Low Flows Investigations River Avon SAC

Final Report for Steering Group Consultation

March 2008

Report no: DM-#956729

a YTL company

Cover Picture: River Wylye (SAC reach) at Steeple Langford September 2006

Executive Summary

This report summarises the work carried out in the Low Flow investigation of the impact of public water supply (PWS) sources on the River Avon Special Area of Conservation (SAC). The report presents the details of the work which comprises a desk review, a groundwater/river flow model and two years of ecological survey. The area of investigation comprises the Greensand and chalk aquifers which feed the River (Hampshire) Avon and its tributaries, the Wylye, Bourne, Nadder, Nine Mile River and Ebble. Within the catchment Wessex Water (WW) operates 20 groundwater sources and one river abstraction (downstream of Fordingbridge). Other PWS sources operated by neighbouring water companies are located in the eastern portion of the catchment and from the lower river, close to its discharge into Christchurch harbour.

The River Avon SAC is designated for its chalk stream community (water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation), the salmon, lamprey and bullhead populations.

The overall objective of the investigation is to collate such information needed for the Environment Agency to determine whether the abstraction licences, alone or in combination, cause a loss of integrity of the SAC features, as required by the European Habitats Directive, 1994. The study has two main objectives:

- To define the hydrological impact upon the River Avon SAC (and tributaries) due to Wessex Water groundwater abstractions
- To determine whether these river flow changes, due to abstractions, adversely impact the integrity of the SAC.

Hydrology
A computer based numerical groundwater/river flow model of the Hampshire Avon catchment has been developed, jointly funded by the EA and WW. This model has been calibrated to historic river flows and is considered ‘fit for purpose’, though refinement work to improve the calibration/representation of the River Till is ongoing. The model allows natural (no abstraction, no discharges) river flows to be predicted. In addition the river flow under Full Licence abstraction conditions has been predicted. The model has also been used to assess the impact of individual sources. The key impact investigated is at summer low flows or Q95 but impacts at Q70 and Q50 have also been assessed.

Natural England guidelines on ‘acceptable’ river flow reductions has been used to screen the model output to define whether flow reductions are ‘compliant’ or ‘non-compliant’. For the extent of the River Avon SAC impacted by WW operations, the allowable flow reduction is 10% of natural. At Full Licence the following impacts are predicted along the SAC reach of each tributary:

Avon – small exceedance reach (~3km) around Durrington at Q95, which is mitigated in effect by leakage from the Kennet and Avon canal into the aquifer.

Bourne – The largest impacts on the Bourne occur at times of low flow (> Q95). At Q95 exceedance occurs along the entire SAC reach, with a maximum reduction from natural of

34%. An additional 5 Ml/d of water would be required in the river at Q95 to achieve compliance.

Nadder **–** No exceedance of guideline values.

Till **–** Awaiting model refinement.

Wylye **–** Small reaches of exceedance occur at low flows (Q95), stream support and storage development affords a large degree of protection to flow at natural low flow times. Greater reductions in flow occur at higher river flows. Maximum reductions in river flow occur near the start of the SAC (25% at Q44) and between the confluences with the Chitterne Brook and River Till (29% at Q50). The reduction in flow at the start of the SAC is attributable to the Brixton Deverill PWS source. The reductions observed between the Chitterne and Till are in part a cumulative impact, but the large abstraction from the Codford PWS source has a major influence.

The above impacts are theoretically possible but have never occurred to date. The contemporary impact of abstraction (i.e. the typical impact experienced in the river between 1995 and 2003) has been determined to establish the relationship between river flow (or drying period) and the present ecology:

Bourne – contemporary abstraction has resulted in exceedance of guideline values, with up to a 25% reduction in flow (at Q95) compared to natural.

Wylye – contemporary impacts along the Wylye are close to the guideline values at all Q values. The main exception is at the start of SAC, where reductions of up to 25% occur.

The largest impacts due to abstraction occurs along the headwater triburtaries: Bourne, Wylye (upstream of Warminster) and Fonthill Brook (non SAC watercourse)

Ecology

Although the Avon has been intensively studied, as both a Site of Special Scientific Interest (SSSI) and due to public concerns over the decline of the fishery, the existing data failed to show a clear effect of abstraction and was unsuitable for doing so. Consequently a bespoke ecological survey programme for fish, plants and macroinvertebrates (aquatic insects) was undertaken in 2006 and 2007 in the headwaters where abstraction impacts occur. This aimed to separate the effects of historical abstraction from those of climatic flow change against the varying parameters of water quality, river shape and management. Independent technical experts to this study, advised that the macroinvertebrates were the organisms most likely to exhibit a 'flow' related stress.

The survey years were climatically different. 2006 followed on from two low recharge winter and 'dry' summers. Whereas the 2006/07 winter was relatively wet and the 2007 summer was 'wet'.

Physical measurements were collected and the results were subject to statistical analysis against the modelled percentage of impact of abstraction on the flow. Areas with no abstraction pressure were included, such as the River Ebble.

The data were subject to various statistical analyses to detect the effect of percentage impact of abstraction on permanently flowing stretches, and on drying period in the winterbourne stretches. This included identifying the key associations between the plant or macroinvertebrate community and the physical nature of the channel, water quality and flow, as well as with the degree of abstraction.

The study was primarily undertaken on headwaters upto 30Ml/d of late summer flow (Q95), where tributaries with impacts of over 10% were located, along with non abstracted comparators. However, additional studies were done on the lower Wylye, which has more marginal impacts but is subject to considerable interest amongst fisheries associations, comparing it with the less abstracted Upper Avon tributary. The effect of abstraction on river temperature, water depth and plant life was also assessed. Where historical data was available this was also analysed.

Relationships were found with the antecedent period of no flow, in the previous 12 or 24 months, along the winterbourne which allows the macroinvertebrate and macrophyte communities to be predicted. These community predictors, together with output from the model defining the period of extra drying due to abstraction, have been used to model the ecological change that would be produced by abstraction at Full Licence.

For the perennial streams, no relationship was detected at present between the percentage reduction in flow and a change in ecological measure which would allow a relationship at that site to be predicted for full licensed abstraction rates. However, it is concluded that recent flows may dictate the riverine communities more closely than historical impacts and so further comparison with recent flows will be completed once the modelled values for 2007 are completed. The impact of current abstraction however is reported on the river ecology.

Regarding the designated SAC interest the study has concluded that the River Avon headwaters and winterbournes contained diverse macroinvertebrate and plant communities of high conservation value, as befits it's designated status. With regard to the effect of abstraction, the following effects were detected:

Lamprey **–** No abstraction impact upon the juvenile Lamprey population was detected.

Bullhead – An abstraction impact (at flow reduction >15%) has been detected by the Bullhead numbers, but the mechanism for impact has not been established. The 2006 survey found more Bullheads at umimpacted sites than impacted sites however, this difference was not detected in the 2007 data.

Salmon **–** The survey area is outside of the majority of the known salmon habitat so few salmon were recorded except in the lower Wylye. Instead, juvenile trout numbers were examined as an indicator of likely juvenile salmon survival rates, though stocking will exert an unquantifiable influence on the numbers recorded. The survey found no relationship between abstraction impacts and trout numbers. Relationships between flow and trout numbers have been established for a limited number of sites on the Bourne but are insufficient at present to predict the effects of abstraction.

Except for the River Bourne, the contemporary impact of abstraction has been within or just above the Natural England guideline values. It could therefore be concluded that a historic decline in Salmon numbers cannot be attributable to abstraction. The alternative argument is that the abstraction impact has contributed to the salmon reduction, allowing a ‘trigger’ point for population decline to be reached. However, the influences on salmon are varied and occur both within the Avon catchment and outside it. Consequently, a simple relationship with abstraction is unlikely to be found.

Mechanisms where by abstraction could influence salmon numbers have been explored as part of this study. The review concluded it was not possible to demonstrate a clear effect of groundwater abstractions on the salmon population. It is considered that the observed decline in salmon numbers is due to a combination of effects common to the other Southern Britain chalk streams and it is noted that recent work exploring river water temperature and salmon numbers in Southern Britain chalk stream may establish a causal relationship.

Chalk stream community

The conservation status of this designated habitat is measured by it’s physical parameters, such as retaining within 10% of natural flows. The potential health of the communities which live in this habitat were assessed via one of the key component plant species, *Ranunculus*, plus plant and macroinvertebrate communities and indices.

Ranunculus (*principle floating species*) - No relationship to the degree of abstraction and *Ranunculus* cover was found. Examination (on going) of long term data set indicates that winter/spring (Q5) flows influence the *Ranunculus* cover, in other words the higher the winter/spring flow the better the *Ranunculus* cover in the summer. This initial conclusion supports the widely held view that high winter flows will clear away senesced plant material, silt and potential competitors and so prepare the river bed substrate for growth in the spring, with high spring flows stimulating growth early in the year.

Macroinvertebrates

When macroinvertebrate data is examined the only consistent, significant effects of abstraction on macroinvertebrate indices were found at just one sampling location (Bourne 19, near Idmiston) where abstraction prolongs both the cessation of flow and natural drying periods. Along the perennial reaches (which do not dry) an impact upon the macroinvertebrate community due to the effects of abstraction was not clear. Indices such as LIFE which reflects flow sensitive species present did not show clear relationships with abstraction.

Macrophyte communities did not show a significant relationship with abstraction degree, although a flow index did show some variation with percentage abstraction in both survey years.

Winterbourne streams.

Abstraction was concluded to extend the drying period of winterbourne stretches which, given the predictable nature of their macroinvertebrate and macropyte communities, allowed the effect of Full licence abstraction to be predicted. The only winterbourne stretch within the SAC is the River Till, for which more accurate assessment of modelled flows is awaited. However, the winterbourne stretch was found to contain good communities of *Ranunculus* and the classical macroinvertebrate species. The effect of abstraction on this is considered to be a further small shift downstream, with no loss of conservation value.

Other Findings from Associated Work

Geomorphological survey of the Wylye and Bourne has shown that over 50% of the length of each river has very low or low diversity, indicating the poor condition of the river to provide the flow and channel diversity needed to form niches for the designated species.

Hydraulic modelling shows that increasing river flow (by reducing abstraction) has little effect in increasing the extent of the habitat for the designated species where the geomorphological condition of the channel is ‘poor’. The hydraulic modelling showed that restoration work did yield suitable habitat conditions (water depth and velocity).

River water temperature

A literature review and results from a small scale monitoring programme concluded that groundwater abstraction does reduce river water temperature but the main and potentially harmful effects of changing temperature on salmon are driven by increasing air temperature both in the nursery areas and the main river. The effects of abstraction on river water temperature are unlikely to be detected against the variation caused by shade and impoundment.

Non SAC impacts

The more significant changes in river flow and drying period occurred upstream of the SAC boundaries. The typical effect on ecology was a downward shift in perennial head in dry years resulting in a small loss of perennial community, rather than winterbourne community. The effects on macroinvertebrate and macrophyte species were as for the SAC areas, with few clear relationships established between ecology and percentage abstraction effect.

Conclusion

Thus the study surveys failed to show significant effects of abstraction above the variation caused by climatic driven flow variations and the various effects of the nature of the river channel and water quality on aquatic communities. No relationships could be established to confirm whether the 10% natural flow threshold is appropriate for the protection of site integrity, although it would appear to be a realistic limit of detection of any ecological impact.

Contents

1 Introduction

1.1 INTRODUCTION

From 2005 to March 2008 Wessex Water (WW) is required to undertake an investigation to determine whether its public water supply (PWS) abstractions in the Hampshire Avon catchment adversely impact the conservation interests of the River Avon Special Area of Conservation (SAC). To address whether PWS abstractions affects the SAC interests, two questions need to be answered, these are;

1. What is the reduction in river flow due to PWS abstractions and
2. Does this river flow reduction cause an adverse impact on the conservation interests.

This report details the work undertaken to determine the river flow changes due to abstraction and presents the results from ecological monitoring of the perennial and winterbourne reach of the River Avon.

The findings from the investigations will contribute to the Environment Agency's (EA) review of consents (RoCs). The abstraction licences issued by the EA, which authorise WW to abstract water, are the 'consents' to be reviewed. The EA's review will be completed in 2008, in partnership with Natural England (NE), and if a damaging effect is found or predicted, it may result in a requirement to reduce the amount of water abstracted, or for other improvements to be made.

This report summaries the works undertaken and findings from the hydrological and ecological studies.

1.2 BACKGROUND

The majority of the perennial River Avon and part of one of the winterbournes (River Till) is designated as a Special Area of Conservation (SAC). The extent of the River Avon SAC is shown on Figure 1.1 (Section 9). The designation is due to the inherent richness of flora and fauna of the River Avon, which drains predominately chalk aquifers. Specifically, the presence of the following internationally rare or vulnerable species and habitat underpin the designation.

- Water courses of plain to montane levels with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation (classic chalk stream habitat)
- Population of Atlantic salmon (*Salmo salar*)
- Population of bullhead (*Cottus gobio*)
- Population of brook lamprey (*Lampetra planeri*) and sea lamprey (*Petromyzon marinus*)
- The river and adjoining land a habitat for populations of Desmoulin's whorl snail (*Vertigo moulinsiana*)

The conservation objectives are to maintain the river as a habitat for these species.

The River Avon SAC is designated under the 1992 European Commission's Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (implemented through the Habitats Regulations in the UK). Under the Habitat Regulations (Hab. Regs.) the Environment Agency is required to assess all existing permissions ('Review of Consents') which may impact upon the SAC and the interest features for which it was designated.

Of the 523 abstraction consents in the River Avon catchment (Section 2.3.2), the EA has identified in the region of 80 abstractions (surface and groundwater) which could potentially have an impact upon the River Avon SAC. Wessex Water operates 21 of these abstractions. The Hab. Regs. require the impact of each consent to be determined, both alone and in combination with other consents. Wessex Water have been funded during the AMP4 period (2005 to 2010) to collect the information required by the EA to assess the impact of its abstractions by March 2008.

English Nature have issued guidelines for allowable river flow reductions under different flow regimes (Q values) these are presented in Table 1.1 (extract from EA's Water Resource Technical document). A brief explanation of how Q values are calculated is provided in Section 3.7.3 Using the EA's RAM methodology (User Manual v.3) the River Avon and its tributaries have a **high** Ecological Weighting. There are two exceptions, the River Nadder and the River Avon downstream of Fordingbridge, which have **moderate** Ecological Weighting.

Table 1.1: Allowable River Flow Reductions

Environmental Weighting (Sensitivity)	Maximum Percentage Reduction from Daily Naturalised Flow		
	$<Q50^*_{nat}$	$Q50\text{-}95_{nat}$	$>Q95_{nat}$
Very High	10	10	1-5
High	15	10	5-10
Moderate	20	15	10-15
Low	-	-	-
Very Low	20	20	15

**Q - flow percentile value*

If predicted flow reductions are greater than the allowable reduction (Table 1.1) then the effect of the flow changes need to be equated to an impact on the designated interest/features. Wessex Water have commissioned work to quantify this potential impact. In the absence of robust hydro-ecological information, to demonstrate that greater flow reductions to not cause damage, then the criteria in Table 1.1 may be applied by the regulators.

The review of consents is done in four stages:

Stage 1: identified all relevant permissions, which include Abstraction consents.
Stage 2: screened all consents to determine whether there was a likely 'significant effect'. Those which have pass to stage 3.
Stage 3: Appropriate Assessment - assess each consent both alone and in-combination. All sources pass to stage 4.
Stage 4: for each source the EA will write a Site Action Plan outlining the preferred options, (to affirm, modify or revoke the permissions) to meet the environmental requirements of the site (as outlined by the Conservation Objectives)

This Low Flow investigation for the River Avon SAC site contribute to the Stage 3 appropriate assessment to be completed by the EA, and will therefore inform the Stage 4 decision.

The outcome from Stage 4 is a Site Action Plan for each source, which could involve the need to reduce abstraction at certain sources. Such reductions as required by the Hab. Regs are referred to as ‘sustainability reductions’. In May 2007, as part of the Draft Water Resource Management Plan (WRMP) preparation procedure the EA provided Wessex Water with draft sustainability reductions for sources that impact the River Avon SAC. The details of these draft sustainability reductions are given in Section 3.11. The HAM has been used to define the benefit to river flow that these reductions in abstraction will make, the findings are presented in Section 3.11. The EA are required to supply Wessex Water with final sustainability reduction values in August 2008.

1.3 OBJECTIVES

The objectives of this study, summarised in this report, are:

- To define the hydrological impact upon the River Avon SAC (and tributaries) due to Wessex Water groundwater abstractions
- Do the river flow changes, due to abstractions, adversely impact the integrity of the SAC?

The river flow reductions and impact upon the ecology need to quantified based on full licence use of the sources.

In addition to the direct effect of reducing river flow, abstraction may have indirect effects, one that has been considered is:

- Reducing ‘cool’ groundwater inflows to the river, contributing to river water temperature rises

1.4 SCOPE AND APPROACH

The following approaches have been used to assess the hydrological and ecological impacts.

Hydrological
A computer based numerical model of the Hampshire Avon groundwater and river system has been constructed, to test individual and in combination impacts (Section 3). The model is referred to as the Hampshire Avon Model (HAM) and this short hand is used in this report.

Ecological

Following a data review, that concluded existing data was inadequate to define an abstraction impact, a targeted two year survey of macrophytes, macroinvertebrates and fish in headwater catchments has been undertaken. The design selected unimpacted and impact (reduced flow due to abstraction) reaches of the river to see if there was an ecological difference.

Winterbournes were also monitored and models that predict where different communities occur along the winterbourne based on period of antecedent dryness have been developed for macrophytes and macroinvertebrates. These allow the distribution and extent of communities under full licence conditions to be predicted.

Temperature

A literature review and a monitoring of temperature change along headwater streams have been undertaken.

1.5 PROJECT TEAMS AND TECHNICAL AUDIT

The Low Flow project is being undertaken by Wessex Water, in partnership with staff from the EA and NE. A number of groups were established at the start of the project to oversee and facilitate the project:

- Technical Steering Group: Wessex Water, EA and NE
- Investigation Project Group (G1/G2): Members from Wessex Water, local EA and NE offices, Wildlife Trust and Bournemouth and West Hampshire Water (B&WHW).
- Expert review panel – for independent advice on technical matters.

The following technical experts have been employed to independently review certain aspects of the work:

Jane Dottridge – Groundwater/river flow model
David Solomon – Fisheries biology
Nigel Holmes – Aquatic plant biology
Paul Wood – Aquatic macroinvertebrate biology

1.6 REPORT STRUCTURE

This report summarises three main reports and several technical notes/reports that comprise the AMP4 investigation of the River Avon SAC. Before the findings are presented Section 2 describes the River Avon SAC designation and the concerns that the River Avon is not as ‘healthy’ as it used to be. This concern regarding the health of the River Avon is not restricted to just the River Avon, the same phenomena is observed in other chalk stream and has been dubbed the ‘chalk stream malaise’.

The extent of the abstraction pressure the Hampshire Avon is also described in Section 2.

In the following sections the main investigation work undertaken and findings are detailed. Each section provides a summary of the larger report, with method, sampling techniques, analysis undertaken and finding provided. These sections are:

Section 3: Abstraction Impacts on River flow (impacts on Winterbournes described in Section 5)
Section 4: Ecological Study – Perennial Rivers
Section 5: Ecological Study – Winterbournes

The results from temperature monitoring are detailed in Section 6. Also in Section 6 other factors, apart from abstraction, that influence the river appearance and its suitability for the designated species are discussed.

The overall findings from the investigation are summarised in Section 7.

The majority of the figures accompanying this report are located within the text, however, several figures (mainly A3 figures) are located in the Figure Section (Section 9). If a Figure is located in Section 8 this is noted in parenthesis after the figure note e.g. Figure 1.1 (Section 9).

1.7 SUPPORTING DOCUMENTATION

The reports and technical notes which have been prepared as part of this investigation and which are summarised in this report are listed below with copies of each report/notes contained on the CD to be found in the wallet attached to the back cover of this report.

- Assessing the ecological impact of abstraction on winterbournes in the Hampshire Avon catchment – Wessex Water
- River Avon SAC Low Flow Project Ecological Investigation - APEM
- Impact of Wessex Water abstraction consent on river flows – Wessex Water
- Salmon technical note – Wessex Water
- River Wylye hydraulic Modelling – the effects of abstraction and restoration on the River Wylye - Halcrow

1.8 CONFIDENCE

River Till
As detailed the Section 3 the hydrological model is considered 'fit for purpose' however, the representation of the River Till is not as good as the rest of the model area. The Technical Steering Group for the model development recommended refinement of the model in the River Till area if new data to justify changes become available. Over the last few months a revised conceptual understanding of the Till has been developed and this is being tested using the numerical model. This work is ongoing and should be completed by the end of June. Limited results for the Till (winterbourne) are presented in this report (Section 5) to provide a guide as to the likely level of abstraction impact, however, those results will be superceded in due course.

Ecological results
In the ecological design, sites along the River Till were classified as 'impacted' due to historic high level use of Chitterne PWS. However, during the monitoring period the Chitterne source has been used at a low rate of output and therefore the River Till is potential

'unimpacted'. The implication is that River Till sites in 'paired' analysis are wrongly paired, this issue became known too late in the analysis/reporting to be altered (for the March deadline). The analysis will be reworked with the correct impact in due course. Initial assessments indicate that the reclassification will not alter the findings presented in this report.

The ecological survey hypothesis is that the historic (over last 10 years) abstraction pressures have 'built up' an ecological difference between impacted and unimpacted sites. During the course of the study the time period of the hydrological model was extented so that impacts at the time of sampling were available. Using actual impacts has increased the some of the ecological relationship with abstraction. Therefore it is proposed to obtain actual 2007 impact (once the model is extended) to investigate whether more recent impacts are more significant than the average impact over 10 years. This analysis will be completed during the spring and summer of 2008.

2 River Avon SAC and Wessex Water Abstraction Consents

2.1 INTRODUCTION

The reason for the River Avon being a SAC is described in this section, together with a brief description of the chalk stream malaise. The dramatic decline in salmon numbers in the Avon is also explored in this Section. Finally the abstraction pressures in the catchment are presented.

2.2 RIVER AVON - DESIGNATION

The River Avon rises in the Pewsey Vale in Wiltshire, and flows South through Salisbury to the sea at Christchurch in Hampshire. It is considered to be one of the UK's most biologically diverse chalk rivers (Wheeldon, 2003). Due to this inherent richness, the site was one of the first rivers in the UK to be designated as a Special Areas of Conservation (SAC) under the EU Habitats Directive. Specifically, the presence of the following internationally rare or vulnerable species and habitats underpin the designation:

- Rivers with floating vegetation often dominated by water crowfoot (*Ranunculus*),
- populations of Atlantic salmon (*Salmo salar*),
- populations of Bullhead (*Cottus gobio*),
- populations of Brook lamprey (*Lampetra planeri*) and Sea lamprey (*Petromyzon marinus*),
- the river and adjoining land as habitat for populations of Desmoulin's whorl snail (*Vertigo moulinsiana*)

In addition to these special interest features, the River Avon also has a flora with over 180 macrophyte species recorded along with the relatively diverse and particularly abundant community of macroinvertebrates typical of an English chalk stream environment (including two nationally rare molluscs), which together help to provide the habitat and food source necessary to support one of the most diverse fish faunas to be found in UK (Southey, 1998). The Avon system also constitutes a brown trout fishery of national repute, although most of these populations are artificially manipulated by stocking.

This diversity springs partly from the geology of the catchment; the rich influence of chalk combined with clay and acid sands results in a mixture of river types and therefore habitats through the length of the catchment (Wheeldon, 2003). As for all chalk streams, the stable base flow regime supplied by the groundwater sources is also influential in supporting the rich biota of the river.

The habitat of chalk rivers, including the Avon, is characterised by a diverse macrophyte community, dominated by submerged/floating beds of water crowfoots, water starworts, milfoils, lesser water parsnip, and pondweeds. Extensive marginal vegetation can include beds of emergent reeds and mixed herbs such as watercress, fool's watercress and water forget-me-not. These plant communities determine habitat heterogeneity in a number of ways. Firstly they provide a three dimensional structure within the water column thereby providing a greater extent of habitat for algae (epiphytes) and macroinvertebrates to colonise. Different plant species provide structural complexity and therefore a high diversity of plant species will provide more diversity of habitat.

In addition to this direct provision of habitat, macrophytes also affect the in-stream habitat by influencing localised flow and sedimentation patterns. Beds of submerged plants and emergent herbs provide resistance to water flow, reducing current velocity and causing suspended sediment to settle out in and upstream of the beds. This creates areas of silt in amongst the plant beds, whilst in the areas around and between the beds the water velocity is accelerated, resulting in the maintenance of clean gravels. In times of low flow, the encroachment of emergent herbs into the channel can effectively narrow the channel, maintaining areas of depth and velocity which may otherwise be dissipated across the whole channel width. Submerged and floating beds of macrophytes such as water crowfoot (*Ranunculus* spp.) also hold back the water flow, generating a depth of water within and across the channel which is lost if the plants are removed (Section 6.3). Thus aquatic macrophytes provide direct habitat in the form of physical structure which acts as both a refuge and food source for fish and invertebrate species, but also influences the distribution and composition of other in-stream habitat factors such as sediment type and water depth and velocities.

The abundance and heterogeneity of habitat, along with the chemical composition of the water resulting from the chalk geology provide suitable conditions for a relatively diverse and abundant macroinvertebrate community to thrive. This in turn acts as a food source to support the fish population. The abundance of 'riverflies' (mayflies, caddisflies and stoneflies) in particular is seen as a key indicator as to the health of the river, and provides an important food source for fish populations, particularly the salmonid species (salmon, brown trout and grayling) which are key to the angling interest on the River Avon catchment. Many of these invertebrate species require clean gravel interstices in which to move and seek refuge from predators and their respiratory systems are relatively inefficient at low current velocities.

The array of fish species present in the Avon catchment have a range of habitat requirements. Internationally important species such as bullhead prefer the clean gravels and moderate water velocities commonly to be found in riffle areas on lowland streams, but also require a range of habitat to provide refuges against higher flows and predators. Atlantic salmon and brown trout also require clean gravel areas for spawning, and again a diverse habitat provides both an abundance of food and refuge for the different life stages of these species. Sea and brook lamprey also have habitat requirements that vary with their life stage. The adults require clean gravels or cobbles in which they excavate their nests to spawn. Once hatched, the larval ammocoete stage burrow into areas of silt in still or slow flowing waters, usually found in the shallow margins of the river, although it is now known that sea lamprey ammocoetes also use bottom sediments of deep waters in the downstream reaches of some rivers systems (APEM, unpublished data). Coarse fish such as barbel and chub also benefit from the shelter provided by macrophyte beds and the abundance of food such as freshwater shrimps that colonise clean gravel beds.

Managed Catchment

However, it should be remembered when considering the ecology of the River Avon, and indeed UK chalk streams in general, that it is almost entirely unnatural in character, having been extensively modified and managed over the centuries. The exploitation of the natural energy of the river to power mills and the associated use of weirs, sluices and hatches gives the river a stepped profile, and this teamed with engineering such as re-sectioning and realigning for flood defence and land drainage purposes has resulted in the loss of much of the natural hydrodynamics of the river (Section 6.4). Further historical modifications have occurred to feed water meadow systems and channel vegetation has traditionally been managed in the interests of angling and also for flood defence. Many of these modifications have contributed to the valuable habitat and high biodiversity that is now seen in the river; however, they also add artificial pressures such that, without constant management, this range of habitat and biodiversity would not naturally be retained.

Chalk Stream Malaise

Over the past decade there has been concern over the health of the Avon catchment, particularly through the drought years that were experienced in the mid 1990s. The apparent decline in ecological condition, recorded mainly through anecdotal evidence from river keepers, fishermen, landowners and regulatory officers, was typical of the "chalk stream malaise" reported on many of the southern UK chalk streams at the time. The symptoms of this malaise include a decline in the growth of typical chalk stream macrophytes, particularly *Ranunculus,* and their replacement by species such as fennel leaved pondweed (*Potamogeton pectinatus*) which are less sensitive to nutrient concentrations, siltation and current velocities (Grieve *et al*., 1999 & 2000). Overgrowths of epiphytic and epilithic diatoms forming brown scums across the substratum and macrophyte beds is often cited as another key symptom considered to represent a decline in condition. In common with many other UK rivers, there has also been concern regarding a perceived decline in the numbers of hatching 'riverflies' in chalkstreams over this timescale.

There are a range of often interlinked or compounding factors and drivers that may have contributed to this perceived decline in ecological condition of the River Avon.

2.2.1 Atlantic Salmon

Salmon are an emblematic species of the River Avon SAC and since the early 1990's the number present in the river have decline considerably (Figure 2.1). Before examining the decline in salmon number, the life cycle and current distribution of Salmon is presented.

Atlantic salmon, like sea trout are found in hard rock and chalk rivers of suitable water quality and size, spawning in the fresh waters. Juveniles hatch and grow before smoltifying and travelling to sea. The mature adults return to their native streams to spawn as adults in December. Smolts may return at one or two years of age and adults may return after one (grilse) or more (multi sea winter) winters at sea. Unlike some Pacific species, spent Atlantic salmon may recover and return to sea after spawning.

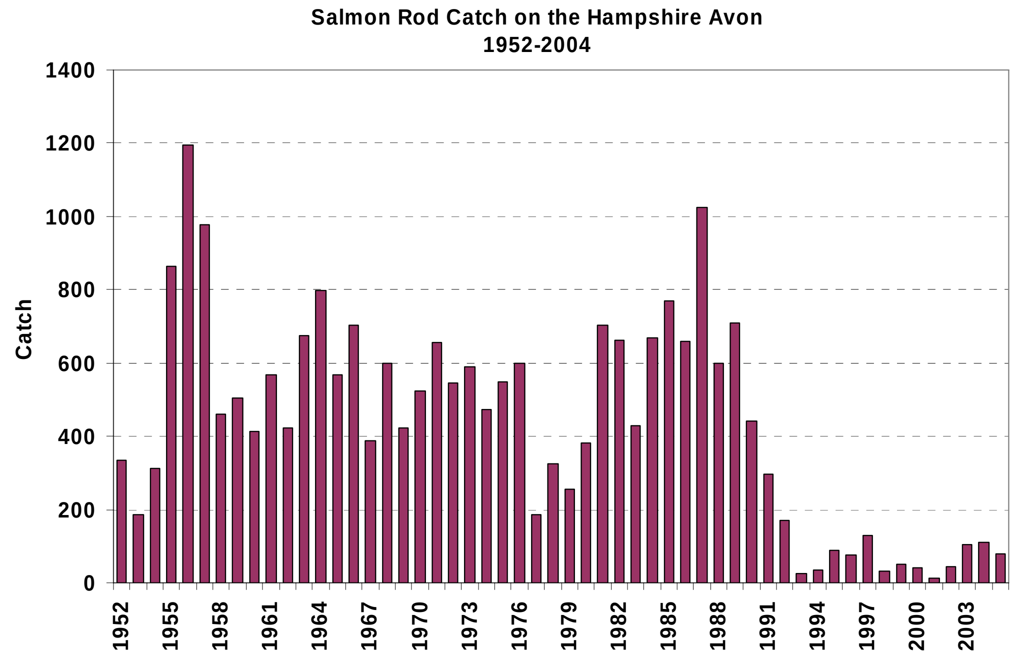


Figure 2.1: Salmon Rod Catch on the Hampshire Avon 1952-2004

Salmon currently enter the river at Christchurch throughout the spring to autumn period and migrate to spawning areas to cut redds in December. These are distributed throughout the main river, within the Nadder, the Wylye (upto the A303), and the upper Avon. The Ebble is used little, probably due to an obstruction located near the confluence with the River Avon. Although there are few redds recorded on the River Bourne, apart from near the confluence, and the Till, fry have been recorded in both rivers. The redds from 2004/5 are shown in Figure 2.2 (Section 9) being the most widespread distribution available from the data obtained from the EA.

The spawning location and timing varies between years, probably associated with river flows that winter, stronger flows encouraging spawning further upstream. Water temperature influence the time of entry and movement upstream (Solomon, D 2005).

The adult salmon are exploited by netting at the river mouth (Mudeford) and rod fisheries, primarily below Salisbury. For the last 10 years these have operated on a catch and return basis.

The success of spawning is therefore affected by the number of returning adults entering the river, the egg quality and quantity. These two factors are used to calculate whether the conservation limit set for the Avon has been achieved.

Species in Decline

Throughout their native range, numbers of wild anadromous (move from salt to fresh water) Atlantic salmon (*Salmo salar*) have declined demonstrably (Parrish et al. 1998). The status of salmon runs on rivers that have historically supported salmon have indicated widespread declines, and even extirpations, in Europe and North America, particularly in the southern portions of their range (Parrish et al. 1998). Factors constraining salmon production in the freshwater life-phase include blockage of migratory routes, low flows and siltation of spawning gravels inhibiting egg survival (Heywood & Walling 2006). In the marine life-phase, factors include over exploitation, and more recently, changing ocean conditions and intensive aquaculture. The range of different threats during the lifecycle of salmon are shown on Figure 2.3.

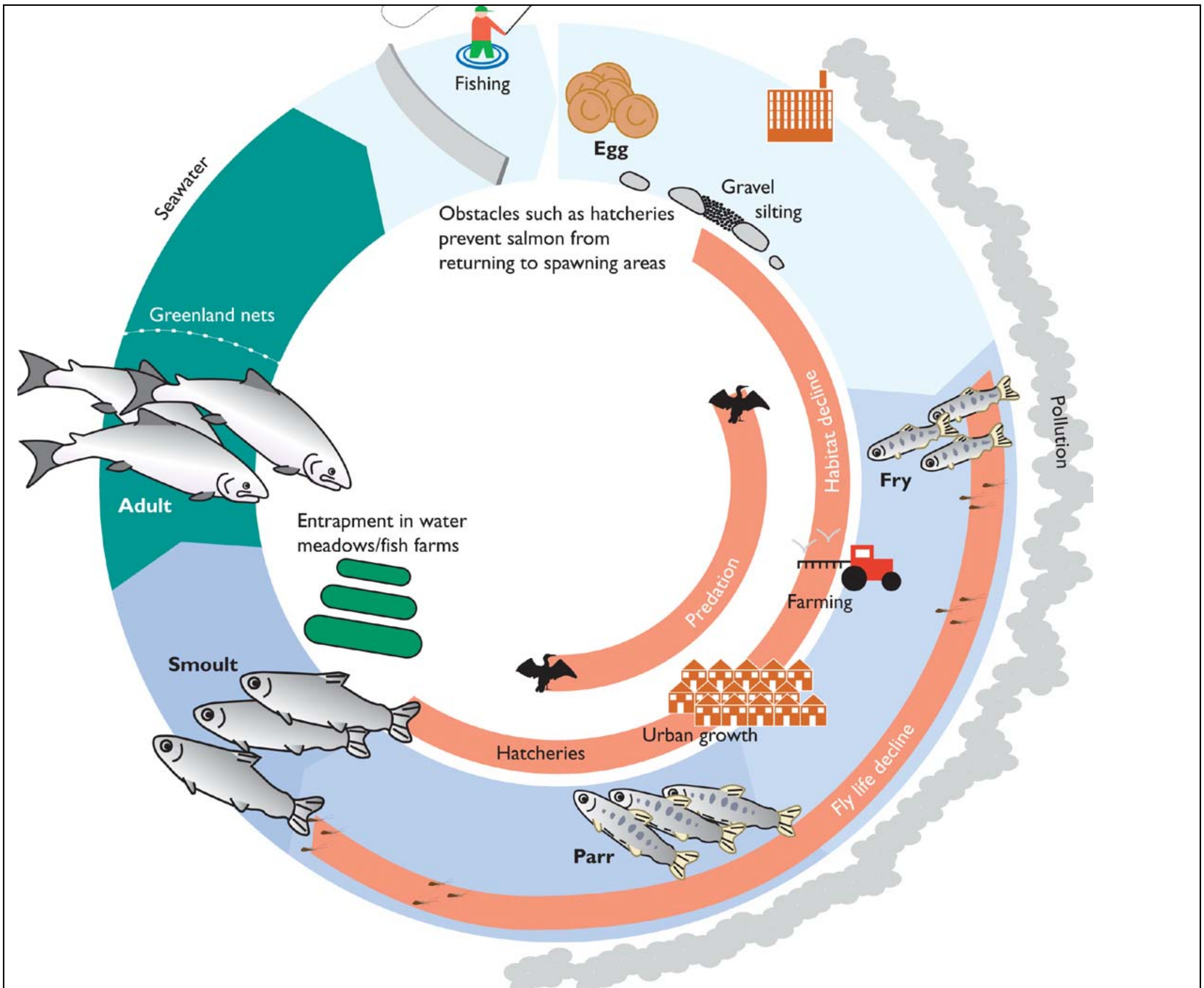


Figure 2.3 Potential impacts on Salmon through their cycle

Decline – Adjacent catchments

A decline in salmon numbers has been recorded in the Frome, Itchen and Test. The data from the Frome (Figure 2.4) shows a decline in salmon number, albeit with marked annual variations.

There has been a substantial decline in salmon rod catches for the River Test since the 1970s, with all time lows recorded in 1992 and 1997. However, numbers have increased since 1997 and may indicate a population recovery.

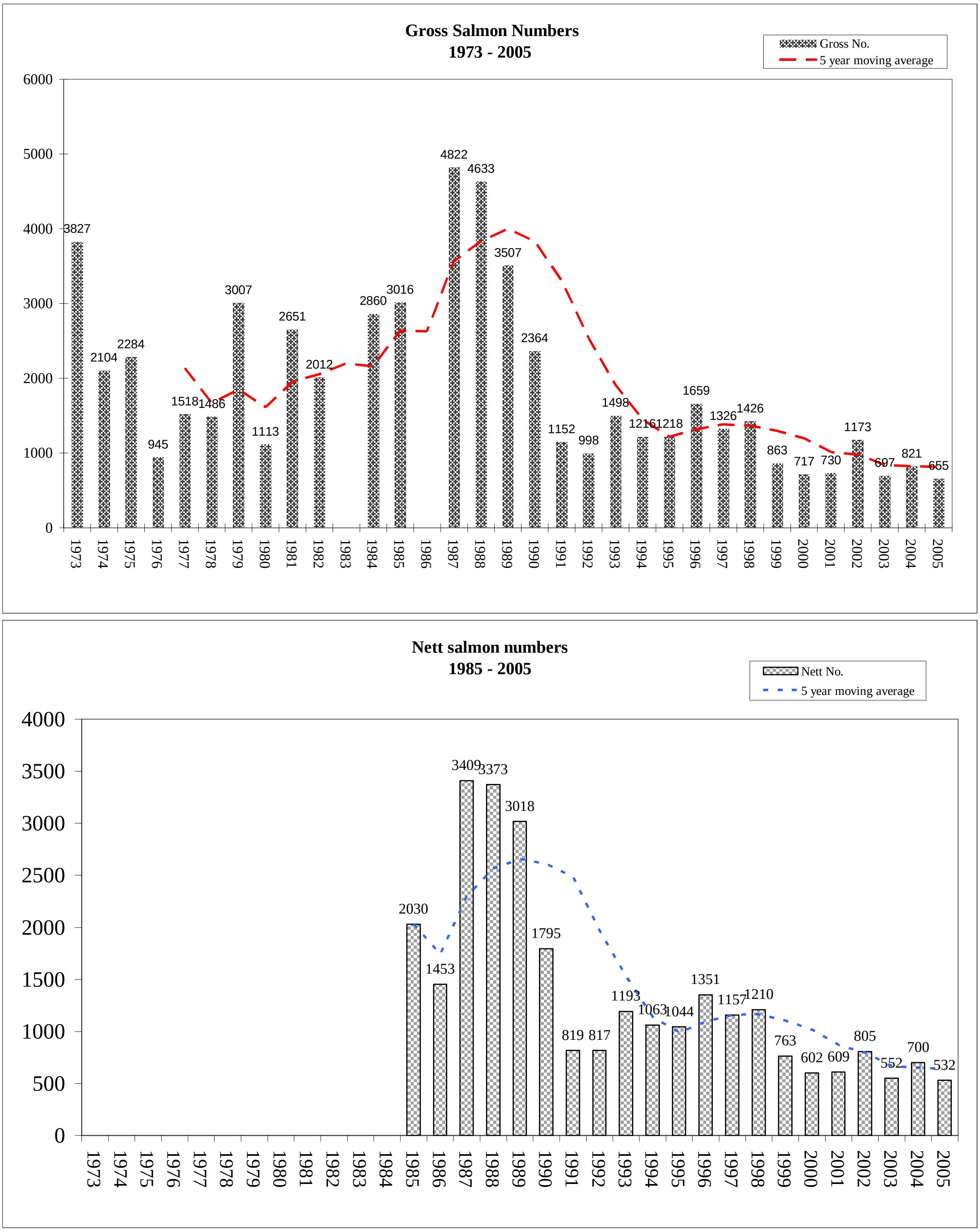


Figure 2.4: River Frome – Adult Salmon Trends

Salmon Action Plan

The Salmon Action Plan (EA 1997) highlights the decline in both rod caught and net caught fish, for the spring salmon and the late run salmon. The former peaked in 1930s and has formed a reduced proportion of the population since. The late run fish were particularly hit in 1988-91 when 4 dry summers occurred and 2 years of high mortality of smolts at sea occurred (1989 and 1990). The strong decline through the 1990s led to catch and return being developed throughout the river from 2005 in a 10 year agreement by the Avon Salmon group (until 400 salmon were caught). The net fishery was returned to a limit of 240 fish in the same agreement.

The Salmon Action Plan (1997) identifies a number of possible constraints on the population:

- Land use change- both farming and MOD activity on Salisbury plan increasing silt run off
- Channel Modification- from 1100 for milling and from 1600s for water meadow management
- Legal net fishery (since bought out)
- Licensed rod catch (since made catch and return)
- Legal Irish Fishery (improved 2007)
- Silt from without channel sources impact on spawning
- Competition from trout
- Piscivorous predation fry and parr
- Adult migration barriers- blind channels and obstacles
- Flow perturbations lower river – AMP4 investigation and Review of consents on abstraction
- Channel morphology effects on fry parr and spawning habitats
- Silt from within river sources
- Poor pre-fishery survival.

Temperature

Since the SAP publication further work by Dr Solomon and Dr Lighfoot have shown that the decline in chalk river salmon fisheries is coincident with a change in precipitation, more variable river flow rates and temperature increase as well as other biotic change, including river fly numbers and *Ranunculus* decline. A review of long term Avon Net data from 1863 shows that similar periods of low salmon catches are broadly coincident with the North Atlantic oscillation, with its associated changes in rainfall and temperature. The sudden shift in the late 80's has been followed by a further steady temperature rise. The spate salmon rivers to the west of Dorset did not suffer the sharp decline in numbers that the chalk stream suffered and the temperature of the Fowey and Tamar stayed up to 5 degrees cooler in the summer (2005). Thus temperature is now considered to be one of the key issues challenging the Avon salmon population. The influence of abstraction on river temperature is examined in Section 6.2.

Mechanisms for abstraction Impact

The mechanisms listed in Table 2.1 are considered to be means by which abstraction could potentially affect the salmon population of the Avon.

Table 2.1 Key potential impacts of abstraction on salmon

Salmon Population constraint	Potential effect of abstraction
Land use and siltation increase	Could increase deposition
Silt from within river sources	Could increase deposition
Flow perturbations	Reduction in flow and thus velocity and depth
Barriers to migration	Increase at lower flows
Reduced rate of river entry	Reduced flow at mouth
Increasing temperature	Reduced input of cooling ground water

Each of the mechanisms listed in Table 2.1 (except temperature, Section 6.2) are review in Section 4.8 as to whether an impact on salmon success is likely.

2.3 ABSTRACTION ACTIVITIES

2.3.1 Introduction

A brief overview of the abstraction activities in the Hampshire Avon catchment is presented in this Section. A full account is given the CAMS document for this catchment (EA 2005).

2.3.2 Hampshire Avon

Within the Hampshire Avon catchment there are 523 consented water abstractions. Over half of these abstractions are for agriculture (Figure 2.5), but these only account for <2% of the total authorised volume (Figure 2.6). When consumptive consents are considered (excludes non-consumptive consents: fish farms etc, the largest abstractions by volume are for public water supply (89%). Wessex Water operate 21 PWS sources, three other water companies hold licences; Thames, Bournemouth & West Hants and Cholderton within the Avon catchment. In addition, the MOD operates several large abstractions and discharges. Several large PWS abstractions export water from the catchment.

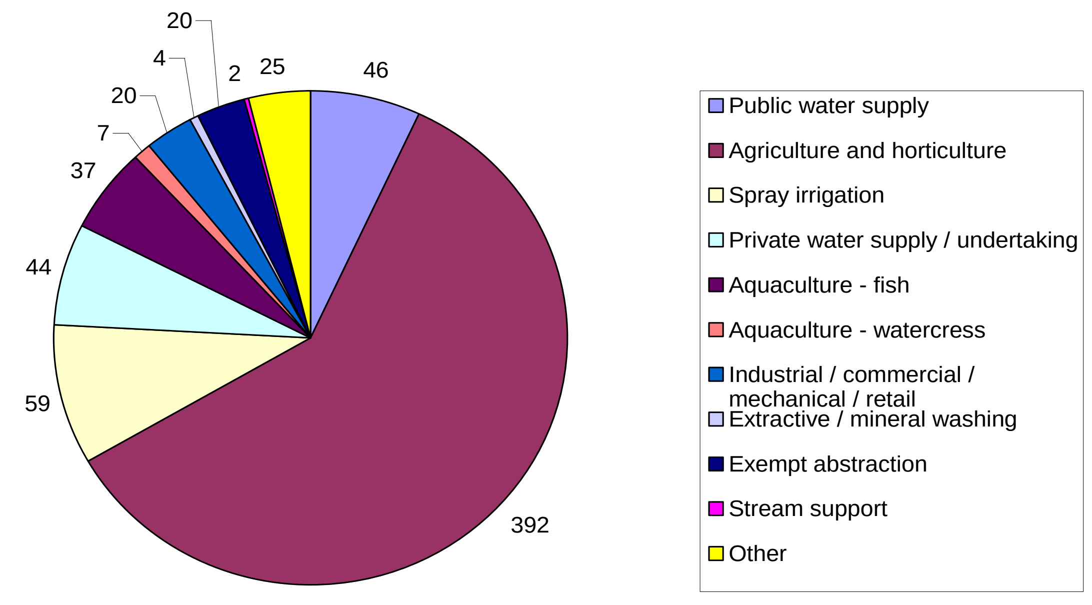


Figure 2.5 Summary of abstraction licence purposes by number of licensed points

In assessing the in combination effect of consents the return of water needs to be considered. Within the Hampshire Avon catchment ~54 ML/d of treated effluent is discharge to river or to ground via soakaways. Approximately 80% of this discharge volume arise from sewage treatment works

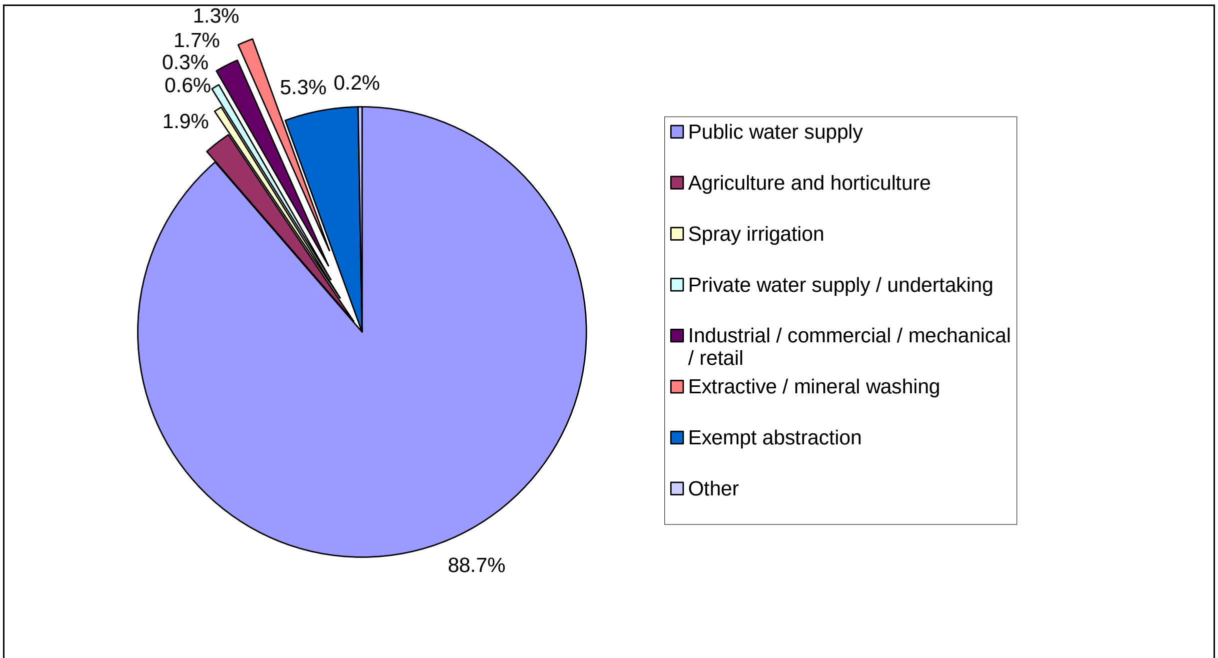


Figure 2.2: Summary of consumptive abstraction licence purposes by annual volume

2.3.3 Wessex Water – surface water

The location of the one Wessex Water surface water source, known as Blashford (or Ibsley Off take), in the catchment is shown on Figure 2.7 (Section 9). The source is licensed to abstraction 20 ML/d, though at times of high river flow up 50 ML/d can be taken. The Avon is a substantial river at Blashford and the abstraction pressure from upstream source at this point represents only 5% of the summer (Q_{95} flow). This source is not considered in this report as it impact is detailed in the AMP4 Avon valley SPA report.

2.3.4 Wessex Water – Groundwater

The locations of the 20 groundwater sources, operated by Wessex Water in the Hampshire Avon catchment, are shown on Figure 2.7 (Section 9) and listed in Table 2.1. The sources are located in the tributary catchments upstream of Salisbury. The licences for these sources permit a summer abstraction of ~99 ML/d, of this ~50 % (47.1 ML/d) is exported from the catchment (at full licence use). The exporting sources and the amount exported are listed in Table 2.1.

The local supply network within the Hampshire Avon catchment results in intra-catchment of water, which can results in local flow depleted reaches, but conversely flow augmentation in a neighbouring catchment. The Newton Tony source in the Bourne is an example of this, with the water abstracted from Newton Tony used by communities in the Avon catchment. The effluent returns from these communities discharge to the River Avon (Ratfyn and Amesbury STWs) and hence the river flow is higher than natural due to in the import from the Bourne catchment. In determining the impact of individual PWS source the local supply network and relevant waste water collection system have been taken into account.

Table 2.1: Hampshire Avon Groundwater PWS Sources and Summer Licensed Usage

Sub Catchment	PWS Source	Summer Usage (ML)	Export from Hampshire Avon catchment (ML)
Avon	Bishop Canning	1.15	0.73
	Bourton	2.1	2.1
	Chirton	2.27	2.08
	Compton	2.7	
	Deans Farm	11.8	
	Durrington	5.5	
Bourne	Clarendon/Devizes Rd	11	2.2
	Leckford	2.73	
	Newton Tony	6.5	
Nadder	Bulbridge	0.76	
	Fonthill	7	7
	Fovant	2.1	
Wylye	Arn Hill	1.8	
	Brixton Deverill	9.04	8.14
	Chitterne	13	12.8
	Codford	6	6
	Heytesbury	9.04	8.29
	Shrewton	2.73	
	Wylye	1.7	
	Total	**98.9**	**49.3**

3 Wessex Water Abstraction Impact on River Flow

3.1 INTRODUCTION

The individual source impacts and the in-combination effect of all sources operating at full licence on flows in the River Avon SAC are described in this Section. In addition the impact upon non-designated reaches of the River Avon are noted where a Wessex Water abstraction induced impact is detected. The impact of the recent history (last 10 years) of abstraction on river flows is also presented, as this 'comtemporary' impact is what the river ecology has been exposed to and hence this data has been used by the ecologists in their survey design as detailed in Section 4 and 5.

Before detailing the flow impact findings, the development, construction and calibration of the model are briefly outlined.

3.2 NEED FOR A MODEL

The large number of consents and their geographic and geological spread means a numerical groundwater/river flow model provides the only method to define individual consent effects on river flow and their in combination effect under different river flow conditions. A flow model was required by both WW and the EA to fulfil the requirements of the Hab. Regs.

3.3 PROJECT MANAGEMENT AND FUNDING

3.3.1 Funding

The funding for the model development and use has been provided 50:50 by Wessex Water plc and the Environment Agency.

3.3.2 Appointed contractor

Following a competitive tendering procedure Entec UK Ltd were appointed to undertake the modelling work.

3.3.3 Technical steering group (TSG)

The technical work of the modelling contractor was steered by a group of hydrogeologists and hydrologists with local and national experience. The group comprised members of both funding agencies and an external expert, Jane Dottridge of Mott MacDonald. A list of the TSG member is provided in Table 3.1. The group met at regular intervals to evaluate modelling progress, and to provide guidance and direction for the next phase.

The TSG also determined whether the developed model was fit for purpose – to assess the impact of consents of river flow. To aid in deciding whether a model was fit for purpose a series of target acceptance criteria were defined. A model is calibrated by comparing predicted historic river flows and groundwater levels with actual field data. The acceptance document sets acceptable numerical criteria, based on a percentage error from observed; it was acknowledged by the TSG that any model of this nature cannot meet the criteria at all points and/or all of the time. Hence the TSG can deem the model to be fit for purpose, though the acceptance criteria may not be fully met, based on their professional judgement and collective agreement that the error is acceptable.

Table 3.1: Avon Model Technical Steering Group – Members

Name	Organisation	Project Role
Giles Bryan	Environment Agency	Project Executive
Jim Grundy	Environment Agency	Project Manager
Karen Croker	Environment Agency	Hydrology reviewer & Hydro-ecology liaison with EN
Paul Shaw	Environment Agency	Hydrogeology review
Ian Colley	Hyder Consulting	Project Manager for Wessex Water
John Eastwood	Consultant	Reviewer representing B&WH Water
Jane Dottridge	Mott MacDonald	External Reviewer
Rob Soley	Entec	Contractor Project Director
Tim Power	Entec	Contractor Project Manager

3.4 MODELLING AIMS AND OBJECTIVES

The aims and objectives of the Hampshire Avon Numerical groundwater Modelling Project are set out by the TSG. In summary the project aims/objectives were to:

- Develop a recharge and run-off simulation for catchments of the Hampshire Avon, Dorset Stour and Frome and Piddle.
- For the Hampshire Avon, develop unified conceptual understanding of natural recharge, groundwater flow and runoff/interflow processes across the whole catchment together with anthropogenic influences on these.
- To update and join recently constructed and calibrated numerical models for the Bourne & Nine Mile and Wylye & Nadder models, extend these south to produce one calibrated numerical model for the Hampshire Avon which meets the specified acceptance criteria. Model area shown on Figure 3.1 (Section 9).
- Use the numerical model to carry scenario runs to meet the Habs Regs. review of consent requirements.

3.5 MODEL DEVELOPMENT

3.5.1 Conceptual Model

Before a numerical model can be built the modellers need to review available data and results from previous models. From this information they formulate how water enters the aquifer, travels through the aquifer and where this water will enter the river, this is done on a sub catchment basis. This process is referred to as developing a conceptual model. The conceptual model developed by Entec has been documented (Entec 2005). The TSG approved the conceptual model in July 2005 and allowed construction of the numerical model to start.

3.5.2 Model Construction and Calibration

A two layer model was constructed: a layer for the Upper Greensand and one for the overlying chalk. The outcrop areas for these aquifers within the model boundary are shown on Figure 3.1 (Section 9). The model consists of a grid of squares which represent 250m by 250m squares at the catchment scale. Each cell is assigned aquifer properties (permeability and storage) and whether it a stream cell or not. Stream cells represent the rivers in the catchment and within the model water enters or leave the aquifer into the stream cells depending of local water levels in the aquifer.

Calibration is an iterative process, which can lead to changes to the conceptual understanding. Although the models predicted flows after Run 3 were good in some respects, it can be seen from Figure 3.2 (Section 9) that by Run 60 (final calibration) they were much better. During the modelling process the following changes contributed to the fit seen by Run 60:

- Increasing the storage value for the Greensand in the Upper Wylye area.
- Changed Upper Greensand properties in the Upper Avon – more chert like deposit.
- Modifications to ensure groundwater under the Great Ridge between Wylye and Nadder flows preferentially to the Nadder.
- Change to stream bed leakage to improve the representation of the River Bourne along its winterbourne reach.

3.6 MODEL SIGN-OFF AND REFINEMENTS

The model was signed-off as fit for purpose by the TSG on the 21 July 2006.

Full documentation of the model build and calibration has been prepared by Entec (Entec 2006). Although considered fit for purpose the model could not fully represent the groundwater behaviour in two areas of the Hampshire Avon: River Till and Great Ridge. The model limitations are documented in the model report (Entec 2006).

3.6.1 Model refinements

It should be remembered that models are 'work in progress' and should be improved when new data becomes available.

Work is currently being undertaken to improve the model's representation of the River Till and improvements to the Nine Mile River have been made. The TSG recommended that if further data became available which improved the conceptual understanding of the River Till and Lower Wylye then refinements to the model should be attempted. Results from groundwater level and surface water monitoring of the Till during 2006 and 2007 has lead to a revision of the conceptual model and hence Entec are seeking to improve the calibration of the Till in the model based on this conceptual model.

Examination of the model's representation of the Nine Mile River flow and associated groundwater levels during the individual source assessments identified a calibration weakness, with too little flow in the River at times of low flow and the river recessing too quickly. Examination of the model input data indicated that changes to river bed levels (new detailed bed survey completed in 2007) should readily improve the Nine Mile River calibration. Entec have undertaken model runs to implement these changes (Run 156).

3.7 MODEL OUTPUT

3.7.1 Introduction

Brief descriptions of the model runs and types of output that can be generated from the model are given in this section. These outputs are used in Section 3.8 to present the results of individual and in-combination source impacts.

3.7.2 Model Runs

Model Run 60 is the approved calibration run, this is also referred to as the Historic run. The model configuration of aquifer transmissivity, and storage, recharge etc in Run 60 gives the best fit to observed historic river flow and groundwater level data. Once calibrated the model can then be used to predict river flow under different conditions, for example:

- No or more abstraction
- Different landuse
- Variations to rainfall and evaporation.

For the purposes of this study alterations to the base model run (60) have been to the abstraction rate for sources. The following key runs have been undertaken:

Natural (Run 62 & 136)	No abstractions No discharge No mains or canal leakage *This allows the natural flow to be predicted based on recent landuse*.
Contemporary scenario (Run 84)	As Run 60, but the abstraction rates for each source set with a fixed annual profile. This profile is based on the last 9 years of actual use. *This allows the impact of recent use, applied over the 34 years of model duration to be determined.*
Full Licence scenario (Run 85, 150 & 159)	As Run 60, but with all licences at full abstraction rates; where appropriate the STW discharges have been increased to ensure a water balance. *This allows the impact of the in-combination effect of all licences to be determined*

Individual Source Impacts

One of the requirements of the Habs. Regs is to determine individual source impacts. Following approval from the TSG and Natural England (Hans Schutten) the contemporary scenario was used as the base Run for these assessments. The following procedure was used, using Clarendon as an example:

Run 88 – No Clarendon abstraction	As run 84 (contemporary), but with no abstraction from Clarendon. The STW works that Clarendon indirectly supply (Hurdcott and Petersfinger) were reduced to ensure a water balance
Run 89 – Full licence abstraction from Clarendon	As Run 84, (contemporary), but with the abstraction from Clarendon increased to full licence. Commensurate increases in STW were made to ensure a water balance.

The only difference between these runs therefore is the Clarendon source abstraction (and STWs changes). The river flow and groundwater level difference between the model runs therefore gives the impact due to the Clarendon source. The difference between the two runs, e.g. river flow change, can be subtracted from the natural flow to see if compliance with the reduction guideline values (Table 1.1) is or isn't achieved.

Model Run Numbers

Since calibration (Run 60) approximately 100 further runs have been undertaken as part of investigating source impacts and as part of model refinement work. A list of model run undertaken, post calibration is provided on the enclosed CD.

Time Frame Extension

The original modelling time period was 1970 to 2003. To allow the actual (modelled) abstraction impacts at the ecological survey sites to be determined the time period of the model has been extended to the end of 2006, this is Run 135. Over the extended time period the Natural flow was predicted (Run 136) and the flow under Full Licence use was also determined (Run 150).

Model refinements

Work to improve the model's representation of the Nine Mile River has been carried out during 2007. Consequently revised natural and full licence run has been undertaken; these are Run 158 and 159 respectively.

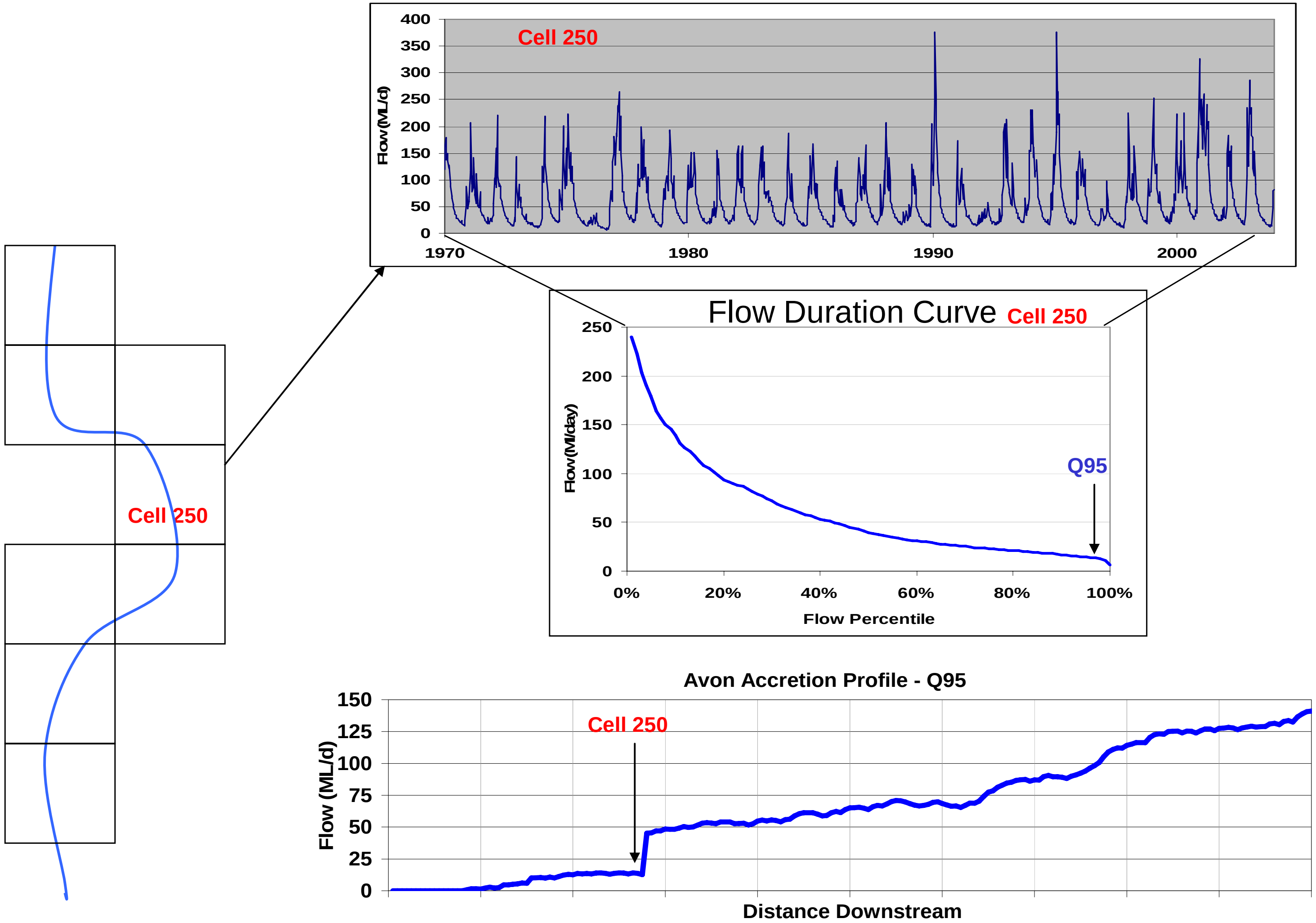


Figure 3.3: Model Output – Examples of Using Cell 250

3.7.3 Output data

The primary output data from the model are time series (1970 to 2003) of groundwater level or stream flow fluctuation, depending on the cell type. An example of time series river flow in cell 250 is shown on Figure 3.3. Post processing of the model output allows the data to be presented in different formats. One common type of analysis, used in this study and reported later, is the production of a Flow Duration Curve (FDC). A FDC for cell 250 is shown on Figure 3.3, a FDC provides a summary of flow condition that have occurred between 1970 and 2003. For example at Cell 250, the Q80 value is 20 Ml/d, which means that 80% of the time the flow in this cell has been greater than 20 Ml/d. In other words if you visited the river every day between 1970 and 2003, which is represented by Cell 250, on 80% of those visits the river flow would have been greater than 20 Ml/d, conversely during 20% of the visits the river flow would have been less than 20 Ml/d. The extreme low flows in a drought condition are given by the Q99–100 values, which in this case equates to the flows in September 1976.

Data from the FDCs for each cell can be used to construct a flow duration curve along each river at different Q values, an example of this is shown on Figure 3.3.

3.7.4 Impact Maps

The difference between the river flow model runs can readily be displayed by these maps. For example, the difference between natural flow and the river flow under full licence for each stream cell in the model can be calculated. The absolute difference (Ml/d) can be plotted or the percentage difference from natural can be plotted, for different Q values or on a specific date. The percentage difference between natural (Run 62) and full licence (Run 159) use at Q95 is shown on Figure 3.4 (Section 9).

Figure 3.4 shows that at Q95 abstraction flow reductions greater than 10% of natural are evident along the Bourne, Wylye and Fonthill Brook. The Avon upstream of Salisbury has flows higher than natural, this is due to canal leakage and STW discharges. The Kennet and Avon canal traverses the headwater catchments of the River Avon. The additional flow in the River Avon due to the canal is detailed in Section 3.9.2. Additional flow is also provided by the intra-catchment transfer of water from the River Bourne to the River Avon. The Newton Tony PWS source in the Bourne catchment supplies waters to communities in the Avon catchment with the wastewater from these communities draining to the Avon.

3.7.5 River Flow (‘drought’ periods)

Flow hydrographs are available for every stream cell within the model. Any time period within the 34 years of the modelled period can be examined. Of particular interest is the impact of abstractions on river flows during a drought/low recharge periods i.e. 1975/76, 1989/92 and 1995/97. Impacted river flows during these periods have been examined and comparison to natural flows made.

3.8 INDIVIDUAL SOURCE IMPACTS

The findings from the individual source impacts assessments are summarised in Table 3.2. The impact along the Hampshire Avon SAC reaches are presented, with compliance/non compliance identified by a tick (✓) or a cross (×).

The screening criteria (taken from Table 1.1) are:

- Whether flow reduction exceed 10% at along the river at Q50, Q70 and Q95 (accretion profiles)
- Whether flow reduction exceed 10% during drought/prolonged dry periods

Of the 16 sources assessed 9 sources were compliant against all the screening criteria, though it is noted that the impact upon the River Till is not defined. A brief note on the magnitude and location of non compliance due to the other sources is given below:

Durrington (Avon) **–** exceedance only in September 1976 and then the reduction was only 11%.

Deans Farm (Bourne) **–** a maximum reduction of 17% occurred in September 1976.

Newton Tony (Bourne) **–** the impact occurs over the first 2km of the SAC reach with reduction of upto 20% (at Q70). During droughts the impact can be greater, with a ~46% reduction in natural flow predicted in September 1976.

Clarendon (Bourne) **–** Flow reductions at Q95 close the confluence with the Avon are approaching 20%. Flow reductions during September 1976 are 30%.

Brixton Deverill (Wylye) **–** A flow reduction in excess of 10% occurs for ~12km downstream from the start of the SAC at Q70 and Q50, with a maximum reduction of 28% (Q50). Stream support maintains acceptable flows at Q95.

Codford (Wylye) **–** Exceedance occurs at Q50 for ~5km, with a maximum reduction from natural of 12.5%. The reduction in September 1976 is 12% of natural.

Heytesbury (Wylye) **–** At Q95 the maximum reduction is 11.7%, with ~3.5km of the river non-compliant. In September 1976 the maximum reduction is predicted to be 15% of natural.

The individual impacts of several sources is sufficient for non-compliance to occur along the River Wylye and River Bourne. Therefore, the in-combination effects will be greater, these are considered next.

Table 3.2: Summary of Individual PWS Source Impact on the River Avon SAC reaches

Source	SAC River at risk	Accretion Profile: Compliance?			Assessment points on SAC River	'Drought' Period Compliance		
		Q50	Q70	Q95		1975-76	1989-92	1995-97
Bishop Canning/Bourton	**Avon**	✓	✓	✓	Upavon confluence	✓	✓	✓
Chirton	**Avon**	✓	✓	✓	Upavon West	✓	✓	✓
Compton	**Avon**	✓	✓	✓	Ensford	✓	✓	✓
Durrington	**Avon**	✓	✓	✓	Ratfyn	✗	✓	✓
Deans Farm	**Avon**							
	Bourne	✓	✓	✓	Laverstock	✗	✗	✗
Leckford Bridge	**Bourne**	✓	✓	✓	Winterb. Gunner	✓	✓	✓
Newton Tony	**Bourne**	✓	✗	✗	Winterb. Gunner	✗	✗	✗
Clarendon	**Bourne**	✓	✗	✗	Laverstock	✗	✗	✗
Fonthill	**Nadder**	✓	✓	✓	Nadder start SAC	✓	✓	✓
	Wylye	✓	✓	✓	South Newton	✓	✓	✓
Arn Hill	**Wylye**	✓	✓	✓	Norton Bavant	✓	✓	✓
Brixton Deverill	**Wylye**	✗	✗	✓	Longbridge/N. Bavant	✗ / ✗	✗ / ✗	✗ / ✗
Codford	**Wylye**	✗	✓	✓	Stockton Park	✗	✓	✓
Heytesbury	**Wylye**	✓	✓	✗	Norton / Stockton Pk	✓/ ✗	✓/ ✗	✓ / ✗
Chitterne	**Wylye**	✓	✓	✓	South Newton	✓	✓	✓

3.9 IN-COMBINATION IMPACT

3.9.1 Introduction

The in-combination effect requires all sources to be operating at full licence, not just the in-combination effect of Wessex Water sources. Where a non Wessex Water source is exerting effect on river flow this is reported. As with the individual source assessments, the 'acceptable' flow reductions listed in Table 1.1 are used to determine 'compliant' and 'non-complaint' reaches.

Inspection of impact maps at Q95, Q70 and Q50, show that Wessex Water abstraction impacts exceed the 10% guideline values along the Tributaries upstream of Salisbury, i.e. Bourne and Wylye. The incombination effect on the main Avon below Salisbury is <10%, until the near the mouth of the river where reductions exceed 10% due to two surface water abstractions operated by B& WH Water. Therefore the Wessex Water impact on the tributaries upstream of Salisbury has been considered in detail and reported here. The abstraction impact on each sub-catchment is considered. In addition to reporting the impact on the SAC reaches the incombination effects on the non-SAC reaches is also noted.

The abstraction impact upon the bourne reaches on the Avon tributaries is reported in Section 5.

The impact of abstraction along each river system at all Q values has been assessed, with data presented for Q50, Q70 and Q95 in this report. Time series data, FDCs an daccretion profiles are used to examine the abstraction impact.

3.9.2 River Avon

A schematic diagram showing the location of the Wessex Water PWS sources in the Avon catchment are shown on Figure 3.5 (Section 9). This figure also shows whether the abstracted water is exported (and the proportion) i.e. Chirton, or returned via STWs (or soakaway) to the catchment. Figure 3.5 shows that intra-catchment transfer of water is occurring with water abstracted in the Bourne catchment i.e. Leckford bridge and Newton Tony discharging by STW to the Avon (Pewsey and Ratfyn/Amesbury STW, respectively).

SAC River

The following assumes that **no** leakage is occurring from the canal under natural conditions (Run 158) and Full Licence conditions (160), the latter thereby giving a conservative bias to the findings.

The in-combination plot of accretion along the River Avon (upstream of Salisbury) at Q50, Q70 and Q95 are shown on Figure 3.5 (Section 9). These charts show compliance along the River Avon at Q50 and Q70, a short reach (2.75 km) exceeds the 10% guideline adjacent to the Durrington source at Q95. The maximum reduction at Q95 along this exceedance reach is 15%, to achieve compliance an extra 4 Ml/d of flow would be required.

Flow reductions during 'drought' and low recharge periods for a stream cell near to Durrington, but upstream of the Ratfyn STW discharge have been assessed. The output for 1976 is shown on Figure 3.6, during the 1976 drought the reductions in flow reaches 30% of the natural flow. These impacts affect only a short reach of river, as effluent discharges from Ratfyn and Amesbury STW mean the impact of abstraction become neutral. Plus these impacts are not solely due to Wessex Water, as the individual Wessex Water source impact when aggregated do not total these levels of impact, it is concluded that the MOD source at Bulford is also exerting an influence.

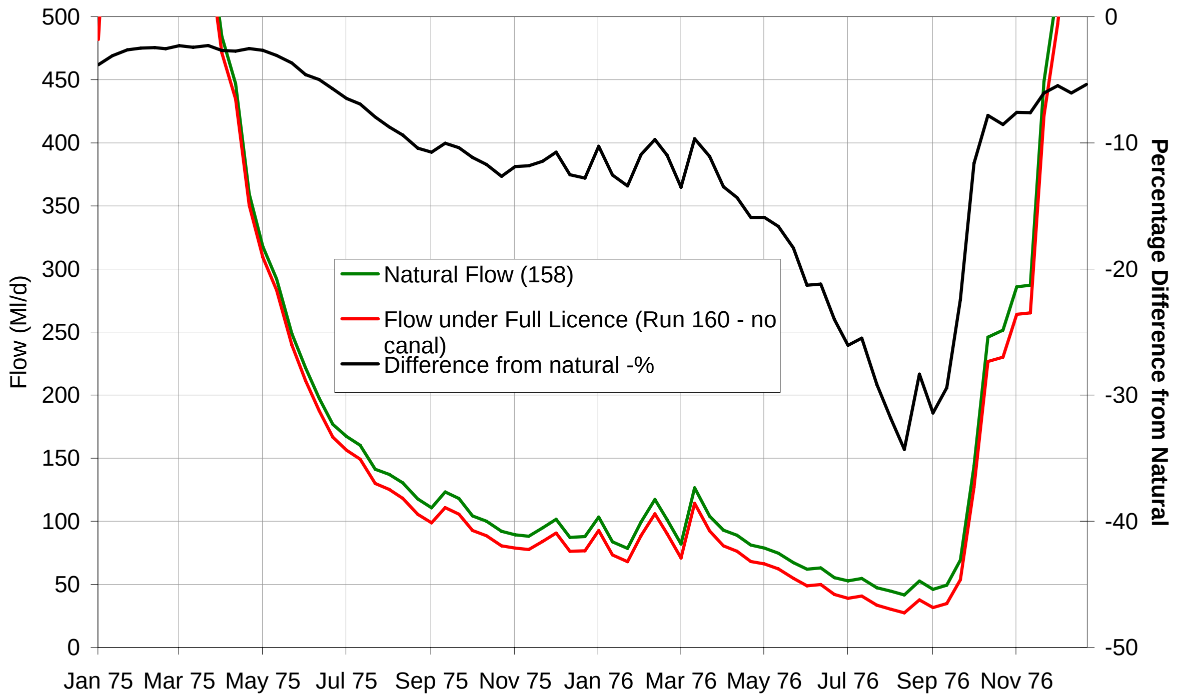


Figure 3.6 River Avon at Durrington Predicted Flow in 1975 and 1976

In the HAM leakage is assumed to occur from the Kennet and Avon canal based on a limited data set provided by British Waterways. The 'extra' water in the River Avon compared to natural, as measured (modelled) at Amesbury, due to the canal leakage is listed in Table 3.3.

Table 3.3: Contribution from Canal to flow in the River Avon at Amesbury

Q Value	Extra flow (ML/d)
50	12.1
70	9.8
95	9.7

The 'extra' water in the Avon could be viewed as mitigating the abstraction impact. Even halving the canal leakage would still provide sufficient water to allow compliance with flow reduction guidelines around Durrington at Q95.

Non SAC – Up Avon West

The in-combination impact of Bishop Canning and Bourton reduces flow in the Up Avon West tributary of the Avon by more than 10% at Q95 (Figure 3.7). Compliance is achieved at Q70 and Q50. To achieve the 10% guideline at Q95 an additional 0.5 ML/d of flow is required in the tributary. It is noted that these impact predictions assume no leakage from the canal. Along this reach the canal is modelled to provide ~3 ML/d at Q95, therefore, even a fifth of this leakage would mitigate the PWS flow reductions.

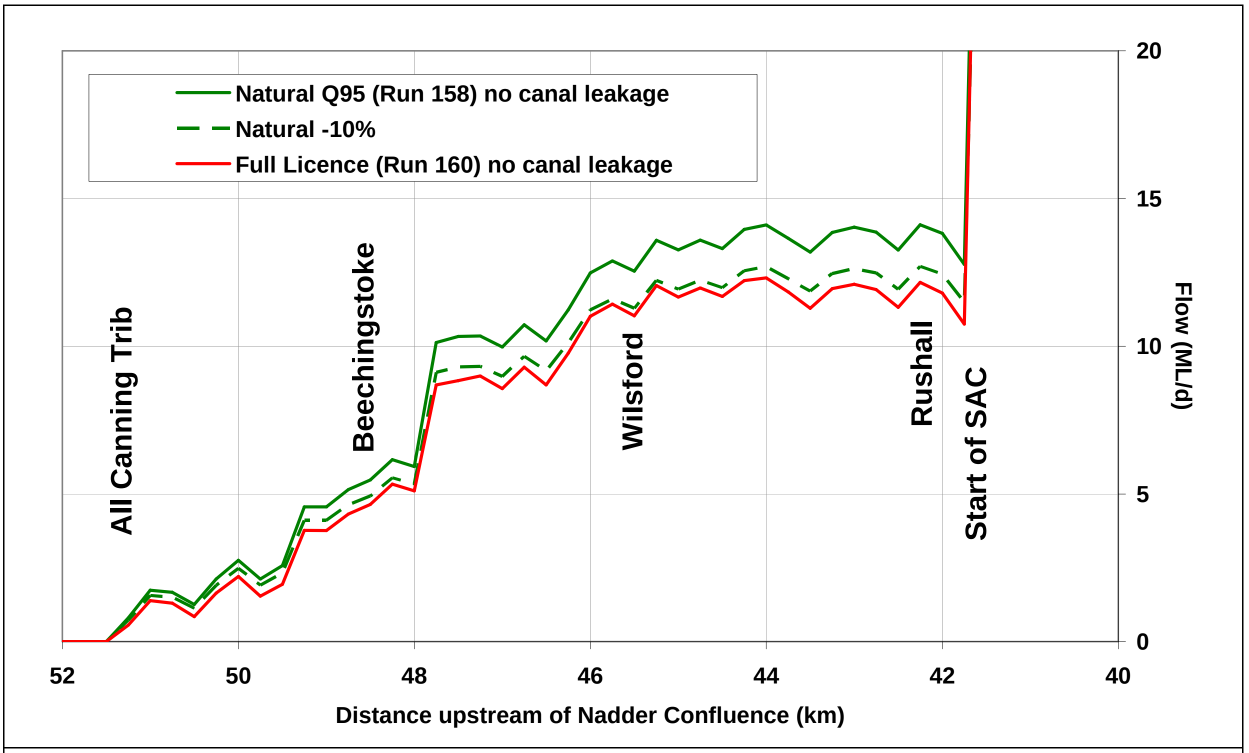


Figure 3.7: Up Avon West Tributary Accretion at Q95

Non SAC – Nine Mile

Nine Mile River has been the subject of a separate Low Flow investigation, the findings from that study concerning the river flow are given here.

The in-combination impact on flows along the Nine Mile River are shown on Figure 3.8 (Section 9). Figure 3.8 shows exceedance of the 10% guideline at all three Q values, with the natural flow reduced by ~50% under full licence conditions at Q95 and Q70. The flow reductions are attributable to two sources: Wessex Water's Newton Tony PWS source and the MOD source at Bulford. The proportion of individual source impacts varies at each Q value, but in general the Wessex Water source accounts for ~30% of the flow reduction (between Full licence and natural). For example at Q70 the flow reduction is ~2 Ml/d, the Newton Tony abstraction accounts for 0.52 Ml/d (27%) of this reduction. Days of additional drying along this bourne due to abstraction (all sources) is detailed in Section 5.

The canal leakage provides no mitigation for these impacts.

3.9.3 River Bourne

A schematic diagram showing the location of Wessex Water PWS sources in the Bourne catchment are shown on Figure 3.9 (Section 9). This figure also shows where the abstracted water is returned. As noted there is intra-catchment export from the catchment, Leckford and Newton Tony, plus the water that is abstracted from the Clarendon and Deans Farm sources, is returned to the Avon via the Petersfinger STW.

SAC River

The River Bourne section of the River Avon starts in Winterbourne Gunner. The in-combination plot of accretion along the River Bourne (Boscombe, just upstream of the perennial head, to Salisbury) at Q50, Q70 and Q95 are shown on Figure 3.9. These charts show non-compliance along the River Bourne SAC at Q50, Q70 and Q95, the impact, as percentage of natural, progressively increases as natural flows decline, i.e. the biggest impacts occur at Q95. Full licence abstraction reduces flows by up to 34%, to achieve compliance along the SAC an additional 1.3 Ml/d is needed at the start of the SAC, increasing to 5 Ml/d in the lower reach, at Q95.

The individual Wessex Water source impacts have been aggregated to determine the relative contribution each source makes to the exceedance of the guidelines described above. This approach will not equate to the full licence impact as 'interference effects' and other sources are not included, but allows a visual assessment of the relative contribution to be made. The findings at Q95 are shown on Figure 3.10.

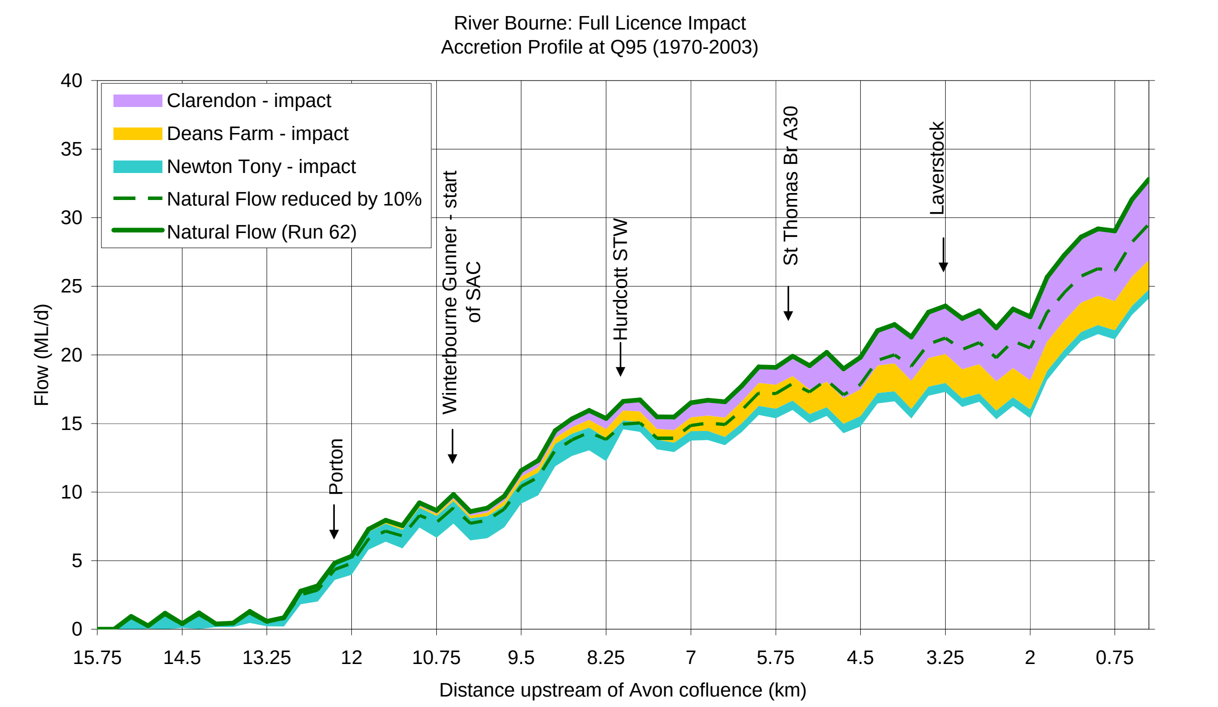


Figure 3.10: River Bourne: Individual source contribution to impact at Q95

At the start of the SAC (Winterbourne Gunner) the Newton Tony source is the primary cause of non compliance, though contribution from the other sources is evident. Moving downstream the impact due to Newton Tony reduces, as the stream flow increases, however, the impact due to other sources notably Deans Farm (middle reach) and Clarendon (lower reach) increase. The implication of these observations is that to achieve compliance, reductions to the Newton Tony output will increase flow at the start of the SAC and reducing output from Clarendon/Deans Farm will increase flows in the middle/lower reaches of the SAC.

Flow reductions during 'drought' and low recharge periods towards the bottom of the Bourne, at Laverstock, have been assessed. The output for 1976 is shown on Figure 3.11, during the 1976 drought the reductions in flow reached ~50% of the natural flow. The model overpredicts the actual flow in the Bourne at Laverstock in 1976, by ~50%, consequently under full licence conditions the Bourne may dry if 1975-76 conditions or worse occur again.

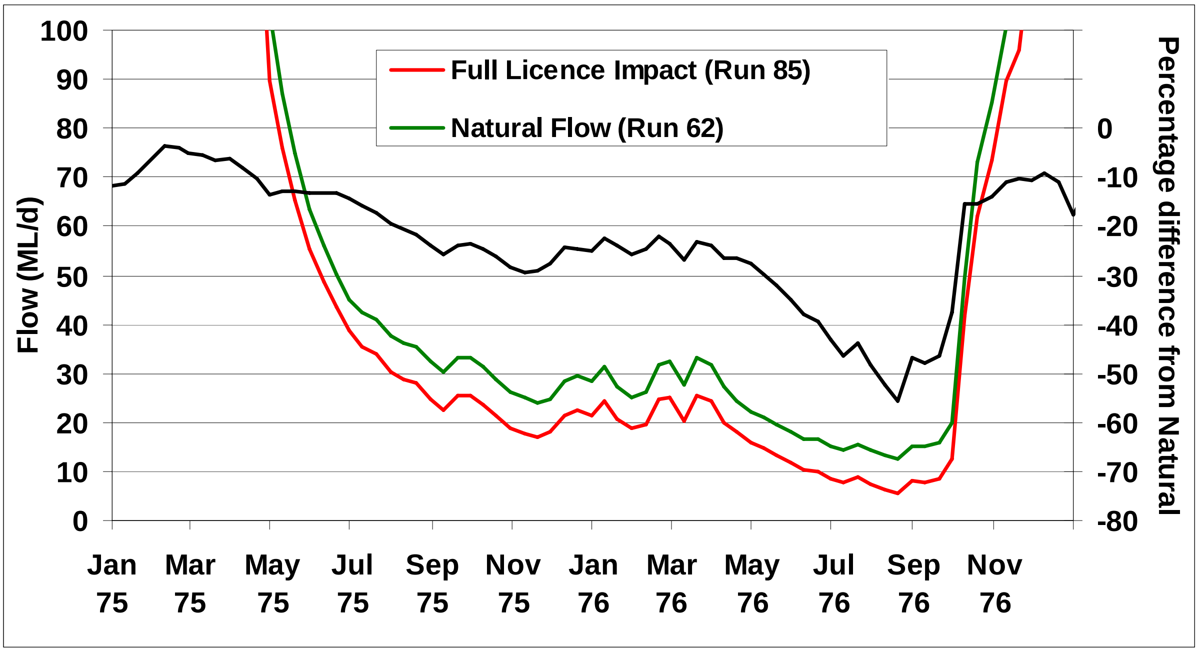


Figure 3.11: River Bourne at Laverstock – modelled natural and full licence flows in 1975-76

The impact of abstraction upon the winterbourne reach of the River Bourne is examined in Section 5.

The impact of the three sources shown on Figure 3.10 is not a 1:1 impact on river flow, the sources derive some of their yield from other catchments. For example if the Clarendon source was switched off, an abstraction reduction of 11 ML/d, the flow in the Bourne (at Q95) would only increase by 3.7 ML/d, an efficiency of 33%. The other catchments benefiting from the switch off would be the main Avon (below Salisbury) and tributaries of the River Test.

In summary by reducing Wessex Water source outputs compliant flows along the Bourne SAC can be achieved, however, to achieve an additional 5 Ml/d of river flow source outputs would need to be reduced 17.5 ML/d, an efficiency of only 30%.

3.9.4 River Nadder

A schematic diagram showing the locations of the Wessex Water PWS sources in the Nadder catchment are shown on Figure 3.12 (Section 9). This figure also shows where the abstracted water is returned, with a large proportion of the abstracted water exported from the catchment, with the Fonthill Source supplying Shaftesbury. The sources at Bulbridge and Fovant transfer water to other sub-catchments of the Avon. In total the export/transfer of water from the catchment is 8.7 Ml/d.

SAC River

The River Nadder part of the River Avon SAC occurs downstream of Upper Chicksgrove (Figure 1.1, Section 9). The ecological designation of the Nadder is 'moderate' (Section 1.2), consequently, the allowable reduction in flow at Q95 is 15% (Table 1.1). The in-combination plots of accretion along the River Nadder at Q50, Q70 and Q95 are shown on Figure 3.12 (Section 9), which show that the river maintains compliance at all flows.

Non SAC River

Flow reductions due to abstraction along the Nadder upstream of the River Avon SAC reach are less than 15% at Q95.

Reductions in river flow of greater than 15% are predicted along the Fonthill Stream, Teffont Brook (River Teff) and Fovant Stream due to Wessex Water abstractions. The Fonthill Brook has been the subject of a separate Low Flow investigation, which also encompassed the Teffont Stream and Chilmark Stream. The findings from the empirical studies presented in the Fonthill Low Flow report are summarised here.

The Chilmark Stream dries naturally every year (winterbourne) before the effects of the Fonthill PWS abstraction are felt in this catchment.

The Fonthill PWS Source impact flows in the Fonthill Brook and Teffont Stream, with the flow impact greatest at time of natural low flow (Q95). Under full licence conditions the flow in the perennial Fonthill Brook and Teffont Stream are reduced at Q95 by ~30 and ~80% respectively. The impact upon the Fonthill Brook winterbourne is examined in Section 5.

Full licence use of the Fovant source reduces flows in the Fovant Stream by: 11% at Q50, 13% at Q70 and 16% at Q95. Below the STW on the Fovant Brook the return of some of the abstracted water reduces the abstraction impact to less than 10% at Q95, Q70 and Q50.

3.9.5 River Wylye

A schematic diagram showing the location of the Wessex Water PWS sources in the Wylye catchment are shown on Figure 3.13 (Section 9). This figure also shows where the abstracted water is returned, some water is used locally but the majority is exported, north to Trowbridge/Bath and South to Yeovil and the surrounding area.

SAC River

The River Wylye forms part of the River Avon SAC downstream of Longbridge Deverill. The in-combination plot of flow accretion along the River Wylye at Q50, Q70 and Q95 are shown on Figure 3.13 (Section 9). These charts show a variable picture of impact both along the Wylye and at different Q values.

At Q95, flows above natural occur at the start of the SAC and extend for ~10 km. The higher than natural flow is due to stream support, the cress beds activities at Hill Deverill and the discharge of water from Warminster STW. Part of the catchment for Warminster STW is supplied with public drinking water from a Wessex Water source in the Bristol Avon catchment (River Frome) to the east. Consequently, this PWS import augments flow in the River Wylye. After ~10 km downstream of the start of the SAC the cumulative effect of abstraction takes the river flow below natural and the 10% guideline is exceeded downstream of Codford PWS. Below South Newton flows become compliant. A maximum reduction of 14% is modelled to occur downstream of the A303. An additional flow of 3.5 Ml/d would be required at this point in the river to achieve compliance.

A marked dip in river flow occurs between the A303 and River Till, both in the natural and full licence runs, therefore the dip is not due to abstraction. The dip is caused by an incorrect river bed elevation in the model (too high), which cause water to leave the river (enter the aquifer) only to return to the river a few cells further downstream. This small error has no bearing on the predictions reported here.

At Q70, flow reductions exceed the 10% guideline at the start of the SAC, the maximum reduction being 16% (1.5 Ml/d more water is needed to achieve compliance); however, ~4km downstream flow become compliant due to the input from Warminster STW. Approximately 12km downstream from the start of the SAC, flow under full licence conditions become less than the guideline values. The exceedance increases due to the Codford PWS abstraction and full licence flows remain non compliant until the confluence with the River Nadder. The maximum exceedance is 18% below natural, an additional flow of ~8 Ml/d would be required at this time to achieve compliance.

The abstraction impacts at Q50 are more severe than at Q70 and Q95, a consequent of storage development at times of lower flow. At the start of the SAC flows are reduced by ~30%, the STW input at Warminster reduce the impact to 10%, but flow reductions exceed the guideline again below Norton Bavant. Only at the confluence with the Nadder is compliance achieved. In this lower reach the maximum exceedance predicted is 22%, an additional 17 Ml/d of flow would be required to achieve compliance.

Unlike the River Bourne where the abstraction impact is greatest at times of low flow, the greatest impacts on flow in the River Wylye are at ‘medium’ flows. Spatially the greatest reductions occur at the start of the SAC, due to the pumping activities associated with Brixton Deverill and between the Chitterne Brook and Till River confluence. This latter impact is due to the cumulative impact of abstraction, though the large (up to 26 Ml/d) abstraction at Codford is exerting a significant effect. To explore the temporal nature of the abstraction impact flow duration curves have been generated for two locations: start of SAC and Stockton Park GS, these are shown on Figure 3.14 and 3.15 respectively.

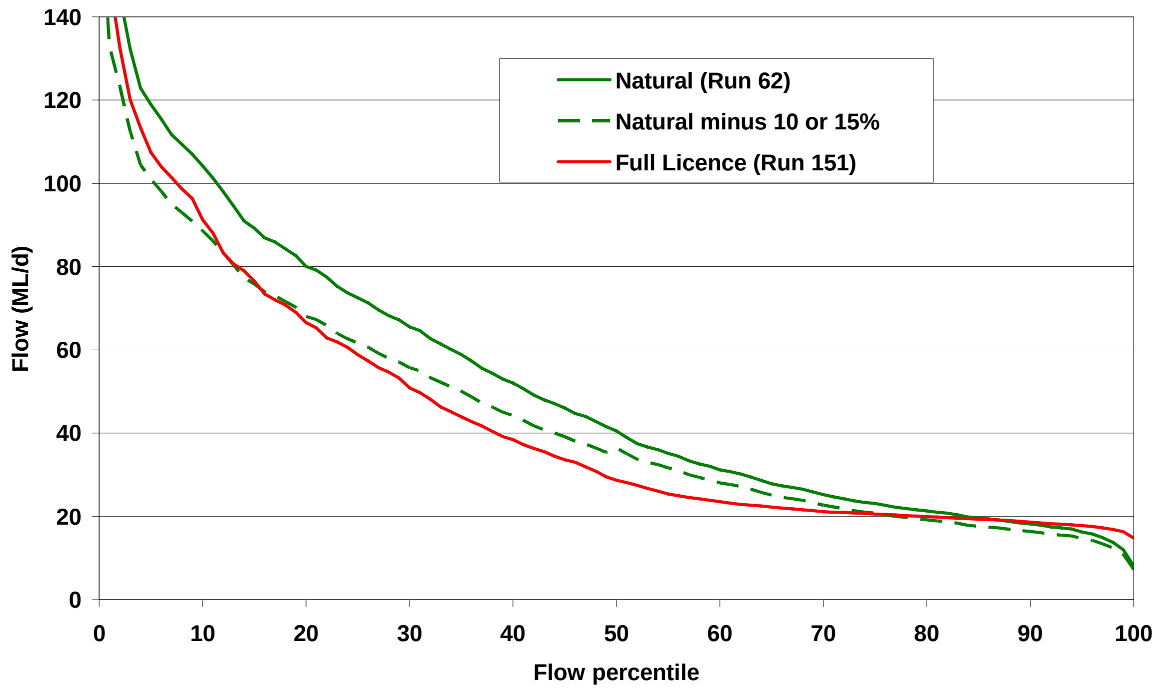


Figure 3.14: River Wylye at Longbridge Deverill (start of SAC) – Flow duration curves

At the start of the River Avon on the River Wylye (Longbridge Deverill) flow reduction exceed the guidelines between Q17 and Q74, with a maximum reduction of 29% at Q50.

At Stockton Park exceedance occurs from Q15 to Q98. A maximum exceedance of 25% occurs at Q44.

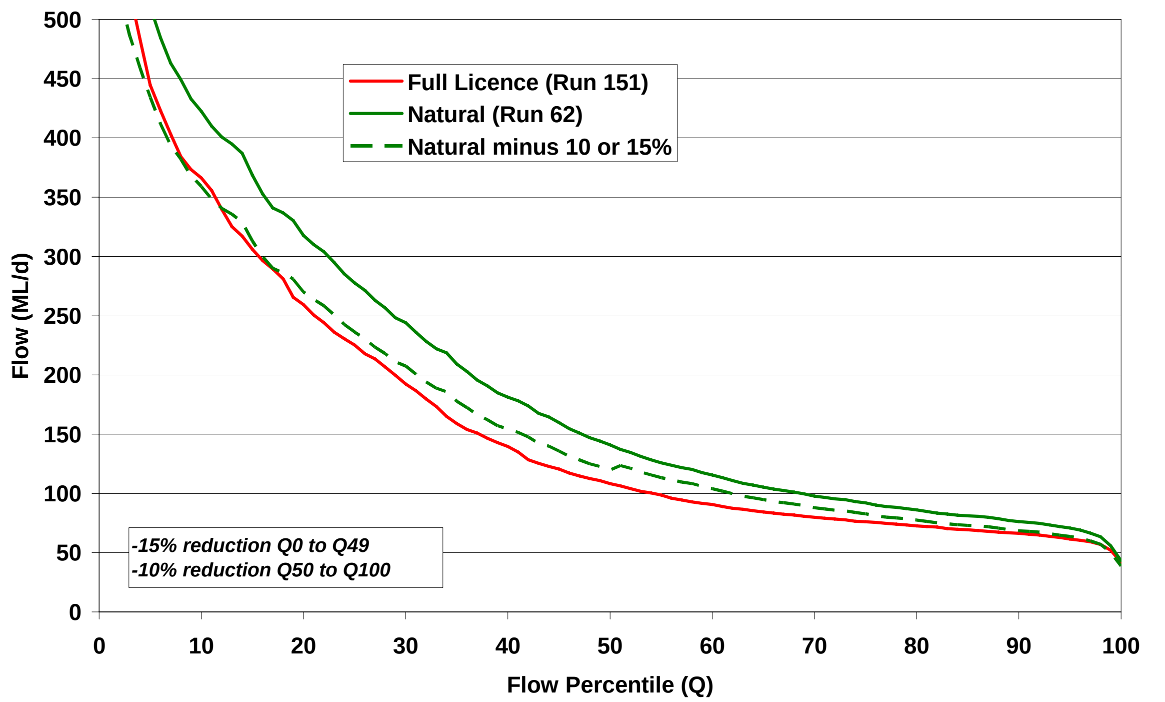


Figure 3.15: River Wylye at Stockton Park – modelled Flow Duration Curves

The protection afforded by stream support and storage development means flows during droughts are maintained. For example Figure 3.16 shows the modelled flow hydrograph for the River Wylye at Stockton Park during 1975 and 1976 under natural and Full Licence conditions. Figure 3.16 shows river flow under full licence conditions in September 1976 being very similar to natural conditions. The pay back occurs in the autumn, with the onset of rains, although flows under full licence conditions do pick up, the flow is ~70 Ml/d lower than the modelled natural flow.

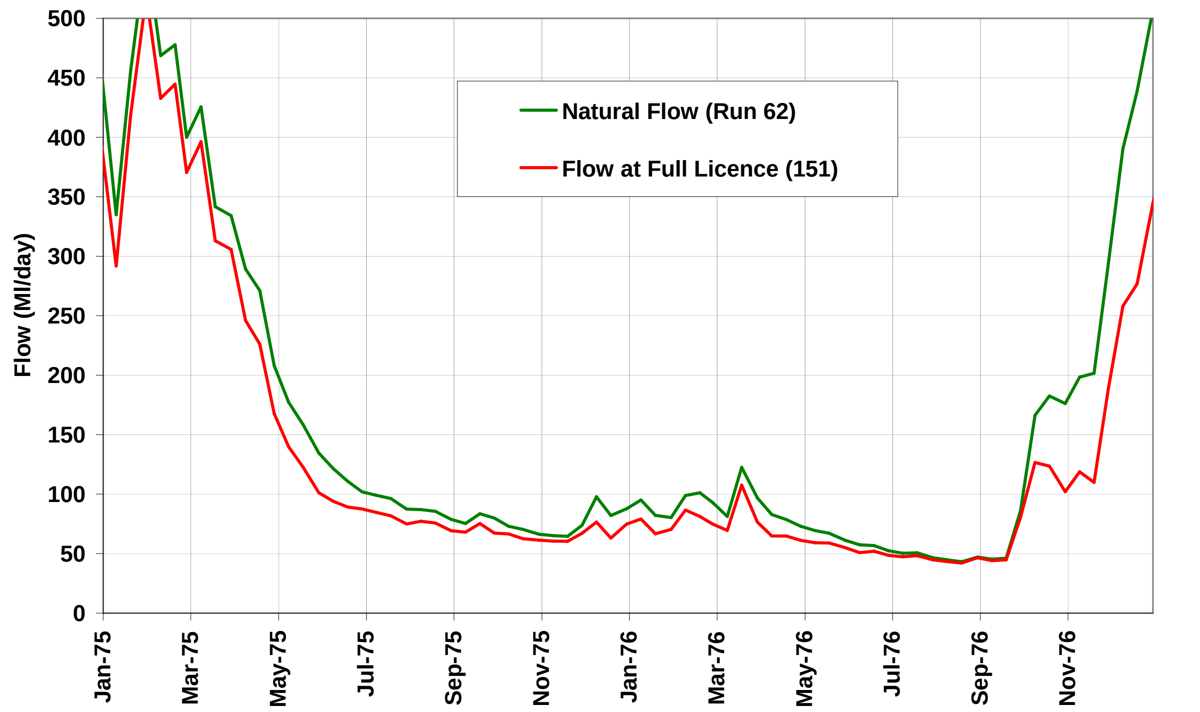


Figure 3.16: River Wylye at Stockton Park – Modelled River during 1975 & 1976

River Till

This area of the model is subject to refinement and therefore no results are presented at this stage.

Non SAC

Upper Wylye – The abstraction at Brixton Deverill results in the River becoming perched. To maintain flow along this perched reach stream support water is added at two locations: Kingston Deverill and Brixton Deverill. The pattern of abstraction impact is variable both spatially and temporally along this reach. When stream support is active some part of the reach have higher than natural flow (>100%), whilst others are less than natural. When aquifer levels are recovering in the autumn/winter following rains, the flows are less than natural exceeding the 10% reduction guideline.

The Chitterne Brook is a bourne and naturally dries to its confluence with the River Wylye. The impact upon the bourne due to abstraction is examined in Section 5.

Summary
The above descriptions of abstraction impact on the SAC reaches of the perennial tributaries upstream of Salisbury are summarised in Table 3.4. The SAC lengths have been calculated from the HAM stream cells. The length of the non-compliant reaches along each tributary at Q95, Q70 and Q50 are detailed in Table 3.4. The greatest impact occurs at Q50, when at full licence abstraction 41% of the SAC (tributaries) would have flow reduced by more than 10% of natural.

Table 3.4: Impact on perennial tributaries upstream of Salisbury – at Full Licence (Run 85)

Tributary	**SAC length (km)**	**Non Compliance* at Q50**		**Non Compliance at Q70**		**Non Compliance at Q95**	
		Length	**% of SAC**	**Length**	**% of SAC**	**Length**	**% of SAC**
Avon	41	0	0	0	0	0	0
Bourne	10.25	9.75	95	10.25	100	10.25	100
Nadder	23.5	0	0	0	0	0	0
*Till***	3.25	-	-	-	-	-	-
Wylye	40	38.75	97	27.25	68	5	12.5
Total	**118**	**48.5**	**41**	**37.75**	**32**	**15.25**	**12.9**

** Non-compliance defined as a flow reduction of greater than 10% of the natural flow (Run 62)*
*** Awaiting results from HAM refinement*

3.10 CONTEMPORARY USE

The forgoing has reported the impact of Full Licence use of all sources on river flow, which is a theoretically possible impact but an impact that has not occurred to date. To gauge the impact of recent abstraction use and in particular to assist in the design of the ecological survey ‘contemporary’ impacts have been determined.

The greatest impacts occur along the River Bourne and River Wylye and so the contemporary impact on these rivers is presented.

River Bourne
The contemporary impact at Q95 along the Bourne is shown on Figure 3.17. Figure 3.17 shows contemporary use results in exceedance of the guideline values along the entire SAC reach, which impacts ranging from -10.5 to -23% of natural. Though not up to the level of full licence predicted impacts, contemporary use has resulted in the exceedance of the guideline values.

River Wylye
At contemporary rates of use the majority of the River Wylye is compliant with reduction guideline values at all Q values. The contemporary impact at Q95, Q70 and Q50 are shown on Figure 3.18 (Section 9). In this scenario Chitterne Road Stream support borehole is operational, as required to maintain the target flow at Codford gauging station on the Chitterne Brook. Although not licensed, the Chitterne Road source has been operated under Section 32(3) consent since 1995 and therefore has become a feature of the contemporary environment.

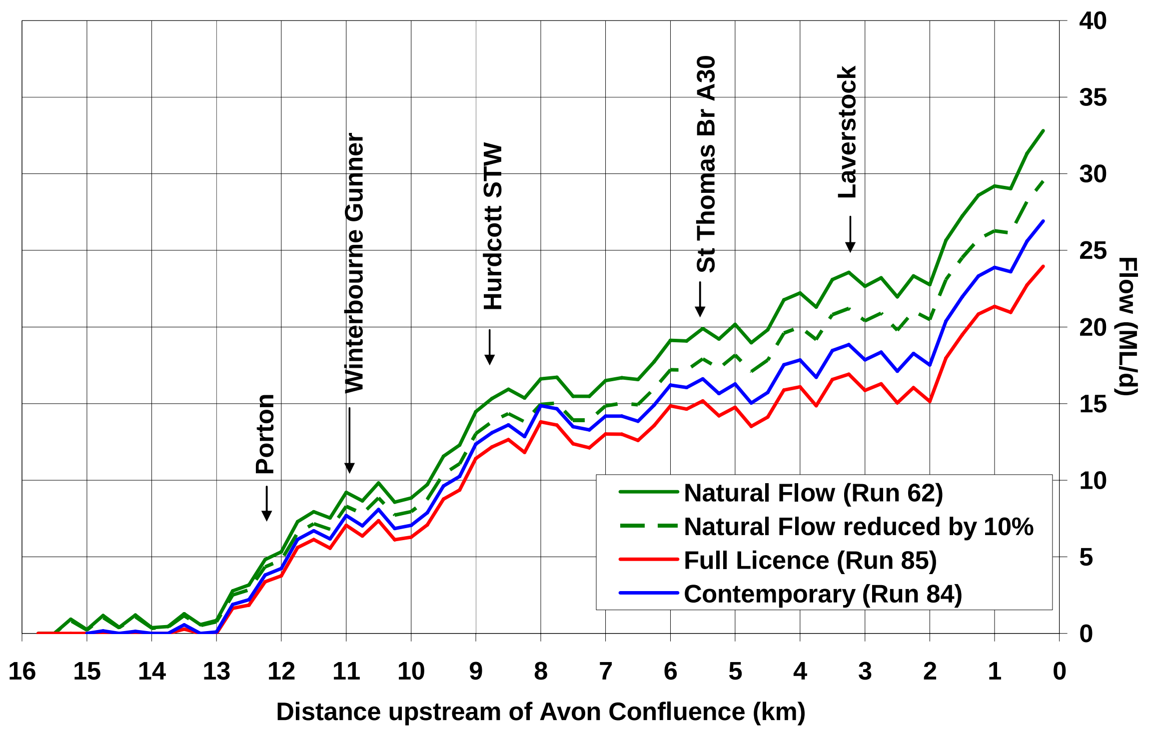


Figure 3.17: River Bourne Contemporary Impact at Q95

Along the SAC reach at contemporary abstraction rate compliance is achieved at Q95, except for ~1km downstream of the Codford source where the reduction from natural is 11.5%. At Q70 a short reach of non-compliance occurs at the start of the SAC (-16% of natural), with another non-compliant reach (up to 13%) for ~3km downstream of Codford PWS, otherwise the Wylye is compliant.

At Q50, a non-compliant reach occurs from the start of SAC and extends to Warminster STW, with a maximum reduction of 25%. Again a non compliant reach exists around Codford, with a maximum reduction of 14%.

The contemporary impact at Stockton Park GS is presented as a flow duration curve, together with natural and full licence curves on Figure 3.19. At contemporary rates compliance is generally achieved, with the maximum reduction being 14% between Q50 and Q65.

Along the SAC reach of the River Wylye, except near the start of SAC, contemporary flow reductions are close to or within guideline reduction values. The influence of Brixton Deverill PWS and associated stream support abstractions means that the Wylye headwater is effected by periods of greater than and less than natural flows, with reductions at certain time (Qs) exceeding the acceptable flow reduction guideline values.

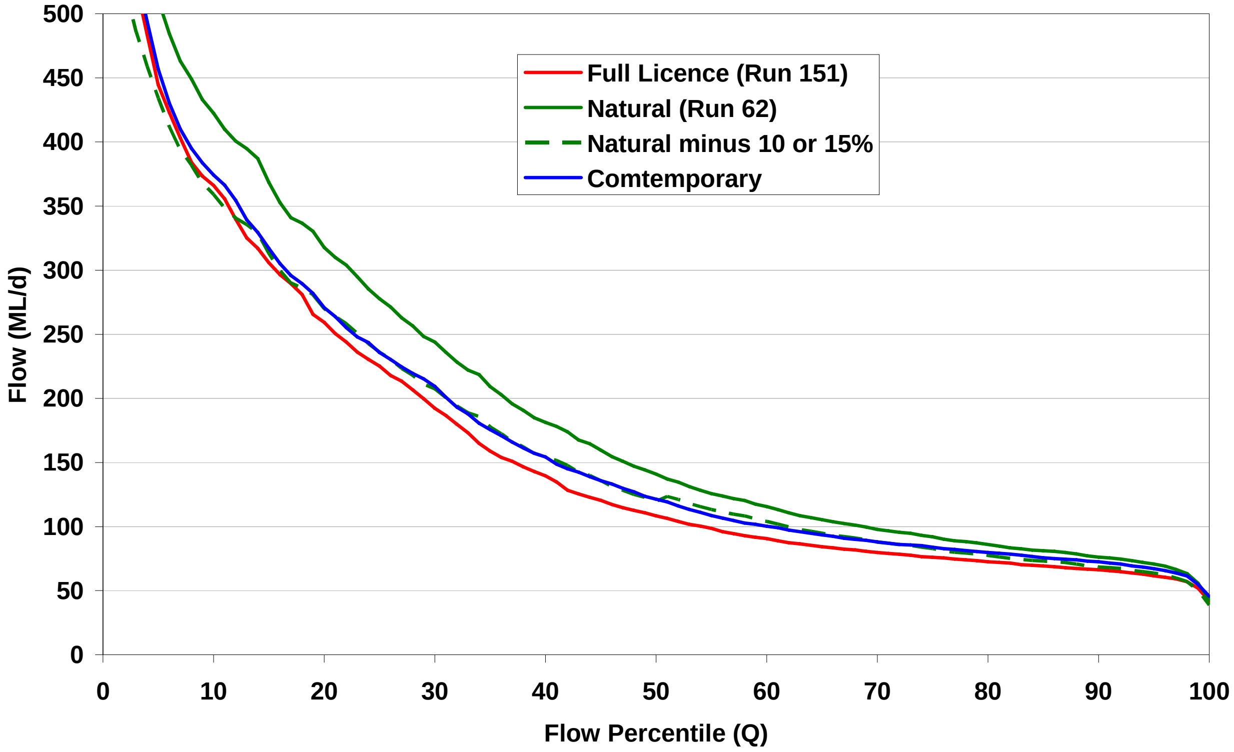


Figure 3.19: River Wylye at Stockton Park – Contemporary Flow Duration Curve

3.11 SUSTAINABILITY REDUCTIONS

The EA has provided WW with draft sustainability reductions (Section 1.2). These reductions in PWS source output have been trialled using the HAM to determine the resultant improvements to river flow, the results are presented in this Section. The draft reductions relate to improving flow along the River Bourne and River Wylye. The sources affected and the revised and current summer outputs are listed in Table 3.5. The net effect of these changes is a 23.5 Ml/d reduction in PWS summer output.

Table 3.5: Draft Sustainability Reductions

Catchment	Source	Current (summer) Output (Ml/d)	Output based on draft Sustainability Reductions (Ml/d)
Bourne	Newton Tony	6.5	5
	Clarendon	11	0
Wylye	Brixton Deverill	9	4
	Codford	6	0

The benefits that occur due to the Sustainability Reductions along the River Wylye and River Bourne are shown on Figures 3.20 (Section 9) and Figure 3.21 respectively. Along the Wylye SAC designated reach compliance is achieved at Q95 and Q70, a stretch of non compliance occurs downstream of Codford at Q50.

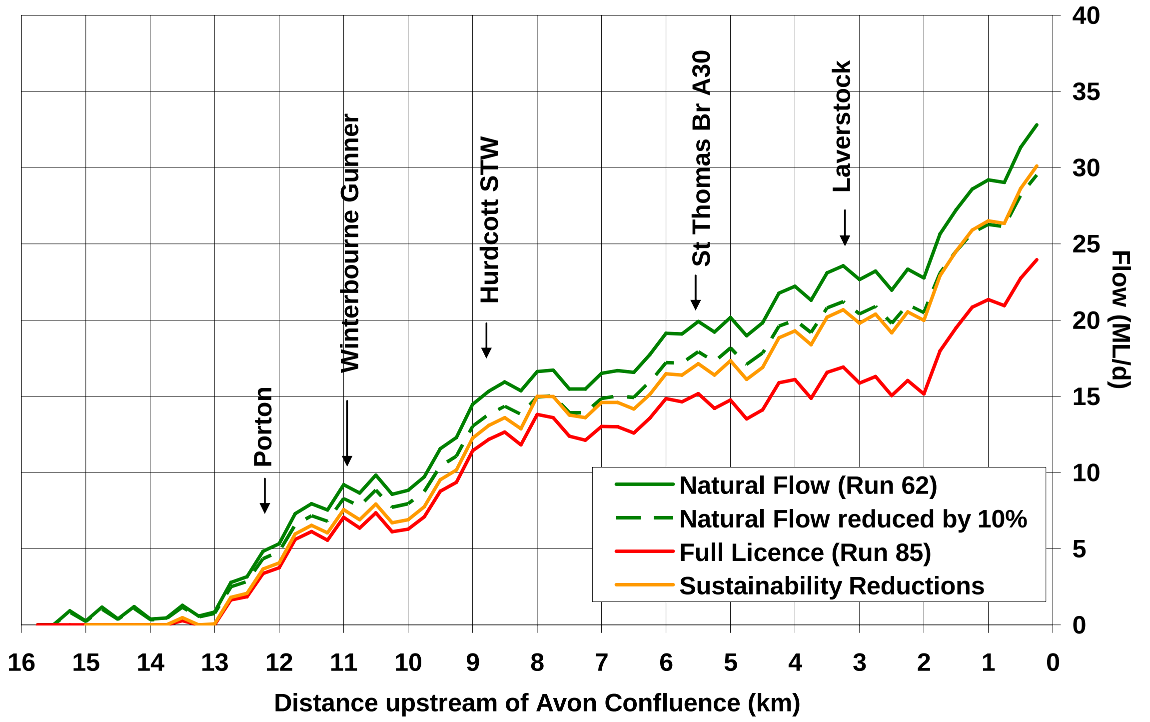


Figure 3.21 River Bourne Accretion at Q95, following draft sustainability reductions

Along the River Bourne (SAC reach) compliance occurs at Q50, but sections of the reach exhibit non-compliance at Q70 and Q95, with the greatest exceedance at Q95 (Figure 3.21).

3.12 SUMMARY

Full Licence Impact

The Natural England guidelines (Table 1.1) have been used to screen whether river flow reductions due to abstraction potentially impact river ecology (-10% (high) to -15% (moderate)). The in-combination effect of full licence abstraction exceeds these guidelines on tributaries of the Avon upstream of Salisbury. The impact on the River Avon reach of each tributary is as follows:

Avon – small exceedance reach (~3km) around Durrington at Q95, this conclusion assumes **no** canal leakage.

Bourne – The largest impacts on the Bourne occur at times of low flow (>Q95). At Q95 exceedance occurs along the entire SAC reach, with a maximum reduction from natural of 34%. An additional 5 ML/d of water would be required in the river at Q95 to achieve compliance.

Nadder – No exceedance of guideline values.

Till – Awaiting model refinement.

Wylye – Small reaches of exceedance occur at low flows (Q95), stream support and storage development affords a large degree of protection to flow at natural low flow times. Greater reductions in flow occur at higher river flows. Maximum reductions in river flow occur near the start of the SAC (25% at Q44) and between the Chitterne Brook and River Till (29% at Q50). The reduction in flow at the start of the SAC is attributable to the Brixton Deverill PWS source. The reductions observed between the Chitterne and Till are in part a cumulative impact, but the large abstraction from the Codford PWS source has a major influence.

Contemporary Impact

The above impacts are theoretically possible but have never occurred to date. The contemporary impact of abstraction has been determined to allow the variance with Full Licence predictions to be established plus to assist in the design of the ecological survey.

Bourne – contemporary abstraction has resulted in exceedance of guideline values, with up to a 25% reduction in flow (at Q95) compared to natural.

Wylye – contemporary impacts along the Wylye are close to the guideline values at all Q values. The main exception is at the start of SAC, where reductions of up to 25% occur.

4 Ecological Study Findings – Perennial Rivers

4.1 INTRODUCTION

The results from the extensive aquatic ecological survey undertaken as part of the Low Flows Investigtations on the River Avon SAC are presented in this section. Results from long running studies on the aquatic ecology of the River Avon SAC which have continued during this study period are also presented. In this summary the results that demonstrate the main findings are presented.

Desmoulin's whorl snail
The Desmoulin's whorl snail has not been assessed because it is regarded as a terrestrial species and does not form part of the aquatic communities.

4.2 REVIEW OF HISTORIC DATA

At the outset of this study the available ecological and associated physical and chemical data for the River Avon SAC were collected and reviewed (APEM 2005). The review sought to identify whether existing data showed an ecological effect to abstraction or low flows. To identify the effects of abstraction pressure on river flows preliminary HAM output identified river reaches where abstraction induced river flow reductions exceed allowable values i.e. > 10% reduction at Q95.

A series of statistical analyses were undertaken on the existing data to determine whether significant relationships between ecology (e.g. macrophyte community) and abstraction/low flow impacts could be identified. Multivariate analysis (described in Section 4.4.1) was used to measure the relative effects of abstraction/flow and other physico-chemical parameters in determining community change across different sites and through time. Population changes in salmon and trout over time were also analysed where long term data were available.

Although reasonably good ecological data sets have been built up over time, the objectives of the existing surveys were not to detect impact due to flow changes, being generally intended to monitor impacts of pollution or as sentinel sites to monitor long-term environmental changes.

The review concluded that the available data did not show any significant effects of abstraction on river ecology. However, the data set was unlikely to detect such impacts due to the coarse resolution and lack of baseline data for the pre-abstraction condition. Consequently, APEM recommended that a targeted monitoring programme was required to assess the impact of abstraction over and above other confounding factors, by comparing the ecology at sites that have never been affected by abstraction with sites that have been affected, both historically and recently.

4.3 SURVEY DESIGN

The survey was designed to isolate the affects of abstraction from the myriad of confounding influences in this managed catchment. The review work and model identified key potential areas of ecological impact as:

- Winterbournes (Section 5) and
- Upper perennial stretches (both within and outside the SAC), a river upper flow cut-off of 30 Ml/d (Q95) was set.

The ecological technical experts advised that the middle and lower river reaches were unsuitable for investigation. This judgement was based on the fact that the higher actual flows and lower degree of abstraction pressure (up to 10%) was unlikely to have a measurable ecological impact. However, a series of long-term data sets exist for sites along the middle and lower River Wylye and the collection of data at these sites was continued by Wessex Water. In addition, given the local concern related to the River Wylye, monitoring points along the middle and lower reaches of the Wylye were established.

Within the upper perennial reaches the habitat most at risk of ‘lower flows’ was identified as riffles. The review process also concluded that if abstraction is exerting an influence then the macroinvertebate community was more likely to exhibit a measurable change than the plant or fish populations.

To detect an abstraction influence the sampling sites were selected as ‘control’ and ‘impact’ sites. The HAM was used to identify the degree of flow change at Q95 within the upper perennial reaches. Within control or impacted reaches the flow sensitive habitat (riffles) were identified by walkover surveys. These survey sites are mapped using GIS.

The degree of abstraction impact varies along the rivers and at certain locations flows are higher than natural due to river augmentation (stream support), which is undertaken as a condition of the abstraction licence. The sampling sites were distributed between five abstraction impact categories (at Q95):

- Augmented: more than 10% positive change in flow, mostly located in Upper Wylye
- Unimpacted: 0 to 10% decrease in natural flow
- Impacted: -10 to 20% decrease in natural flow
- Impacted: >20% decrease in natural flow
- Transitional: see Bourne upstream of Porton text below

Categorisation was based on Q95 as the abstraction pressure is usually greatest at these times. Analysis against higher flows was also undertaken, with sites also categorised due to impacts at Q50 and Q70, with some site changed categories at higher flows.

Within each abstraction impact category sampling locations were distributed equally across a range of natural stream sizes to prevent bias in the analysis and to prevent collinearly between abstraction bands and natural stream size.

Bourne upstream of Porton the HAM indicates that under natural conditions the ecological monitoring sites between Porton and Idmiston have perennial flow (at Q95), though it may dry 1 in every 5 years. The effect of abstraction has been to increase the frequency of drying to 1 in every 2 years on average. This level of impact (drying out) is not experienced at other sites in the survey, so they have been assigned a different impact band – transitional. In relation to the macrophyte and macroinvertebrate monitoring this relates to site Bourne 19.

As the ecological survey was restricted to just 2 years, the lack of temporal data was substituted by extensive spatial coverage across the upper River Avon catchment in the form of multiple replicates within each abstraction impact category.

Fish Site Impact Categories

Due to the fact that many of the fish survey sites were clustered around -15% abstraction impact level, using the same abstraction impact categories as the macroinvertebrate and macrophyte analysis would have meant splitting sites with very similar abstraction impacts into different impact categories. Initial exploratory analysis revealed an inherent break in the impact of abstraction occurring at each site at Q95. With the intention of undertaking paired analysis it was considered important to separate the data in such a away as to increase the number of pairs available to analyse in order to improve the power of the analysis. A gap occurring at -15% abstraction impact allowed for sufficient number of pairs to be formed to undertake the pairwise analysis. Abstraction impact categories used for the fish population were;

- Augmented: more than 10% increase compared to natural river flow
- Unimpacted: +10 to -15% change compared to natural river flow
- Impacted: <-15% change compared to natural river flow.

Paired Analysis

A dendrogram was produced which grouped the most similar site together, based on key habitat parameters (substrate composition, width, depth and naturalised flow). For any given site, its partner within a pair was the site nearest it which was in a different impact category.

5% rule

Concern existed that pairs could exist with very similar impacts, though located either side of the threshold line 9-15%. For example sites where flow was impacted by -14% and 16% respectively could be viewed as unimpacted and impacted members of a pair. To control for this pairs were omitted where the difference in % impact of abstraction was less than 5% (the 5% rule). This resulted in fewer pairs, but any relationships found would be more robust.

Design Philosophy

The effect of natural droughts and prolonged low-flows in rivers is perceived as a ‘ramp disturbance’ and their effects on aquatic biota is ‘stepped’; whereby the longer the disturbance lasts, the greater the ecological change that is observed (Boulton, 2003; Humphries & Baldwin, 2003). The survey was designed to take this into account as the HAM predicted the average abstraction impacts that had occurred over a period from 1995 to 2003 (contemporary impact).

Therefore, the theory underpinning the survey design was that if abstraction was exerting a measurable effect on the ecosystem over this time period there should be a sufficient detectable change at the impacted sites when compared with the unimpacted/control sites. In other words, despite the effects of other environmental influences and processes assumed to be acting across all locations equally, the difference between the biota at 'impact' and 'control' locations (that differ only in their long-term hydrological abstraction impacts) provides a measure of abstraction impact. However, it is acknowledged that without concomitant long-term ecological data, the effects of short-term abstraction impacts and recovery within this timescale cannot be tracked.

Although macroinvertebrate data from impact and control sites are considered the most likely to detect an abstraction impact, the designated species were also included in the survey. In additional other environmental variable were recorded, these as listed in Table 4.1.

Table 4.1 – Environmental Parameters Collected at Survey Sites

Parameter	Detail/Comment
Water Quality	pH, dissolved oxygen, temperature and EC
Current velocity (m/sec)	Measured in centre of Surber samples and at 3 points across the width of the channel
Channel wetted width (m)	
Water depth (cm)	
Substratum composition	% clay, silt, sand, gravel, cobble & boulders
% mass of volatile solids in substratum	
Total phosphorous concentration in substratum (TP)	
Total organic nitrogen concentration in substratum (TON)	
Ammonia concentration in substratum	
Bed compaction	Using dynamic cone penetronometry
Channel vegetation	% cover of sampling area from algae to broad leafed herbs
Geomorphical character and flow type	Riffle, runs, glides, pool, slacks
Bankside character	Trees, tall herbs etc
Shading	Of whole sampling area
Bank stability	
Adjacent landuse	

In addition variables were obtained from the Environment Agency's long term General Quality Assessment (GQA) monitoring of river quality (2001 to 2007) at sampling sites that were close to this study's survey points: temperature (12 month mean), BOD, DO, nitrate, ammonia, o-phosphate, copper and zinc.

These data allowed multivariate analysis to be undertaken which related differences in species composition and abundance between sampling locations to the effects of abstraction in relation to the other environmental influences.

Using Actual flow impacts

The survey design has assumed a difference in community type due to the prevailing abstraction, a legacy of abstraction. The recent levels of abstraction (1995 to 2003) have been used to define impact at Q95, Q70 and Q50. The time base for the model has been extended so actual (as modelled) flow changes at the time of sampling are available for 2006. These became available too far into the reporting stage of this project for their full incorporation in the analysis. However, some analysis has been undertaken and this is presented. In some cases this has strengthened observed relationships between ecology and the flow impacts of abstraction, and further analysis of actual 2006 and 2007 abstraction impacts is planned.

4.4 ASSESSMENT METHODS

A brief description of the survey methods and assessment techniques is presented. The location of the survey sites is shown on Figure 4.1. A full description, of methods used, laboratory techniques, assessment techniques and quality assurance are given APEM, 2008 (on the CD).

4.4.1 Macrophytes

30 sites were sampled in 2006 (3 -14 July) and these same sites sampled in 2007 (2 -19 July), in addition, six new sites were sampled on the Upper Wylye. These were undertaken to address a co-linearity issue and to provide enough sites on the Upper Wylye itself to allow separate analysis of the Upper Wylye.

At each site macrophytes were recorded to species level, where possible, the survey covered a 100 m length of river by wading in an upstream direction and following a zig-zag track, recording all plant species occurring in the channel (i.e. those that are submerged for 85% of the time), as per standard MTR (Mean Trophic Rank) survey methods.

MTR and MFR-A

The data were used to calculate Mean Trophic Rank (MTR) (Holmes *et al*., 1999a) and Mean Flow Rank (MFR) scores for each site. MTR gives an assessment of the trophic status (i.e how nutrient enriched it is) of a site, with low scores indicating low trophic (nutrient) status. MFR gives an assessment of the flow sensitivity of the macrophyte community with low scores indicating a tolerance of low flows or slower velocities. MFR scores were adjusted to take into account the abundance of species, in the same way as MTR does, rather than just the presence or absence that is usually used. These adjusted scores are referred to as MFR-A.

Rannunculus

R. penicillatus subsp. pseudofluitans (Stream Water-crowfoot) is widely regarded as a species that is not tolerant to low flows. Therefore, this species is a useful indicator for the effects of abstraction. Consequently, the *R penicillatus* data have been assessed separately. However, the variation in stream habitat occupied by this species (Cranston & Darby, 2004) which is often present in one stream, whilst absent in a nearby stream with very similar environmental conditions (N. T. H. Holmes, *pers. comm.*) has been taken into account when considering the results.

Emergent:Submerged Ratio
The ratio of emergent to submerged vegetation was also considered. In drier years with low flows, emergent vegetation may encroach into areas usually inhabited by species growing submerged. If a greater amount of the channel at impacted sites is used by emergent species, relative to the growth of submerged species, than at unimpacted sites then this may give an indication of long-term effects of abstraction.

Data Analysis
Possible effects of abstraction on the macrophyte community were investigated using four main analytical approaches:

1. Scores e.g. MFR-A and indicator species e.g. *Ranunculus* were used to detect differences between sites across abstraction impact categories. Any trends were tested statistically to see if the effects were significant. This approach is referred to as univariate analysis.

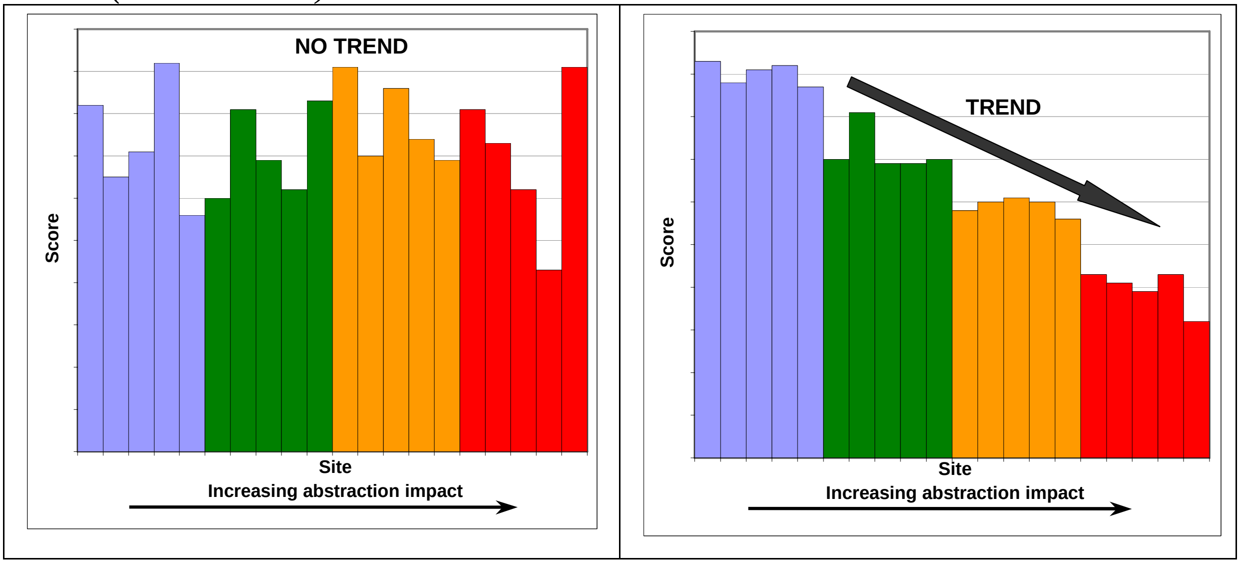
2. Regression analysis has been used to test the influence of environmental variables on these individual scores across the actual gradient of abstraction impacts, rather than between bands of impact.

3. Community Analysis: Assess the dissimilarity between samples: Non-metric Multidimensional scaling (NMDS). This is a type of multivariate analysis that examines differences between whole communities by considering all the different species were recorded.

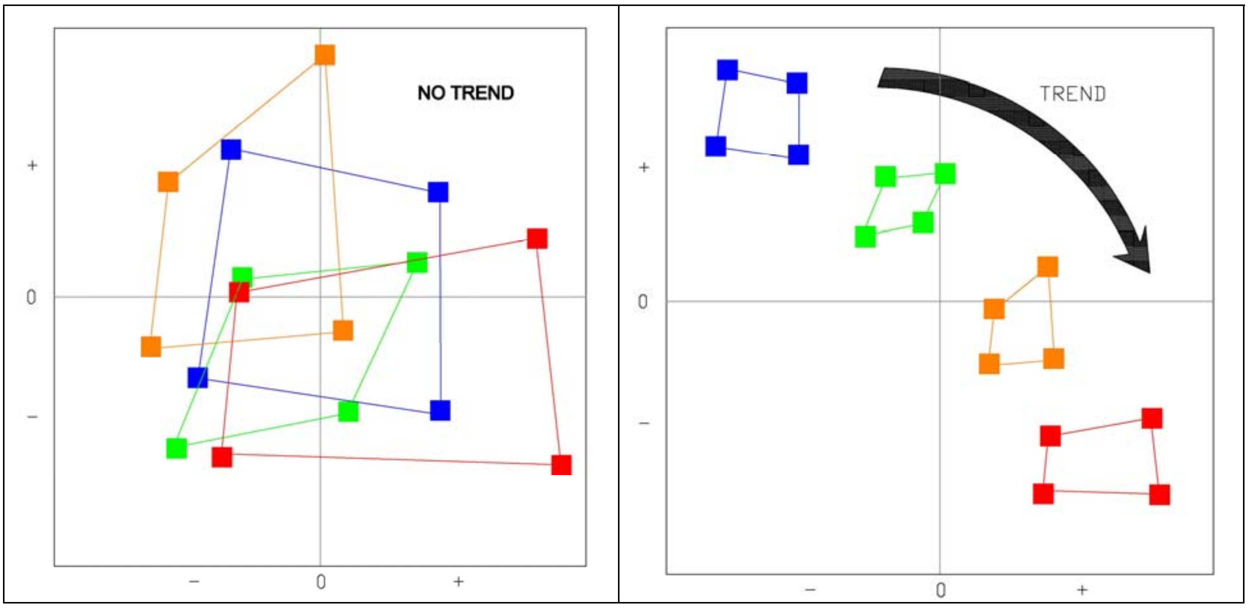
4. Differences in plant community composition (i.e. whole data set) were also analysed (using partial Canonical Correspondance Analysis, CCA) in relation to different environmental factors including percentage abstraction impact, referred to as multivariate analysis. This is another form of multivariate analysis that relates the patterns among the different species recorded to the patterns among the environmental variables.

Types of Output
Graphical output from approaches 1, 3 and 4 above are used in the following results Section. To explain how the data are presented and how an impact due to abstraction would be revealed, example output which no impact and an impact are presented below.

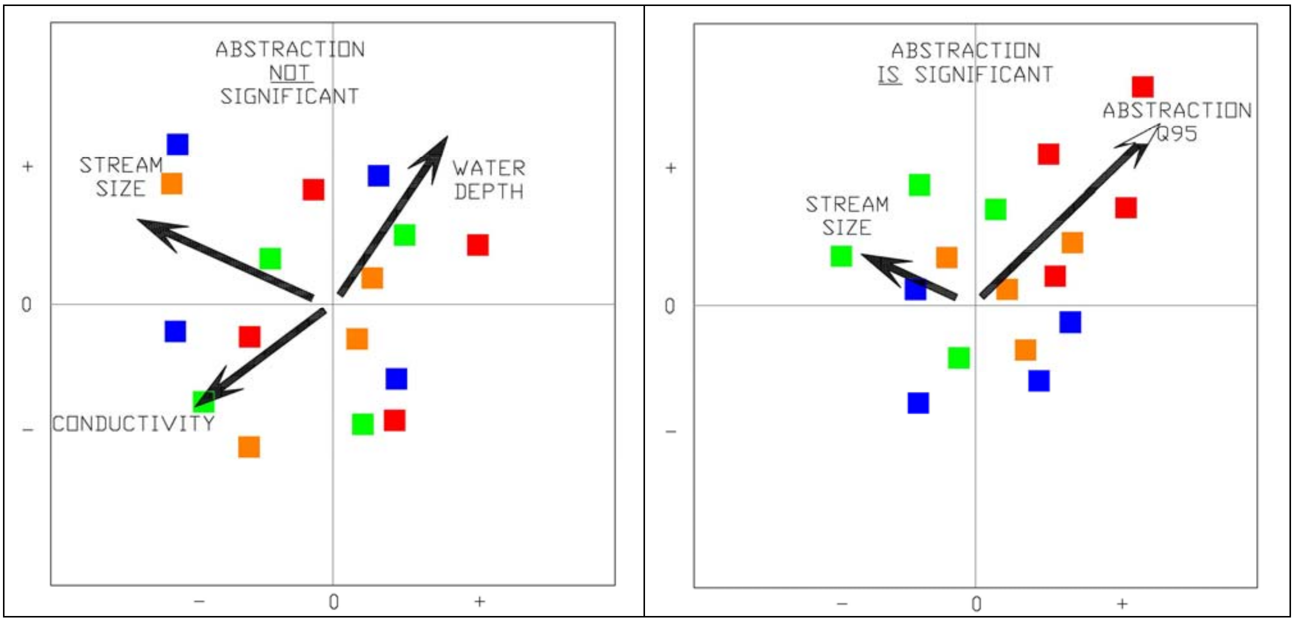
Scores (metrics/indices)



NMDS – differences in species composition of samples



CCA – Difference in species composition of samples related to abstraction and other environmental variables.



4.4.2 Macroinvertebrates

Macroinvertebrates were collected from a total of 30 and 33 sampling locations, using both quantitative and semi-quantitative methods, in spring, summer and autumn of 2006 and 2007 respectively.

Surber Sampling - Quantitative

Surber samples collect macroinvertabrates from the stream bed gravels in shallow riffle area. At each sampling location, 3 replicate Surber sample units were collected from shallow gravel habitats. The operator approached each sampling site in an upstream direction to prevent any prior disturbance of the sampling site. The Surber quadrat (0.1 m^2) was lowered quickly and firmly on to the gravel substratum and a tight contact maintained between the sampler frame and riverbed at all times during sample collection. The substratum within the quadrat was agitated using a hand-held metal claw up to a depth of 5 cm for a timed duration of 2-minutes. All organic particles and light inorganic particles, including animals and their cases would drift into the collecting net; care was taken not to allow large stones or gravel into the net. Large stones were scrubbed by hand just upstream of the net to remove any attached animals and then discarded (this was conducted within the 2-minute total sampling time). The three replicates were collected successively upstream of each other and were greater than 2 m apart; ideally one was collected towards the centre of the river, one towards the left of centre and one towards the right of centre to prevent any sample bias.

Kick/sweep Samples – Semi-quantitative

In addition to surber sampling, kick samples were collected, this is an industry standard method with macroinvertebrates collected from the stream bed and plants presented in the area of sampling. Within each sampling location a single three-minute kick/sweep sample was collected. This sample encompassed all in stream habitats present in proportion to their occurrence over the three-minutes sampling time. Additionally, a further one-minute hand search was performed to capture any additional animals that might have evaded the kick/sweep sample. This sample was collected from a undisturbed area at least 2 m upstream of any other samples collected at the sampling site.

Table 4.2 Metrics and Indices Used

Metric or Indices	Comments
Total macroinvertebrate abundance and density (Surber samples);	
Macroinvertebrate taxon richness	
Lotic Invertebrate Index for Flow Evaluation (LIFE) score	This index was derived from the individual current velocity preferences of macroinvertebrate species and encapsulates macroinvertebrate community responses to flow variation
Actual abundance and density of LIFE flow group I & II species.	LIFE I & II species are those invertebrates that have preferences for rapid to moderate current velocities
Actual abundance and of LIFE flow group III – VI species	LIFE III – VI species are those invertebrates that have preferences for slow/sluggish velocities, still/standing water and includes drought resistant species
Abundance and density of Ephemeroptera, Plecoptera and Trichoptera (EPT taxa or 'riverflies')	EPT taxa are among the most sensitive groups of freshwater macroinvertebrates to environmental disturbances and their abundance and richness is often negatively related to increasing water pollution, decreasing current velocity and increasing fine sediment deposition in streams
Ratio of EPT abundance: Chironomidae and Oligochaeta abundance	In contrast to EPT taxa, Chironomidae and Oligochaeta are relatively resistant to environmental disturbances involving water pollution, drought (e.g. Ledger & Hildrew, 2001) and increased fine sediment deposition that is often associated with low-flows in chalk rivers (e.g. Morris, 2007). Studies elsewhere have shown that during extreme low-flow events, involving channel dewatering, the proportional abundance of Chironomidae increased dramatically, reflecting both their resistance to the cessation of flow and the elimination of other taxa under these conditions
Community Conservation Index (CCI)	This index is derived from the conservation status of the individual invertebrate species that are collected in a sample and provides a comparative measure of conservation value between sampling locations.
Ecological Quality Index (EQI) for family LIFE scores	River InVertebrate Prediction and Classification System (RIVPACS) (Version III+, Release 2.2, June 2004; Centre for Ecology and Hydrology) was used to predict family LIFE scores for each kick/sweep sample from a suite of physico-chemical parameters that characters that described each sampling location.

Laboratory Analysis

In the laboratory, small aliquots (one teaspoon) of sample material were transferred to a shallow, white tray containing water and all invertebrates that seen with the naked eye were removed for taxonomic identification and enumeration. Identification of animals was to species level where possible. Particular attention was paid to the identification of macroinvertebrate species that are reported to be specialists of transient winterbourne habitats. One in 10 samples were reanalysed internally by a Senior Biologist for the purpose of quality assurance. Additionally, an external audit was performed on a proportion of the samples by a competent laboratory.

Data Analysis
The metrics and indices used in the analysis of the marcroinvertebrate data are listed in Table 4.2. The results are presented in the formats described for macrophytes.

The collected data and results from metrics and indices were subjected to the same analysis as detailed for macrophytes above.

4.4.3 Fish

The APEM designed study demonstrated that 82 sites would need to be surveyed in order to provide sufficient data against which impacts can be assessed (APEM, 2005). Of these sites 25% were surveyed quantitatively using depletion electric-fishing. The remaining 75% of sites were fished semi-quantitatively. The 82 sites were divided up into 6 clusters, primarily according to river size, with a fully quantitative catch depletion site within each cluster. The cluster based approach enables robust extrapolation of population size from semi-quantitative data by calibrating catches from 'similar' sites (i.e. those with similar habitat characteristics as identified by the walkover survey).

In considering the impacts of abstraction on fish populations within the study area, analysis has focused on the SAC fish species Atlantic salmon (*Salmo salar*), bullhead (*Cottus gobio*), and lamprey sp. along with brown trout (*Salmo trutta*). However, it was acknowledged at the start of the study that the survey sites were not typically located in the main areas of the River Avon used by salmon. The data collected include density and fish size at each site, facilitating comparisons both between years and between impacted and non-impacted sites. Electric-fishing is generally accepted as being the best technique for assessing populations of salmon, trout, bullhead and lamprey.

Survey Methods – salmon, bullhead and trout
The survey method employed consisted of three tiers of detail, covering both quantitative and semi-quantitative studies, and was consistent between years:

<u>Catch-depletion electric-fishing</u>: Undertaken at 6 sites to provide quantitative fish population data for salmonids and bullhead.

<u>Single-run electric-fishing</u>: was carried out at 18 sites to provide quantitative fish population data for salmonids and bullhead.

<u>5-minute timed runs</u>: stopwatch timed runs were carried out without stop nets at the remaining 58 sites.

A cluster based approach allowed calibration of the 5-minute timed and single runs with the multiple pass catch depletion results to provide density estimates for each site.

Lamprey Surveys
Juvenile lampreys occupy a different habitat niche in the river compared to salmon, bullheads and trout, preferring silt deposits in ammocoetes phase. Consequently a different survey method is required.

Both the optimal and sub-optimal habitats were surveyed quantitatively using an enclosed area as a barrier to fish movement. Following standard protocol a 1 m^2 quadrat was positioned over the selected habitat to fully enclose the sampling area. This was then left to settle. Electric-fishing was undertaken in such a way as to draw individual lamprey out of the sediment rather than stunning and trapping them in the silt. This was achieved by energising the anode in short bursts of 20 seconds followed by 5 second gaps and was carried out over a two minute period. This procedure was classed as a single-run, and was repeated twice more within the same quadrat (with a 5-minute gap between runs) for catch-depletion. This enabled an absolute population estimate to be made.

Data Analysis
The approach taken for macrophytes was also undertaken for fish where site data (number/density/size) was plotted, with sites ranked according to their degree of abstraction impact. Mean and standard error between impacted, unimpacted and augmented sites can provide an overview of differences between these abstraction impact bands, and between years, and give an indication of the statistical significance of any difference.

4.5 MACROPHYTE AND ALGAE FINDINGS

4.5.1 Introduction

The results derived from the two year study are presented in this section, in addition findings from long term studies of *Ranunculus* cover in the Avon and Wylye are also presented.

4.5.2 2006-2007 study

A total of 82 macrophyte taxa were detected during the surveys over both years. The communities seen represented typical chalk stream macrophyte communities, and range in diversity from 11 taxa to over 34. *Ranunculus penicillatus subsp. pseudofluitans* was amongst the most frequent and abundant species recorded in both years. *Ranunculus peltatus* (Pond Water-crowfoot) was also recorded at several sites. Other notable species included *Oenanthe fluviatilis* (River Water-dropwort).

Individual Score - MFR-A
No trend with increasing abstraction was detected with MFR-A scored categorised for Q95 and Q50 abstraction impact. A statistically significant effect occurred when the data were categorised for Q70 impact (Figure 4.2). The effect was attributable to the influence of Bourne 19. Figure 4.3 plots the mean MFR-A score for each impact band. The transitional site score was markedly lower than the other bands, but there was no statistically significant difference between the mean score of the other abstraction impact categories.

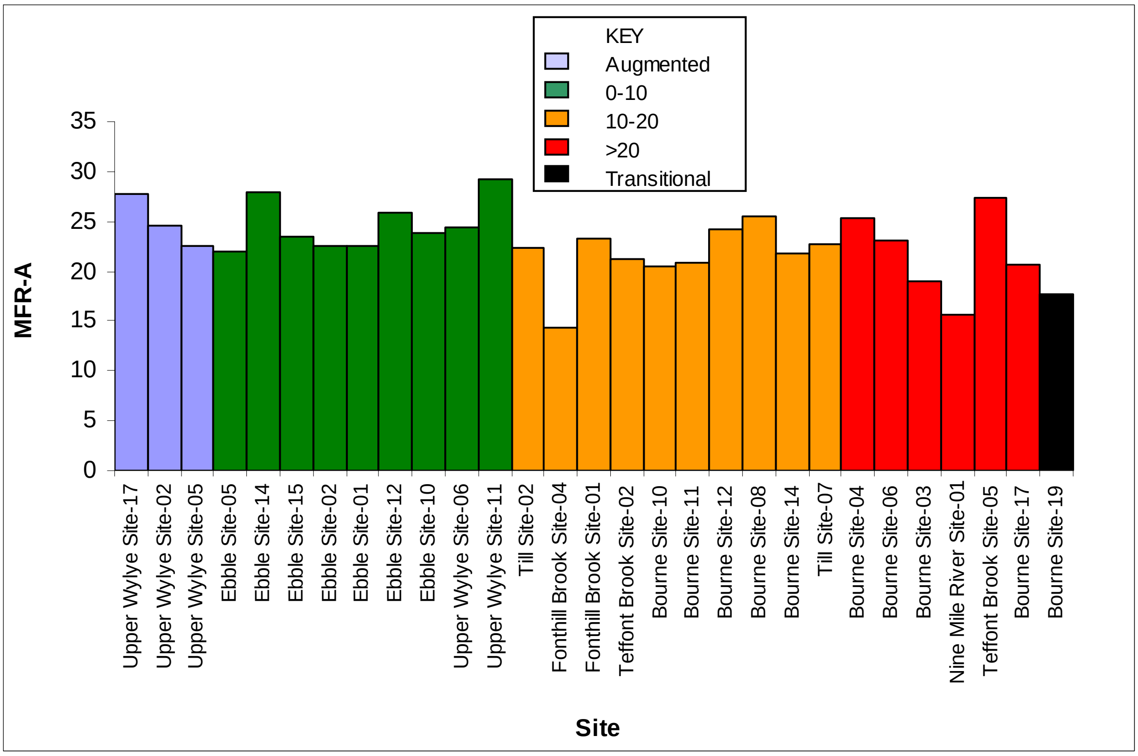


Figure 4.2: MFR-A scores in 2006 ranked according to Q70 abstraction impacts

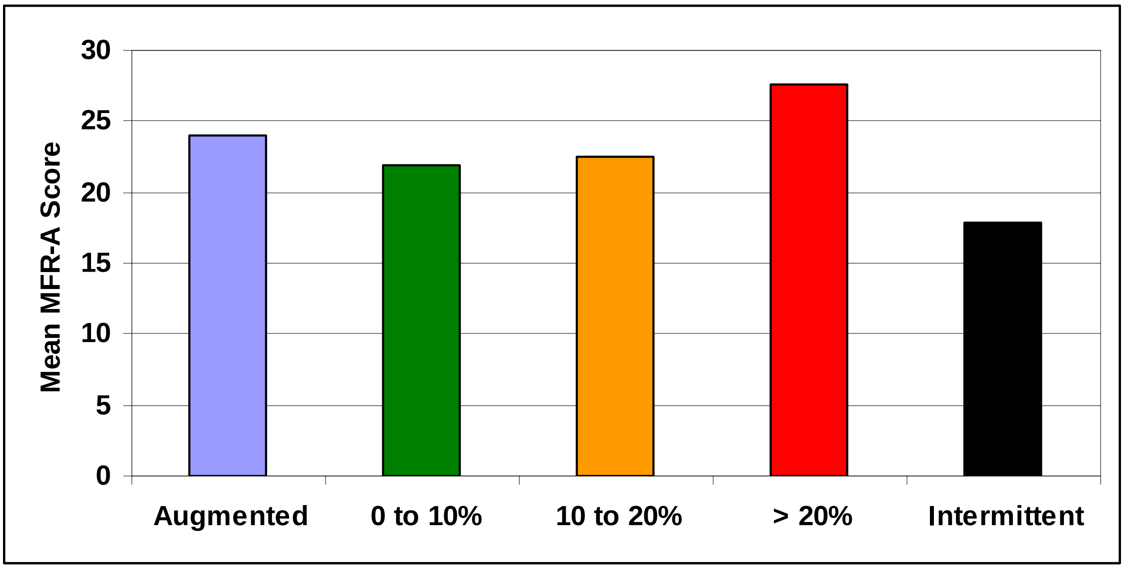


Figure 4.3: Mean MFR-A Score from 2006 at Q70 Impact Bands

Stepwise regression analysis was used to assess whether MFR-A scores are related to other environmental variable. The 2006 data suggested a significant relationship with: Total organic nitrogen concentration in the river sediment and abstraction impact at Q95 flows. However, in 2007 MFR-A was statistically significantly correlated with channel type as well as abstraction impact at Q95. Abstraction explains 20% of the variation in MFR-A score in 2006 and 2007.

Percentage cover of Ranunculus

The percentage cover of *Ranunculus* was variable within and between impact bands, see Figure 4.4 data from 2007. There was no statistically significant difference in percentage cover of *Ranunculus* between the abstraction impact bands in either 2006 or 2007. The variation in *Ranunculus* cover across sites could be due to a number of factors, including weed cutting, swan grazing, river temperature and shade.

Stepwise regression analysis was used to assess whether *Ranunculus* cover was related to other environmental variable, the only significant relationship was with the percentage of run, riffle and slack habitat.

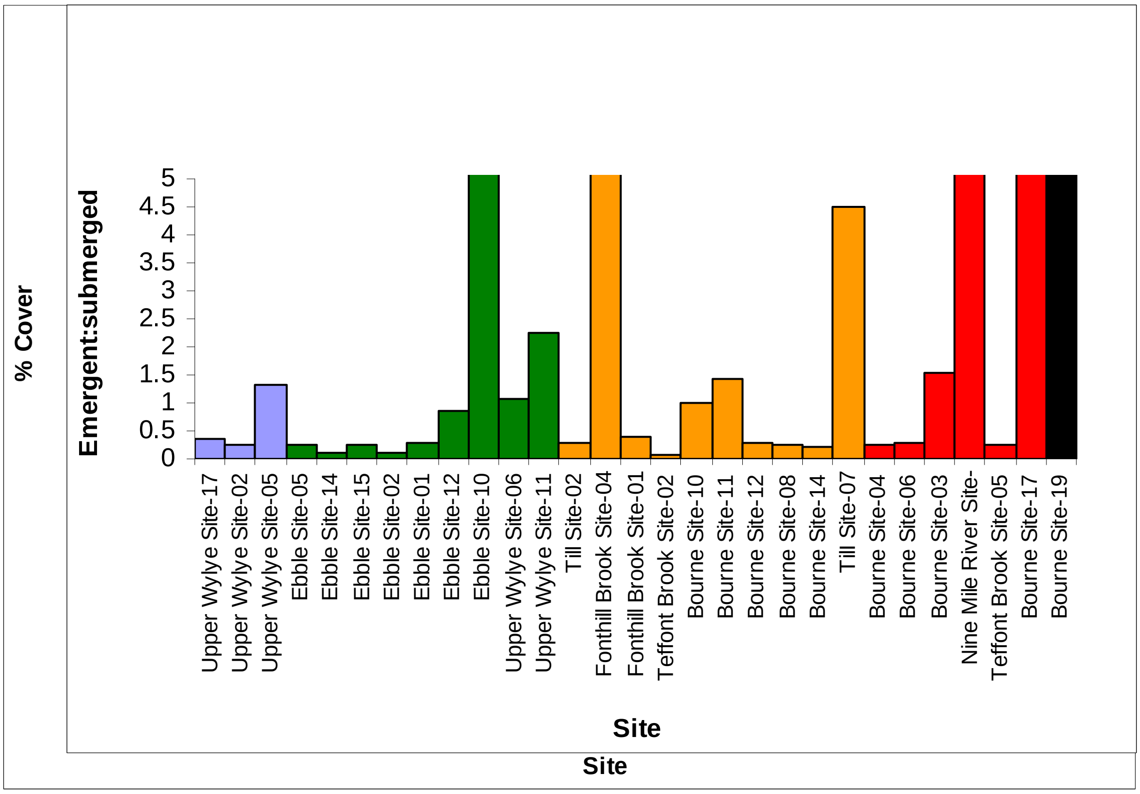


Figure 4.4: % Cover of Ranunculus in 2007 ranked according to abstraction impact at Q95

Emergent and Submerged Vegetation ratio

The emergent:submerged ratio recorded in 2006 banded for Q95 impact are shown on Figure 4.5. No statistically significant difference was detected between impact categories at Q95, Q70 or Q50, in either 2006 or 2007.

MTR Scores

MTR scores did not differ between abstraction impact categories. The data do, however, suggest that several sites were eutrophic or at risk of becoming eutrophic. In 2007 there were five such sites, however in 2006 the total was 14. The 14 sites in 2006 occurred in the Ebble, Fonthill, Teffont, Till, Bourne and Wylye. The higher count in 2006 suggests that the lower flows in 2006 resulted in higher nutrient concentrations leading to a higher trophic status in some sites, than was the case in 2007.

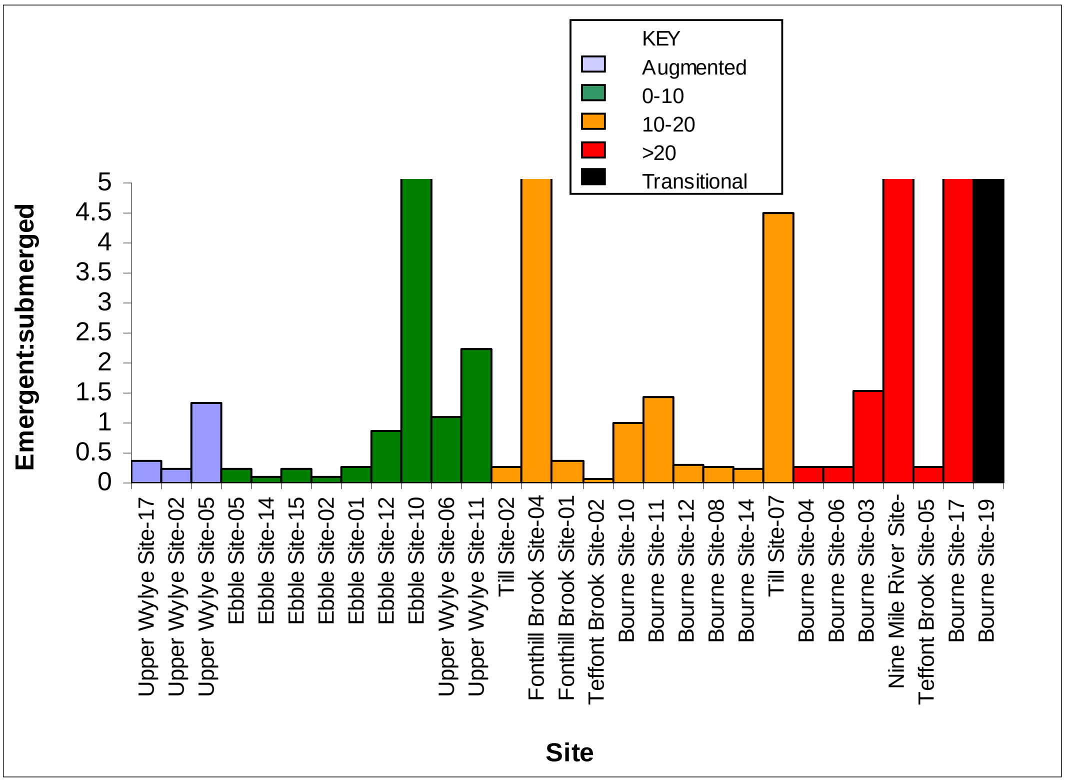


Figure 4.5: Emergent:Submerged ratio in 2006 banded according to Q95 impacts

Epiphytic and epilithic algae

Algae did not differ significantly between abstraction impact categories. Although the relationships between algae abstraction impact were not significant, it is interesting to note that the relationship was negative in 2006 (i.e. algae tended to decline with increased abstraction impact); whereas in 2007, the relationship was positive (i.e. algae tended to increase with increasing abstraction impact). These relationships were consistent for both epiphytic and epilithic algae. Across all surveys the percentage cover of epiphytic algae and epilithic algae was highly positively correlated.

Both types of algae were more abundant in 2007 compared to 2006. A possible reason for the increased proliferation of algae in 2007 compared to 2006 was the warm, dry period that occurred during April 2007. During this period rapid algal growth was reported at many locations within the upper Avon catchment, and this persisted throughout the summer despite the relatively high runoff that occurred during this period in 2007 (J. Drewitt, *Pers. Comm.*). This effect appeared to occur across all locations and there was no evidence to suggest any interaction with abstraction impact.

Gradient Analysis (NMDS plots)

NMDS plot were used to show the similarity of the plant community at each site in relation to all other sites. The sites showed a lot of overlap, with no distinct grouping. A number of statistically significantly difference were detected, for example in 2007 (Figure 4.6) between site with less than 10% impact and those with greater than 20%. However the plots also showed that most of the outlying sites driving the difference between bands occurred on the smaller rivers, on which fewer sites are placed and which tend to fall into the more impacted categories (Teffont Brook and Nine Mile River). This suggested that although the pattern seen could have been due to abstraction, it may also have been related to the differences in floras that are seen between rivers regardless of abstraction impact.

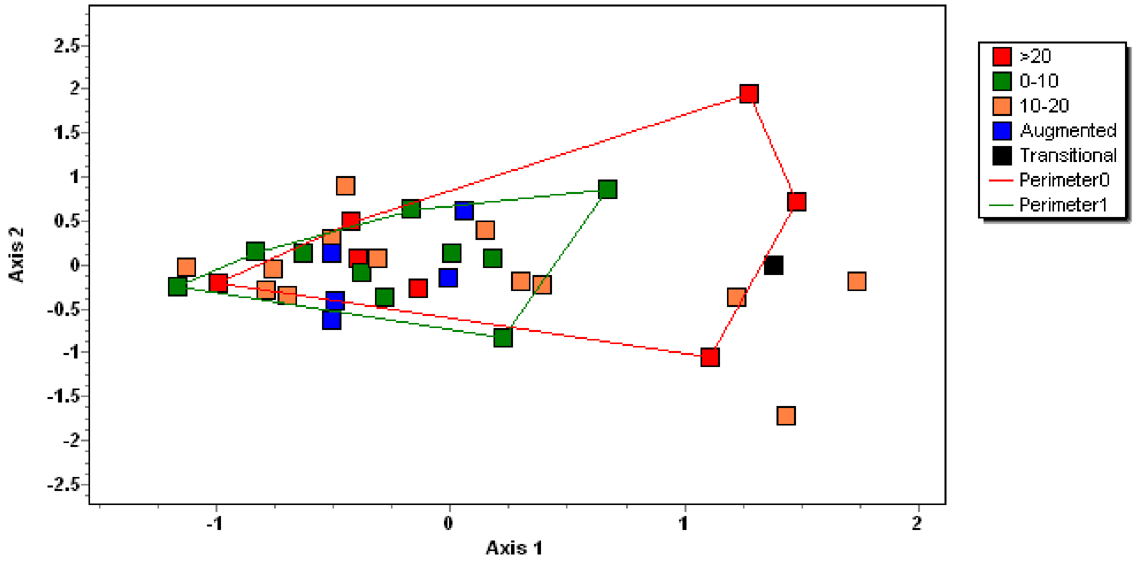


Figure 4.6. NMDS plot of channel macrophyte communities in 2007 at Q95 flows

Canonical Correspondance Analysis

This method tests the effect of a range of environmental variables on the whole plant community (all species together), rather than a single aspect of the plant community or derived score e.g. MFR-A.

Using this type of analysis it was also possible to investigate the influence that the river on which the site occurs has on determining the macrophyte community composition, independent of environmental variables such as stream size, habitat type, extent of shading, nutrient levels etc. CCA analysis using all environmental variables is shown in Figures 4.7 and 4.8 below. This revealed that in both 2006 and 2007 the ‘river’ represented significant variables, i.e. Till and Teffont. Other significant variables included:

- stream size (as represented by naturalised Q95, Q70 and Q50 flows (Run 62));
- habitat type, (Run, riffle or slack);
- nutrient concentration;
- Ammonia and
- substratum composition.

The analysis also showed a small but significant relationship with abstraction impact at Q50 in 2006. Abstraction did not appear to have a significant role in determining the plant community in 2007.

The strength of CCA is that a dominating factor, like ‘river’ can be discounted to allow the other important factors to be clearly observed. This is done by accounting for the variation caused by ‘river’ by including them as co-variables and then looking at the remaining variation in relation to abstraction and environmental variables. The results from this exercise are shown on Figures 4.9.

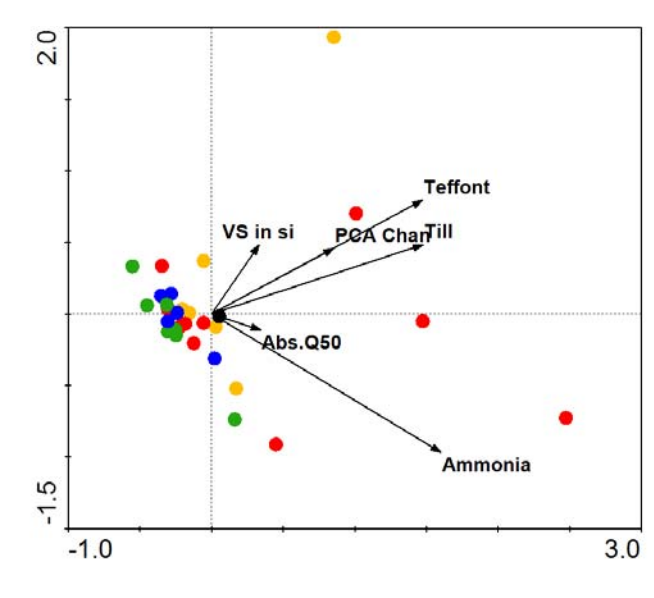


Figure 4.7: CCA Analysis Using 2006 data

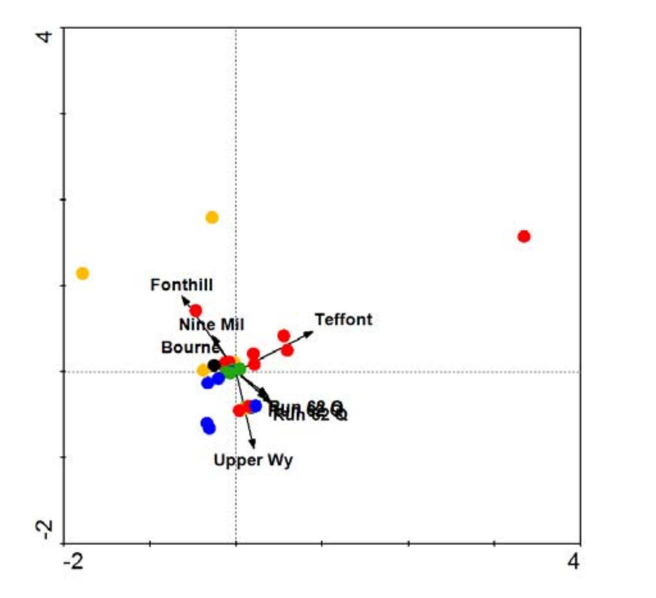


Figure 4.8 CCA Analysis Using 2007 data

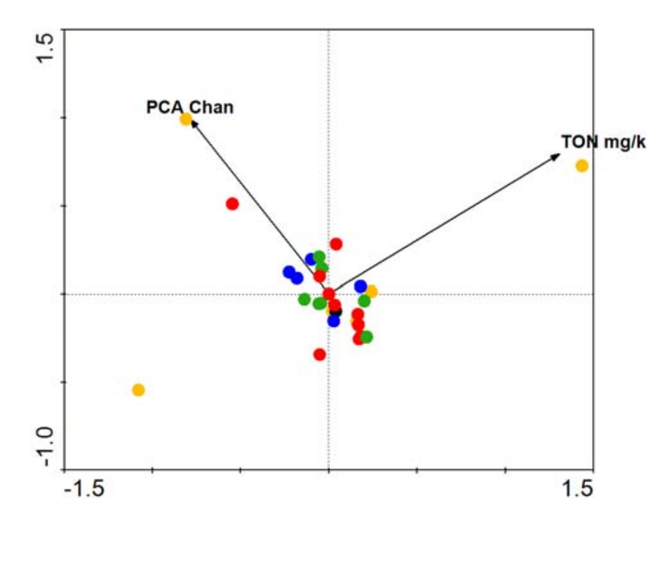


Figure 4.9 CCA Analysis excluding ‘river’ as a variable, using 2006 data

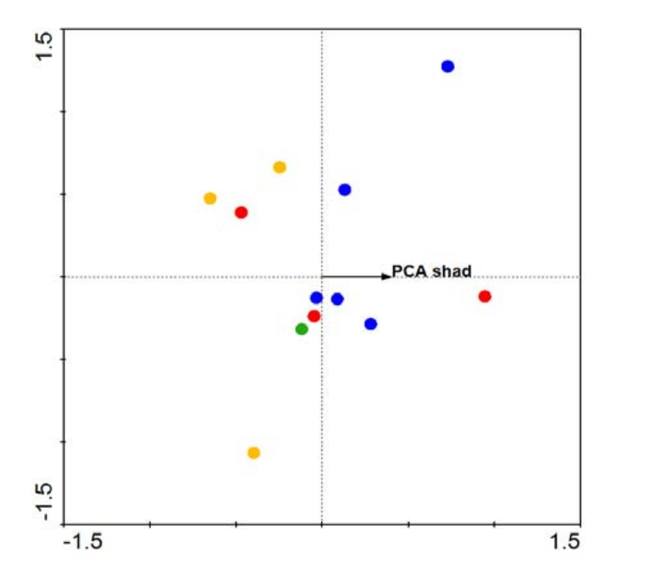


Figure 4.10CA Analysis of sites on the River Wylye in 2007, including all variables

In 2006, the main influences on channel plant community were nitrogen concentrations in the sediment and channel type (percentage of run, riffle and slack). In 2007 the main influence was stream size as defined by the naturalised Q50 flow.

As the influence of the river on which the site occurs was recognised by this analysis in 2006, six extra sites were included on the Wylye in 2007 in order to allow the analysis to be performed on one river that has sites with a range of abstraction categories. In this analysis, shading (measured as PCA shade) was the only environmental variable to show a significant relationship with the plant communities on the River Wylye. Abstraction was not detected to have a significant influence.

Using Actual 2006 flow impact data

A significant difference in MFR-A scores was detected, but this was between augmented and the unimpacted categories. MFR-A scores were higher at augmented sites compared to unimpacted sites. No other significant relationships were found between aquatic macrophytes and abstraction that occurred in August 2006.

The effects of environmental variables, including actual abstraction impact in August 2006, on MFR-A scores in 2006 and 2007 were investigated using multiple regression analysis.

A statistically very significant correlation ($P = 0.0002$) occurred between 2007 MFR-A scores and actual abstraction impact in August 2006. No other environmental variables were significant. Analysis of the 2006 scores also revealed the actual abstraction impact in August 2006 to be the most important variable determining MFR-A scores, with total phosphate and nitrogen in the sediment, and flow type also having a significant influence. These observed relationships were more significant than the relationship when the contemporary abstraction impacts were used. However, as the detailed above it was probably the difference between augmented and unimpacted sites that was driving this statistical difference.

Although not showing an impact from reduced flow due to abstraction the above analysis indicated that actual abstraction impact around the time of investigation or in the preceding year had a greater effect on the macrophyte community present, measured in terms of MFR-A scores, than abstraction pressure over the previous 10 years. These observations warrant further investigation using actual impact in 2006 and 2007.

4.5.3 Avon- Lower Wylye comparison

The Environment Agency (EA) has undertaken annual surveys of reaches of the Wylye and the Avon since 1998. Output from the Hampshire Avon Model for these reaches show that approximately 7 km of river on the lower Wylye and 5 km of the middle Avon are both in the same naturalised Q95 range of 113-133 Ml/d. The naturalised flow (Run62) and the percentage impact due to abstraction (Contemorary Run 84) for each reach are shown in Table 2.2. The abstraction pressures in the Wylye and Avon along these reaches are different, with the Wylyle having less than natural flow and the Avon more than natural, a consequence of canal leakage (Section 3.9.2) and STW returns.

Table 4.3 – Extended macrophyte surveys on Rivers Wylye and Avon

River	**Wylye**	**Avon**
Survey	Lower Wylye	Middle Avon
NGR upstream end	SU09216 33395	SU12694 37284
NGR downstream end	SU06832 36582	SU14004 41149
Length Km (approx)	7	5
No of reaches (500m approx)	14	10
Flow Band naturalised Q95 Ml/d	123-133	113-127
Abstraction impact range	-4.1 to -6.4	+6.3 to +8.1

Annual *Ranunculus* cover data have been analysed to see if any differences between the impacted Wylye and the unimpacted/enhanced Avon that may be linked to abstraction.

The average cover of *Ranunculus* from 1998-2007 on the Middle Avon and Lower Wylye is shown in Figure 4.11. It can be seen that this section of the Wylye had fairly high coverage of *Ranunculus* in 2000 that crashed between 2000 and 2002 (no sampling in 2001 due to the outbreak of Foot & Mouth disease and associated access restrictions imposed). *Ranunculus* cover gradually increased before crashing in 2007. *Ranunculus* cover was less variable in the middle Avon between 1998 and 2007, and was relatively high in 2007 compared to other sites.

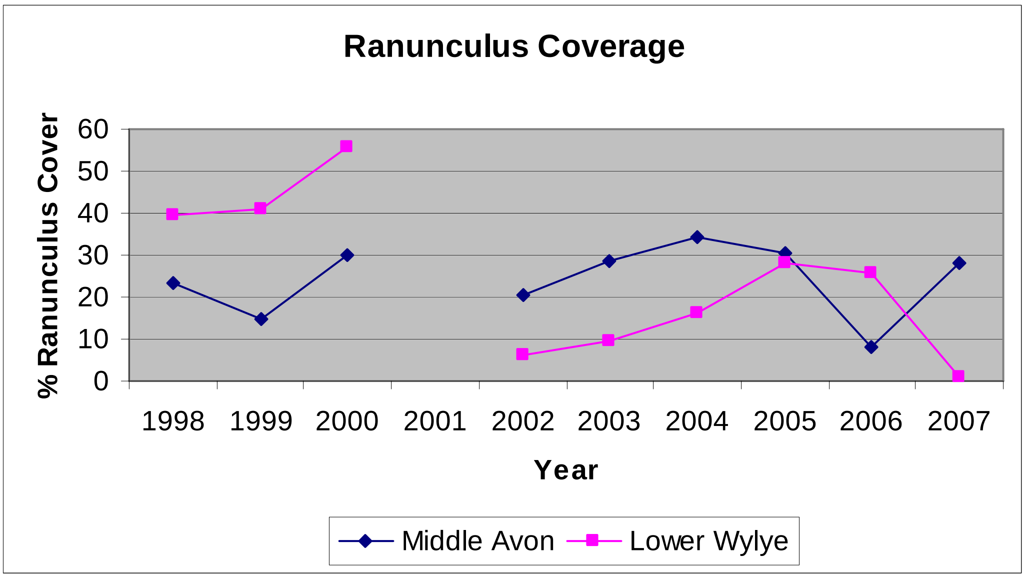


Figure 4.11: Comparison of *Ranunculus* Cover in Avon and Wylye Catchments

It is worth noting that the change on the Wylye did not appear to correlate with flow variations i.e. it crashed between 2000 and 2002 at a time of relatively high river flows, underwent a degree of recovery between 2003-5 during a period of lower river flows and then crashed in 2007 in a wet summer following a wet winter.

This stretch of the Wylye was chosen because it was the only one with long term data that overlapped with Avon sites to allow a comparison of sites with the same naturalised Q95 flow but differing abstraction impacts. It is not one that would have been chosen to look for such correlations between *Ranunculus* growth and flow because of its low *Ranunculus* cover in recent years and other factors such as the high number of juvenile swans in the area.

A more detailed study is currently being undertaken on the 100m lengths that make up the 500m reaches used in this analysis and other reaches surveyed on the upper and middle Wylye. It is hoped that this will result in a better understanding of the effect of flow at different times of the year on *Ranunculus* growth. The main goals of this investigation are to:

- Identify the most critical flow period and flow parameter i.e. Q5, Q50, Q70 & Q95. influencing *Ranunculus* growth.
- Identify stretches where *Ranunculus* growth responds to changes in flow.
- Investigate differences, such as channel shape, between 100m stretches that respond and do not respond to flow changes.

Initial results indicated that 12 out of the 49 reaches showed a statistically significant positive relationship with one or more of the flow parameters tested, 11 of these were with Q5 in the winter and spring flows. In other words the higher the winter/spring flow the better the *Ranunculus* cover in the summer. This initial analysis supports the widely held view that high winter flows will clear away senesced plant material, silt and potential competitors and so prepare the substratum for growth in the spring, with high spring flows stimulating growth early in the year.

4.6 MACROINVERTEBRATE FINDINGS

4.6.1 Introduction

The results derived from the two year study are presented in this section, in addition findings from a comparison of macroinvertebrates communities in the Lower Wylye and Avon (upstream of Salisbury) also presented.

4.6.2 2006-2007 Study

A total of 756 macroinvertebrate samples have been collected and processed from 2006 and 2007 on the perennial reaches of the upper River Avon tributaries.

Over 450 different macroinvertebrate taxa have been identified in these surveys and over 1,000,000 individuals have been counted. In general, the abundances and taxon richness of macroinvertebrates was high in all samples in relation to rivers UK-wide and highly typical of chalk rivers in southern England. The maximum number of taxa recorded in a single sample was 95 (River Bourne, Site 11 kick-sample 09/05/06) and the minimum was 12 (Nine-Mile River, Surber 17/07/06).

4.6.3 Impact vs non-impacted - univariate

The following text focuses only on the statistically significant effects of abstraction on macroinvertebrates in relation to the other effects of natural stream size, sampling year and sampling season.

The testing for significant differences between impact bands for the indices listed in Table 4.2 has been undertaken. Of these LIFE had the most consistent and strongest relationship with abstraction impact, with the difference most apparent in summer 2006 Surber samples. However, this result was strongly influenced by data from one sampling location (Bourne 19) as discussed in the Section 4.5.

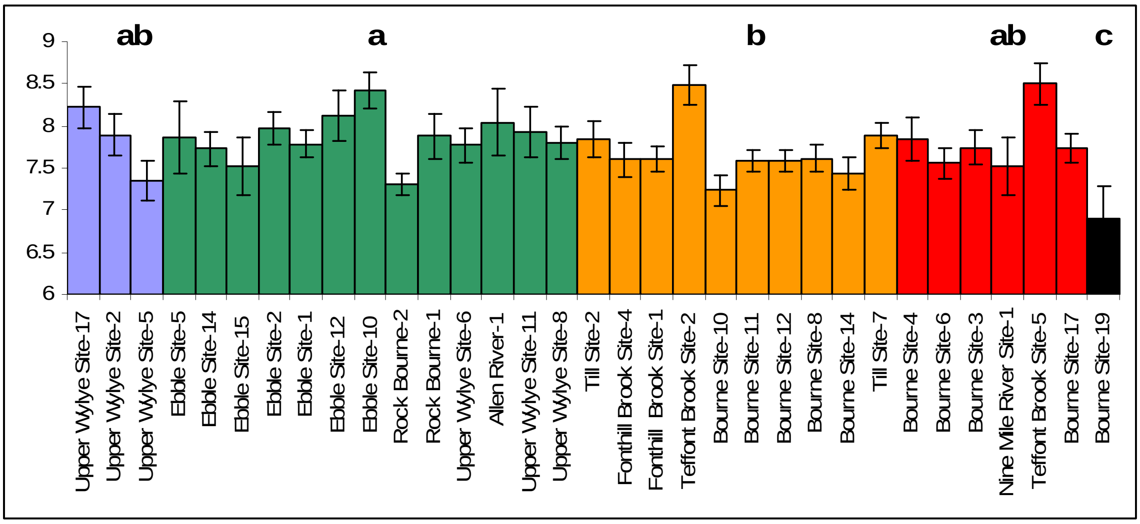


Figure 4.12: Mean ± SD LIFE scores (summer 2006) for each sampling location. Letters indicate where significant differences occurred between abstraction impact categories

Figure 4.12 shows the individual LIFE scores for Surber samples collected in summer 2006, banded for abstraction impact at Q95. There was much variation within bands and no overall trend in the data was evident that could be related to increasing or decreasing abstraction impact. However, the LIFE scores were significantly lower at Bourne 19 compared to the other locations. This difference is also evident on Figure 4.13, where the mean LIFE score of each band is presented, for Q95 impacts. When Bourne 19 was excluded from the analysis there remained no obvious trend among LIFE scores in relation to increasing or decreasing abstraction. In fact the mean LIFE score was higher for locations where natural flows were reduction by >20%, than for the -10 to -20% category.

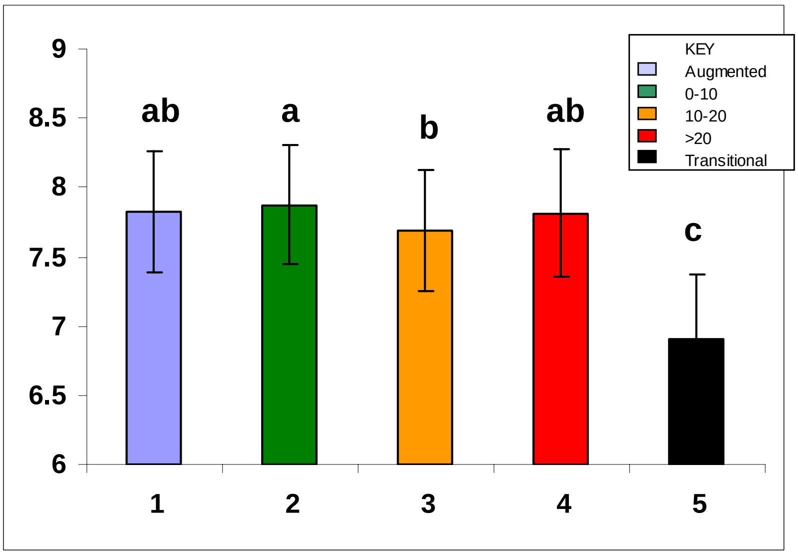


Figure 4.13: Mean (+/- SD) LIFE scores between abstraction impact banded at Q95 (all surveys together)

As discussed, rather than having depleted flow, Bourne 19 appeared to have experienced 'no' flow and consequently a markedly different macroinvertebrate community was present at this transitional site.

EPT abundance
The 'river flies' are among the most sensitive groups of freshwater macroinvertebrates to environmental disturbance. River fly taxa include Ephemeroptera (may flies), Plecoptera (stone flies) and Trichoptera (caddisflies), an abbreviation of EPT taxa is used. The abundance of riverflies differed significantly between abstraction impact bands. However, Bourne 19 was driving most of the abstraction impact (Figure 4.14). When Bourne 19 was excluded from analysis, the effect of abstraction became not significant in all cases except Q50 abstraction, where the effect remained but was weak.

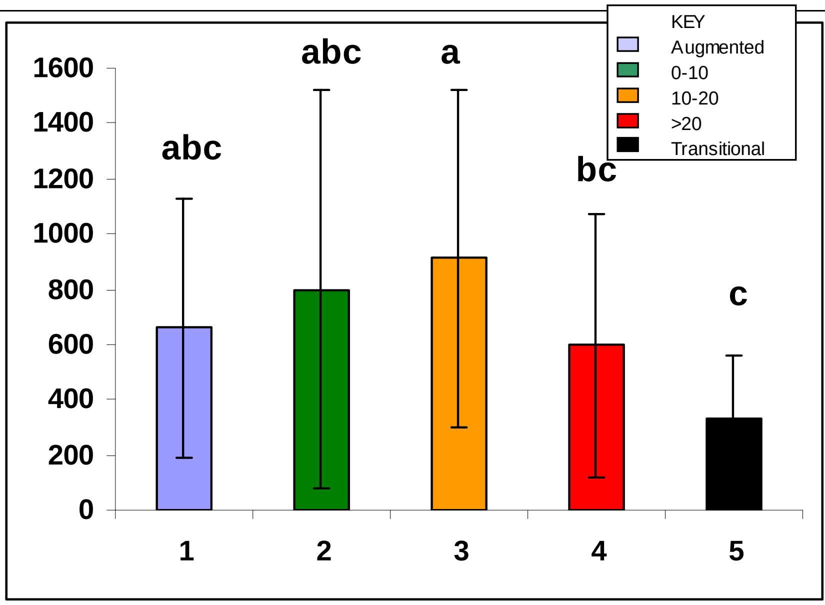


Figure 4.14: Mean (+/- SD) abundance of EPT between abstraction impacts banded at Q95

4.6.4 Impact vs unimpacted – Community Analysis

The NMDS analysis of the combined Surber samples collected in summer 2006, are shown on Figure 4.15, coloured for the abstraction impacts bands at Q95. There is overlap of each bands, except the transitional site (Bourne 19). Two locations on the Fonthill Brook (FO01 & FO04) also standout, this may have an abstraction affect but the high water temperature (over 20^{o}C in summer 2006) may have exerted a greater influence on the stream ecology. Further consideration of the influence of temperature is needed in the next phase of analysis. The analysis indicates no trend with abstraction pressure, except at Bourne 19.

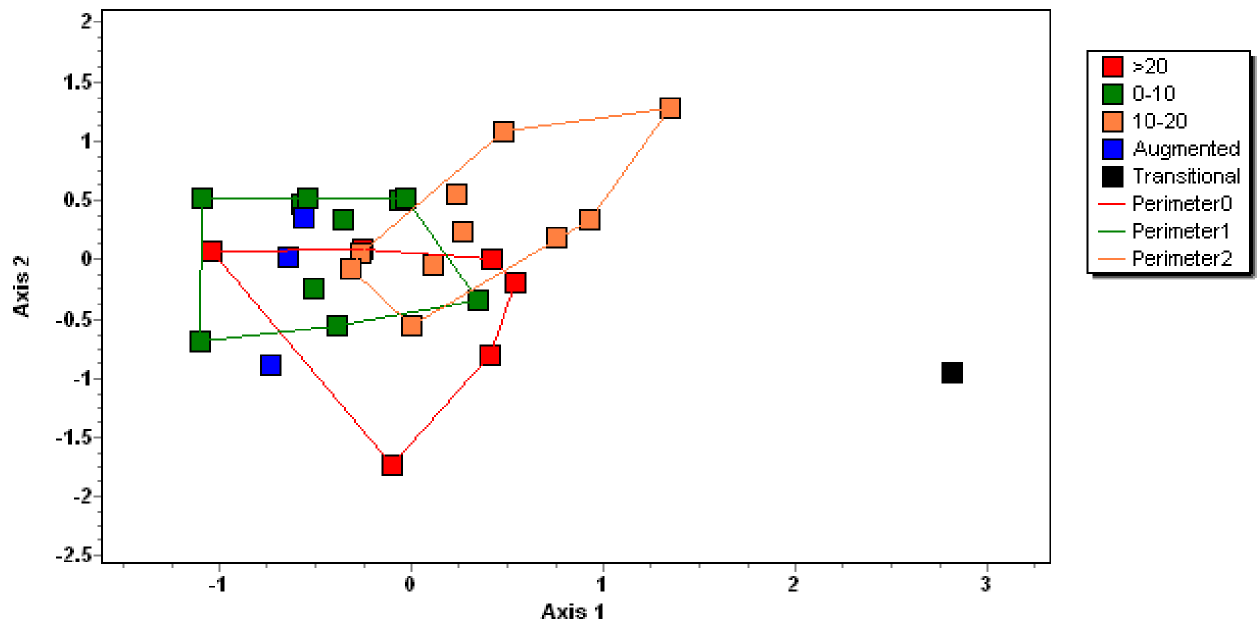


Figure 4.15: NMDS plot of combined Surber sample replicates collected in summer 2006. Samples are colour-coded by abstraction impact categories at Q95 flows.

4.6.5 Macroinvertebrates and other environmental variables

Multivariate analysis has been used test the significance of abstraction and the other environmental variables, listed in Table 4.2, upon the observed macroinvertebrate community. Partial CCA was used to examine directly the linear correlations between macroinvertebrates and the environmental variable after first removing the effect that was due to the particular river that the samples were collected from.

Treating each survey year separately, when the ‘kick’ sample data were used abstraction impacts did not explain any significant amount of the variation in relation to other environmental variables. Naturalised Q95 flow was the single most important environmental variable explaining differences between sampling locations.

Using the Surber sample data, abstraction impacts were only significant in the autumn 2006 survey (Figure 4.16). The environmental parameters in the CCA analysis accounted for 83% of the variance identified between the samples. Of this 83%, abstraction effects accounted for the 7.4%. The relative contribution of each variable to explain the observed variance is shown in Figure 4.17.

The other principle factors influencing the observed difference in community were:

- Channel Vegetation;
- River sediment phosphorous levels;
- Percentage of volatile solids in the river sediments;
- Percentage silt/clay in river sediments;
- Abstraction impact at Q70.

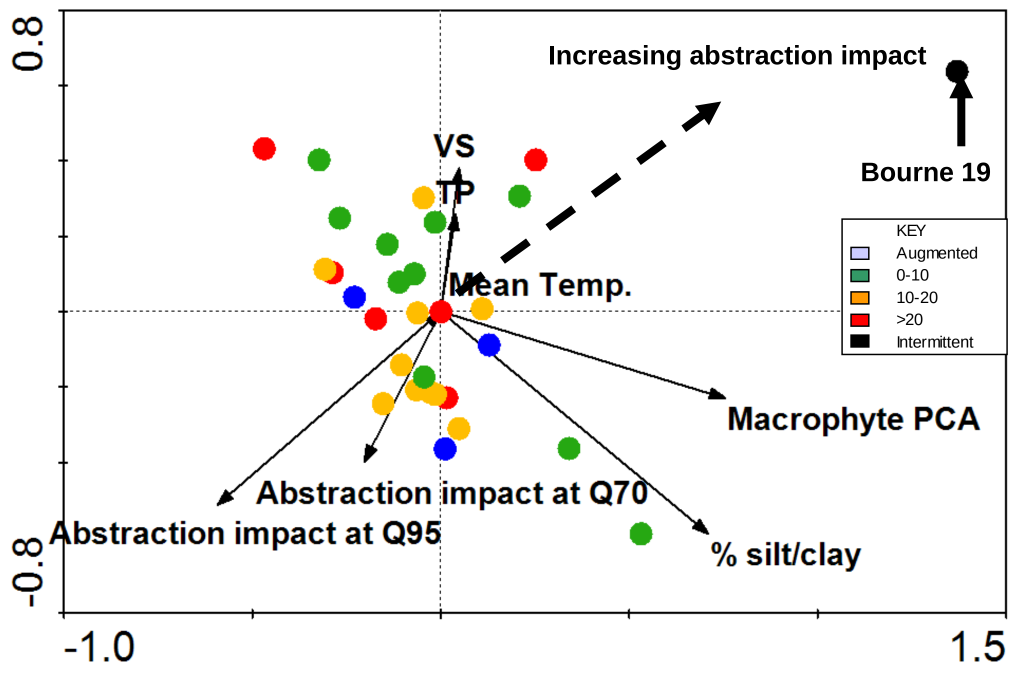


Figure 4.16: Partial CCA ordination biplot of autumn 2006 combined-replicate Surber samples showing the direction and strength of significant linear correlations with environmental variables. Samples are colour-coded to denote abstraction impact categories

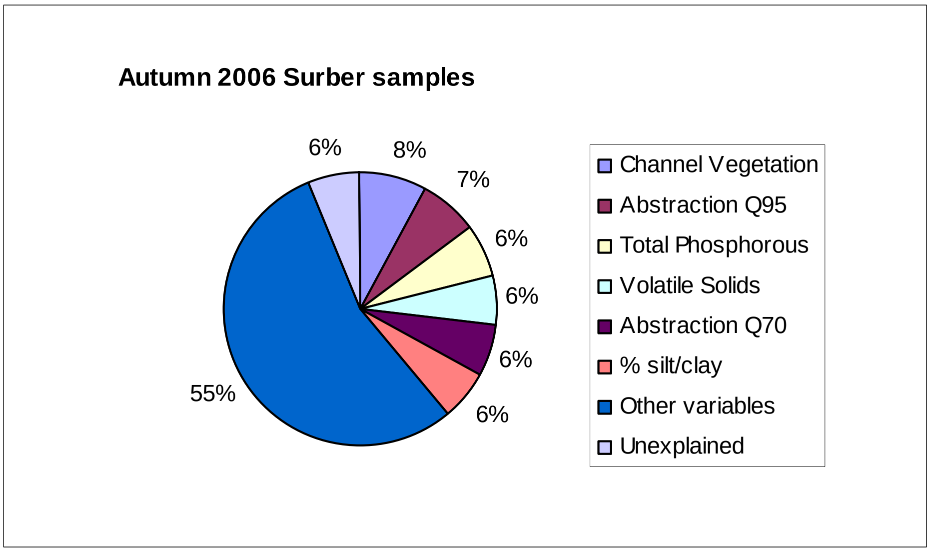


Figure 4.17: Contribution of environmental parameters to explaining the macroinvertebrate communities recorded in Autumn 2006

In summary, only in one data set (autumn 2006) did abstraction explain some of the macroinvertebrate community difference, but then it only accounted for <10% of the difference. It is clear from Figure 4.16 that Bourne 19 exerted a strong influence on this relationship; it is likely that the influence of Bourne 19 alone has caused the model to show an abstraction impact.

4.6.6 Avon-Lower Wylye comparison

Five sites were selected on the Avon that had the same Naturalised Q_{95} as sites previously surveyed in 2006 on the lower Wylye. The pairs of sites and their Naturalised Q_{95} are shown in Table 4.4.

Table 4.4 Flow and abstraction impacts at paired sites (Natural run 136 Historical run 135)

Q_{95} natural flow (ML/d)	Avon	% abstraction impact at Q_{95}	Wylye	% abstraction impact at Q_{95}
54	West Chisenbury	+15	Upton Lovell	-2
68	Gated Crossing	+10	Sherrington	-10
75	Milston	+10	Codford	-8
100-130	d/s Amesbury	+13	Steeple Langford	-5
136	Lower Woodford	+5	Quidhampton	-4

Sites were selected to be as similar as possible to those on the Wylye however the choice was restricted by:

- Limited length having the same Naturalised Q_{95}
- The need to chose a section of river receiving total flow i.e. no leats or side channels
- Access

Macroinvertebrates were collected from each site using both quantitative (3 Surber samples) and semi-quantitative (kick sample) methods in spring, summer and autumn 2007. A comprehensive suite of environmental variables were recorded on site at the same time that invertebrates were collected.

The limited number of pairs used in this analysis does not allow robust statistical analysis but does allow an assessment of the more obvious differences between the two rivers. The main differences are listed below:

- The Wylye sites generally have higher LIFE scores than the Avon sites in all three seasons surveyed for both kick and Surber samples.
- No consistent difference in velocity between the two rivers. Wylye higher in spring but very similar in summer and autumn.
- Avon sites have more *Ranunculus* at the kick sample sites in summer and autumn.
- Avon sites water depths deeper than Wylye in autumn, due to more *Ranunculus* at the Avon sites.
- Avon sites have a higher number of LIFE scorers (a surrogate measure of diversity) in kick samples in all seasons but not such a clear difference in Surber sample.
- Most Avon sites have higher number of LIFE 1+2 scores.
- Most Avon sites have a higher number of 3-6 scorers.

A simple model that would explain the differences listed above would be that the greater abundance of *Ranunculus* on the Avon results in a wider range of habitat availability for invertebrates resulting in a higher diversity in kick samples, where the invertebrates from all river habitats including the plants are collected, but not in the Surber samples where only the substratum was sampled. The greater diversity of flow conditions created by the abundant *Ranunculus* on the Avon has resulted in a wider range of invertebrates including those that prefer high velocities and those preferring low velocities. Overall the greater number of low LIFE scorers results in the Wylye recording higher LIFE scores.

4.7 FISH

4.7.1 Introduction

The abstraction influence on number/density and length of designated SAC species, plus trout are detailed in this section.

4.7.2 Bullheads

Bullheads were well distributed throughout the catchment during both years of the study (Figure 4.18), although densities were observed to be highly variable between sites and abstraction impact categories. In general, bullhead densities (all ages) were greater in 2007 than 2006 at all sites. This was also represented in the 0+ age group, indicating that recruitment in 2007 had been more successful than during the previous year, irrespective of abstraction impact.

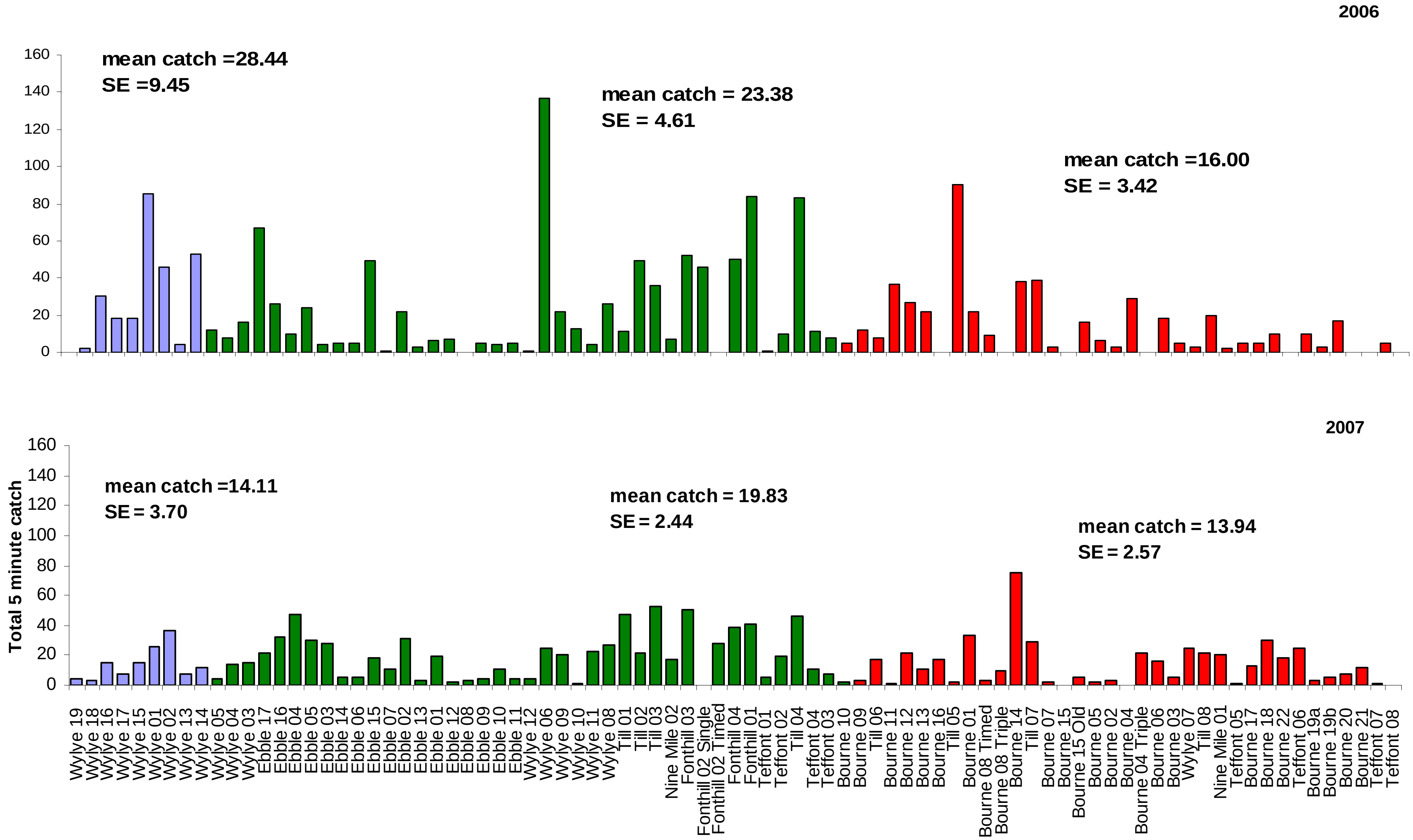
When bullhead density was analysed no statistically significant relationships were found between impact and un-impacted bands or between years. When absolute catch values (5 minute) were used, a significant difference between impact and unimpacted sites was detected in 2006, but not 2007 (Figure 4.19). When the 2006 and 2007 data set are combined a significant variation between bands was found.

In general bullheads were bigger at all sites in 2006 than in 2007. In 2006 growth of 0+ bullhead was consistent between impacted and unimpacted bands; however, bullheads achieved significantly higher growth rates at the augmented sites. This was also true in 2007, although, in this year, growth at unimpacted sites was also significantly greater than at impacted sites. (Figure 4.20).

Paired Analysis

In this analysis sites with differing impacts were paired due to their similarity of key habitat parameter e.g. % gravel, substratum composition, channel width, depth and natural stream size. This effectively removes these key habitat features from influencing the analysis, allowing any impact due to abstraction to be detected.

Figure 4.18: Bullhead catch data (all ages) from 5 minute timed catches at each site during 2006 and 2007. Sites are ranked according to the abstraction impact at Q95.



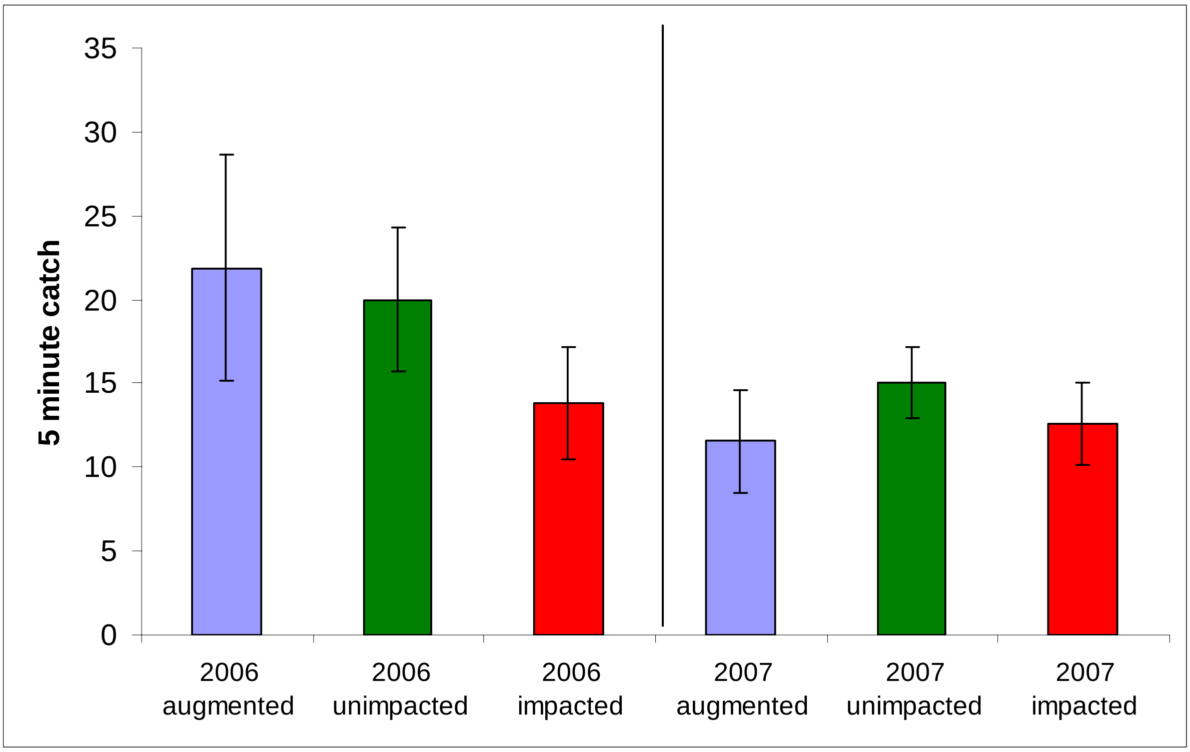


Figure 4.19: 2006 & 2007 0+ bullhead 5 minute timed mean catches by abstraction impact category

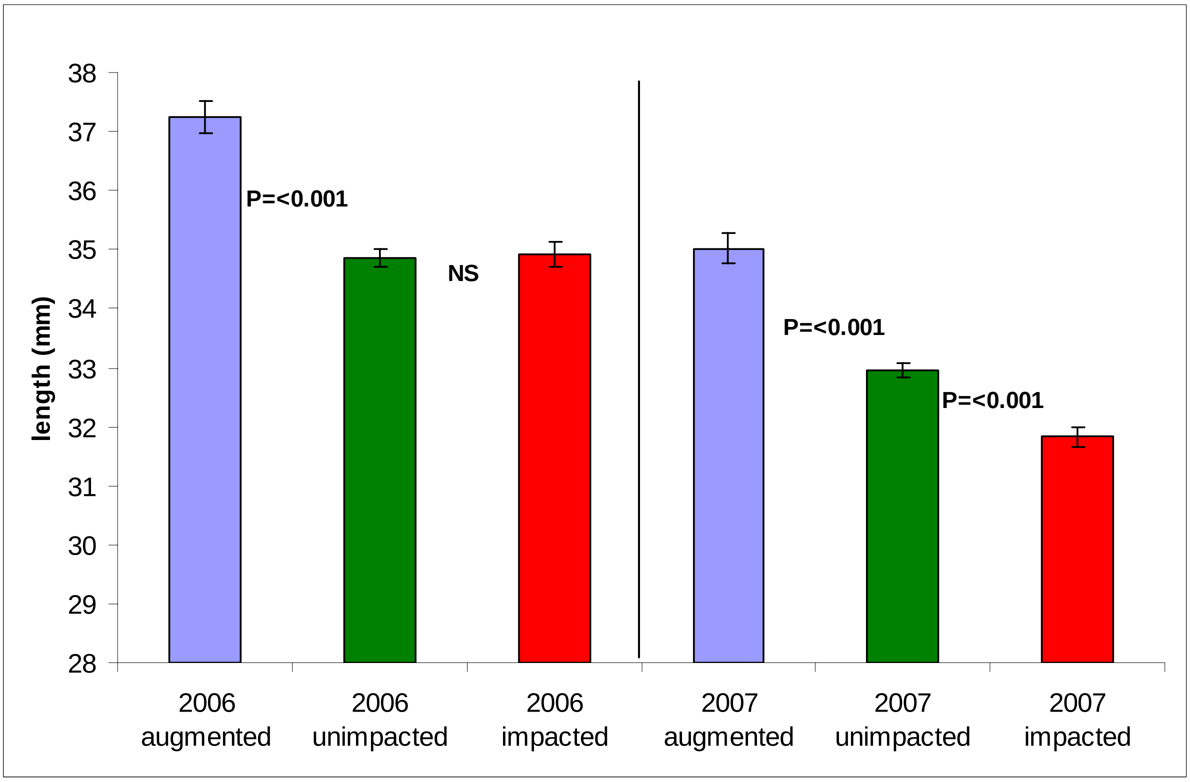


Figure 4.20: 2006 and 2007 0+ bullhead length (mm ± SE) within each abstraction impact category

In 2006, bullheads of all ages were significantly more abundant at unimpacted sites than at impacted sites when the 5% rule was applied. Similarly in 2007, 0+ bullheads were significantly more abundant in unimpacted sites compared to impacted sites (Figure 4.21) Although the same was true of larger bullheads the differences were not statistically significant. These effects of abstraction impact were the same for both extrapolated bullhead densities (per meter square) and for the actual numbers of fish that were caught in 5-minutes of sampling.

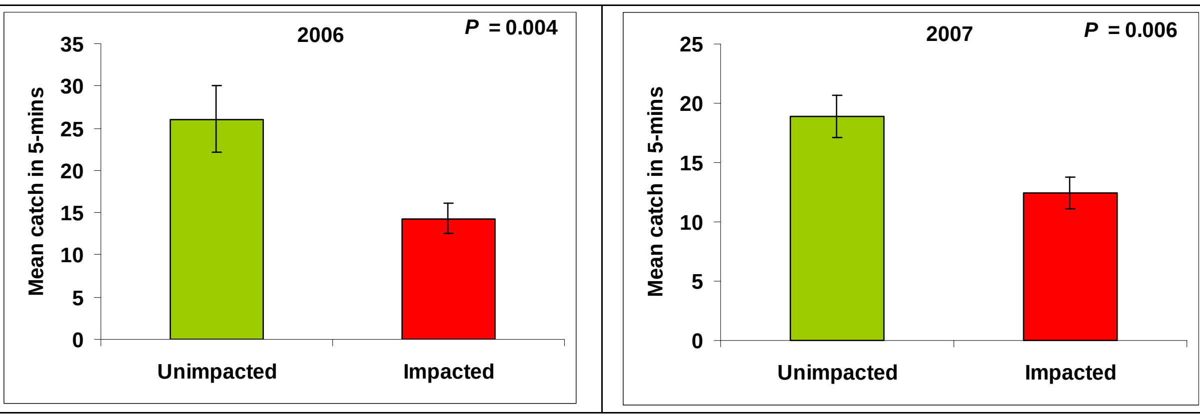


Fig. 4.21 Mean ±SE numbers of bullheads that were caught in 5-minutes of survey at a sub-set of sites that were used in pairwise comparisons between unimpacted and impacted locations in (left) 2006 and (right) 2007

Augmentation

In 2006 the mean number of bullheads at augmented sites was consistent with the number at non-impacted sites. During 2007, however, considerable reduction in mean bullhead density occurred at augmented sites compared with unimpacted sites (Figure 4.18). In the case of 0+ and greater than 0+ age groups, densities were also lower than they were at impacted sites. These observations raise questions regarding the relative flows experienced within the augmented sites between years. Data worthy of further investigation include the timing of stream support operations, relative water temperature, which may have delayed spawning and embryonic incubation times and also the frequency, duration and quantity of augmentation which could potentially disturb adult bullheads from their territories, causing them to relocate.

4.7.3 Lampreys

Lampreys were present throughout the catchments from the upper perennial reaches of headwater streams to the lower reaches of tributaries such as the Bourne and Ebble. These species were absent from the Teffont Brook and the Nine Mile River.

More juvenile lampreys were caught in 2006 than in 2007. These data also suggest that in 2006 (Figure 4.22) there were significantly more lamprey at impacted sites than at unimpacted sites; whilst the trend was still evident in 2007, it was not statistically significant.

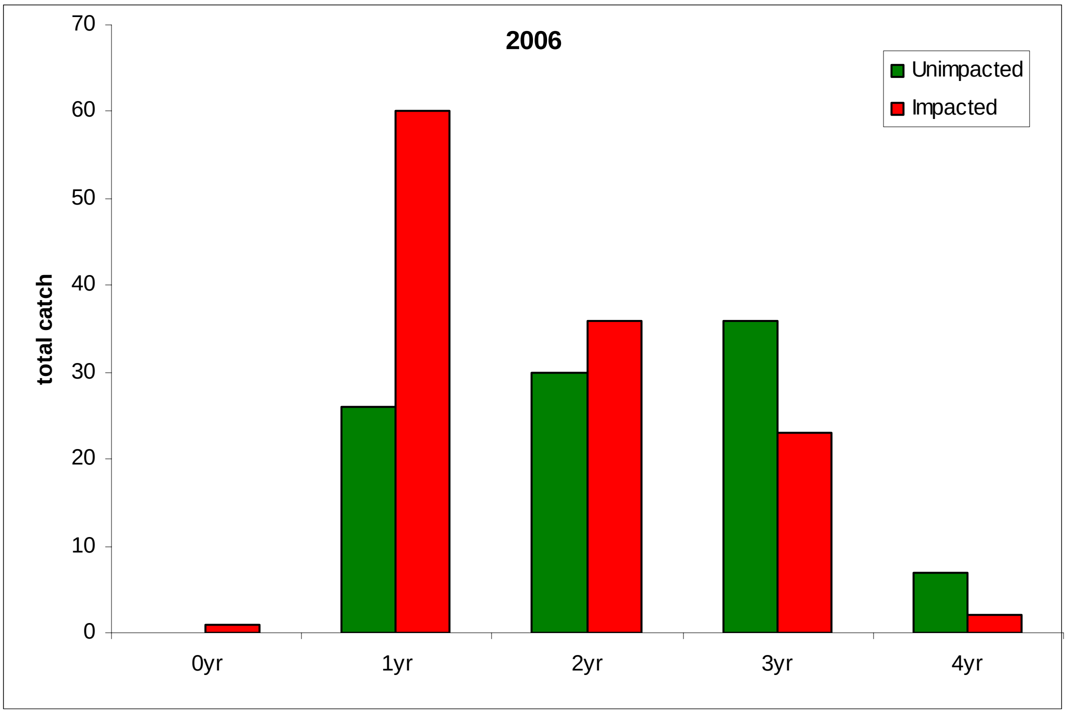


Figure 4.22: 2006 Lamprey catch split into age classes and relative abundance between impact categories at modelled Q95 impacts.

In considering the impacts of flow category on 0+ lamprey, the only 0+ individual captured in 2006 was at an impacted site (Figure 4.19). In 2007 the 0+ year class also demonstrated a preference for the impacted sites, while the 1+ age group were also more abundant at impacted sites in 2006. In all other year classes in both years, there was little evidence of any difference in the abundance of lamprey between impact categories. While the data are subject to temporal limitations (two years only) it would appear that the significantly greater abundance observed at impacted sites in 2006 was driven by the younger year classes.

There are several hypotheses for the increased lamprey densities at impacted locations including increased silt deposition at these locations, providing increased optimal habitat and decrease in wetted perimeter causing the lamprey to become more concentrated in the available habitat. Whilst the available data from this investigation do not indicate a positive correlation between silt and abstraction, further work is planned to investigate the key environmental drivers determining lamprey distribution in the upper River Avon catchment.

Although the data collected for lamprey have facilitated some interesting observations, the data currently available are not sufficient to observe any statistically robust trends. As such it has not been possible to identify any impacts of abstraction (positive or negative) on the distribution and abundance of ammocoetes.

4.7.4 Atlantic Salmon

A total of 4 and 46 salmon were caught in 2006 and 2007 respectively. Of the 46 salmon caught in 2007, 10 of these were salmon that had been artificially introduced into the River Till from egg boxes as part of study that was undertaken by Bournemouth University on behalf of the Wessex Salmon and Rivers Trust. Such low numbers overall, compounded by known stocking on the River Till, precluded meaningful analysis of the data with regard to the effects of abstraction.

However, it is considered that salmon are unlikely to naturally disperse to many of the headwaters where this survey was conducted and it is thought that this would still be the case in the absence of any abstraction. Further evaluation of the potential for abstraction to impact salmon is examined in Section 4.9.

4.7.5 Trout

Brown trout have been assessed as a surrogate for salmon. Although authorised stocking did not occur in the survey reaches, it has been acknowledged that there is the possibility that unauthorised stocking of juvenile trout might have caused an unquantifiable bias in the data.

Brown trout were present throughout the catchment in streams of varying size, and abstraction impact. Young of the year brown trout (0+) were more broadly represented than older trout in both years, although they were noticeably absent from the sites most heavily impacted by abstraction in 2006.

Figure 4.20 shows the relative proportion of 0+ and older trout within each impact category in 2006. Densities of both 0+ and older trout were greater at unimpacted than impacted sites, although due to the low sample sizes these differences were not statistically significant. Figure 4.23 clearly demonstrates the low numbers of older fish captured in 2006 at all sites, irrespective of abstraction impact.

One of the most striking observations regarding trout density was the relatively low numbers of older fish (>0+) captured during the 2006 survey. Indeed, only two sites within the impacted category supported low numbers of older trout, with small populations also restricted to a small proportion of the unimpacted sites. The low densities of >0+ trout observed in 2006 may be an indication of poor recruitment in 2005.

The length (surrogate for growth rate) of 0+ trout was not related to abstraction impact in 2006 or 2007. This suggests that sufficient food was available for growth at all sites irrespective of flow or abstraction impact. However, the fish were generally bigger at all sites during 2007 than in 2006. There are several potential explanations for this, including earlier hatching as a result of the warm spring, or enhanced growth rates governed by increased habitat available during 2007. The hypothesis that higher growth rates in 2007 was due to more food being available was rejected on the basis that the abundance of macroinvertebrates was lower in 2007 compared to 2006. Regardless of the mechanism, the effect was evident across all sites, irrespective of the degree of abstraction impact.

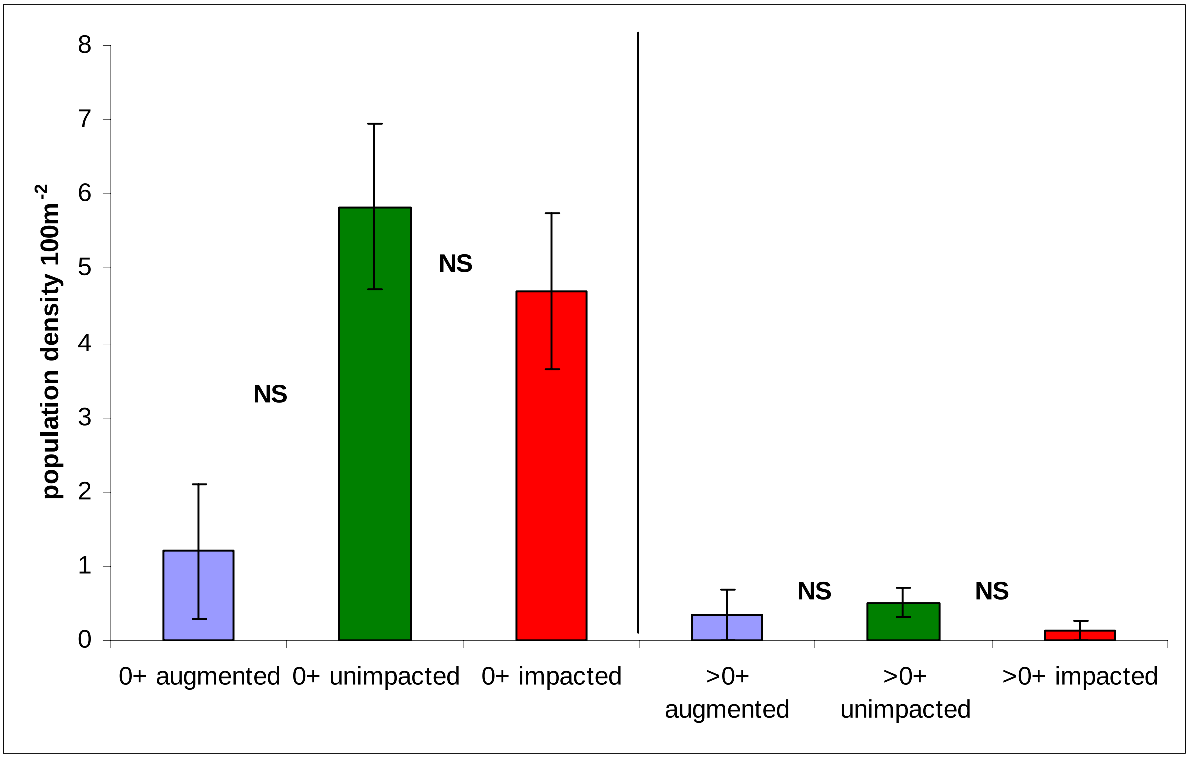


Figure 4.23: 2006 Brown trout (0+ and >0+) population estimates (No./100m^2 ± SE) within each flow category

The results of the paired analysis support the broad scale conclusions of impacts on brown trout. Paired analysis of 0+ densities at impacted and unimpacted sites confirms that there was no significant relationship between abstraction impact and 0+ density during 2006, even when the 5% rule is enforced. The paired analysis also supports the observation that 0+ trout densities were higher at the impacted sites during 2007.

4.7.6 Candover Brook Relationship

The Candover Brook relationship refers to that found between the flow in April and the number of 0+ brown trout caught later that year in October (Solomon and Paterson 1980). It was concluded that the mechanism for this relationship was by higher flows increasing the area of stream bed providing suitable habitat for young fish territories or by the increased velocity leading to smaller territories and therefore a higher density of fish. April was considered to be the critical period for the establishment of initial territories by young fish.

This Candover Brook relationship was used to predict the impact of abstraction on brown trout 0+ numbers in AMP 3 studies. Insufficient data were available for a similar analysis on salmon but it was considered likely that impacts on 0+ salmon were of at least a similar magnitude.

The longest data sets on the Bourne are from juvenile salmonid surveys at Laverstock and St Thomas Bridge, 9 and 13 years respectively between 1988 and 2001. These data are however from surveys of typically <100m compared to the 1 km surveys undertaken on the Candover Brook study and are therefore not strictly comparable. These data do not show any relationship between April flow and 0+ numbers trout.

Data sets from 6 sites on the Bourne compiled from surveys undertaken by a variety of organisations between are available for some years between 1985 and 2007. This data set is a lot less robust than the juvenile salmonid data set because of differences in the exact location of survey, length of survey, operator efficiency, equipment efficiency and the method used. However it does show a relationship between April flow and brown trout fry numbers at Winterbourne Gunner and a relationship between Q95 flow and salmon and trout numbers at St Thomas Bridge. Winterbourne Gunner is outside the normal range of salmon (usually restricted to Ford and below). Salmon are usually recorded at Laverstock or St Thomas Bridge and are found in most years surveyed on the Bourne.

Therefore there is some indication of a response of juvenile salmon and trout to flow but currently the relationships are insufficiently robust to use to assess the impact of abstraction on salmon populations.

4.8 SALMON – ABSTRACTION IMPACT

The decline in salmon number in Southern Britain chalk river was examined in Section 2.2.1, with a list (Table 2.1, repeated below) of potential impact effects due to abstraction presented. Each of those potential constraints on the salmon population is examined in this section.

Table 2.1 Key potential impacts of abstraction on salmon

Salmon Population constraint	Potential effect of abstraction
Land use and siltation increase	Could increase deposition
Silt from within river sources	Could increase deposition
Flow perturbations	Reduction in flow and thus velocity and depth
Barriers to migration	Increase at lower flows
Reduced rate of river entry	Reduced flow at mouth
Increasing temperature	Reduced input of cooling ground water

Siltation

Lower river flows due to abstraction could provide a greater opportunity for silt deposition. Substratum samples from the ecological survey sites were analysed to determine the percentage of silt and clay. Analysis of the silt/clay data against abstraction impact categories found no relationship, but it was inversely related to natural Q95 flows, depth and wetted width.

It is concluded that abstraction is unlikely to affect salmon success through increased siltation of the head water.

Flow Perturbation

The main areas of abstraction impact (contemporary) do not overlap with the preferential salmon habitat areas. At full licence the overlap is greater, but the reductions in river flow are seldom greater than 15% of natural. Given the low salmon number in the headwaters, trout have been used as a surrogate. Where the largest abstraction pressure exist (River Bourne) clear abstraction related impacts on trout fry are difficult to show. Based on these impacts, it is considered unlikely that flow changes due to abstraction are contributing significantly to the salmon success within this impacted area.

Barrier to migration
There are no known sites in the headwaters where low flows due to abstraction, in combination with an obstruction are considered to limit the spawning range of salmon

River Entry
The Wessex Water impact on river flow is neutral by Ringwood, due to STW returns, therefore no impact on entry flow is predicted.

Temperature
The effect of abstraction on river water temperature is examined in Section 6.2. The finding from which is that groundwater abstraction does reduce water temperature but the main and potentially harmful effects of changing temperature on salmon are driven by increasing air temperature both in the nursery areas and the main river. The effects of abstraction on river water temperature are unlikely to be detected against the variation caused by shade and impoundment.

Summary
It is concluded that groundwater abstraction affects a small proportion of the Salmon habitat and is unlikely to affect the population success. The decline in salmon numbers is more likely to have been caused by a combination of effects common to the other southern chalk streams and rivers.

4.9 SUMMARY

Macrophytes
The macrophyte communities recorded at all sites were typical of chalk streams and taxon richness (number of groups or species) ranged from 11 taxa to over 34. *Ranunculus penicillatus subsp. pseudofluitans* a species prone to suffer under low flow conditions was amongst the most frequent and abundant species recorded in both years.

When survey locations were grouped into 3 main categories that described abstraction impacts (0-10%, 10-20% and >20% decrease in natural flow at Q95), no statistically significant difference was found between aquatic macrophytes and the degree of abstraction impact in either year, across all sampling locations.

However, when macrophyte indices were examined against the actual impacts of abstraction on natural flow at each site using stepwise multiple regression, abstraction impact (with some other environmental variables) explained around 20% of the variation in MFR-A scores in 2006 and 2007 and 14% for MTR scores in 2007.

Examination of the whole macrophyte community indicated that communities at survey locations on the same river were often more similar to each other than communities on different rivers. More detailed multivariate statistical analysis was used to examine whether the effect of ‘river name’ was actually driving the variation that appeared to be related to the effects of abstraction. This analysis indicated that after the effect of ‘river name’ was accounted for, environmental variables such as sediment nutrient concentration and channel type most strongly described macrophyte community structure and composition rather than any abstraction effects.

The use of 2006 actual 'impact' data did reveal a difference between augmented site and non-augmented sites. Further work is required to understand the mechanism for this difference and whether the relationship holds when 2007 actual impacts are used.

Macroinvertebrates
In general, the abundance and taxon richness of macroinvertebrates was relatively high in all samples in relation to other UK rivers and was highly typical of chalk rivers in southern England.

When survey locations were grouped into 3 main categories that described abstraction impacts (0-10%, 10-20% and >20% decrease in natural flow at Q95), no statistically significant difference was found between macroinvertebrate indices and the degree of abstraction impact in either year, across all sampling locations (Bourne 19 excluded). There were some differences between abstraction impact categories but there were no trends that could be related to increasing or decreasing abstraction impact. The only consistent, significant effects of abstraction on macroinvertebrate indices were found at just one sampling location (Bourne 19, near Idmiston) where abstraction prolongs both the cessation of flow and natural drying periods.

Examination of all the macroinvertebrate species and taxa suggested that there was some evidence suggesting that macroinvertebrate communities differed significantly between abstraction impact categories. However, this effect might also have been an artefact of the tendency for samples from the same river to more similar to each other than samples from different rivers and at the same time for abstraction impacts to be broadly similar on individual rivers. For example, macroinvertebrates at the 2 sampling locations on the Fonthill Brook in summer 2006 were noticeably dissimilar to other sites in the same impact category and this might have exacerbated any effects that were apparently due to abstraction. In this particular case is has been suggested that higher water temperatures (>20^{o}C) that occurred in this watercourse in summer 2006 compared to other locations might have affected macroinvertebrates. Further analysis of the influence of temperature on macroinvertebrates is planned.

More detailed multivariate statistical analysis indicated that after taking account of the effects of 'river name' natural stream size was the most important variable describing macroinvertebrate variation. Abstraction impact explained a small (around 4%) but significant amount of variation after natural stream size in summer and autumn, but this was almost entirely driven by the influence of Bourne 19 only. Further analysis will be conducted to measure the effect of abstraction on perennial locations only.

The use of actual abstraction impact in 2006, identified the same relationship, albeit slightly stronger, though again Bourne 19 was driving the difference. When Bourne 19 was excluded from the analysis a statistically significant difference between impact bands was detected, however, natural stream size exerted a greater influence on the observed community.

Along the perennial reaches (which do not dry) an impact upon the macroinvertebrate community due to the effects of abstraction was not clear.

A comparison of the lower Wylye and Avon macroinvertebrates, revealed as greater diversity at the Avon Site, though the Wylye site scored higher LIFE scores. The disparity is due to the greater prevalence of Ranunclus at the Avon sampling sites Avon more diversity macros, due to greater presence of Ranunculus

Fish

When absolute catch number were compared (5 minute) a statistically significance was detected between between 2006 catches and degree of abstraction impact. This difference was not statistically significant in 2007 or when density values were used.

Pairwise analysis also reveals difference in catch number between impacted and unimpacted sites.

Too few salmon were caught to allow analysis. However, the surveyed site where not sited in the preferential salmon habitat along the Avon and its tributaries. Abstraction is likely to only to have a small influence on Salmon number in the River Avon SAC.

No abstraction impact upon the Lamprey population was detected.

No abstraction impact upon the trout population was detected.

5 Ecological Study Findings - Winterbournes

5.1 INTRODUCTION

The impact on winterbourne communities is examined in this section. Only one of the Hampshire Avon winterbournes, the River Till is designated within the SAC. Output from the HAM is used to define the hydrological impact upon the winterbourne reaches due to abstraction. As mentioned the HAM's representation of the River Till is currently being refined, therefore explicit impacts upon the Till are not available. However, the findings from other winterbourne catchments are considered to be transferable in principle, to give an indication of the likely impact upon the designated species in the River Till.

The work and findings presented in the report entitled 'Assessing the ecological impact of abstraction on the winterbournes of the Hampshire Avon' are summarised in this Section.

5.2 WHAT IS A WINTERBOURNE

A 'bourne' is the name given to an intermittently flowing river, being a notable feature of chalk catchments. The flow behaviour of the bourne is governed principally by the climate.

Winter rainfall leads to high groundwater levels and consequently water flows in the winterbourne high upcatchment. The highest point up the catchment that flow starts depends on how wet the winter was. As groundwater level recesses during the spring the head of the bourne concurrently moves downstream, though there are local variations to this pattern. The lowest starting point of the bourne is governed by two factors: geology and climate. Again climate is the key factor, with the summer head of the bourne located further downstream following a 'dry spring/summer', than if it had been a 'wet' summer. In certain catchments the bourne head reaches a fixed location, a perennial head, these are typically geologically controlled, whereby due to the local geological structure e.g. faulting/folding, groundwater is 'forced' to the surface producing perennial springs, the River Bourne is an example of this, with the perennial head at Porton. In other catchments the winterbourne may dry in some years to the confluence with a perennial river e.g. the Chitterne Brook.

It is noted that present day 'dry' valleys within the chalk catchment of the Hampshire Avon, would historically have been winterbournes at one stage.

The variable nature of the flow along the bourne can be illustrated by its winterbourne signature, an example for the Chitterne Brook is shown in Figure 5.1.

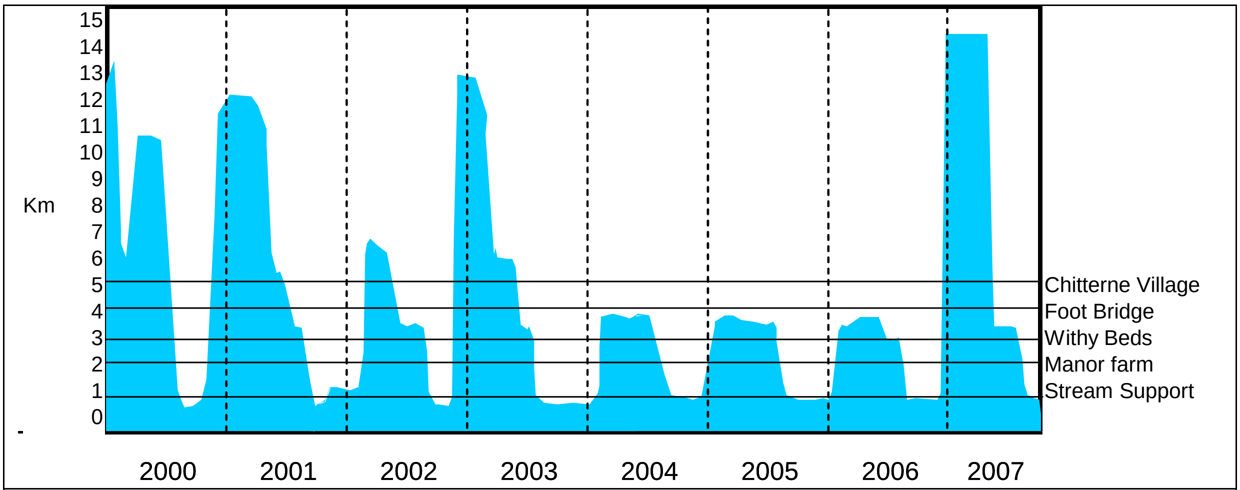


Figure 5.1 - Chitterne Brook winterbourne signature 2000-2007

Figure 5.1 shows that during wet winters the winterbourne length can be over 14km, although lower winter rainfall restricts the winter length to ~3.5 km e.g. 2004-2006.

5.3 STUDY CATCHMENTS

Ecological sampling has been undertaken on nine winterbourne catchment, these are listed in Table 5.1 and their geographical distribution shown on Figure 5.2 (Section 9).

Table 5.1: Winterbourne: Studied and Type

Winterbourne Name	Type of Winterbourne
Bourne	Short – reliable Idmiston area, the remainder long and unreliable
Chitterne Brook	Long and reliable
Chilmark	Short reliable in Chilmark – remainder long and unreliable
Ebble	Long and reliable
Fonthill	Short and reliable
Heytesbury	Short and unreliable
Nine Mile River	Long/short* and reliable
Till	Long and reliable
Wylye	Short and reliable

** short after dry winter*

Also displayed on Figure 5.2 (Section 9) are large scale plot of each winterbourne, plotted to the same scale. The length of the winterbournes is variable ranging from ~4km (Fonthill) to ~32km (Bourne). The length of each bourne and the frequency of flow has a major influence on the observed ecology, this is examined further in Section 5.6. The frequency of flow refers to how reliably winter flow occurs along the winterbourne. Sections of certain winterbournes receive flow each winter, whereas others may not have flow for 2-3 years.

Based on these observations the study winterbournes have been defined as either ‘short’ or ‘long’ and whether it is a ‘reliable’ or ‘unreliable’ winterbourne (Table 5.1)

The landuse of all study catchments, except the Nine Mile River are very similar being a mixture of either improved pasture or arable. As a consequence of its use as a military range, the Nine Mile catchment is predominately unimproved chalk grassland, shrub and woodland. This landuse difference results in the Nine Mile River having a distinctive winterbourne ecology.

5.4 WINTERBOURNES ECOLOGICAL INTEREST

The intermittent nature of flow is exploited by several notable species that have evolved to cope under these conditions, having a competitive advantage over other species.

Macrophytes that have adaptation for this winterbourne environment include *Ranunculus peltatus* that flowers earlier than other water crowfoots enabling it to utilise temporary flow.

A variety of strategies are used by macroinvertebrates found in winterbournes, these include:

- Upstream migrants – most noticeably *Gammarus pulex*, they colonise quicker than their main predator the bullhead.
- Semi aquatic residents surviving in damp conditions – e.g *Pisidium personatum* survive by burying into gravel in drying winterbournes.
- Aerial migration – the flying stages of Coleoptra, Trichoptera and others that colonise the winterbourne as soon as flow returns.
- Hyporheic species – associated with spring heads and are washed out when the springs break.
- Aestivating eggs or early instar – lay dormant for several months during dry conditions, and activated by the return of flow.

Trout are the predominate fish species to use winterbournes, primarily for spawning. To be a successful spawning area a reliable winterbourne is needed, this is discussed further in Section 5.7.4. Although trout are known to leave the winterbourne reach as flows recess and the bourne dries during spring/summer, not every trout makes it and they become stranded in pool, providing good picking for predators like herons. The presence of trout fisheries means that to keep stock numbers up in the main river fish rescues are undertaken to transfer stranded fish to the main rivers. This is a long established practice and records show that this has been occurring on the Chitterne Brook since the 1920's.

SAC Interest Feature – River Till
Of the designated species listed in Section 2.2, only the *Ranunculus* community, due to the presence of the winterbourne specialist *Ranunculus peltatus*, is found to any degree in a winterbourne, whereas all the designated species and features are found in the perennial reaches.

5.5 HYDROLOGICAL ABSTRACTION IMPACT

Winterbournes are potentially sensitive to abstraction because:

- Abstractions are located in the winterbourne catchments
- The bournes have relatively small stream size so abstraction may have a proportionally greater effect on river flow than further downstream.

However, winterbourne communities are also well adapted to the widely varying range of flows and drying periods which results from climatic and seasonal variation. The impact of abstraction on the drying period is assessed in this Section, the potential impact on the winterbourne community is presented in Section 5.6.

The HAM model has been used to assess the impact of abstraction along each winterbourne. As detailed in Section 5.1 no output for the River Till is available, in addition no model output for the Chilmark Stream is available. This is because the model's representation of the Chilmark is inadequate, showing a gaining in flow when a loss is occurring. However, field work and conceptual modelling has established that the Chilmark Stream is not affected by abstraction due to Wessex Water activities (Fonthill Low Flow investigation). The River Ebble is not considered in this section as it not impacted by Wessex Water activities.

Changes in the average period of drying along each study winterbourne are shown on Figure 5.3 (Section 9) and summarised in Table 5.2.

Table 5.2: Full Licence Abstraction Impact:Additional Winterbourne drying and lost of Perennial

Winterbourne	Maximum no of average days of additional drying	Length of perennial that has become winterbourne (km)
Bourne	61	0
Chitterne Brook	77	0
Fonthill	52	0.25
Heytesbury	98	0
Nine Mile River	30	0
Wylye	27	0

Bourne

The impact of Newton Tony PWS is particularly evident over the final 8km of the Bourne: Porton to Newton Tony Village. The largest impact occurs around the Newton Tony source. Between Porton and Idmiston under natural conditions the Bourne dries on average once every five years. This frequency increases to an average of once in every two years under full licence conditions.

Chitterne Brook

The natural curve on Figure 5.3(Section 9) shows the influence of the fault controlled spring at the Withy Beds. Downstream of the Withy Beds the stream becomes perched in summer and the stream flow is gradually lost to ground, hence the average number of flow days of flow reduces downstream of the Withy Beds.

Under full licence conditions a reduction in average flows is evident around the Chitterne source and notably below the Withy Beds, with the Chitterne source reducing the spring outflows and resultant stream flow, increasing the average period of no flow by ~60 days.

Fonthill
On average the period of no flow along the Fonthill Brook is increased due to the Fonthill PWS source by ~20 days. The HAM output indicates that the final 250m of the Brook before the head of the lake is naturally perennial and becomes a bourne under full licence conditions, in a drought year.

Heytesbury
This stream has not been calibrated as part the of HAM, due to an absence of spot gauging data, so the accuracy of the model's predictions are not known. The HAM output suggests that the Heytesbury Stream is a short unreliable winterbourne. Abstraction is predicted to increase the period of no flow by ~60 days on average, but these predictions must be treated with caution.

Nine Mile
An impact due to abstraction is seen along the Nine Mile River. As detailed in the Low Flow Bourne & Nine Mile report, this impact is attributed to the Newton Tony source and the MOD abstraction at Bulford, with the later having the greater influence. The in-combination effect reduces the period of no flows toward the bottom of the river by ~30 days a year on average.

Wylye
This is a short winterbourne with abstraction increasing the period of no flow by an average of ~15 days. The Kingston Deverill stream support appears to be well sited at the natural perennial head. Though, in 1976 the river dried at Monkton Deverill (2km upstream of Brixton Deverill).

In the sections that follow the graphical outputs for the Bourne and Chitterne Brooks are used to show the impact of abstraction, with the impact upon the other winterbournes summarised in the text.

5.6 APPROACH TO DETERMINE ABSTRACTION IMPACT

The approach taken to investigate the impact of abstraction on the ecology of winterbournes differs from that used on the perennial section. Sites were selected on the perennial headwaters to have similar naturalised flow but varying abstraction impact. The ecology would therefore be expected to be very similar allowing any differences that are caused by abstraction to be detected. By contrast the ecology of a winterbourne varies markedly from the top, where flow may only occur after a wet winter, to the bottom where it always flows except for in a dry summer.

Flow duration has been cited as being the most significant factor influencing community structure in temporary aquatic habitats (Langton & Cass 1998).

To measure the ecological impact of abstraction the following have been done:

1. Establish robust relationship between flow period and the macroinvertebrate and macrophyte communities based on measured dry period (winterbourne signature)
2. Use Hampshire Avon model to calculate the impact of abstraction on the flow period,
3. Calculate the impact of abstraction on the macroinvertebrate and macrophyte communities and predict the impact on fish.

The main thrust of the investigation is therefore on predicting how the macroinvertebrate and macrophyte communities have been affected by abstraction. These communities are made up of numerous taxa and changes in community composition allow for more subtle abstraction effects to be predicted. The effect of abstraction on fish is largely restricted to how the life cycle of brown trout is affected by reduced flow as this is the only fish species to actively exploit the Avon winterbournes.

5.6.1 Macrophytes

Two parallel methods have been used to relate macrophytes to flow period, these are:

- Community types – classified based on the taxa present and their percentage cover
- Ellenberg Abundance Score – index related to wetness of community

A brief description of how a predictive model, 'macrophyte predictor', was developed for the above methods is given below.

Community Type

An extensive data base of macrophyte data for the winterbournes exist, comprising 585 surveys collected between 1992 and 2007. A classification of this data set using TWINSPAN analysis was undertaken and the surveys divided into 10 community types (seven main types). The 10 community types are listed in Table 5.3, with the key taxa that define that community listed.

Multivariate analysis was used to test which environmental parameters (Table 5.4) are the most significant in influencing the macrophyte community. The period of no flow in the previous 12, 24 and 36 months before sampling was included in this analysis, these values were obtained from actual winterbourne signature plots.

Table 5.4: Environmental Parameter used in Multivariate Analysis

Parameter	Parameter
Period of no flow in previous 12 months	Silt/clay in river substrate (%)
Period of no flow in previous 24 months	Sand in river substrate (%)
Period of no flow in previous 36 months	Gravel in river substrate (%)
Channel width	Survey length
Altitude	Shading
Surveyor	Channel gradient

Table 5.3: Macrophyte Community Types

General Type	General Characteristics	Type	Taxon richness	Distinguishing Characteristics
Perennial	Large range of aquatic taxa possible including: *Veronica anagallis-aquat./catenata*, *Nasturtium officinale*, *Apium nodiflorum*, *Berula erecta*, *Myosotis scorpiodes*, *Mentha aquatica* and *Oenanthe crocata*. *Ranunculus peltatus* sometimes recorded. *Ranunculus penicillatus pseudofluitans* occasionally recorded.	**1a**	High	Generally low % cover of *Veronica*, *Nasturtium*, filamentous algae and *Apium*. *Myosotis* and *Mentha*
		1b	High/ moderate	Dominated by *Berula*, some *Apium* and *Oenanthe crocata*. *Ranunculus* unlikely.
Winterbourne	Similar to above but *Alopecurus geniculatus*, sweet grass, non-aquatic grass and herbs more likely although still at relatively low % cover. *Apium* likely to dominate. *Ranunculus peltatus* often recorded - sometimes at high abundance.	**2a**	Moderate	Dominated by *Apium*. Generally low percentage cover. Grasses and *Ranunculus peltatus* rarely present.
		2b	Very high	Similar to 1b but with less *Berula* and *Apium* and more *Mentha* and filamentous algae. *Myosotis scorpiodes* usually present.
		3	High	Similar to 2a but grasses and *Veronica* often present. *Ranunculus peltatus* usually present sometimes at high abundance.
		4	Low/ moderate	Similar to above. Less *Apium*, more grasses.
Intermittent	Fewer taxa. Dominated by non-aquatic grass. Non-aquatic herbs also always present. Aquatic herbs less likely.	**5**	Low	Non-aquatic herbs relatively low. Sweet grass and *Alopecurus geniculatus* usually present. Aquatic herbs occasionally present.
		6	Low	As above but sweet grass less likely. Less *Alopecurus*. More non-aquatic grass and non-aquatic herbs.
		7a	Low	Similar to above but *Alopecurus* less likely. *Mentha* and *Phalaris arundinacea* usually present.
		7b	Low/ moderate	Similar to above but *Phalaris* less likely and less non-aquatic herbs. *Deschampsia caespitosa* occasionally present.

The graphical output from this analysis is shown on Figure 5.4. The most influential parameter was the period of no flow in the previous 24 months; shade and sand in the substrate were also important.

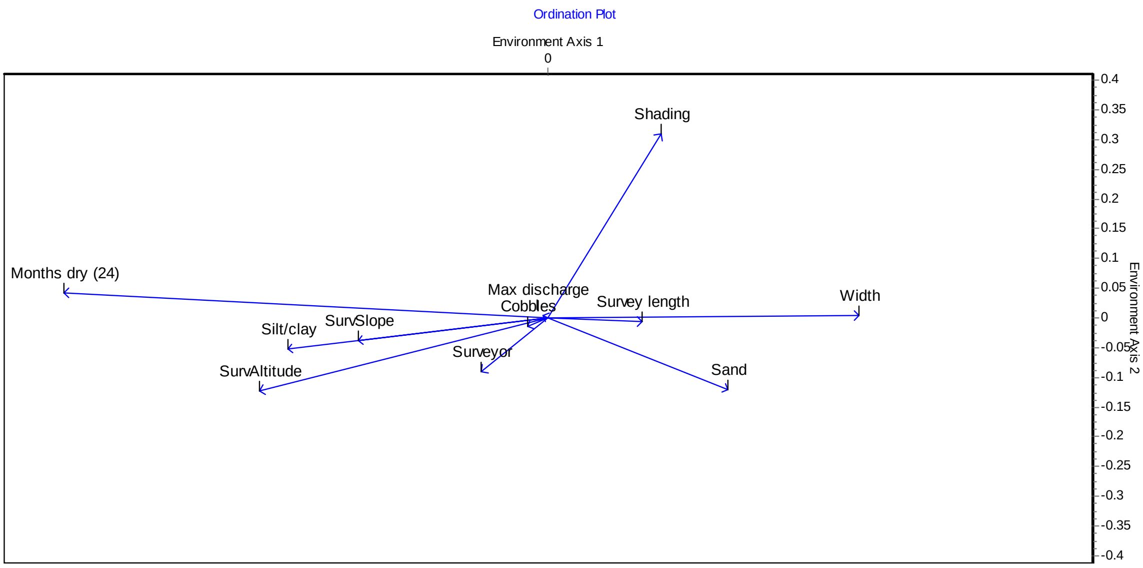


Figure 5.4: Macrophyte Correspondence Analysis Ordination plot

The relationship between community type and months of no flow in the preceding 24 months has allowed predictive equations to be formed (Figure 5.5). The macrophyte predictor can be used to predict which community types could occur at a site (point along a river), in summer, as shown on Figure 5.6. The 5 and 95 percentile best fit regression lines have been used to remove any outliers from the data set.

There is considerable overlap of communities predicted because the community types can occur over a range of dry periods and are influenced by the community that was present in the previous years.

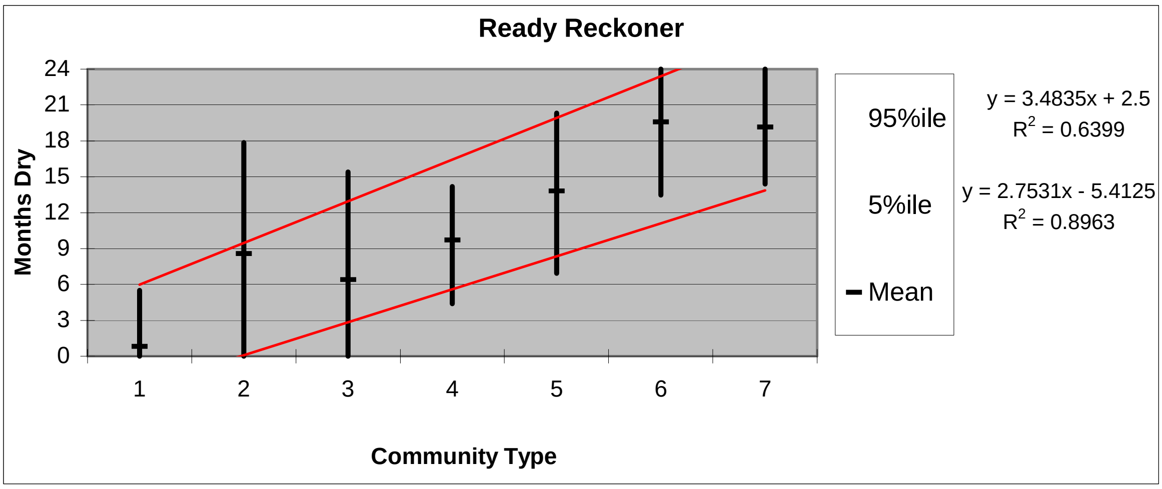


Figure 5.5 Regression equations used to calculate boundaries for Community Types

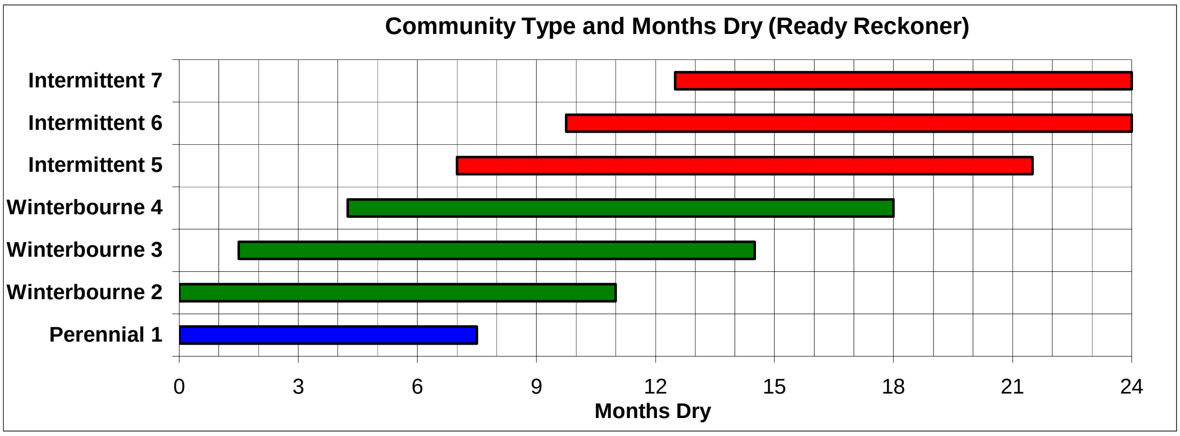


Figure 5.6: Community type Predictor

EllenbergAbundance Score

Ellenberg Abundance score (EAS) is developed from the Ellenberg (F) score (Hill et al, 1999) with an adjustment to account for abundance. Each higher plant species has a score based on their affinity for moisture. The lower the EAS the drier the site. As undertaken for the community type the relationship between EAS and dry period experienced in the preceding 12, 24 and 36 months was investigated. The 24 month flow period was found to be most closely correlated to EAS. The relationship and predictive equation 'EAS predictor' is shown on Figure 5.7.

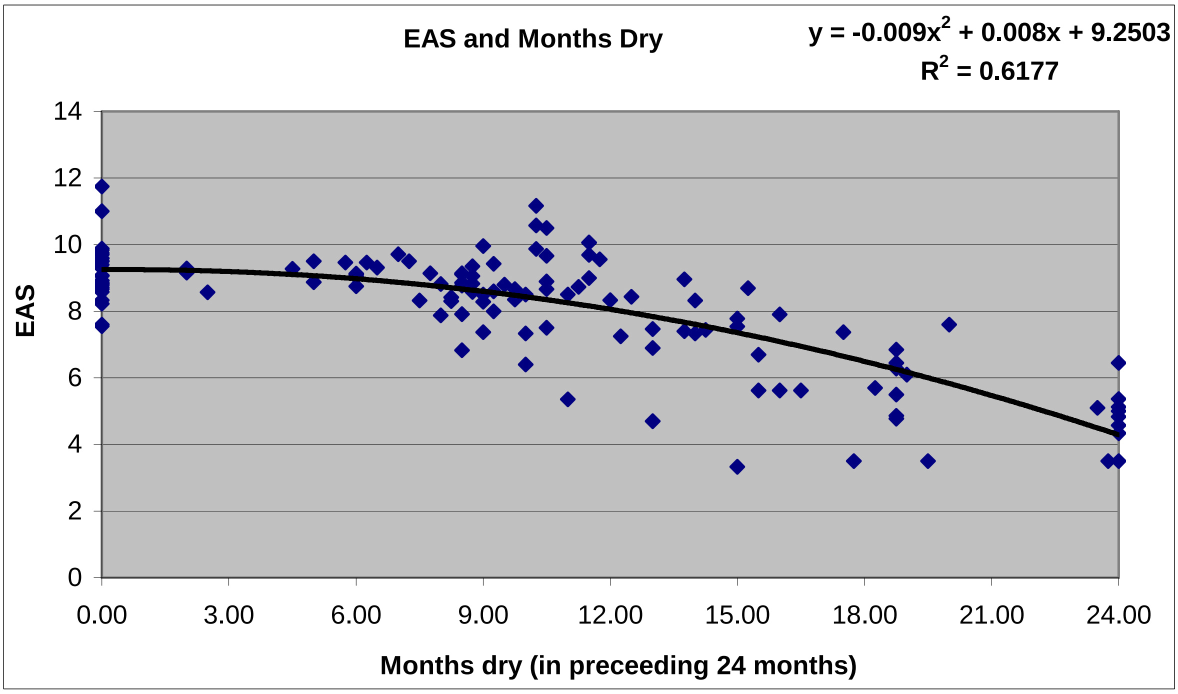


Figure 5.7: Summer Ellenberg Abundance Score and flow duration data

5.6.2 Macroinvertebrates

The approach to quantifying the macroinvertebrate data comprise a predictive model based on community type and a conservation value index (related to community type).

Community Type

Similar to the procedure undertaken for macrophytes the macroinvertebrate data were subjected to TWINSPAN analysis which clustered the 171 samples into seven similar community assemblages. These seven community types are described in Table 5.5.

Table 5.5: TWINSPAN clusters combined into community types

Cluster	Community Type	Mean number of families	Key community characteristics
1	**Perennial**	36	Contains families dependant on permanent flow e.g. Sericostomatidae, Leptoceridae, Glossosomatidae
2			
3			
4			
5			
6			
7	**Transitional A**	25	Abundant Gammaridae – fewer families than in perennial community. No families that depend on permanent flow
8			
9	**Winterbourne A**	21	No Gammaridae but abundant Ephemerllidae and Perlodidae
10	**Winterbourne B**	17	No Gammaridae, but abundant Nemouridae and Simuliidae
11	**Winterbourne C**	15	Similar to Winterbourne B but fewer families
12	**Transitional B**	15	Abundant Gammaridae but few families
13	**Intermittent**	13	Few families and community dominated by Gastropods and Simuliidae
14			
15			
16			

Multivariate analysis identified the environmental parameter that influenced the communities most. The output from this analysis is displayed graphically on Figure 5.8. This shows that the number of months dry in the receding 12 month and distance from the perennial head have a greater influence in the macroinvertebrate community than any other variables.

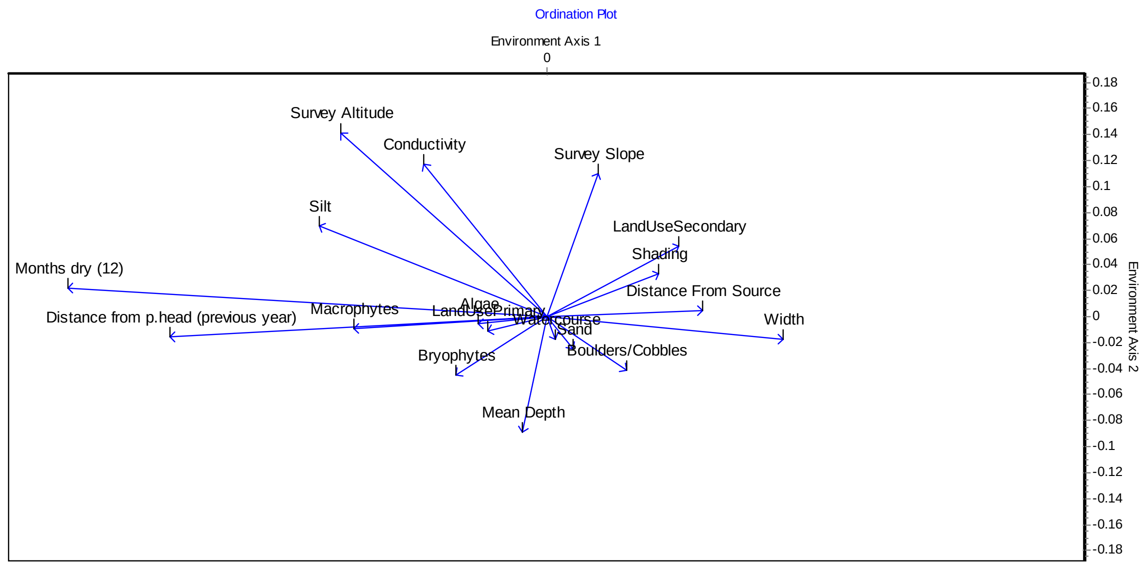


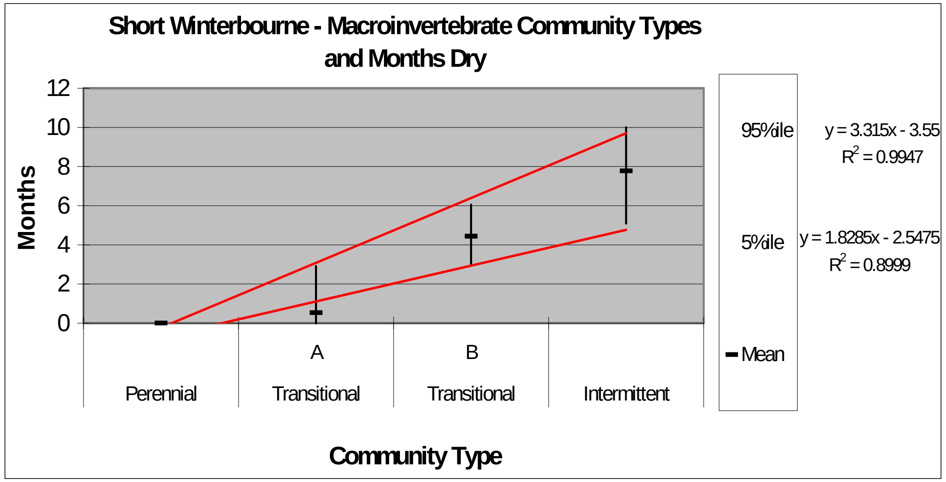
Figure 5.8: Macroinvertebrate Correspondence Analysis Ordination Plot

Table 5.5 shows two transitional communities (A & B), analysis has revealed that these relate to whether the winterbourne is short or long. This has resulted in the need for two 'macroinvertebrate predictors' one for short winterbournes e.g. Bourne & Fonthill and one for long winterbournes e.g. Chitterne.

The equations for the long and short macroinvertebrate predictors, and the graphical output from each model is shown on Figure 5.9 and Figure 5.10.

The 'predictors' show the range of flow duration over which any community type can occur but also demonstrate that more than one community type can occur at most flow durations. If a site on a long winterbourne, such as the River Till, dried for less than 1 month in the previous year, the community type recorded in the following spring could be 'Perennial' or 'Transitional A'. If the site dried for 5 months it could be 'Winterbourne A', 'Winterbourne B', 'Winterbourne C', or Intermittent.

There appears to be a degree of 'site affinity' of any particular community i.e. if it was a 'Winterbourne A' in the previous year, and the flow duration experienced was within the range over which this community type occurs, then it is very likely this community will occur again. This can be seen on the Chitterne Brook at sites WB1 and WB2 which recorded 'Winterbourne A' communities at the end of a period of wet years in 2002 and 2003 but continued recording this community type after the drier years of 2004 and 2005 before changing to a drier community type of Winterbourne B. Although number of months dry in the previous 12 months explains more of the variation than any other factor there are also longer term influences and a degree of resistance to change.



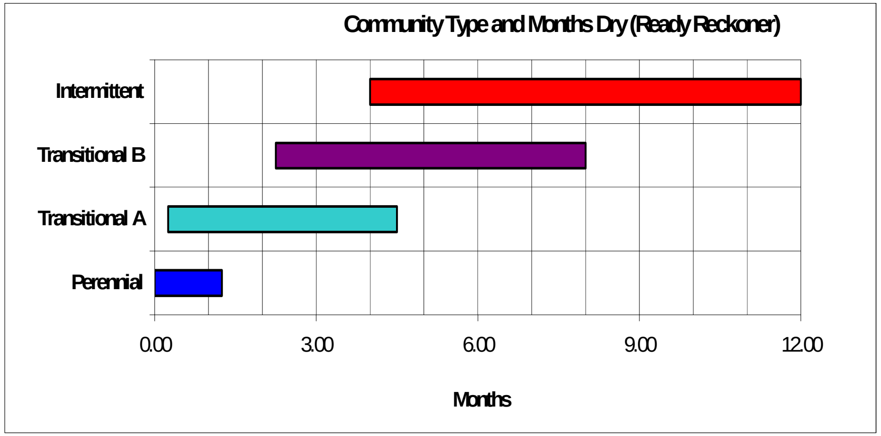
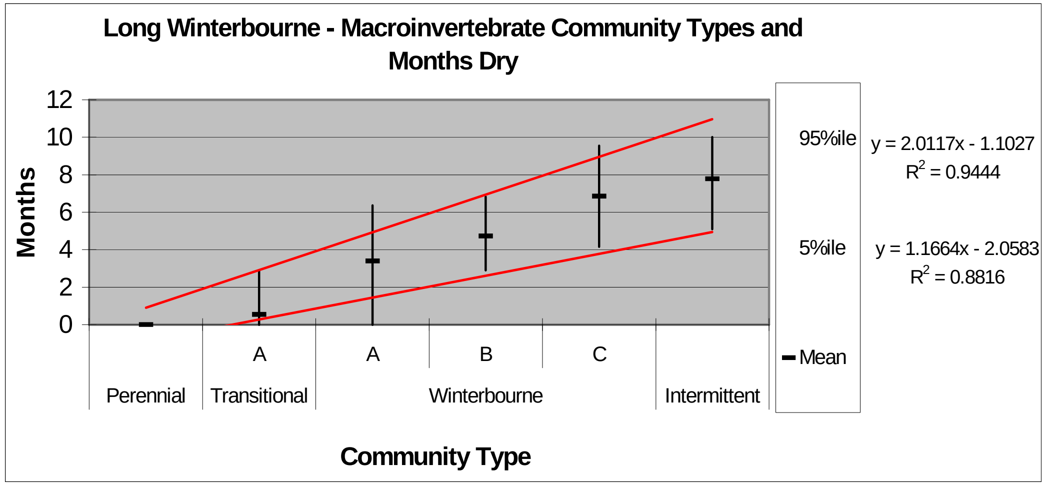


Figure 5.9: Macroinvertebrate Short Winterbourne Predictor



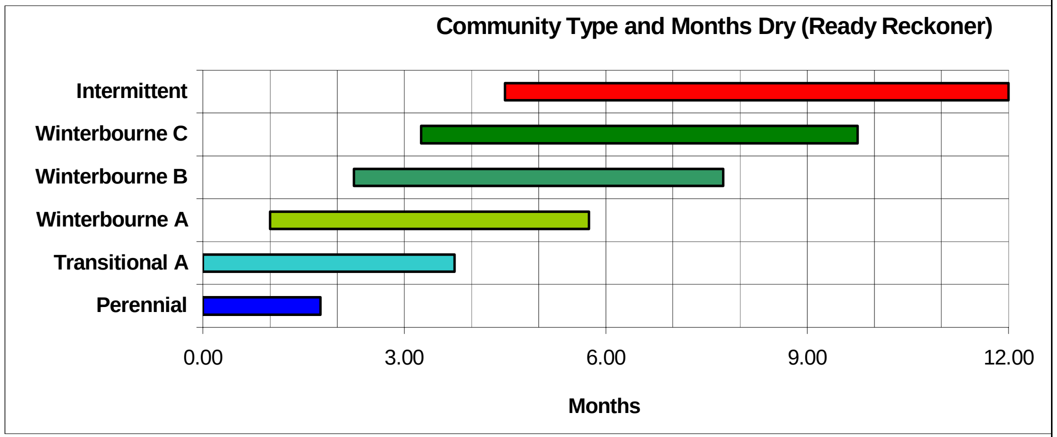


Figure 5.10: Macroinvertebrate Long Winterbourne Predictor

Conservation value of winterbourne sites

The Community Conservation Index (CCI) (Chadd & Entence, 2004) has been used to assess how the conservation value of the macroinvertebrate community varies along a winterbourne. The CCI protocol accounts for macroinvertebrate community richness as well as the relative rarity of the species present. CCI values have been calculated for 123 of 170 samples, as these were analysed to species level.

The typical range of CCI values for each community type are shown in Table 5.6, along with a description of the conservation interest.

Table 5.6: Community Type and CCI

Community Type	Number of Familes*	Community Conservation Index	Macroinvertebrate conservation interest
Perennial	36	13.8	Few rare species, but fairly high taxon richness
Transitional A	25	9.3	Few rare species low taxon richness
Transitional B	15	9.6	Few rare species low taxon richness
Winterbourne A	21	22.2	Rare species such as *P. werneri* but lower taxon richness than transitional A
Winterbourne B	17	29.2	Rare species such as *P. werneri* but lower taxon richness than above
Winterbourne C	15	28.7	Rare hypoheric species such as *Niphargus sp* and *A. biguttatus* but lower taxon richness than above
Intermittent	13	18.7	Low taxon richness but rare *Simulium sp*. And some hypoheric species found

* *a scale of taxon richness*

In general moving upstream toward drier conditions there are fewer families recorded and the CCI score peaks in the wintebourne section. A model for the change of conservation interest of the macroinvertebrates community along a 'long' winterbourne is shown in Figure 5.11.

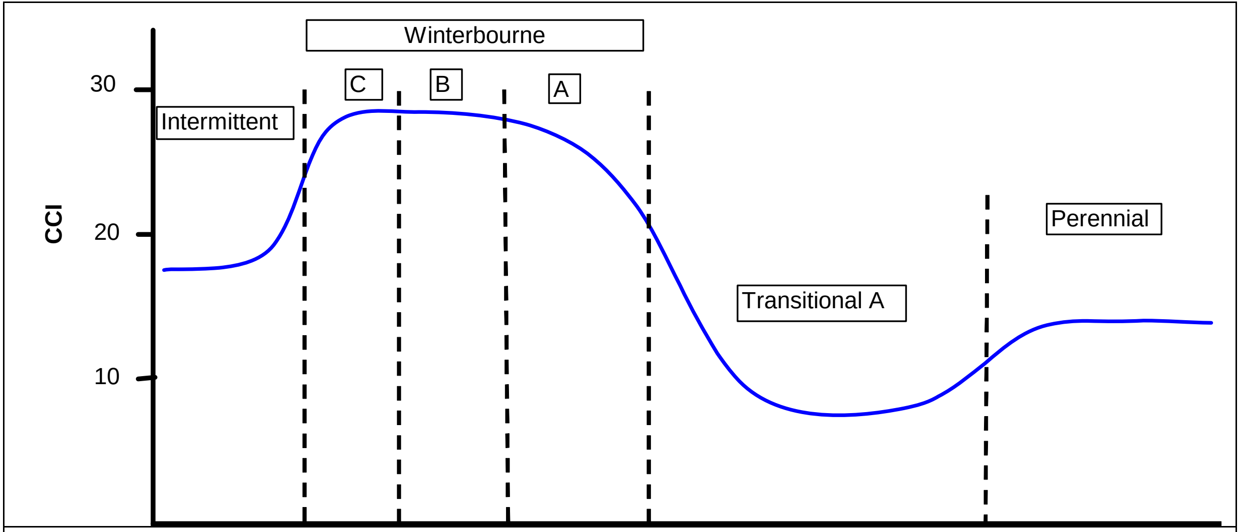


Figure 5.11: Typical change in Community Conservation Index in chalk headwater streams

It should be noted that these community types and conservation interests are not fixed at a site and will move depending on how wet the previous year or years have been. Orcheston (sample site WB7) on the River Till for example received flow in the winter of 2002/03 and the winterbourne specialists *P.werneri* and *N.cinerea* were recorded in samples collected in spring 2003. In spring 2007 after Orcheston had received flow for the first time in three years, neither species were present, possible because the egg dispause (suspended animation) lasts for months rather than years and they are unable to survive an extended dry period at this site.

5.6.3 Fish

There are two main mechanisms by which abstraction could affect the use of winterbournes by brown trout populations.

- Delayed recovery of winter flow restricting the upstream spawning migration of mature brown trout
- Increase in rate of flow recession (drying) making the winterbourne dry too early for the downstream migration of juvenile and adults in the summer

These two mechanisms increase the dry period resulting in a site not flowing for long enough for fry to hatch and develop to a sufficient size to migrate downstream.

The approach taken to assess abstraction impact has been to determine whether a site receives a minimum period of 180 days flow within a November to June (inclusive) window. This has been judged to be the minimum period of time for trout to spawn, eggs to hatch and fry to grow large enough to migrate downstream as flow recedes. In this analysis a site has been defined as ‘flowing’ when the flow is greater than 1 ML/d.

5.7 ABSTRACTION IMPACTS – ECOLOGICAL

5.7.1 Introduction

Using the Predictor

The models have been used to predict the macrophytes community along each winterbourne under Natural and Full Licence conditions. To explore the natural variation in type and location of communities, predictions for 2003 and 2006 have been examined. 2003 follows several 'wet' winters, whereas the winters preceding the summer of 2006 were 'dry'. Results from the River Bourne and Chitterne Brook are presented in this section, with the findings for each winterbourne summarised.

5.7.2 Macophytes

Community Type and EAS predictors

The predicted macrophyte community along the Bourne and Chitterne in 2003 and 2006 under natural and full licence conditions are displayed on Figure 5.12 (Section 9) and 5.13 (Section 9) respectively.

The EAS predictor for the Bourne and Chitterne Brook under natural and full licence conditions in 2003 and 2006 are shown on Figure 5.14 and 5.15 respectively.

River Bourne

In 2003 following a relatively 'wet' period (relatively good winter recharge in previous years) a 'Perennial' community type is most likely between Porton and Idmiston. The section between Allington and Boscombe is likely to have a 'Winterbourne' community.

The section around Cholderton is likely to have an 'Intermittent' community. US Snoddington Bridge and Leckford Bridge may have a 'Winterbourne' community although an 'Intermittent' is most likely. Sunton is likely to have a 'Winterbourne' community.

These conditions exist under both Natural and Full Licence conditions although under Full Licence there appears to be some abstraction pressure around Allington that could make an 'Intermittent' community more likely.

In 2006 following a dry period (relatively poor winter recharge in previous years) a 'Winterbourne' community is more likely between Porton and Idmiston, especially under Full Licence conditions, which may cause the section between Idmiston and Boscombe to be 'Intermittent' when it would have been 'Winterbourne'.

An 'Intermittent' community is likely to occur in the section between Boscombe and Allington under Natural and Full Licence conditions and throughout most of the upper Bourne, including Cholderton, Snoddington and Leckford Bridge and is even more likely at Sunton compared to 2003.

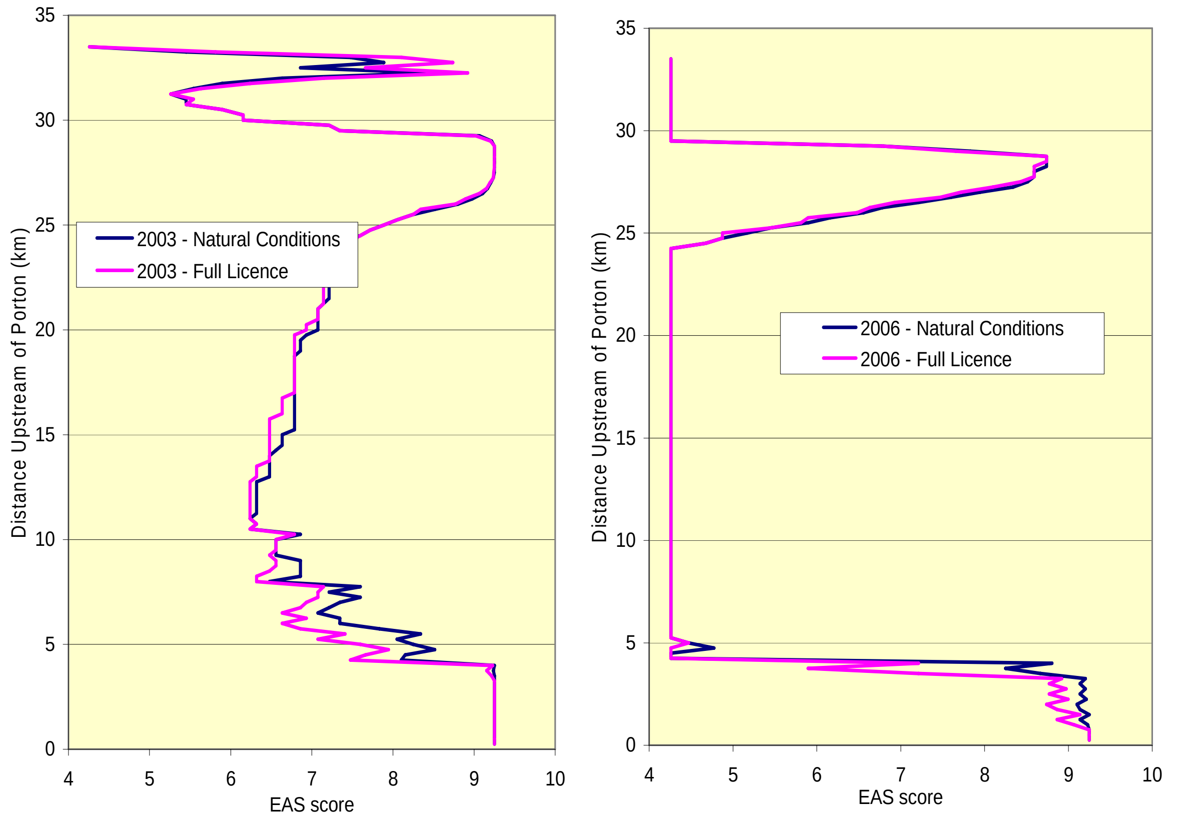


Figure 5.14 : EAS Model predictions for the River Bourne 2003 and 2006

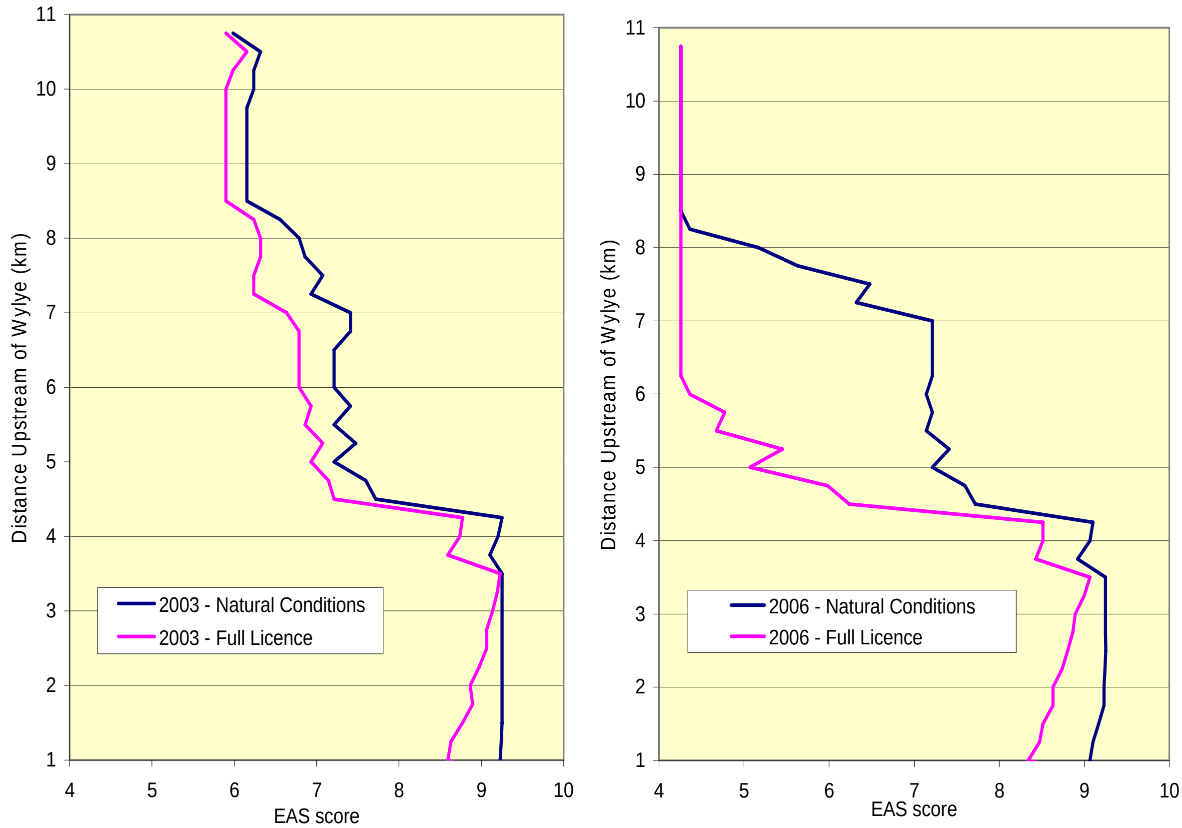


Figure 5.15 : EAS Model predictions for the Chitterne Brook in 2003 and 2006

In both years the EAS ('wetness' index) is very similar under Natural and Full Licence conditions. In 2003 the EAS is slightly lower, in particular, in the section 5-10km upstream of Porton such as at Allington. In 2006 it is lower in the section 1-4km upstream of Porton, including Idmiston.

Summary

The macrophyte community of the Bourne winterbourne appears to be largely determined by its position along the winterbourne and climate. Impact of Full Licence abstraction on the macrophyte community of the Bourne winterbourne is predicted as slight and occurring further downstream during dry periods. The classic 'Winterbourne' community that can exist between Porton and Allington occurs further downstream during dry periods. There may be a small zone where greater impact is predicted to occur at Full Licence in a dry period i.e the section just downstream of Boscombe in 2006 but this is for less than 1km with 'Winterbourne' community type occurring below this albeit slightly further downstream than would have occurred without Full Licence abstraction.

Chitterne Brook

In 2003 and 2006, under Natural conditions, the lower Chitterne winterbourne (from downstream of the Withy Beds) is most likely to have a 'Perennial' community. Under Full Licence conditions, a 'Winterbourne' community is more likely to occur in this section which is likely to make conditions (i.e. some drying) more suitable for *Ranunculus peltatus* to thrive. However, abstraction pressures would be such that an 'Intermittent 5' community type could even be possible, especially in 2006 after a dry period. As such, conditions are predicted to be unsuitable for *Ranunculus* during dry periods as a consequence of Full Licence abstraction.

An 'Intermittent' Community is most likely to occur in the upper Chitterne winterbourne (e.g Kings Head) under Natural and Full Licence conditions in 2003 and 2006. However, there is greater potential for a 'Winterbourne' community to occur under Natural conditions. Under Full Licence abstraction in 2006 an 'Intermittent 5' community type is less likely for a section of around 2.5km including King's Head. The 'Intermittent 5' community type may contain some aquatic herbs and is 'wetter' than the other 'Intermittent' types. The EAS ('wetness' index) reveals the impact that is occurring and how this is greater during dry periods for around 4km of the upper Chitterne Brook.

Summary

The macrophyte community of the Chitterne Brook appears to be determined by it's position along the winterbourne, abstraction and to a lesser degree climate.

Impact of Full Licence abstraction on the macrophyte community of the Chitterne Brook can be large during dry periods. The lower Chitterne Brook is generally predicted as 'Winterbourne' under Full Licence abstraction and more likely to be 'Perennial' under Natural conditions after both wet and dry periods. The upper Chitterne Brook is generally predicted to be 'Intermittent' under Natural and Full Licence although the community composition reflects drier conditions under Full Licence abstraction.

Fonthill
In 2003 and 2006 under Full Licence and Natural conditions a 'Winterbourne' community is likely to occur for the lower winterbourne (1.5km upstream of the Lake including around Berwick) the lowermost 0.5km may have a 'Perennial' community. The upper 1.5-2km is likely to be 'Intermittent'. The section in between, including Hindon, is likely to be 'Winterbourne' although dries for longer than the section below so is less likely to support *Ranunculus*. Very slight impacts are predicted as shown by the slightly lower EAS although this is unlikely to result in a community type change in either year.

Heytesbury Brook
In 2003 and 2006 under Natural conditions a 'Winterbourne' macrophyte community is predicted to be likely for around 3km from the Heytesbury PWS downstream to the confluence with the Wylye. The model may be over predicting flow but if not then conditions may be suitable for *Ranunculus peltatus*. However, the Heytesbury Brook is likely to naturally be 'unreliable' so *Ranunculus peltatus* would not be expected to thrive under natural conditions. The 'Winterbourne' community is unlikely to persist under conditions predicted at Full Licence abstraction and an 'Intermittent' community type is likely to occur. As such, abstraction is likely to be having a relatively large impact. This is well illustrated by the relatively large discrepancies between the Natural and Full Licence EAS, particularly in 2006. Please note these conclusions need to be treated with caution as the HAM is not calibrated for this stream.

Nine Mile River
In 2003 under Full Licence and Natural conditions the lower 2.5km of the Nine Mile River is likely to have a 'Perennial' community, the next 2-3km likely to have a 'Winterbourne' community with the upper 3.5km 'Intermittent'. Slightly lower EAS are predicted at Full Licence revealing slight impact but no change in community type is expected.

After the dry period 2004-2006 the macrophyte communities predicted under Natural conditions in 2006 have shifted downstream when compared to 2003. The upper 5.5km is all predicted to be 'Intermittent'. The lower 2.5km is now likely to be 'Winterbourne' with perhaps the lower 0.5km 'Perennial'. This is very similar at Full Licence although conditions are again slightly drier, particularly at the lower end as shown by the EAS.

Wylye
In 2003 no impact is predicted on the upper Wylye – the same community types and EAS are predicted. In 2006 after a dry period a very slight impact is predicted for around 3km upstream of Kingston Deverill SS. Full Licence EAS is slightly lower than Natural EAS reflecting slightly drier conditions but this is unlikely to cause a change in community type.

Summary
The macrophyte community of all winterbournes is dictated primarily by the position that it occurs along the winterbourne. The macrophyte community of the Chitterne Brook is determined less by winter recharge (naturally 'reliable') than the Bourne and NMR winterbournes (naturally 'unreliable'). Along the Chitterne Brook, under Full Licence conditions, a community change is predicted at the Withy Bed/Manor farm, with a winterbourne community replaced by an intermittent community, though the winterbourne community is predicted to be located further downstream.

The impact on the Bourne and Nine Mile River winterbournes (from Wessex Water abstractions) is predicted to be slight, with only small spatial shifts in community. The Wylye and Fonthill winterbournes, are naturally 'reliable' but neither are predicted to be impacted by abstraction.

The predicted impact on the macrophyte community under Full Licence conditions for each winterbourne is summarised in Table 5.7

Table 5.7: Summary of abstraction impact on Winterbourne macrophytes

Winterbourne	Type	**Full Licence Impact**	Reliable*	Made unreliable	*Ranunculus* able to persist
Bourne	Long	Small	No	No	Yes
Chitterne	Long	Large	Yes	No	Yes***
Fonthill	Short	Small	Yes	No	Yes
Heytesbury	Short	Large	No	No?	Uncertain
NMR	Long/short**	Small	No	No	Yes
Wylye	Short	Small	Yes	No	N/A

* Flows every year under Natural conditions
**short following dry winters
***edge of range in dry periods

5.7.3 Macroinvertebrates

Using the Predictor
A similar approach to that undertaken for macrophytes has been applied for macroinvertebrates. The models have been used to predict the macroinvertebrate community along each winterbourne under natural and full licence conditions. The years of 2003 and 2006, due to their contrasting antecedent climate conditions, are used to explore climatic and abstraction influences. Results from the Bourne and Chitterne Brook are presented in this section, with the findings for each winterbourne summarised in Table 5.8.

Community Type
The predicted macrophyte community along the Bourne and Chitterne in 2003 and 2006 under natural and full licence conditions are displayed on Figure 5.16 and 5.17 respectively (both in Section 9).

River Bourne
In 2003 the Natural and Full Licence scenarios are very similar with a short 'Perennial/Transitional' community section at Collingbourne Kingston. Downstream to Allington would be 'Intermittent' as it is an unreliable reach (stays dry in some winters). Idmiston to Allington could be 'Transitional' as they are close enough to perennial flow for taxa such as *Gammarus* to colonise. In 2006 under Natural conditions there is insufficient flow in most of the winterbourne to support any community. In both 2006 abstraction scenarios the wetter reach at Collingbourne Kingston has enough flow for a 'Transitional/Intermittent' community but the rest of the winterbourne remains dry as far as Allington. The Full Licence scenario makes the Allington to Idmiston reach a drier 'Transitional' B community but no high conservation value 'Winterbourne' community is likely in either scenario.

Chitterne Brook
In the 2003 Natural scenario the conditions suiting a 'Winterbourne' community are all above the springs arising from the Withy Beds. Strong flow from the springs at the Withy Beds has made the reach downstream transitional/perennial. At Full Licence this reach has been made drier and conditions are suitable for the 'Winterbourne' community to exist both up and downstream of the Withy Beds. In fact the 2003 Full Licence scenario is very similar to that of 2006 Natural apart from the longer 'Intermittent' reach stretching above 10 km in 2003. In the 2006 Full Licence scenario the 'Winterbourne' community is almost entirely downstream of the Withy Beds' and the 'Intermittent' community above has become shorter.

Community Conservation Index
An estimate of the CCI score along the Bourne and Chitterne Brook under natural and full licence conditions in 2003 and 2006 are shown on Figure 5.16 and 5.17 (both in Section 9). The high CCI scoring 'Winterbourne' community on the Chitterne Brook is further downstream in the drier conditions of 2006 than in 2003. In both years Full Licence abstraction moves the high CCI score downstream but does not reduce it.

Abstraction has no discernible impact on the CCI score of the Bourne.

Summary
The impact on the macroinvertebrate community under full licence conditions for each winterbourne is summarised in Table 5.8

Table 5.8: Summary of abstraction impact on Winterbourne macroinverrtebrates

Winterbourne	Full licence impact on winterbourne macroinvertebrates
Bourne	Only impact on Transitional zone between Idmiston and Allington in dry years.
Chitterne Brook	A downstream shift of the 'Winterbourne' community but little loss of conservation value.
Fonthill	Slightly drier community type predicted over 250m reach.
Heytesbury	This is a naturally unreliable winterbourne but may support a 'Transitional' community near the Wylye confluence under Natural conditions
Nine Mile River	Drier community types predicted over 1.5 km upstream of Bulford. No loss of 'Winterbourne' community predicted.
Wylye	This is a naturally unreliable winterbourne but may support a 'Transitional' rather than an 'Intermittent' community near the stream support under Natural conditions

5.7.4 Fish

Trout
The winterbourne reach that can naturally be used by trout has been defined by assessing where along each winterbourne flow (>1 Ml/d) occurs for 180 days on average (1970 to 2003/6) between November and June. An example of the output from this analysis is shown on Figure 5.18 for the Bourne. Figure 5.18 shows that the reach between Porton and Allington has favourable flow conditions for trout spawning and rearing. Figure 5.18 also shows the average number of days with flow between November and June under full licence

conditions. Under full licence condition the number of days of favourable flow is reduced by 20 compared to natural.

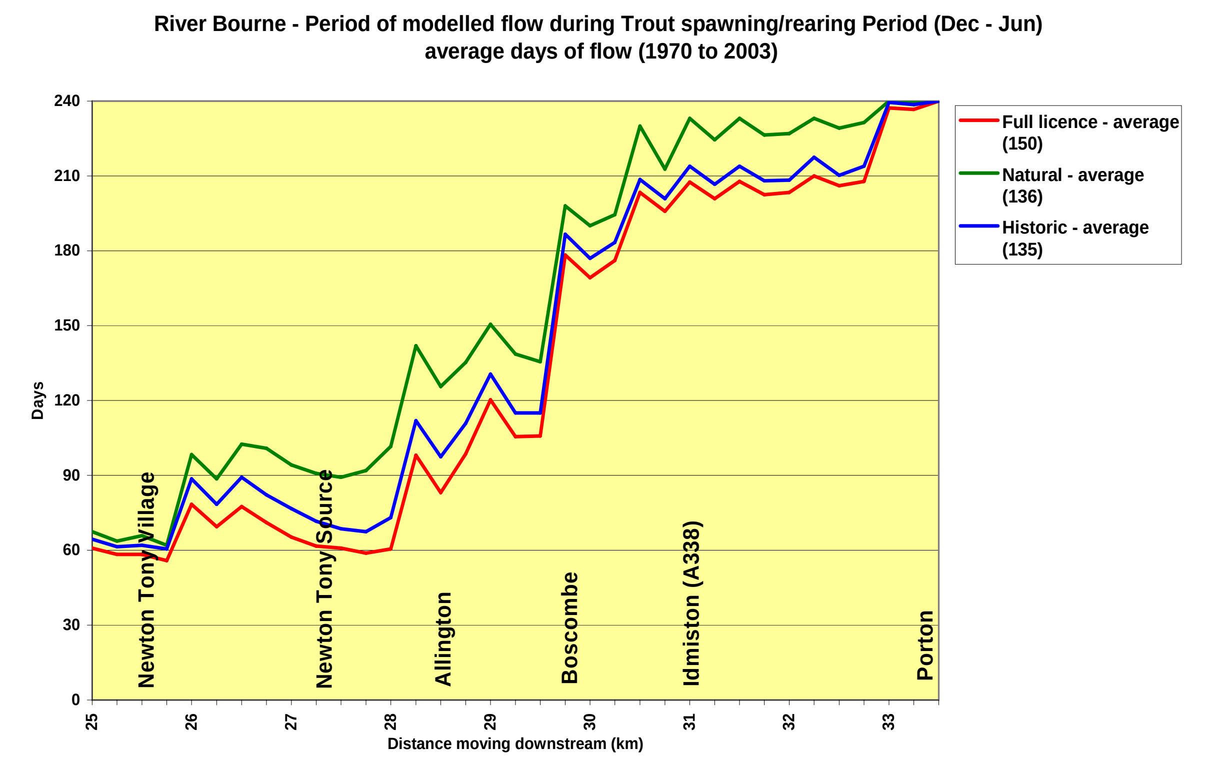


Figure 5.18: River Bourne – Reach suitable for trout under natural and full licence conditions

An average can be masking a wide range of impacts on a year by year basis, so the annual impacts has been assessed. A site in the favourable reach has been examined and results shown in Figure 5.19 for the River Bourne at Idmiston (A338). The days of additional drying (flow <1 ML/d) range from 0 to 170 days, though typically this site remains suitable for trout under full licence conditions.

The number of suitable years, between 1971 and 2006 for trout spawning/rearing under natural and full licence conditions for each winterbourne is presented in Table 5.9, as an absolute number and as a percentage.

Table 5.9: Predicted Frequency of adequate Trout Rearing

Winterbourne	Location	Number of year*		Percentage of Year	
		Natural	Full licence	Natural	Full Licence
Bourne	Idmiston	35	30	97	83
Chitterne Brook	Withy Beds	34	21	94	58
Fonthill	B3089	33	31	92	86
Heytesbury	A36	10	2	28	5
Nine Mile	Bulford Leas	32	29	89	81
Wylye	Kingston	35	36	97	100**

** maximum number of years is 36*
*** stream support now makes this site perennial*

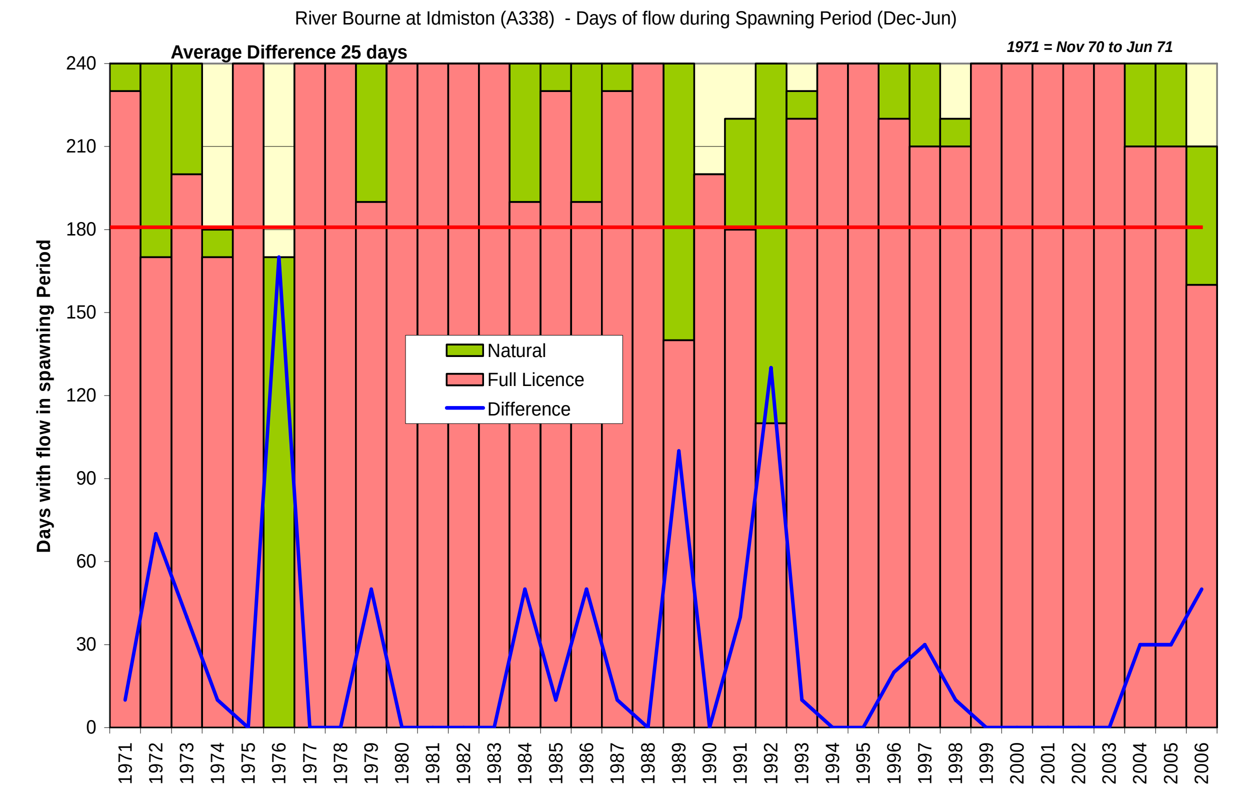


Figure 5.19: River Bourne at Idmiston: Days of flow during Trout Spawning Period under natural and full licence conditions

The biggest impacts can be seen on the Chitterne Brook and Heytesbury Brook. The Withy Beds area of the Chitterne Brook has been changed from a reliable to an unreliable spawning habitat. The Heytesbury Brook provides unreliable spawning habitat under Natural conditions and so abstraction would cause little impact on trout reproduction. While abstraction can reduce the availability of some winterbourne sites in a dry winter it does not prevent trout from spawning downstream in the perennial headwater where suitable flow conditions and spawning gravels exist. In the case of Chitterne Brook the stream support provides suitable habitat in 1.2 km of the brook even in years of very late or very low recharge. Therefore, the reductions listed in Table 5.9 are not considered to threaten the integrity of the trout population

SAC species

The SAC interests are salmon, bullhead and lamprey. Winterbournes do not provide a habitat suitable for lamprey under natural conditions, as perennial flow for up to six years is required. Winterbourne provide a marginal habitat for both salmon and bullhead.

Salmon very rarely venture into the perennial headwaters to spawn and so the impact of abstraction in the winterbourne area would only constitute a very minor impact on the population and their overall habitat requirement.

Bullhead will colonise the transitional zone following a period of several wet years and will then become vulnerable when a dry summer results in this reach becoming dry. This could clearly be seen on the River Till, where abundant bullhead were found at Winterbourne Stoke in 2003 following several 'wet' years but were lost when the Till dried to Bewick St James later that year. Bullhead were not found at Winterbourne Stoke in 2004-6, but in 2007 high densities were found. The wet 2006/07 winter and the a series of not exceptionally dry summers (2005 & 2006) had allowed the bullhead to gradually recolonise back upstream. The loss of bullhead from a drying transitional zone is a result of natural variations but the location of the zone will be further downstream due to abstraction.

5.8 SUMMARY

The winterbourne communities have adapted to survive in conditions that change each year due to variations in rainfall. Abstraction increases the dry period but not to the same extent as climate variation. Abstraction will be most significant in dry years when it may cause drying to occur outside the range experienced naturally. This would be potentially serious if it resulted in changing a reliable winterbourne, with high conservation value to an unreliable winterbourne. Modelling has shown that under full licence conditions all reliable winterbournes remain as such.

The main impact of abstraction is to move the 'intermittent-winterbourne-transitional' communities reaches downstream. Where the perennial head of the river is fixed e.g. Bourne, this results in a reduction in the length of the 'transitional' community. Where the spring head is not fixed, the downward movement of community can result in a loss of 'perennial' community, e.g. Fonthill Brook.

5.8.1 Macrophytes

Abstraction causes a slight change in community composition and in certain years could cause a change in general type, such as from 'Winterbourne' to 'Intermittent'. However, changes are reversible with recovery usually within one or two years following a wet period. A major driver on community type is winter recharge.

Impact on SAC interest - Ranunculus

Based on the findings from other catchments, the impact of abstraction on the River Till will be to move the communities downstream. HAM model output (subject to refinement) indicates under full licence conditions that the Till will remain a reliable winterbourne and conditions suitable for *Ranunculus peltatus* will exist, though slightly further downstream. It is noted that the PWS source that exerts the greatest influence on the River Till is Chitterne. Wessex Water is committed to reducing the abstraction from this source, lower output is currently being trialled. Therefore, the current full licence impact will never be experienced on the River Till.

5.8.2 Macroinvertebrates

The winterbournes of the Avon contain a diverse range of taxa specially adapted to varying climatic conditions. The community has been shown to respond to increased drying by a downstream shift followed by a gradual recovery when wetter conditions return. As long as a reliable winterbourne remains then there is little loss of macroinvertebrate conservation value. Modelling has shown that under full licence conditions all reliable winterbournes remain as such.

5.8.3 Fish

Trout

Abstraction can render certain years as unsuitable for trout spawning/rearing along winterbournes. The most noticeable impact occurs on the Chitterne Brook under full licence. However, these impact will never be realised because Wessex Water has reduced the level of abstraction from Chitterne PWS which is responsible for these impacts. In addition stream support has been provided as mitigation for any residual impact. In many rivers the winterbournes provide only part of the river habitat suitable for trout spawning and suitable flow conditions and spawning gravels exist downstream where permanent flow occurs.

SAC Species

The SAC interests are salmon, bullhead and lamprey. Winterbournes do not provide a habitat suitable for lamprey under natural conditions, as perennial flow for up to six years is required. Winterbournes provide a marginal habitat for both salmon and bullhead.

Salmon very rarely venture into the perennial headwaters to spawn and so the impact of abstraction in the winterbourne area would only constitute a very minor impact on their population and their overall habitat requirement.

6 Other Factors

6.1 INTRODUCTION

In this section a secondary influence of abstraction on river temperature is considered. In addition factors that control river water depth and hence the appearance of the river are examined, with attention given to the relative merits of river restoration and increasing river flow (by reducing abstraction) in obtaining favourable conditions for the designated species.

6.2 ABSTRACTION INFLUENCE – RIVER TEMPERATURE

In recent years the river water temperature has been identified as a possible factor in the reported decline in salmon numbers in the River Avon and may limit their recovery. Research has identified that adult salmon movement was limited on the Avon at 21^{o}C and above, with egg survival reduced at 22^{o}C compared to those at 14 and 18^{o}C. The temperature of the Avon, at the mouth of the river, has reached 24^{o}C in 2005.

Ranunculus growth is restricted above a water temperature of 17^{o}C (Dawson H et al).

Solomon et al (2005) identified that 80% of the river temperature was dictated by air temperature, but the report queried the effect of groundwater abstraction (export) and sewage treatment works on the overall temperature at the mouth of the river.

The good summer flow in chalk streams is a notable feature compared to flow in hard rock catchments. This summer flow (baseflow) is derived from groundwater which has a temperature of ~11^{o}C. Consequently, it has been a widely held view that this cool groundwater will keep the river temperature 'cool'. As noted above, and shown on Figure 6.1, this is not the case, with temperatures exceeding 20^{o}C. The data shown on Figure 6.1 is from lower reaches of tributaries or the main Avon stem. The rate of heating (cooling) in the headwater was not known, so during the 2007 summer monitoring points along the Wylye, Chitterne Brook and Till were established, locations shown on Figure 6.2 (Section 9).

The data from the Chitterne Brook is particularly pertinent. During the summer the flow in the Chitterne Brook is maintained by a stream support discharge of 3 ML/d. This water is not lost to ground and no water enters, so the monitoring of temperature downstream allows an assessment of how the water temperature changes due to climate.

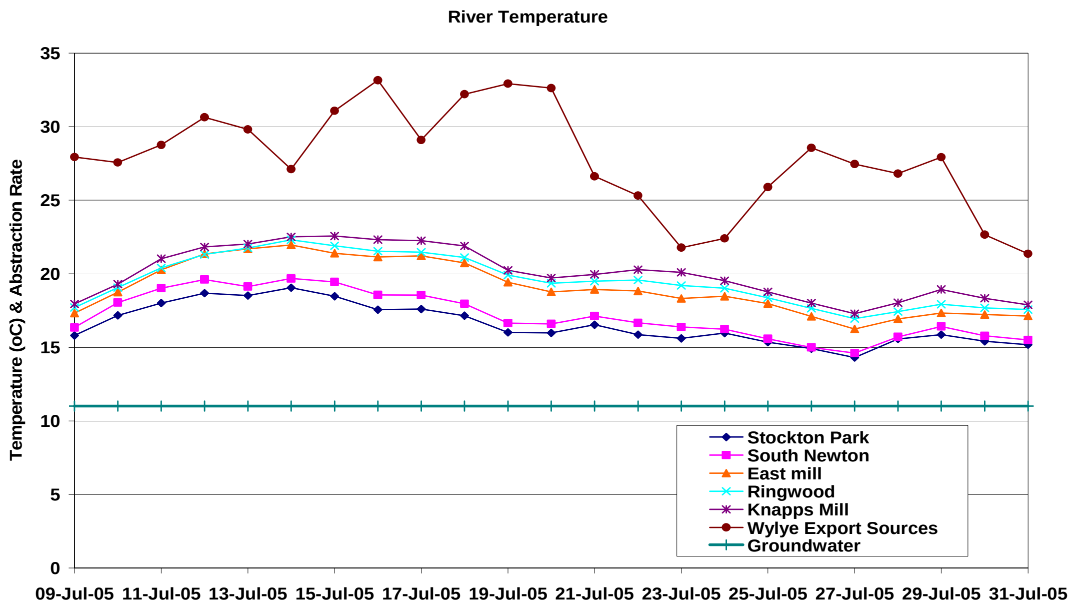


Figure 6.1: River Avon Water Temperature and Abstraction in July 2005

Five monitoring points were established, one at the outfall, then at 115m, 250m, 320 and 410m downstream. The monitoring data from August and November is shown on Figure 6.3. During August a temperature increase of 4.3^{o}C occur over 410m and in winter the converse occurs with water temperature cooling by ~2^{o}C.

The head water temperature are subject to rapid temperature change in response to the prevailing climate, with temperature rising further as the water moves downstream with the extra residence time. The reduction of 'cool' water entering the river will increase the speed of temperature change, however, this is considered to be insignificant compared to the role of climate.

The return of abstracted water through treated effluent does not appear to add further temperature gain as was anticipated because sewage works generally rely on air contact or aeration for oxidation treatment processes and thus there is a good relationship with air temperatures. Monitoring in 2007 upstream and downstream of Warminster STW showed no temperature change, although it is acknowledged that this may not hold for all treatment types and sewer catchment types.

In conclusion, groundwater abstraction does reduce water temperature but the main and potentially harmful effects of changing temperature on salmon are driven by increasing air temperature both in the nursery areas and the main river. The effects of abstraction on river water temperature are unlikely to be detected against the variation caused by shade and impoundment.

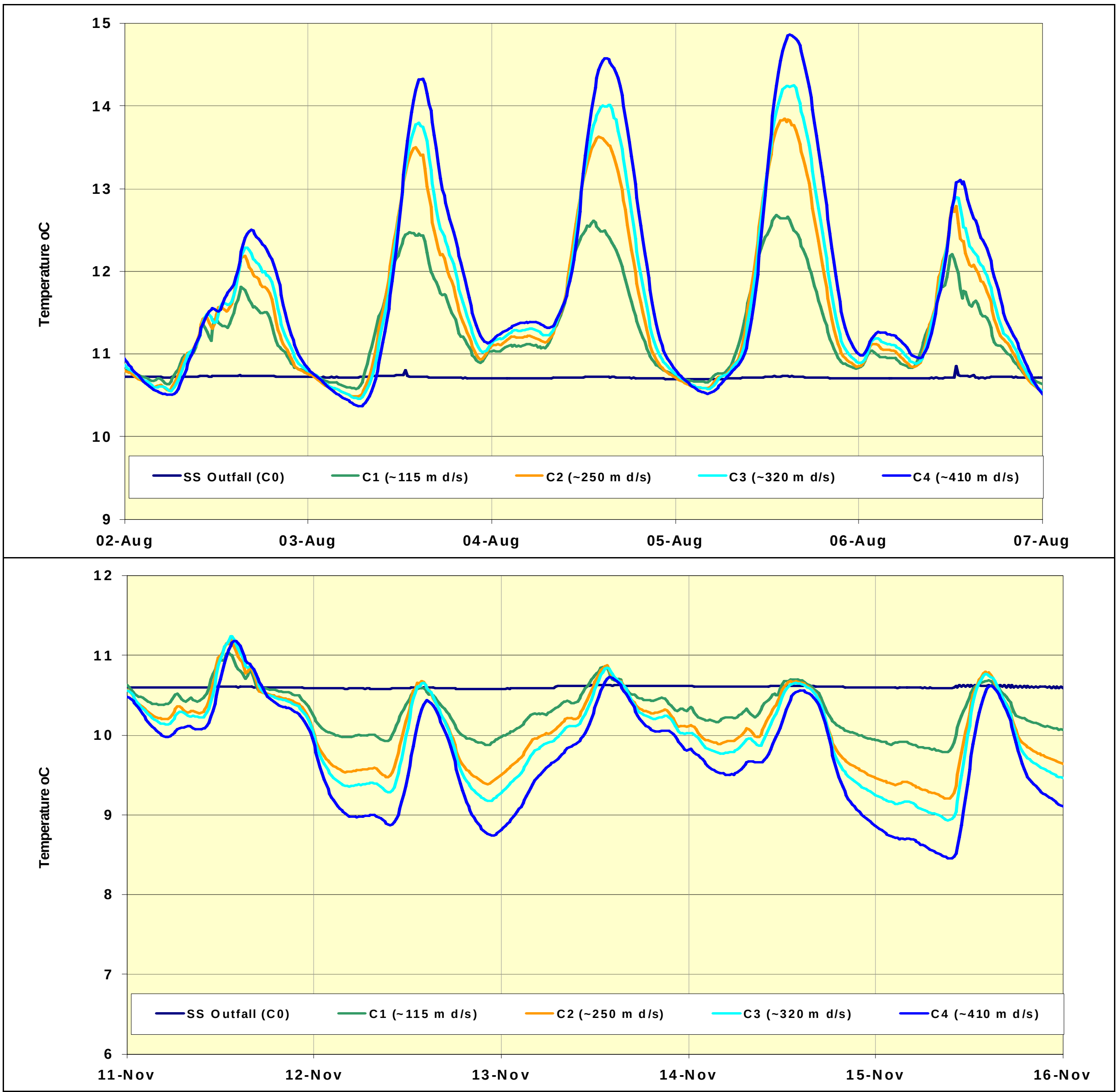


Figure 6.3: Chitterne Brook Temperature changes downstream of Support input

6.3 OTHER FACTORS – RIVER FLOW AND STAGE (WATER DEPTH)

The in-channel macrophytes in chalk streams acts as 'bioengineers' helping to maintain the 'high' water level even during the summer/autumn months, a key feature of chalk rivers. The floating macrophytes, e.g. *Ranunculus*, are responsible for this, their submerged and floating stems, act as partial dams, restricting the water flow and hence 'holding' the water level up.

Within this mass of vegetation a myriad of flow velocities exist, from practically still water to high velocities between the floating strands of vegetation. Numerous niches therefore exist within this flow velocity matrix, providing habitats for a diverse range of macro-invertebrates. The macrophytes and macroinvertebrates in this river channel provide habitat, shelter and food for higher species, principally fish e.g. trout and salmon.

The macrophytes are also a food source for swans and other bird species. Swans have no natural predators in this country and are legally protected, consequently, a large number (over 100 on the River Wylye) use the river as a food source.

The mass of macrophytes is colloquially referred to as weed. The weed can 'choke' the river channel restricting fishing, consequently authorised cutting of the weed is undertaken. Such cutting can result in the water level dropping by 1 to 2 feet. The practice and need for cutting is a contested one and not all sections of the river are subject to cutting. In addition, unauthorised cutting takes place. Weed is considered to promote flooding and so riparian owners remove the weed, this is a practice the EA undertake on the Lower Avon.

During the autumn months, when *Ranunculus* naturally dies back, other species, principally water cress, grow in the river channel from the river edge. With naturally low flow typically present in the early autumn, the incursion of the watercress reduces the river width, helping to maintain depth and velocity.

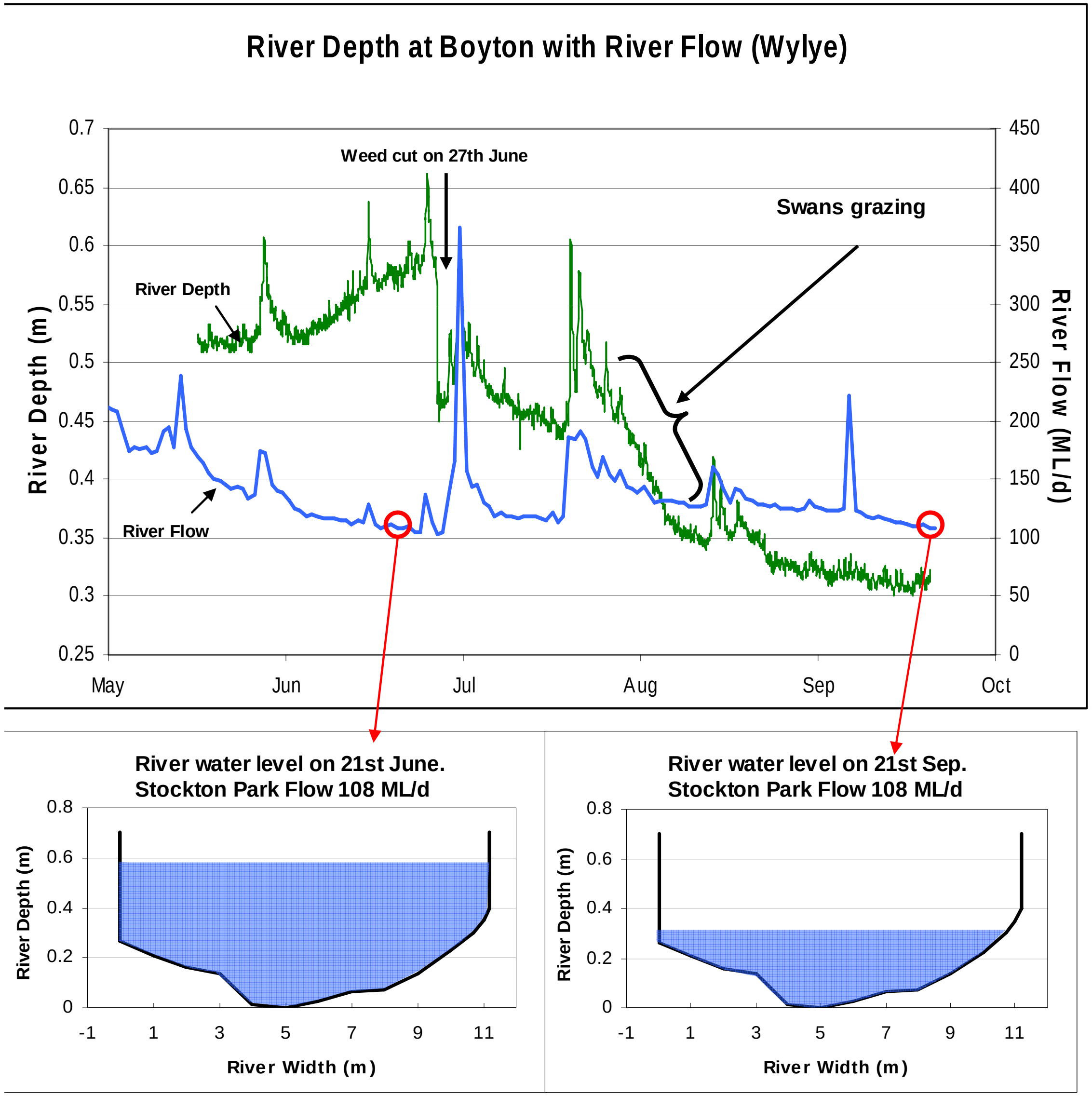
The 'bio-engineering' of in-channel macrophytes greatly influence the visual appearance of the chalk stream. Therefore, the absence of key macrophytes or a loss of macrophytes following initial good growth can lead to a chalk stream looking 'unhealthy'. Without the presence of macrophytes the resulting water depth can look 'low' even if not reduced by abstraction. During this study a small scale investigation exploring the influence of flow and macrophytes on water depth (stage) was undertaken. The primary purpose of this work was to inform the debate on what controls the river appearance.

The work involved the installation of river water level monitoring probes at 8 locations: five along the Wylye and three along the Avon. The locations are shown on Figure 6.2 (Section 9). The cross-section of the stream at each location was also surveyed, to allow the area of flow to be determined. Flow measurements were obtained from the nearest continuous Environment Agency gauging station. The locations were selected for those that:

- Typically have no weed
- Are affected by swans
- Have been reported to suffer low depths.

The resultant stage-flow relationships are contained in Appendix on the CD

The influence of weed growing and decline due to cutting and swan grazing are apparent at the Boyton site, Figure 6.4. In June and September the same flow occurred in the river ~120 Ml/d, however, with weed presence the water depth was 0.5m in August, with little weed the water depth was ~0.25m in September. This data demonstrates that flow alone does not guarantee an acceptable river appearance, controlled and uncontrolled activities exert a far greater influence.



The impact of *Ranunculus* on river water depth. Prior to the weed cut on 27th June the water level was increasing. Following the weed cut and swan grazing water level has fallen despite the river flow remaining relatively constant.

Figure 6.4

River Wylye at Boyton 2007 – With the presence or absence of Weed affecting river water depth

6.4 OTHER FACTORS – CHANNEL MORPHOLOGY AND RESTORATION

Channel morphology has a significant influence on river appearance and more importantly habitat suitability for the designated species. The influence that channel morphology has is discussed in this section, with the 'benefit' of river restoration vis-à-vis increasing river flow (by reducing abstraction) have in producing 'favourable condition' is discussed.

Channels have been heavily modified due to historic anthropogenic activities, for example:

- Bifurcation – to create leat for mill activities
- Sluice & weirs – to control water levels in water meadows.
- Dredging activities – Water Board activities principally in the 1950-1960.

The extent of river channel 'damage' has been assessed via geomorphological audits of the River Wylye and River Bourne. Surveys were conducted to gauge the 'Standard Diversity' of the channel, these are compared to reference conditions to gauge the geomorphological deficit. These criteria are detailed in Table 6.1. The percentage of each river in the 5 classes is presented in Table 6.2.

Table 6.1: Classification of geomorphological diversity

Classification	Standard Diversity	Description
Very Low	0	No variety of channel form or evidence of processes
Low	0.01 to 1.99	Little variety of channel form
Moderate	2 to 7.99	Some variety of channel form but little evidence of processes present
High	8 to 16.99	Good variety of channel form but only some evidence of processes present
Very High	17 to 45	Good variety of channel form and evidence of a variety of processes present.

Table 6.2: Percentage of River in each Diversity Class

Classification	Wylye (%)	Bourne (%)
Very Low	11	11.4
Low	43	40.9
Moderate	34	33.8
High	7	12
Very High	4	2

Over 50% of the length of each river is classed as very low or low diversity, indicating the poor condition of each river to provide the flow and channel diversity needed to form the niches for the designated species.

The degradation of the river habitat due to the activities listed above has been acknowledged. Local action has been taken, mainly by fishery bodies to improve the habitat and hence improve the fishery. A typical outcome from these labours are shown on Figure 6.5. The first photograph, taken in September 2004, shows the river during the installation of restoration measures. The channel was practically devoid of vegetation and water was only ankle deep across the channel. The channel modification involved creation of an eyot along the left hand bank and fencing to control stock access to the river. The appearance of the river twelve months on (2005) is shown in Figure 6.5. At this time the actual flow is less than when the first photograph was taken in 2004, but the water depth was knee deep. The channel now had a mix channel vegetation, including *Ranunculus* (water crowfoot), *Zannichellia* (horned pond weed) and a wide range of marginal plant.

3 Sept 2004 – Flow 115 Ml/d	8 Sept 2005 – Flow 95 Ml/d

Figure 6.5: River Wylye at Great Wishford pre and post restoration

These picture show the dramatic change river restoration can make to the channel appearance and hence ecology. However, little scientific study of the ecology change before and after restoration has been done.

The RoC process can ultimately result in PWS abstraction being reduced, which will result in higher river flows. The premise being that increasing river flow will 'enhance' the ecology, though the findings in this report do not clearly demonstrate that. However, there is a risk that increasing river flow alone will not result in the production of favourable conditions, as the river geomorphology is poor.

To investigate and inform the decision making process the relative benefit of restoration and increasing river flow (reducing abstraction) has been quantified for a restored section of the Lower Wylye.

Restoration Site

The restoration site is known as Seven Hatches and the location is shown on Figure 6.6. These works have been managed by Natural England as part of the Strategic Restoration And Management (STREAM) project. As part if the work a hydraulic model of this section of the river was constructed by consultants Halcrow.

Restoration

Due to impoundment and historic dredging this part of the river has become overly wide and deep resulting in slow flows and silt covered channel beds. The restoration uses a number of techniques to restore habitat features so that the morphology (shape and form) is more characteristic of a chalk stream. The types and location of the restoration applied are shown on Figure 6.6.

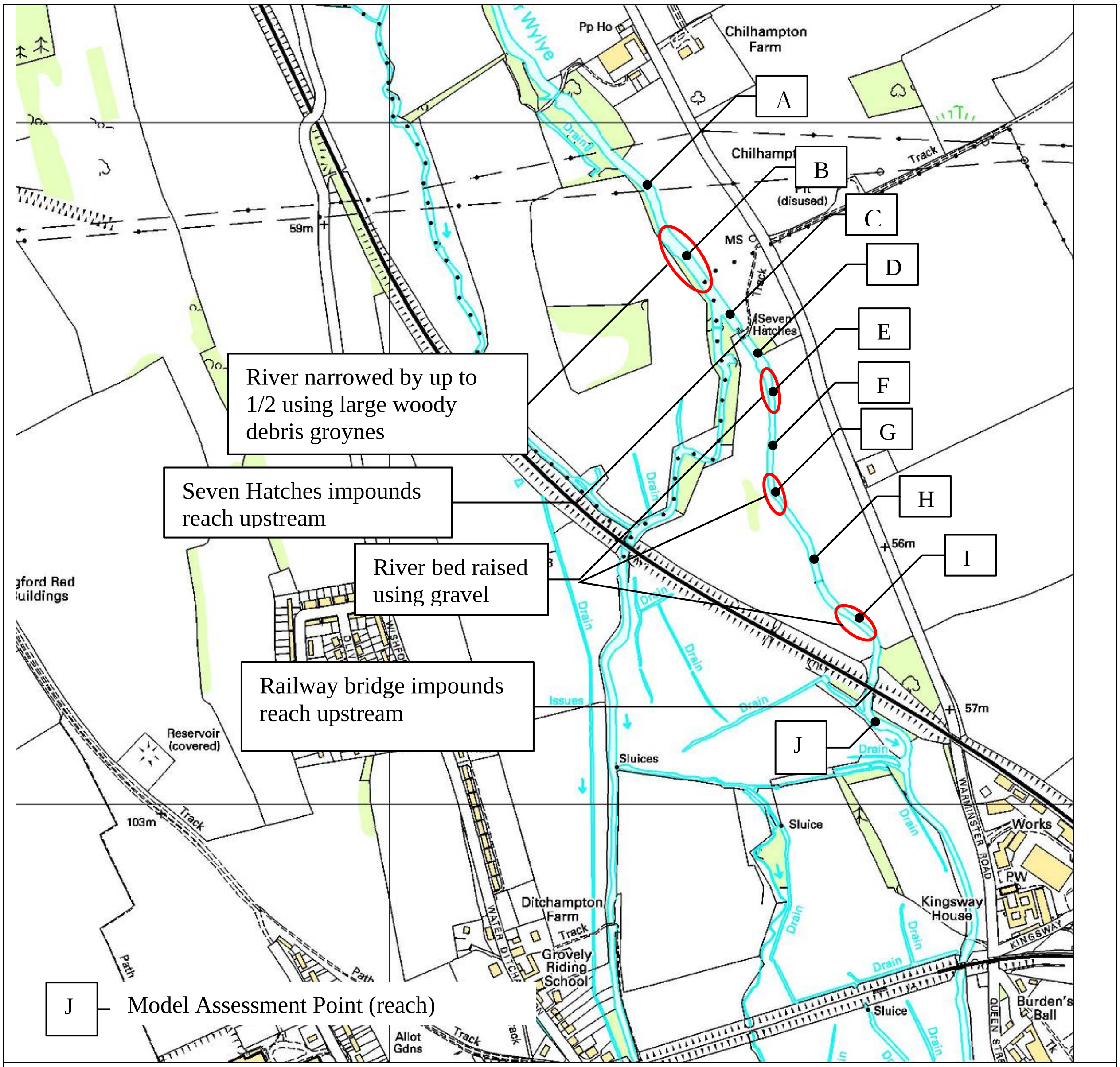


Figure 6.6: Seven Hatches Restoration Sites and measures used

Channel width in overly wide sections were narrowed by placing large woody debris groynes fixed in to the eastern band. The bays between the groynes have been infilled with brushwood and pre-planted coir matting to create a two stage channel.

In the dredged reaches gravel was deposited to raise the river beds levels, so as to create a series of pools and riffles. The channel topography pre and post restoration is shown on Figure 6.7.

Flow changes
The HAM has been used to determine the increase in flow that a reduction in source output from contemporary rate use to no abstraction (natural) would have at Q95 and Q70. The flow increase at Q95 and Q70 are 5 and 13 Ml/d respectively.

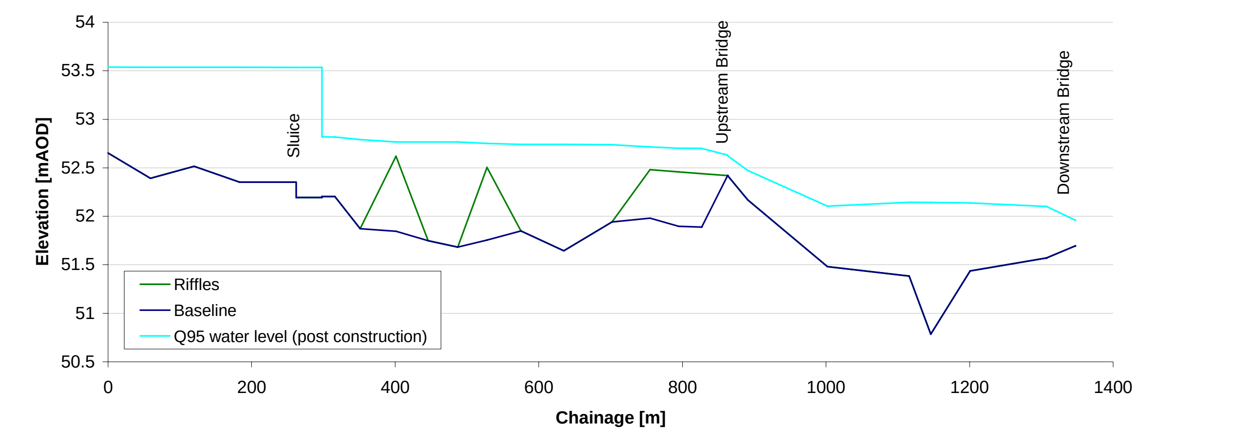


Figure 6.7: Comparison of Channel bed levels – pre and post restoration

Species Requirement – Depth and Velocity

To accommodate the range of SAC species and their various requirements a range of depths between 0.2m and 0.75m is required, with velocities between 0.25 and 0.9 m/s. Ideally a number of holding areas, or pools, of more than 1.5m should be present to accommodate adult salmon, although this is not considered to be a critical feature of the Avon system.

Results

The model has been used to assess the following, with results shown on Figure 6.8, compared to the baseline (pre) condition:

- Restoration: velocity changes at Q95 and Q70
- Restoration: Water depth at Q95 and Q70
- Increasing flow: velocity at Q95 (by 5 Ml/d) and Q70 (by 13 Ml/d)
- Increasing flow: water depth at Q95 and Q70

The habitat requirements, as described above, are shown as 'yellow' shaded boxes on Figure 6.8. The data presented on Figure 6.8 shows that, when compared to the un-restored conditions (contemporary flow), there is little difference in either velocity or depth if abstraction is stopped (natural flow). This suggests that these actions, if carried out alone, would contribute little to restoring the river reach to a favourable condition in this location. However, the model shows that restoring the river, by bed-raising and channel narrowing, would result in a marked change in both depth and velocity, especially on the constructed riffles. At a Q95 flow the un-restored velocity ranges from 0.02 – 0.15m/s, which is not adequate to support any of the life-stages of salmon or spawning trout and only marginally adequate to support adult trout. Restoration of the reach introduces velocities ranging from 0.02 – 0.30m/s, which provides more suitable conditions for both salmon and trout.

It is also likely to provide improved morphological conditions to diversify the habitat, in terms of depth, current velocity and channel substrate, for the range of designated features within the River Wylye. The un-restored depth ranges from 0.46 – 1.38m, showing a distinct lack of shallow areas. Again, restoration of the reach introduces a wider range of depths, including shallower areas and some deeper pools (from 0.12 – 1.38m), thus providing more suitable conditions for the designated features of the river.

Conclusion
The River Avon SAC requires a diversity of water depths, current velocities and channel substrates to fulfil the spawning, juvenile and migratory requirements of the designated fish species and *Ranunculus* community. Changing flow alone (by reducing or removing abstraction) is unlikely to achieve this, as the morphology of the river is not currently providing the conditions to create a diverse habitat. Restoration of this river reach, and other similar reaches is therefore likely to be essential in achieving, or contributing to favourable condition for these interest features, although additional flow would further improve flow and depth diversity.

6.5 OTHER FACTORS – CLIMATE CHANGE

The supporting legislation for the Habitats Regulations (and RoC) was drafted before the scientific and governmental acceptance that climate change is occurring. Consequently there is no requirement within the regulations and associated guidance to address flow changes that climate change may impose upon the Hampshire Avon.

The issue of climate change has been raised by stakeholders during consultation exercises through this work. In response Wessex Water have made a commitment to use the HAM to evaluate the change to the river flow sequence climate change may make, using scenarios as prescribed by DEFRA for the Water Resource Management Plan. This work is scheduled to be undertaken in the summer of 2008.

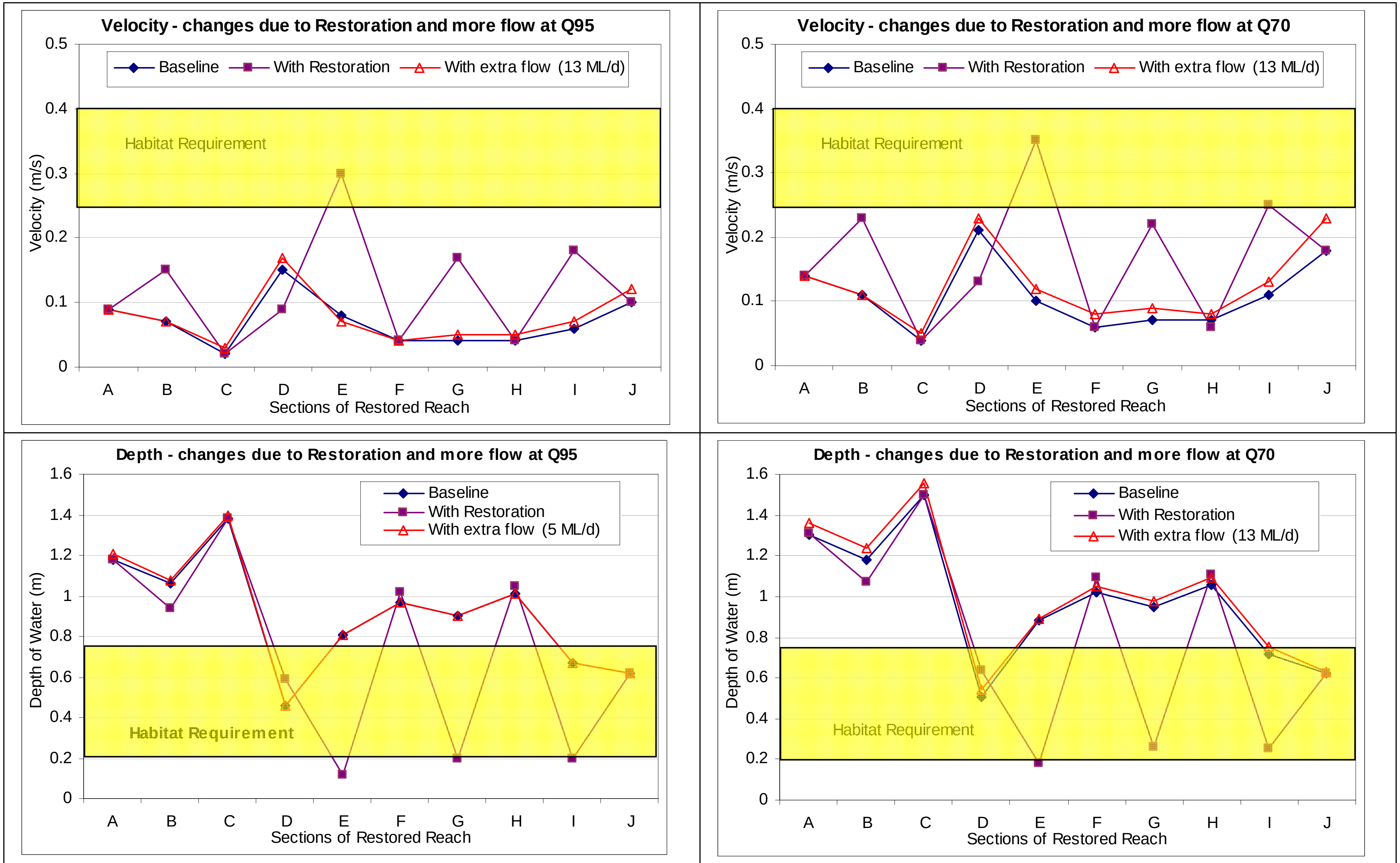


Figure 6.8: Changes to velocity and water depth caused by Restoration and increasing river flow

7 Conclusions of the study

The following conclusions are drawn for the study

7.1 HYDROLOGICAL IMPACT OF ABSTRACTION

7.1.1 Full Licence Impact

The Natural England guidelines have been used to screen whether river flow reductions due to abstraction potentially impact river ecology (-10% (high) to -15% (moderate)). The in-combination effect of full licence abstraction exceeds these guidelines on tributaries of the Avon upstream of Salisbury. The impact on the River Avon reach of each tributary is as follows:

Avon – small exceedance reach (~3km) around Durrington at Q95, this conclusion assumes **no** canal leakage.

Bourne – The largest impacts on the Bourne occur at times of low flow (> Q95). At Q95 exceedance occurs along the entire SAC reach, with a maximum reduction from natural of 34%. An additional 5 Ml/d of water would be required in the river at Q95 to achieve compliance.

Nadder **–** No exceedance of guideline values.

Till – Awaiting model refinement

Wylye **–** Small reaches of exceedance occur at low flows (Q95), though stream support and storage development affords a large degree of protection to flow at natural low flow times. Greater reductions in flow occur at higher river flows. Maximum reductions in river flow occur near the start of the SAC (25% at Q44) and between the Chitterne Brook and River Till (29% at Q50). The reduction in flow at the start of the SAC is attributable to the Brixton Deverill PWS source. The reductions observed between the Chitterne and Till are in part a cumulative impact, but the large abstraction from the Codford PWS source has a major influence.

7.1.2 Contemporary Impact

The above impacts are theoretically possible but have never occurred to date. The contemporary impact of abstraction has been determined to allow the variance with Full Licence predictions to be established plus to assist in the design of the ecological survey.

Bourne – contemporary abstraction has resulted in exceedance of guideline values with reduction in flow (compared to natural of 25%)

Wylye **–** contemporary impacts along the Wylye are close to the guideline values at all Q values. The main exception is at the start of SAC, where reductions of up to 25% occur.

7.2 ECOLOGICAL IMPACT

The ecological survey design sought to elicit abstraction impacts upon river ecology by comparing sites with varying degrees of abstraction impact, that are otherwise comparable in natural stream flow. Based on the hydrological findings, the survey sites were located in headwater stream. In addition, long running survey work on macrophytes and macroinvertebrates was continued through the survey period.

Regarding the designated species the following conclusions are drawn:

***Lamprey* –** No abstraction impact upon the Lamprey population was detected.

***Bullhead* –** An abstraction impact (flow reduction >15%) has been detected by the bullhead numbers, but the mechanism for impact has not been established. The 2006 survey found more bullheads at umimpacted sites than impacted sites, however, this difference was not detected in the 2007 data.

***Salmon* –** The survey conducted as part of this study was not expected to provide information on salmon as the majority of the survey sites were not located in preferential salmon habitat. Instead trout numbers were examined, though stocking will exert an unquantifiable influence on the numbers recorded. The survey found no relationship between abstraction impacts and trout numbers.

Except for the River Bourne the contemporary impact of abstraction has been within or just above the English Nature guideline values. It could therefore be concluded that the decline in salmon numbers cannot be attributable to abstraction. The alternative argument is that the abstraction impact has contributed to the salmon reduction, allowing a ‘trigger’ point for population decline to be reached.

The influences on salmon are varied (Figure 2.3), occurring within the Avon catchment and outside the catchment, including the North Atlantic. Consequently, a simple relationship with abstraction is unlikely to be found. It is noted that recent work exploring river water temperature and salmon numbers in Southern Britain chalk streams may establish a causal relationship.

Mechanisms where by abstraction could influence salmon numbers have been explored as part of this study. The review concluded it was not possible to demonstrate a clear effect of groundwater abstractions on the salmon population. It is considered that the observed decline in salmon numbers is due to a combination of effects common to the other Southern Britain chalk streams.

Designated habitats
The measures to assess the conservation objectives for the ‘chalk stream habitat’ are largely physical, such as the guidance for maintaining flows within 10% of natural. In the absence of other measures on the community make up, or species within it, it has not possible to directly assess the impact on the community. Therefore measures such as the *Ranunculus* distribution and changes in macroinvertebrates and macrophytes communities and indices were assessed.

***Ranunculus* –** No relationship to the degree of abstraction and *Ranunculus* cover was found. Examination (on going) of long term data set indicates that winter/spring (Q5) flows influence the *Ranunculus* cover, in other words the higher the winter/spring flow the better the *Ranunculus* cover in the summer. This initial conclusion supports the widely held view that high winter flows will clear away senesced plant material, silt and potential competitors and so prepare the river bed substrate for growth in the spring, with high spring flows stimulating growth early in the year.

When macrophyte indices were examined against the actual impacts of abstraction on natural flow at each site using stepwise multiple regression, abstraction impact (with some other environmental variables) explained around 20% of the variation in MFR-A scores in 2006 and 2007 and 14% for MTR scores in 2007. When survey locations were grouped into 3 main categories that described abstraction impacts (0-10%, 10-20% and >20% decrease in natural flow at Q95), no statistically significant difference was found between aquatic macrophytes and the degree of abstraction impact in either year, across all sampling locations.

When macroinvertebrate data is examined the only consistent, significant effects of abstraction on macroinvertebrate indices were found at just one sampling location (Bourne 19, near Idmiston) where abstraction prolongs both the cessation of flow and natural drying periods. Along the perennial reaches (which do not dry) an impact upon the macroinvertebrate community due to the effects of abstraction was not clear.

The perennial study concluded that the long term abstraction has not resulted in evident change. It appears more likely that headwater and winterbourne ecology responds to recent flows which are driven by climate and abstraction. Further assessment of this will be possible once modelled flows are available for 2007.

With regards to the assessment of whether 10% of natural is an appropriate value for the protection of highly sensitive designated sites (at Q95), this varied with species or community. Where an impact on a flow index (MRF-A) could be detected it was at 10% as noted above, or 15% on bullhead. However this did not apply to invertebrates at all and does not necessarily reflect the effect on integrity of the SAC designation.

Winterbournes

The winterbournes do not contribute to the populations of designated species downstream within the SAC. However the winterbourne stretch of the River Till does fall within the SAC and contains ‘chalkstream habitat’, characterised by *Ranunculus peltatus*. Subject to final modelling output, assessment of the present winterbourne community suggests that it is currently of high conservation value and the effect of abstraction would be to increase drying by less than 10 days typically, thus moving it downstream, without loss of the winterbourne habitat. The effect on the perennial stretch is as outlined above.

7.3 NON SAC REACHES

Non SAC reaches include perennial reaches and winterbournes. Reductions in river flow, due to abstraction, exceed 10% of natural on several watercourses: Up Avon West, Fonthill Brook, Teffont Stream, Fovant Stream and Upper Wylye.

Models to predict macrophyte and macroinvertebrates along distribution along winterbournes have been developed based on the antecedent periods of flow. Abstraction impacts along the winterbourne are variable, increasing the period of drying from a couple to 70 days a year (on average, 1970 to 2003). Abstraction results in the spatial shift of communities, with no loss of the high conservation value winterbourne communities. A reduction in the length of the Transitional community is predicted. Flow changes along the Nine Mile River are primarily due to another abstractor.

7.4 OTHER OBSERVATIONS

Groundwater abstraction does reduce water temperature but the main and potentially harmful effects of changing temperature on salmon are driven by increasing air temperature both in the nursery areas and the main river. The effects of abstraction on river water temperature are unlikely to be detected against the variation caused by shade and impoundment.

Geomorphological survey of the Wylye and Bourne has shown that over 50% of the length of each river has very low or low diversity, indicating the poor condition of the river to provide the flow and channel diversity needed to form niches for the designated species.

Hydraulic modelling shows that increasing river flow (by reducing abstraction) has little effect in increasing the extent of the habitat for the designated species where the geomorphological condition of the channel is ‘poor’. Suvery work has identified that over 50% of the perennial Wylye and Bourne is in ‘poor’ condition. The hydraulic modelling showed that restoration work did yield suitable habitat conditions (water depth and velocity).

8 References

APEM (2005). River Avon SAC – Low Flow Investigation. Consultancy report for Wessex Water. APEM Report No. WW818 146pp.

APEM (2008) River Avon SAC – Low Flow Investigation

Boulton, A J (2003). Parallels and contrasts in the effects of drought on stream macroinvertebrate assemblages. *Freshwater Biology*, 48, 1173-1185.

Chad, R. & Extence, C. (2004). The conservation of freshwater macroinvertebrate populations: a community-based classification scheme. Aquatic Conserv: Mar. Fresw. Ecosyst. 14: 597-624.

Cranston, E., & Darby, E. (2004). *Ranunculus* in chalk rivers. Environment Agency R&D Technical Report W1-042/TR.

Dawson H; Westlake D; Williams G. An automatic system to study the responses of respiration and photosynthesis by submerged macrophytes to environmental variables

Entec Uk (2005). Hampshire Avon Numerical Groundwater Modelling Project. Phase 1 Hampshire Avon Conceptual Model Review and Numerical Model Proposals. Prepared for the Environment Agency South West Region and Wessex Water Services Ltd.

Entec UK (2006). Hampshire Avon Groundwater Modelling Study, Phase 3 – Model Development and Refinement. Prepared for the Environment Agency South West Region and Wessex Water Services Ltd.

Environment Agency (1997) - Salmon Action Plan- consultation document Hampshire Avon.

Environment Agency (2006). Hampshie Avon Catchment Abstraction Management Strategy.

Grieve, N., Watson, R., Newman, J., & Clarke, S. (1999). Monitoring of *Ranunculus* beds in the Rivers Avon, Wylye and Nadder. Technical report to English Nature.

Grieve, N., Clarke, S., & Newman, J. (2000). Monitoring of *Ranunculus* beds in the Rivers Avon, Bourne and Till. Technical report to English Nature.

Heywood, M.J.T & Walling, D.E. (2006) - The sedimentation of salmonid spawning gravels in the Hampshire Avon catchment, UK: implications for the dissolved oxygen content of intragravel water and embryo survival. Hydrological Processes

Hill, M.O., Mountford, J.O., Roy, D.B. & Bunce, R.G.H. (1999). Ellenberg's indicator values for British Plants ECOFACT 2a Technical Annex, ISBN: 1 870393 48 1, pp 46.

Holmes N.T.H., Newman J.R., Chadd S., Rouen K.J., Saint L. & Dawson F.H. (1999). Mean Trophic Rank: A users manual Environment Agency R&D Technical Report E38.

Humphries, P., & Baldwin, D. (2003). Drought and aquatic systems: an introduction. *Freshwater Biology*, 48, 1141-1146.

Langton, P H. & J. Cass (1998). Changes in Chironomid assemblage composition in two Mediterranean mountain streams over a period of extreme hydrological conditions. Hydrobiologia 390: 37-47

Ledger, M. E. & Hildrew, A. G. (2001). Recolonization by the benthos of an acid stream following a drought. *Archiv Für Hydrobiologie*, 152, 1-17.

Morris, K. S. (2007). The effects of river restoration work on downstream macroinvertebrate communities. A research project submitted in partial fulfilment of the degreeB.Sc. (Hons), University of Southampton.

Parrish, D.L., Behnke, R.J., Gerhard, S.R., McCormick, S.D. & Reeves, G.H. 1998. Why aren't there more Atlantic salmon (Salmo salar)? Canadian Journal of Fisheries Aquatic Science 55 (Suppl. 1): 281–287.

Solomon, D.J. & Paterson, D. (1980). Influence of natural and regulated streamflow on survival of brown trout (*Salmo trutta* L.) in a chalkstream. Environmental Biology of Fishes 5(4): 379-382.

Solomon D J, (2005) - Anthropogenic Influences on the temperature Regime in a Chalk River temperature. EA Science report SC 040025.

Southey, J (1998). River Avon pSAC Ecological Assessment. Technical report to English Nature

UKTAG. (2006). UK Environmental Standards and Conditions (Phase 1). Final Report.

Wessex Water (2008a) Low Flow Investigations – Fonthill Bishop. Final report for the steering group consultation. Report No. DM#928220

Wessex Water. (2008b). Assessing the ecological impact of abstraction on the winterbournes of the Hampshire Avon

Wheeldon, J (2003). Conservation objectives of the River Avon cSAC.