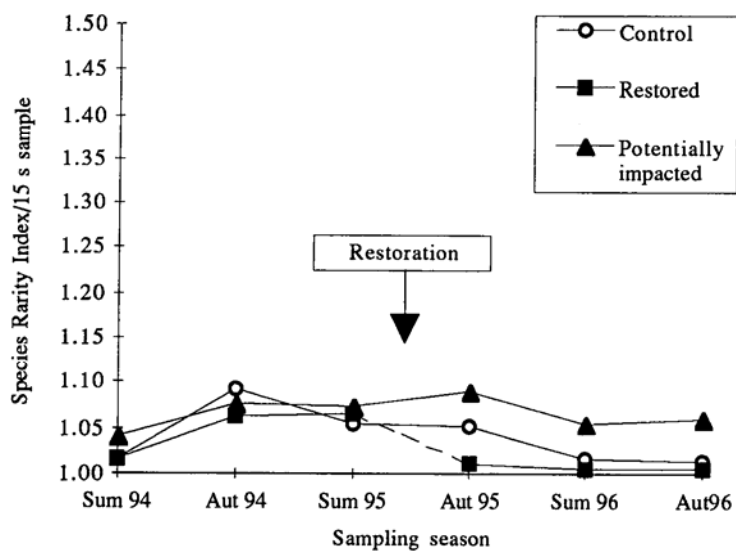


Figure 8.2 Aquatic invertebrate Species Rarity Index values on the R. Cole before and after restoration.

Table 8.1 Local and Nationally Notable species recorded in restored sections of the R. Cole before and after re-meandering**Local (Species Rarity Score = 2)**

Taxon	Species	Before	After
Mollusca	<i>Unio tumidus</i>	+	-
	<i>Sphaerium rivicola</i> (Lamarck)	+	-
Hirudinea	<i>Glossiphonia heteroclita</i> (L.)	-	+
	<i>Erpobdella testacea</i> (Savigny)	+	-
	<i>Trocheta subviridis</i> Dutrochet	+	-
	<i>Hemiclepsis marginata</i> (Müller)	+	-
Odonata	<i>Platynemis pennipes</i> (Pallas)	+	+
Heteroptera	<i>Micronecta scholtzi</i> (Fieber)	-	+
Megaloptera	<i>Sialis fuliginosa</i> Pictet	+	-
Trichoptera	<i>Mystacides nigra</i> (L.)	+	-
	<i>Phryganea grandis</i> L.	+	-
	<i>Limnephilus bipunctatus</i> Curtis	-	+
	<i>Potamophylax rotundipennis</i> (Brauer)	+	-

Nationally Scarce species (Species Rarity Score = 4)

Coleoptera	<i>Gyrinus urinator</i>	+	+
	<i>Riolus cupreus</i>	+	-
Megaloptera	<i>Sialis nigripes</i>	+	-

8.4 Downstream impact of restoration work on invertebrate communities

The downstream impact of restoration works on the invertebrate assemblages was assessed on the R. Cole at sites 300 m, 750 m and 1200 m downstream of the restoration works.

In the pre-restoration phase (summer 1994 to summer 1995) all three sites located downstream of the works showed similar trends in species richness to the upstream control sites (Figure 8.3). In both *upstream* control sections species richness increased immediately post restoration (i.e. in autumn 1995 compared with autumn 1994) with species richness more than doubling. However, in all three sections *downstream* of the works, species richness increased only slightly between autumn 1994 and 1995. This suggests that invertebrate richness underwent a moderate decline in all three sections downstream of the works in the autumn one to two months after the restoration was completed. This was evidenced by a highly significant interaction between time (before vs after) and season (summer vs autumn) (Figure 8.3; three-way ANOVA, $p=0.0001$, $F = 29.44$, $df = 1,12$).

Comparable assessments made during summer and autumn 1996 (up to one year after the main works) are more equivocal with no significant interaction between time and season (Figure 8.3; three-way ANOVA, $p=0.0001$, $F = 29.44$, $df = 1,12$).

Species Rarity Index values for the downstream sites (Figure 8.2) suggest little difference before and after restoration. Overall, therefore, whereas species richness may have shown a relative decline below the works, there was no evidence that uncommon species were at particular risk.

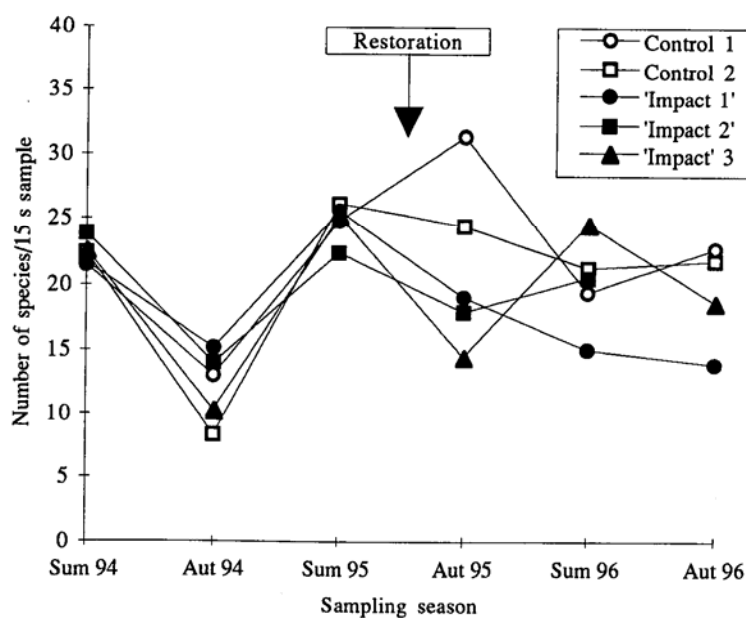


Figure 8.3 Aquatic invertebrate species richness in the potentially impacted area downstream of the R. Cole restoration site

8.5 R. Skerne invertebrate assemblages

Before restoration the four sites included in the R. Skerne monitoring programme all had similar numbers of BMWP families and ASPT scores. The number of taxa recorded varied from 13 to 19 (Table 8.2). The fauna of the river was dominated by a small number of resilient species including the water slater *Asellus aquaticus*, leeches and various water snails.

Control and downstream 'impact' sites showed no evidence of change between 1994/5 (before) and 1997 (after) restoration. This suggests that there were no obvious short-term changes in factors influencing invertebrate taxon richness or ASPT scores in the wider catchment of the R. Skerne, nor any persistent downstream impacts caused by the restoration works.

On the restoration site itself monitoring stations were located (i) downstream of Houghton footbridge and (ii) at John Street at the downstream end of the restoration site. At both sites there were no obvious changes in the invertebrate fauna. Pre-restoration taxa richness and ASPT scores were 13 and 3.11 respectively. After restoration there was little evidence of change, with taxa richness of 14.5 and an ASPT of 3.62. These differences were not statistically significant. However, it should be noted that there were no invertebrate monitoring sites on the new meanders as sites were established in 1994 before the design was finalised.

Table 8.2 R. Skerne: macroinvertebrate monitoring before and after restoration

	Pre-restoration						Post-restoration					
	TAXA			ASPT			TAXA			ASPT		
	Apr. 95	Jul. 95	Sep. 94	Apr. 95	Jul. 95	Sep. 94	Apr. 97	Aug. 97	Oct. 97	Apr. 97	Aug. 97	Oct. 97
<i>Control</i>												
u/s Mill Lane footbridge	n/s	15	19	n/s	4.47	4.21	14	17	20	4.07	3.76	4.65
<i>Restoration</i>												
d/s Houghton Road Bridge	n/s	13	13	n/s	3.38	3.54	9	14	16	2.89	3.36	3.81
John Street	13	14	17	4.08	3.50	4.06	15	16	17	4.33	3.63	3.71
<i>Downstream</i>												
Darlington Town Hall	n/s	13	17	n/s	3.31	4.00	15	16	17	4.20	3.69	4.29

9. FISH

9.1 Aims

The aim of the fish monitoring programme was to assess the changes in fish species richness and biomass in the rivers as a result of restoration. As well as contributing to the ecological description of the site, the data provided information which contributed to assessment of the amenity and economic benefits of river restoration for fisheries (see Chapter 11).

9.2 Methods

All survey work was undertaken by Environment Agency Fisheries staff. Surveys used standard electro-fishing techniques. Methods are described in detail in NRA (1995).

Fish surveys were undertaken in spring 1995 (pre-restoration) and spring 1997, approximately eighteen months after restoration was completed.

9.3 Results

9.3.1 R. Cole fish populations

On the R. Cole the fish populations before restoration (spring 1995) were considered to be of high quality (with a biomass of 39 g m^{-2}) in the gravelly riffle downstream of Coleshill Bridge but of lower quality in the more impounded sections in the upstream half of the restoration site.

After restoration, fish biomass and density in the R. Cole quickly returned to pre-restoration levels. Highest biomasses and densities in the restored section were found in areas of gravelly eroding substrate (respectively, 35.6 g m^{-2} and $1.04 \text{ individuals m}^{-2}$).

Perhaps surprisingly, however, the highest biomasses and densities were seen in the downstream impact reach just below the restoration site where biomass was 78.4 g m^{-2} (at least double all other sites in the R. Cole) and fish density was $1.4 \text{ individuals m}^{-2}$ (also higher than all other sites). Environment Agency fisheries staff suggest that the high abundance of fish in this area may have been a reflection of the improved quality of habitat in the restored section, with fish resting in this area before moving into the faster flowing shallower water of the restored reach to spawn.

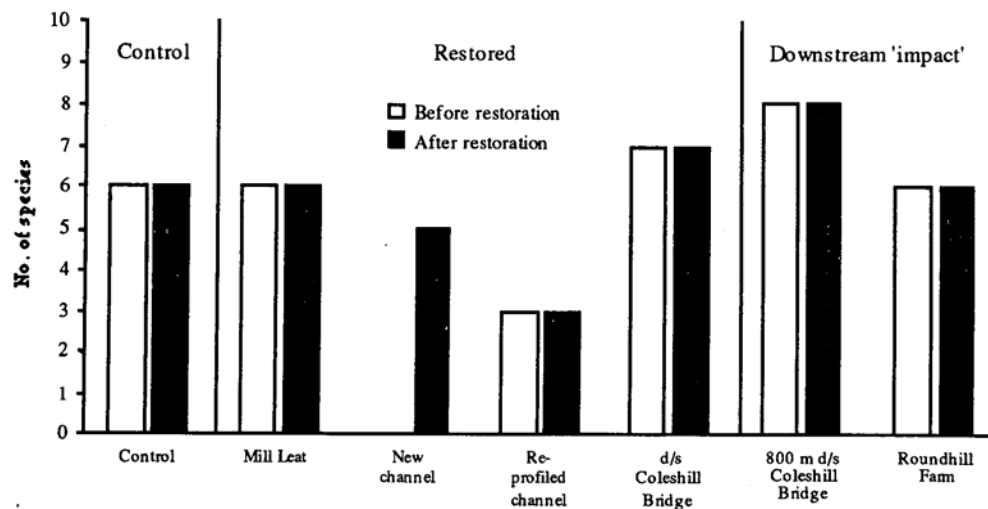
The upstream control site showed a slight decline in biomass, from 34.3 g m^{-2} in 1995 to 28.7 g m^{-2} in 1997, with a corresponding decline in density (0.994 to $0.255 \text{ individuals m}^{-2}$).

Fish species richness generally remained unchanged both in the restoration site and the control and impact reaches.

Table 9.1 Results of fish surveys on the R. Cole

	Species type	Before restoration (1995)		After restoration (1997)	
		No. of spp.	Biomass (g m ⁻²)	No. of spp.	Biomass (g m ⁻²)
Control (Upstream) reaches					
Fresden Farm (CLF4)	Angling species	6	34.3	6	28.7
	Other species	3	-	4	-
Restoration reaches					
Mill Leat (no structural change) (CLF5)	Angling species	6	5.8	5	10.3
	Other species	2	-	2	-
New channel, u/s Coleshill Bridge	Angling species	-	-	4	20.5
	Other species	-	-	4	-
Old channel course (re-profiled) (CLFE)	Angling species	3	Low biomass*	7	18.1
	Other species	4	-	4	-
New channel d/s of Coleshill Bridge (CLFC)	Angling species	7	38.9	5	35.6
	Other species	3	-	3	-
Downstream 'impact' reaches					
800m d/s Coleshill Bridge (CLFD)	Angling species	8	26.6	8	78.4
	Other species	0	-	3	-
Roundhill Farm (CLF6)	Angling species	6	29.4	6	22.9
	Other species	4	-	4	-

* = Qualitative survey, where catch depletion electrofishing was not possible.

**Figure 9.1 R. Cole fish populations before and after restoration: fish species richness**

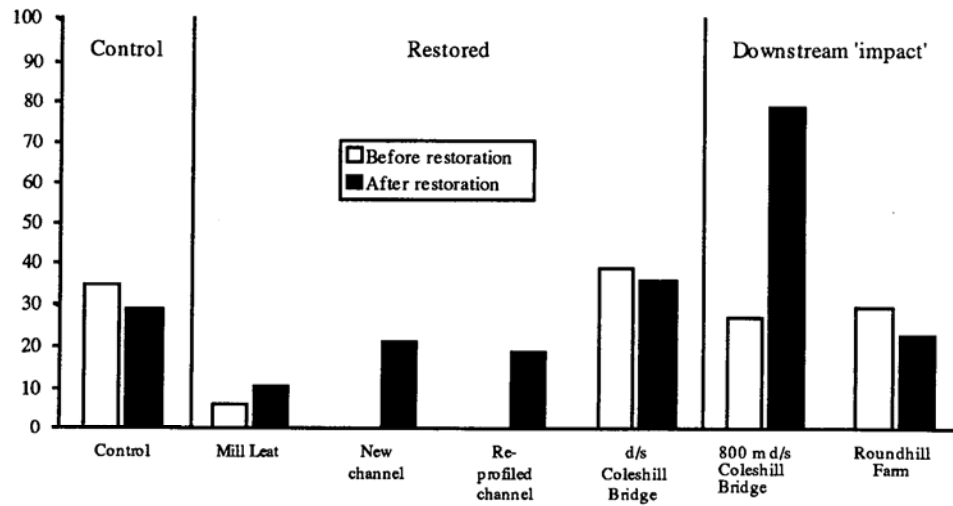


Figure 9.2 R. Cole fish populations before and after restoration: fish biomass.

9.3.2 R. Skerne fish populations

On the R. Skerne prior to restoration, the demonstration site supported mainly 'minor' species (e.g. Three-spined Stickleback *Gasterosteus aculeatus* and Stone Loach *Neomachilus barbatus*) and the only angling species present were stocked Brown Trout (*Salmo trutta*). Dace, which had also been stocked were not recorded at any site in the study area prior to restoration. Brown Trout and 'minor' species also comprised the fauna in the upstream control section and the downstream impact reach.

After restoration on the R. Skerne, the first Roach (*Rutilus rutilus*) and Chub (*Leuciscus cephalus*) to be recorded in this part of the river for some years (i.e. upstream of South Park Weir) were recorded in the restored river reaches. These fish, together with a small number of Dace (wild fish, not those stocked in the early 1990s), had probably swum up the river using the newly installed fish pass below Darlington. Two Brown Trout were also recorded in this area, remnants of earlier stocking.

Although fish species richness clearly increased in the restored section of the R. Skerne, the number of individuals was small (the total catch of Brown Trout, Dace, Chub and Roach was only 16 fish) and biomasses of individual species were less than 1 g m^{-2} .

Angling species were not found in either the upstream control or downstream impact reaches confirming that the observed increases in the richness of the restored section were likely to be a 'real' result of the restoration works. 'Minor' fish species remained abundant in the restored reach with little evidence of changes either in this area or in the upstream control and downstream 'impact' reaches.

9.3.3 Pollution of the R. Skerne in autumn 1997

On 29 September 1997 and again in 14 November, pollution incidents caused severe fish kills on the R. Skerne.

In the September incident, a 6 km stretch of the river was affected, with apparent impacts ending just upstream of the restoration site. This incident killed large numbers of fish. The second incident affected the restoration site and may have eliminated fish which had recolonised since the installation of the new fish weir at South Park. It is not yet known what effect either incident had on the fish population of the restoration site.

Table 9.2 R. Skerne fisheries survey results: before (1994/95) and one year after (1997) restoration

Site	Species	Before restoration		After restoration	
		1994/95		1997	
		No. of individuals	Biomass (g m ⁻²)	No. of individuals	Biomass (g m ⁻²)
Control					
Ketton Bridge	Brown Trout	61	0.9	-	-
	Stone Loach	++	-	+	-
	Minnow	++	-	++	-
	Eel	+	-	+	-
Burdon Hall	Brown Trout	96	0.9	-	-
	Dace	-	-	8	n/a
	3-spined Stickleback	+++	-	+++	-
	Stone Loach	+++	-	+++	-
	Eel	1	-	+	-
Restoration					
Haughton Bridge	Brown Trout	4	0.2	2	2.0
	Dace	-	-	8	0.2
	Roach	-	-	3	0.3
	Chubb	-	-	3	0.8
	Eel	++	-	+	-
	3-spined Stickleback	++	-	++	-
	Stone Loach	-	-	++	-
Riverside Way	3-spined Stickleback	++	-	+++	-
	Stone Loach	+++	-	++	-
	Brook Lamprey	1	-	-	-
	Eel	-	-	+	-
Potentially impacted					
Albert Road Bridge	Minnow	+	-	-	-
	Stone Loach	+	-	++	-
	Eel	-	-	+	-
	Stickleback	-	-	+++	-

10. BIRDS

10.1 Introduction

The aim of the bird monitoring programme was to determine whether populations of breeding and overwintering birds changed following river restoration on the demonstration sites. There was specific interest in 19 target wetland bird species of high nature conservation interest (Table 10.1).

10.2 Survey methods

Birds were surveyed by making counts along transects and (on the R. Cole only) within 'compartments' (mainly fields). Transect counts were primarily intended to monitor changes in populations of riverside species and passerines. Compartment counts were mainly intended to assess the presence of breeding waders and, potentially, waterfowl using flooded grasslands. In the current report data are presented for the R. Cole only. Data from the R. Skerne have yet to be received.

Table 10.1 Wetland associated birds which may benefit from river restoration: monitoring programme 'target' species

Species	Reason for interest
Mute Swan	Recovering from decline in central Southern England and Midlands
Lapwing	National decline
Snipe	Decline on lowland grassland (candidate Red Data Book Species)
Redshank	Decline on lowland grassland (candidate Red Data Book Species)
Curlew	Uncommon breeding wader in lowland England.
Shoveler	Probably declined nationally between 1968-72 and 1988-91.
Teal	Nationally declining species.
Garganey	Nationally rare breeding species
Moorhen	Common species; abundance reduced by river channelisation.
Coot	Common species; abundance probably reduced by river channelisation.
Water Rail	Evidence of national decline between 1968-72 and 1988-91.
Barn Owl	National decline; often forages in river valleys
Kingfisher	Possible population declines due to river pollution and engineering
Yellow Wagtail	Wetland species perhaps affected by land drainage
Grey Wagtail	National decline (climate, and possibly habitat degradation related).
Grasshopper Warbler	National decline; associated with wetland habitats
Sedge Warbler	Wetland species; climate related declines.
Reed Warbler	Wetland species
Reed Bunting	National decline

10.3 Results

Table 10.2 shows the mean number of contacts per transect for wetland bird species on the R. Cole before and after restoration. The mean number of contacts for all other bird species are shown in Table 10.3.

Prior to restoration, the breeding bird assemblages on the R. Cole demonstration site were typical of intensively managed rural landscapes. Of the 19 wetland 'target' species identified as potentially able to benefit from river restoration, five were believed to be breeding on the site at the beginning of the project (Table 10.2).

One year after restoration there was no change in the number of wetland species breeding on the R. Cole site. However, there was a significant increase in the abundance of yellow wagtails (*Motacilla flava*), one of the wetland species already using the restoration area. This contrasted with an apparent decline in the abundance of yellow wagtails on the control site.

Table 10.2 Mean numbers of contacts per transect with 'target' wetland bird species on the R. Cole before and after restoration.

Species believed to be breeding on the demonstration site are highlighted in bold.

	Control			Restoration		
	1994	1996	Signif. Change	1994	1996	Signif. Change
Canada goose	0.00	0.00	None	0.78	0.02	None
Common gull	0.00	0.00	None	0.00	0.06	None
Curlew	0.63	0.08	None	0.06	0.00	None
Grey heron	0.13	0.17	None	0.11	0.11	None
Grey wagtail	0.00	0.00	None	0.00	0.02	None
Kingfisher	0.25	0.00	None	0.06	0.06	None
Lapwing	7.25	0.08	None	0.08	0.11	None
Moorhen	0.00	0.17	None	0.53	0.26	None
Mute swan	0.00	0.17	None	0.00	0.06	None
Pied wagtail	0.00	0.00	None	0.00	0.20	None
Redshank	0.00	0.00	None	0.00	0.02	None
Reed bunting	1.25	1.75	None	0.64	0.65	None
Reed warbler	0.00	0.17	None	0.00	0.02	None
Sand martin	0.00	0.00	None	0.00	0.02	None
Sedge warbler	0.13	0.58	None	0.00	0.07	None
Yellow wagtail¹	2.63	1.42	Down**	0.33	0.59	None

¹Yellow wagtail showed a significant increase along Transect 1a on the restoration site before and after restoration ($p < 0.05$).

Significance level: * $P < 0.05$, ** $P < 0.01$

Table 10.3 Mean numbers of bird contacts per transect on the R. Cole before and after restoration

	Control			Restoration		
	1994	1996	Signif. Change	1994	1996	Signif. Change
Blackbird	2.00	0.42	Down*	1.03	0.63	None
Blackcap	0.00	0.00	None	0.17	0.07	None
Blue tit	0.38	0.25	None	1.61	0.76	None
Bullfinch	0.00	0.00	None	0.03	0.02	None
Carion crow	0.00	0.17	None	0.03	0.11	None
Chaffinch	4.25	3.33	None	2.61	1.78	None
Chiffchaff	0.00	0.00	None	0.11	0.19	None
Collared dove	0.00	0.00	None	0.06	0.00	None
Cuckoo	0.00	0.08	None	0.00	0.02	None
Dunnock	1.13	0.25	None	0.33	0.11	None
Fieldfare	0.00	0.00	None	0.00	0.02	None
Goldfinch	0.75	0.08	Down*	0.58	0.35	None
Great spotted woodpecker	0.00	0.00	None	0.06	0.11	None
Great tit	1.88	0.33	None	0.53	0.22	None
Green woodpecker	0.00	0.00	None	0.00	0.00	None
Greenfinch	0.00	0.08	None	0.31	0.15	None
Grey partridge	0.00	0.00	None	0.03	0.00	None
Hobby	0.00	0.00	None	0.00	0.00	None
House martin	2.75	0.00	None	0.14	0.15	None
House sparrow	0.00	0.00	None	0.00	0.00	None
Jackdaw	0.13	0.00	None	0.94	0.19	None
Jay	0.00	0.00	None	0.00	0.00	None
Kestrel	0.00	0.00	None	0.03	0.06	None
Lesser Black-backed Gull	0.13	0.00	None	0.06	0.00	None
Lesser whitethroat	0.00	0.00	None	0.14	0.04	None
Linnet	2.88	1.92	None	0.17	0.24	None
Little owl	0.00	0.00	None	0.03	0.02	None
Long-tailed tit	0.50	0.00	None	0.58	0.09	None
Magpie	0.00	0.00	None	0.11	0.04	None
Mallard	0.88	0.67	None	0.94	0.35	None
Marsh tit	0.00	0.00	None	0.00	0.02	None
Meadow pipit	0.00	0.00	None	0.00	0.04	None
Mistle thrush	0.13	0.00	None	0.19	0.11	None
Pheasant	0.13	0.17	None	0.14	0.17	None
Quail	0.00	0.00	None	0.00	0.00	None
Red legged partridge	0.25	0.50	None	0.06	0.26	None
Redpoll	0.00	0.00	None	0.00	0.00	None
Robin	0.00	0.00	None	0.39	0.43	None
Rook	0.75	0.00	None	1.36	0.06	None
Skylark	2.88	1.92	None	0.39	0.24	None
Song thrush	0.00	0.00	None	0.14	0.07	None
Sparrowhawk	0.00	0.08	None	0.00	0.04	None
Spotted flycatcher	0.00	0.00	None	0.14	0.04	None
Starling	3.00	0.17	None	0.36	0.11	None
Stock dove	0.50	0.08	None	0.00	0.04	None
Swallow	0.13	0.67	None	0.56	0.52	None

Table 10.3 Mean numbers of bird contacts per transect on the R. Cole before and after restoration (continued)

	Control			Restoration		
	1994	1996	Signif. Change	1994	1996	Signif. Change
Swift	7.00	0.08	Down**	0.89	0.06	None
Wheatear	0.00	0.08	None	0.00	0.00	None
Treecreeper	0.00	0.00	None	0.06	0.00	None
Whitethroat	0.63	0.67	None	0.11	0.26	None
Willow warbler	0.25	0.00	None	0.17	0.09	None
Woodpigeon	3.13	0.83	Down*	4.08	0.98	None
Wren	2.00	0.33	Down**	1.11	0.57	None
Yellowhammer	3.38	1.58	None	0.25	0.35	None

There was no evidence of wading birds breeding on the R. Cole site, other than Lapwing, which also bred prior to restoration. On the control site, however, there were significant declines during the study in the abundance of four common farmland/woodland species which were not matched by changes on the restoration site: Blackbird (*Turdus merula*), Goldfinch (*Carduelis carduelis*), Woodpigeon (*Columba palumbus*) and Wren (*Troglodytes troglodytes*) (Table 10.2). Numbers of contacts with Swifts were also lower.

11. PUBLIC PERCEPTION

11.1 Introduction and aims

The aim of the public perception study was to assess the public appreciation of the objectives and effects of river restoration. The study focused mainly on the R. Skerne restoration site and was designed to (i) evaluate people's views about the river and (ii) to investigate the value of the scheme in economic terms. A smaller post-restoration study was undertaken on the R. Cole.

The public perception study on the R. Skerne had two main stages: (i) a pilot study which made a preliminary assessment of Darlington residents' attitudes to the project; and (ii) a detailed questionnaire survey to investigate the views residents about the restoration of the river. The questionnaire survey was repeated following the completion of the works to investigate the way in which the completed scheme was perceived in practice.

On the R. Cole public perception of the restoration scheme was assessed following the completion of the practical works.

The public perception study was carried out by the Flood Hazard Research Centre (FHRC). Full results are reported in Tapsell *et al.* (1997). This chapter gives a summary of the results from this study.

11.2 Methods

In the structured quantitative survey of local residents in Darlington, the population was defined as those households living in roads within 400 metres from the section of the R. Skerne between Skerne Bridge and Haughton Bridge. A systematic random sample was drawn from the electoral register for Darlington. The total population within the study area was 4,706. As 600 addresses were felt to be necessary to achieve a target of 250 interviews, a sampling interval of eight was arrived at (4,706 divided by 600) and every eighth address was selected for inclusion in the survey. In total, 432 valid addresses were finally approached. The response rate was 58%, giving a quantitative survey of 252 local residents. In the follow-up survey in 1997 260 interviews were undertaken of which 136 were residents which had been first interviewed in 1995.

On the R. Cole interviews with 36 local residents were undertaken in 1997, following targeting of all residences in the village (the electoral register listed only 133 addresses in total). Although the sample population in Coleshill was small it covered around half the households in the village. There were no pre-restoration interviews on the R. Cole.

11.3 Results: R. Skerne

11.3.1 Use of the river and surrounding area

The perception study showed that the R. Skerne demonstration site and surrounding area were well used by local residents for informal recreation activities. A surprisingly high proportion of respondents (85%) visited the river and adjacent floodplain parkland, many on a regular basis both in winter and summer (Figure 11.1). Respondents spent, on average, between 16 and 30 minutes visiting the river.

A variety of reasons were given by respondents for these visits, the most popular being walking and access to elsewhere. Walking the dog and wildlife were amongst the other main reasons for visiting (Figure 11.2).

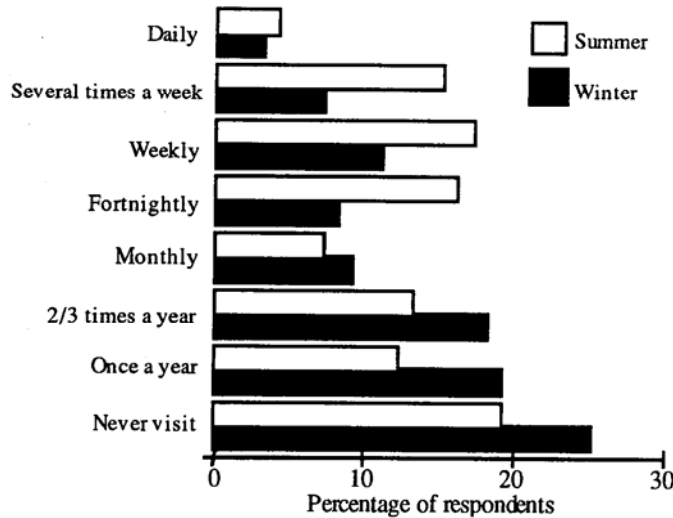


Figure 11.1 Frequency of visits to the R. Skerne

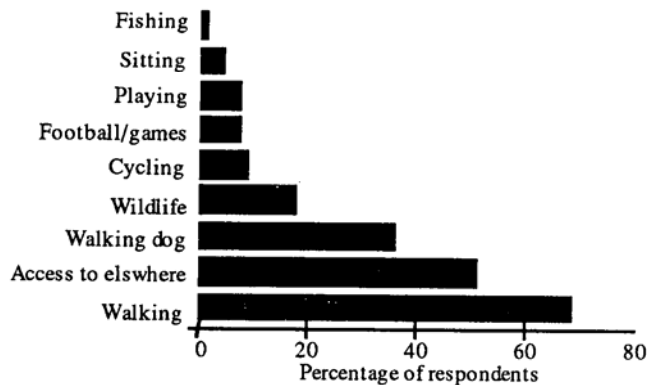


Figure 11.2. Purpose of visits to the R. Skerne

11.3.2 Perception of the river and surrounding parkland

The main attractions of the river area were said to be quiet open space, the more natural habitat, plants and other vegetation, and the wildlife. Several features were mentioned by respondents as aspects they disliked about the area prior to restoration. These included dog fouling, the 'dirty and smelly' river, rubbish and litter. A number of respondents also mentioned the local 'vandals' who used the area.

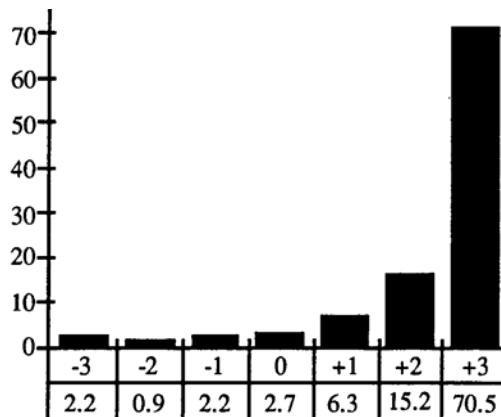


Figure 11.3 Ratings in favour of the scheme as percentage of respondents visiting river (-3 = strongly against scheme, +3 = strongly in favour of the scheme).

11.3.3 Perceptions of the river restoration scheme before the works were undertaken

The proposals for the river restoration scheme were generally welcomed by the majority of the respondents and seen as being a great improvement to the local area (Figure 11.3). The vast majority of respondents (92%) were in favour of the river restoration scheme, 71% strongly in favour. It was felt by 64% of respondent that they would visit the river more often if the proposed scheme were to be carried out. One third of respondents said that they would definitely get more enjoyment from visiting the river should the scheme be completed, and over half felt that they would get more enjoyment from their visits. Concern was expressed by a minority of respondents that the additional vegetation could provide a cover for criminals and burglars.

The restoration project proposal for an additional footbridge and footpaths were generally welcomed: very few residents totally rejected these proposals, which opened up the potential for a circular walk using both sides of the river. Most respondents were in favour of refurbishment of the existing bridge, as well as the provision of an additional bridge.

11.3.4 Economic benefits from restoring the river

Over half the respondents who visited the river were able to place a monetary value on their enjoyment of visiting the river. Results should, however, be treated as provisional, as the population sample was too small for a reliable Contingent Valuation Method study to be undertaken.

Results from both the enjoyment valuation and willingness-to-pay questions in the survey suggest that there was a monetary benefit to be obtained in improving the river and surrounding parkland. In particular, respondents were willing to pay significant sums in additional national and local taxes each year for a R. Skerne restoration scheme (Table 11.1). These findings are broadly comparable with other studies carried out by the Flood Hazard Research Centre.

Table 11.1 The mean value of enjoyment of visit by visitor type

Visitor type	Before scheme			After scheme		
	Respondent able to value		Value given	Respondent able to value		Value given
	n	%		n	%	
Riverside properties	12	66%	£4.67	11	61%	£7.75
Within 250m	29	43%	£6.25	32	47%	£8.53
Between 250-500m	44	56%	£5.15	39	50%	£6.22
Over 500m	36	40%	£7.27	33	37%	£8.45
All respondents	121	48%	£6.00	115	45%	£7.65

11.3.5 Public consultation and involvement in site management

Respondents gave a high importance to the issue of public consultation, and half of them rated this as very important. The most preferred form of consultation was letters or leaflets, although personal visits and public meetings were also quite popular. Many respondents were pleased to have been consulted over the proposed scheme: this gave them a feeling of involvement and a sense that their views were regarded as important. It is recommended that local people should continue to be kept informed at all stages of the project development and construction. There appeared to be a valuable opportunity to utilise local resources (i.e. people and their skills and knowledge) in management of the site.

11.3.6 Perceptions of the R. Skerne following restoration

Following the completion of the works, the majority of Darlington residents expressed approval of the scheme, with 53% mostly approving and 17% strongly approving. The 8% of residents who did not approve of the scheme mainly gave as their reasons the cost of the works or because they did not see the need for the scheme.

Despite the overall approval of the scheme, residents did not report much change in their visiting patterns to the river. This was perhaps to be expected given the very high level of visiting already experienced on the R. Skerne. In addition, at the time of the survey, a bridge providing a circular walk along the river had not been completed. However, the results did suggest that enjoyment of visits had increased after the works were completed.

The majority of Darlington residents (63%) felt that the river landscape had increased in attractiveness after the restoration scheme was completed. This was despite the recent completion, and therefore comparative immaturity, of the landscaping. However, respondents in the 1997 survey had a slightly less positive and more uncertain view on the effects of the scheme on wildlife and river habitats, riverside safety for children and recreational opportunities, compared to their pre-restoration views. The most marked change was in the proportion regarding the river changes as offering increased recreational opportunities: 64% in 1995 compared to 40% in 1997. Broadly, though, the scheme lived up to the high expectations that Darlington residents had placed on it in 1995.

Approval for the scheme appeared to be slightly more qualified after the scheme than before. After the scheme was completed, 30% 'strongly approved' compared to 70% approving strongly beforehand. Overall, however, the view of the scheme was consistently favourable.

11.4 Results: R. Cole

64% of respondents had visited the R. Cole in the 12 months before the survey (compared to 81% in Darlington). Frequency of visiting was also lower with only 28% visiting weekly or more often in summer, compared to 63% on the R. Skerne.

Reasons for visiting were similar on the R. Cole to the R. Skerne.

A lower proportion of Coleshill residents thought the restoration schemes 'very good' or 'quite good' value for money: 42% compared to 63% on the R. Skerne. The residents of Coleshill were also notable for the high proportion who thought it too soon to tell if the scheme was good value for money (42%, compared to 12% on the R. Skerne). A lower proportion also thought that there had been an increase in wildlife and wildlife habitat (28% compared to 70% on the R. Skerne).

Although slightly more uncertain about the benefits of the scheme, the residents of Coleshill did broadly approve. 53% 'mostly approved' and 17% 'strongly approved', compared to 52% and 30% 'mostly' or 'strongly' approving on the R. Skerne. The slightly lower approval rating on the R. Cole may have, in part, reflected the fact that the river was less obviously degraded at the beginning of the project than the R. Skerne.

12. ECONOMIC APPRAISAL

12.1 Aims

The potential for widespread implementation of river restoration schemes will inevitably depend, to a large extent, on their potential to provide economic benefits. The aim of this section of the project was, therefore, to make a first assessment of the likely overall economic benefits which river restoration could provide. The main areas of potential assessed were:

- agriculture and water quality,
- amenity,
- fisheries,
- flood defence,
- recreation.

The combined benefits in each of these areas was evaluated, and projected forwards over 25 years to give an assessment of the medium term benefits of restoration.

12.2 Methods

The economic benefits of restoration were assessed using the procedures set out by the Foundation for Water Research (1996) and the Environment Agency (1997). For most potential benefit categories, lower, middle and upper bounds were calculated. This was necessary to reflect uncertainty in willingness to pay values and other key variables (such as estimates of numbers of people visiting the restoration sites). Further information about project methodology is given by Risk and Policy Analysts (1997).

12.3 Results

12.3.1 Agriculture and water quality

Agriculture

Diversification, creation of new rural enterprises and extensification were identified as potential agricultural benefits which could occur as a result of river restoration in the rural environment. The assessment also took into account direct benefits to farmers from reduction of fertiliser and pesticide applications, and of labour input. Benefits on the R. Cole were calculated using these payments giving an upper bound of £25,000, a mid bound of £19,000 and a lower bound of £0.

Water quality

As the relatively small lengths of river channel altered at both the R. Cole and R. Skerne restoration sites produced no significant alteration in water quality, further analysis of water quality improvements was not undertaken. It is likely that a modelling approach will be necessary to fully assess the catchment-scale benefits of restoration for water quality.

12.3.2 Amenity

Amenity was treated for the purposes of the study as synonymous with property values. It was assumed, using the Foundation for Water Research (FWR) manual, that only houses lying within 2000 feet of rivers would experience a price premium.

In the case of the R. Cole it was considered unlikely that river restoration would alter property values given the historic status and character of the village. On the R. Skerne a number of properties did lie sufficiently close to the river to attract a price premium. A range of benefits was arrived at by assuming premiums applied to all houses within 2000 feet (the upper bound), all houses with direct access to the river (the middle bound), and all houses directly adjoining the river (the lower bound). Benefits were calculated using the Halifax House Price Index to give upper bound benefits of £55,000, mid bound benefits of £13,000 and lower bound benefits of £6,300.

12.3.3 Fisheries and benefits to anglers

Benefits to anglers were calculated with the assumption that, in the medium term, the R. Cole could be expected to improve from a moderate to a good fishery, and the R. Skerne from having no coarse fishery to a poor quality coarse fishery. Categories were taken from the FWR manual (Foundation for Water Research 1996).

For both the R. Cole and R. Skerne, the lower bound estimates used the number of fishing trips and a willingness to pay from increased enjoyment. Willingness to pay and extra trips following improvements were based on the data in the FWR Manual. In addition, on the R. Skerne, the number of residents expecting their enjoyment to increase as reported in the public perception study (Chapter 11) were also included in the assessment. Estimates of the middle, upper and lower bounds are shown in Table 12.1.

Table 12.1 Economic benefits associated with fisheries improvements on the R. Cole and R. Skerne

Bound	R. Cole	R. Skerne
Upper bound	£3,600	£5,600
Mid bound	£1,500	£2,400
Lower bound	£180	£1,000

12.3.4 Flood defence

The potential benefits of restoration with respect to flood defence include:

- reductions in flood damages,
- reduced maintenance costs (both for flood defence works and river maintenance),
- reduced land drainage costs.

Reduced river maintenance costs are the only benefit for the R. Cole. Benefits are however likely to be small with an upper bound estimate of £500, a mid bound estimate of £250 and a lower bound estimate of £0.

12.3.5 Recreation and conservation non-use benefits

To estimate the benefits of recreation and conservation non-use benefits, standard visitor figures and willingness to pay per visit figures were used. Overall the benefits were (i) upper bound £230,000 (ii) mid bound £82,000 and (iii) lower bound £25,000.

12.3.6 Overall benefits

The overall annual economic benefits of restoration on the R. Cole covered a range from £38,000 to £347,000. For the R. Skerne the equivalent values were £30,000 to £181,000 annually.

The largest benefits come from recreation and conservation benefits. If these benefits are excluded, the upper, mid and lower bound values for the R. Cole become £176, £20,000 and £29,000. If the mid bound values are taken then the restoration provides *annual benefits* of about £10,000 per kilometre restored.

On the R. Skerne, the equivalent values (excluding recreation and non-use conservation benefits) were £6,000, £16,000 and £61,000 for lower, mid and upper bound estimates.

A very conservative estimate of the 25 year benefits of the schemes was made (i.e. excluding all the benefits based on public willingness to pay for enhanced landscape and conservation non-use benefits). On the rural R. Cole, the benefits are estimated to be in the order of £67,000 per kilometre of river (assuming that the mid-bound estimate of benefit is the most likely scenario). On the urban R. Skerne the overall benefits are between £600,000 per kilometre and £60,000 per kilometre, due mainly to an increase in the value of riverside properties (Table 12.2).

Overall, assuming the benefits from restoration lie between the lower and middle bound, and excluding (i) any water quality benefits (ii) all non-use recreational benefits (which are large but widely disputed), the economic benefits of restoration probably approach the cost per kilometre of undertaking the schemes.

Table 12.2 Economic benefits over 25 years per kilometre⁷ of restored river (discounted at 6% according to Treasury guidelines)

R. Cole	Upper bound	Mid bound	Lower bound
Agriculture	£157,000	£120,000	£0
Fisheries	£23,000	£10,000	£1,000
Flood defence	£3,000	£2,000	£0
Total	£183,000	£134,000	£1,000
R. Skerne			
Amenity (house prices)	£1,400,000	£333,000	£158,000
Fisheries	£72,000	£31,000	£13,000
Total	£1,472,000	£364,000	£171,000

⁷ For the purposes of the analysis it is assumed that on the R. Cole 2 km of river was restored and on the R. Skerne 1km was restored.

13. CONCLUSIONS

The restoration works resulted in major improvements to the physical structure of both the R. Cole and R. Skerne.

The early results of the monitoring programme suggest that, ecologically, the restoration sites recovered rapidly from the initial disturbance caused by the works, and are currently beginning to show some evidence of ecological improvement above pre-restoration levels. This is particularly evident in species richness of the wetland plant community at both restoration sites and, on the R. Skerne in particular, the return of fish species such as Roach, Chubb and Dace to a section of the river from which they had been absent for many years. Changes on the floodplains are likely to be naturally slow and may have been slowed further by the recent drought. Despite this, increases in the abundance of at least one wetland bird, Yellow Wagtail, were observed on the R. Cole.

A high level of public appreciation for the restoration work was evident at both sites, but particularly the urban R. Skerne where.

Economic analyses of the benefits of the restoration work, give positive results which suggest that, over 25 years the costs of restoration probably approach the cost per kilometre of undertaking the schemes.

Both newly restored rivers are still in a very active phase of their development and, with less than two years of year's post-project assessment data it is too early to draw general conclusions from the project. Future monitoring of the sites (now largely assured) will be critical in providing information on the real success of the restoration works in the medium and longer term.

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Appendix 1. Wetland plant species recorded from the restored sections of the River Cole before (1994), during (1995) and after restoration (1996).

	Mill leat upstream of Coleshill Bridge									Restored channel downstream of Coleshill Bridge						New small channel	
Site	7	7	7	6	6	6	5	5	5	4	4	4	3	3	3	A	B
Year	94	95	96	94	95	96	94	95	96	94	95	96	94	95	96	96	96
Aquatic species																	
<i>Callitriche</i> sp.	-	-	-	-	-	+	-	+	+	+	+	+	+	+	-	+	+
<i>Elodea canadensis</i>	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-
<i>Elodea nuttallii</i>	-	-	-	+	-	-	+	-	+	+	-	-	-	-	-	-	-
<i>Lemna minor</i>	-	+	+	-	+	+	+	+	+	+	+	+	-	-	+	-	-
<i>Myriophyllum spicatum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	-
<i>Nuphar lutea</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
<i>Potamogeton crispus</i>	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Potamogeton pectinatus</i>	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+	-	-
<i>Ranunculus penicillatus</i>	+	+	+	+	+	+	+	-	+	+	-	-	-	-	-	-	-
<i>Sagittaria sagittifolia</i>	-	-	-	-	-	-	-	+	-	+	+	+	+	+	+	-	-
<i>Sparganium emersum</i>	-	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-
<i>Fontinalis antipyretica</i>	+	+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	-
AQUATIC SPECIES	4	7	7	7	7	7	8	7	9	10	7	8	6	5	6	2	1
RICHNSS																	
Emergent wetland plants																	
<i>Agrostis stolonifera</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Alisma lanceolatum</i>	-	+	-	-	-	+	-	-	-	+	+	+	-	-	+	-	+
<i>Alisma plantago-aquatica</i>	-	-	-	+	-	-	+	+	+	+	+	+	+	+	+	+	+
<i>Alopecurus geniculatus</i>	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	+	+
<i>Angelica sylvestris</i>	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	-
<i>Apium nodiflorum</i>	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Barbarea vulgaris</i>	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+
<i>Bidens tripartita</i>	-	-	-	-	-	+	-	-	+	-	+	+	-	+	-	-	-
<i>Butomus umbellatus</i>	+	+	+	-	-	-	+	-	+	-	+	-	-	+	-	-	-
<i>Carex acutiformis</i>	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-
<i>Carex riparia</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
<i>Cirsium palustre</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
<i>Conium maculatum</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-
<i>Deschampsia caespitosa</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
<i>Epilobium hirsutum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Eupatorium cannabinum</i>	+	+	+	+	+	+	-	-	-	+	+	+	+	+	-	-	-
<i>Filipendula ulmaria</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
<i>Glyceria maxima</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Glyceria fluitans</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
<i>Glyceria notata</i>	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Juncus articulatus</i>	-	-	-	-	-	+	-	-	+	-	-	-	+	+	-	+	+
<i>Juncus bufonis</i> agg.	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	+	+
<i>Juncus inflexus</i>	-	-	-	-	-	+	+	-	+	+	+	+	+	+	+	+	+
<i>Juncus effusus</i>	-	-	-	-	-	+	+	-	+	+	+	+	+	+	+	+	+
<i>Lycopus europaeus</i>	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Lysimachia nummularia</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-

(cont.)

Appendix 1. Wetland plant species recorded from the restored sections of the River Cole before (1994), during (1995) and after restoration (1996). (continued)

	Mill leat upstream of Coleshill Bridge									Restored channel downstream of Coleshill Bridge									New small channel	
Site	7	7	7	6	6	6	5	5	5	4	4	4	3	3	3				A	B
Year	94	95	96	94	95	96	94	95	96	94	95	96	94	95	96				96	96
<i>Lythrum salicaria</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>Mentha aquatica</i>	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Myosotis laxa</i>	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
<i>Myosotis scorpioides</i>	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Myosoton aquaticum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Nasturtium officinale</i>	-	+	+	+	+	+	-	-	+	+	+	+	-	-	-	-	-	-	-	+
<i>Phalaris arundinacea</i>	+	+	+	+	+	+	+	+	-	+	+	+	-	-	+	-	-	-	-	-
<i>Phragmites australis</i>	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	-	-	-	-	-
<i>Polygonum amphibium</i>	+	+	+	-	-	+	-	+	+	+	+	+	+	+	+	-	-	-	-	+
<i>Polygonum hydropiper</i>	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	+
<i>Polygonum lapathifolium</i>	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
<i>Ranunculus sceleratus</i>	-	-	+	+	-	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+
<i>Rorippa amphibia</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
<i>Rorippa palustris</i>	-	-	-	-	-	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+
<i>Rumex hydrolapathum</i>	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
<i>Schoenoplectus lacustris</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
<i>Scrophularia auriculata</i>	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Scutellaria galericulata</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-
<i>Solanum dulcamara</i>	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	-	-	-	-	-
<i>Sparganium erectum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+
<i>Stachys palustris</i>	+	+	+	-	-	+	-	+	+	+	+	+	+	+	-	-	-	-	-	+
<i>Symphytum officinale</i>	+	+	-	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
<i>Typha latifolia</i>	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-
<i>Veronica anagallis-aquatica</i>	-	-	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+
<i>Veronica beccabunga</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Veronica catenata</i>	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-	-	-	+
MARGINAL SPP. RICHNESS	18	21	20	23	22	38	24	23	33	33	37	35	32	33	29				24	28
TOTAL SPP. RICHNESS	22	28	27	30	29	45	32	30	42	43	44	43	38	38	35				26	29

Appendix 2. Wetland plant species recorded from 'control' and 'impact' sections of the R. Cole before (1994), during (1995) and after restoration (1996).

SITE YEAR	Upstream 'control' sections						Downstream 'impact' sections					
	2 94	2 95	2 96	1 94	1 95	1 96	9 94	9 95	9 96	8 94	8 95	8 96
Aquatic plants												
<i>Callitriche</i> sp.	-	-	-	-	-	-	+	+	-	-	-	-
<i>Lemna minor</i>	-	-	-	-	-	-	-	-	-	-	-	+
<i>Myriophyllum spicatum</i>	-	-	+	-	-	-	+	+	+	+	+	+
<i>Nuphar lutea</i>	+	+	+	+	+	+	-	+	+	+	+	+
<i>Ranunculus penicillatus</i>	-	-	-	-	-	-	-	-	-	-	+	+
<i>Fontinalis antipyretica</i>	-	-	-	-	-	-	-	-	-	-	-	+
AQUATIC SPP.	1	1	2	1	1	1	2	3	2	2	3	5
RICHNESS												
Emergent plants												
<i>Agrostis stolonifera</i>	-	+	-	+	+	+	+	+	+	+	+	+
<i>Alisma plantago-aquatica</i>	-	-	-	-	-	-	+	-	+	-	-	-
<i>Angelica sylvestris</i>	-	-	-	-	-	-	-	-	-	+	+	+
<i>Apium nodiflorum</i>	-	-	-	+	+	+	+	+	+	-	+	-
<i>Barbarea vulgaris</i>	-	-	-	+	+	-	-	+	+	-	+	+
<i>Bidens tripartita</i>	-	-	-	-	-	-	-	-	+	-	-	-
<i>Carex riparia</i>	-	-	-	-	-	-	+	+	+	+	+	+
<i>Cirsium palustre</i>	+	+	+	-	-	-	-	-	+	-	-	-
<i>Conium maculatum</i>	-	+	+	+	+	+	-	-	-	-	-	+
<i>Deschampsia caespitosa</i>	+	-	-	-	-	-	+	+	+	-	-	-
<i>Epilobium hirsutum</i>	+	+	+	+	+	+	+	+	+	+	+	+
<i>Eupatorium cannabinum</i>	-	-	-	+	+	+	-	-	-	+	+	+
<i>Filipendula ulmaria</i>	+	+	+	+	+	+	+	+	+	+	+	+
<i>Glyceria maxima</i>	-	-	-	-	-	-	+	-	+	+	+	+
<i>Lycopus europaeus</i>	+	+	-	+	+	+	+	-	+	+	-	+
<i>Myosotis scorpioides</i>	+	+	+	+	+	+	+	+	+	-	-	-
<i>Myosoton aquaticum</i>	+	+	+	+	+	+	+	+	+	+	+	+
<i>Phalaris arundinacea</i>	+	+	+	+	+	+	+	+	+	+	+	+
<i>Phragmites australis</i>	-	-	-	-	-	-	+	+	+	-	-	-
<i>Polygonum amphibium</i>	-	-	+	-	-	-	+	-	+	+	+	+
<i>Polygonum hydropiper</i>	+	+	+	+	+	+	+	+	+	-	-	-
<i>Ranunculus sceleratus</i>	-	-	-	-	-	-	+	+	+	-	-	-
<i>Rorippa palustris</i>	-	-	-	-	-	-	-	-	+	-	-	-
<i>Rumex hydrolapathum</i>	-	-	-	-	-	-	-	-	-	-	-	+
<i>Schoenoplectus lacustris</i>	-	-	-	+	+	+	+	+	+	+	+	+
<i>Scrophularia auriculata</i>	-	-	-	+	-	+	-	-	-	-	-	-
<i>Solanum dulcamara</i>	+	+	+	-	+	-	+	+	+	+	+	+
<i>Sparganium erectum</i>	-	-	+	+	+	+	+	+	+	+	+	+
<i>Stachys palustris</i>	-	-	-	-	-	-	-	+	-	-	-	-
<i>Symphytum officinale</i>	+	+	+	+	+	+	+	+	+	+	+	+
<i>Veronica beccabunga</i>	-	-	-	+	+	+	+	+	+	-	-	-
MARGINAL SPP.	11	12	12	17	17	16	21	19	25	15	16	18
RICHNESS												
TOTAL SPP. RICHNESS	12	13	14	18	18	17	23	22	27	17	19	23