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TADNOLL BROOK
A REVIEW OF THE HISTORIC AND PRESENT SALMON POPULATION

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EXECUTIVE SUMMARY

Historically the Tadnoll Brook supported a healthy salmon population at least as recently as the 1970s. Estimates indicate that the smolt output from the Brook may have represented as much as 12-15 % of the current total output for the Frome catchment. However, by the late 1990's this population had become extinct. The most likely cause of this extinction is a series of low winter flows in the late 1980s interacting with a partially impassable barrier at Tadnoll Mill. That is, during low flows in November and December returning adult salmon were unable to pass this obstacle to reach the spawning grounds situated above. This year a suitable pass is being constructed on the Mill that should allow free passage upstream even in years with lower than average winter flows. At the same time, salmon are being re-introduced upstream and the combination of these two events should result in the re-establishment of a natural spawning population. During 2006, the river upstream of Tadnoll Mill will be inhabited by salmon parr.

Since the low winter flows are probably not the result of excessive abstraction, but rather due to a lack of rainfall and floods, the most likely impacts of abstraction will be reduced flows in the late spring to autumn period. There is neither sufficient data on salmon populations or flow levels during these periods to make any reliable assessments of the impacts of flows on the Tadnoll Brook salmon population. This is a major gap in knowledge in the review of the Empool abstraction. If one assumes that all the water from the Empool abstraction would find its way into the Tadnoll brook, then this would represent about one third of the summer flow in the most important salmon juvenile habitat. However, a ground water model may suggest that the Empool abstraction has a much lower impact. Such a model should be developed.

Since there is no data to link the response of the salmon parr population and smolt output to flow levels and given the short timetable for the review, it is recommended that the indirect method of assessing flow impacts on habitat (PHABSIM) is used. For future, longer term assessments it is recommended that a gauging station is installed in the Tadnoll Brook at a location relevant to the salmon population. This would provide data that could be used in conjunction with the Centre for Ecology and Hydrology's intention to estimate annual parr numbers and smolt production from Tadnoll Brook.

1. BACKGROUND

The Tadnoll Brook can be divided into three distinct regions; that below Tadnoll Mill (Section 1) with a low gradient and open canopy; that above Tadnoll Mill with a higher gradient and closed canopy (Section 2) and the river above Crossways road around the cress beds and pump supported Watergates where the stream is smaller.

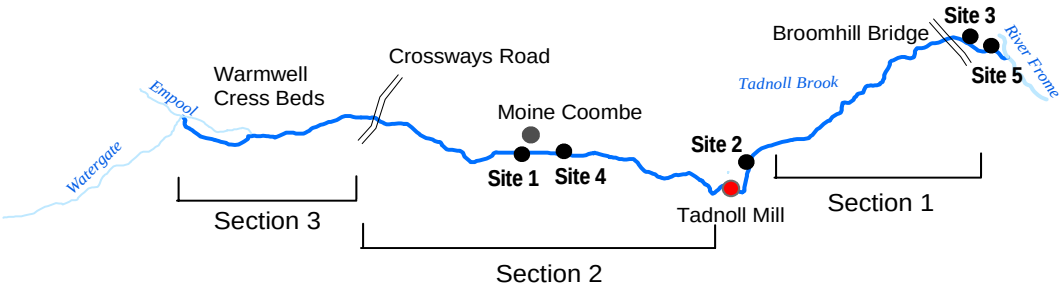

Figure 1 Schematic diagram of the Tadnoll Brook showing fish survey sites

Recently, CEH has tried to re-introduce salmon to the Tadnoll Brook by adding 200 parr moved from the lower Frome in September 2003. The first of these adults could return this year (2005). However, because of the low numbers of these parr we are anticipating a low or nil return from these fish. CEH will be stripping adult salmon from the River Frome this summer and placing the eggs in stream-side egg incubation boxes during December 2005 to re-introduce salmon in the river.

For two years CEH monitored the sea trout population closely with individually marked fish and monthly electric fishing surveys but this ceased in December 2003 because of lack of funding

Currently, CEH has a NERC grant (start March 2005) to study the food web structure in a small section (150 m) of the Tadnoll Brook below Owermoigne, and, in addition, has two PhD students, one to study the biological costs and benefits of migration in the sea trout population and the second to study the use of the habitat by the different family groups of the introduced salmon. Both PhDs will be due to start in October 2005.

There is a requirement for Wessex Water to review the Empool abstraction licence in 2007/8.

This interim report:

- Reviews the historic and current salmon population in the Tadnoll Brook, its significance to the maintenance of the Frome salmon population and its relationship to the flow in the Tadnoll.
- Identifies obstacles to migration and the current state of alterations to those structures
- Reports on those areas of the Tadnoll Brook with suitable habitats for salmon
- Advises on future work needed to clarify the impact of flow on the salmon population.

2. BARRIERS TO UPSTREAM MIGRATION OF SALMON ADULTS

The entire Tadnoll Brook was walked from the Confluence with the river Frome to the fish farm at Watergates. The only potential barrier to migration lies at Tadnoll Mill (Figure.2). Assessment of the seriousness of this barrier is difficult. There is a local view (unproven) that prior to the 1930s all the water passed through the Mill and therefore it was a complete barrier at this stage. However, there is a flood by-pass channel operated by a hatch that circum-navigates the Mill and it would seem likely that this would have been in existence whilst the Mill was there to prevent flooding of the Mill House. A further channelled pipe with a very high gradient diverts flow away from the Mill. In the 1930s a further channel was created through the garden and a step structure (Figure 2), possibly of ornamental design built.

With the flow at Tadnoll Mill split between effectively four channels it is probable that it represents a partial obstruction to upstream migration, with fish under very high flow conditions being able to negotiate the flood relief channel, when open and the step structure. Although, it should be noted that under certain conditions the hatch and spillway of the flood relief channel would not be passable because of the water velocity. And that the current gardener admits to having to help large sea-trout over the step structure during high flows with a net. The channelled pipe is impassable and there are plans to use this to generate electricity. Past operation of the hatches and changes to the management of the various hatches and flow will also have impacted on the level at which this site is a barrier. In low flow winters it seems that this structure would have been impassable.

A fish pass partially funded by the Environment Agency is currently under construction on the step structure to make this more passable. However, this has yet to be completed although a design has been produced. No conditions for the operation of the fish pass have been set in regard to the amount of water flowing over it, although electricity cannot be generated during November and December when salmon are migrating upstream. The operation of so many channels and the incomplete nature of the fish pass makes it impossible to estimate the minimum amount of flow required to allow migration over the pass. However, it is thought that minimal flow over the pass, once completed, will make this structure passable, and since salmon migrate upstream during flood events it is likely that Tadnoll Mill will no longer form a significant barrier to upstream migration.

Figure 2 Photographs of partially completed fish pass and step structure at Tadnoll Mill

3. REVIEW OF HISTORIC AND CURRENT SALMON POPULATIONS

3.1 Parr Densities

In the following discussion of the historic and current state of the Tadnoll Brook salmon population the river has been divided into 3 separate sections (Figure 1). Section 1 lies between Tadnoll Mill and the confluence with the River Frome where the channel has a low gradient and is cut for flood relief. Section 2 lies between Crossways Road and upstream of Tadnoll Mill, where the channel has a higher gradient. The river upstream of Crossways Road is further divided into Section 3 as this incorporates the river up to the Warmwell cress beds, the Tadnoll Brook above the cress beds and Watergates which is supported by ground water pumping.

Fishery surveys in both Section 1 and Section 2 have been completed as part of Environment Agency survey programmes and by CEH for the purpose of individual research projects (Table 1). All the surveys completed by CEH were for specific projects and thus tend to be rather disjointed temporally, spatially and for purpose. Between 1998 and 1997 the Environment Agency and its predecessors completed surveys designed to monitor the status of the Tadnoll Brook and River Frome salmon populations. However, changes in methods of survey from quantitative (where estimates of density are made in discrete sites) to semi-quantitative (where single electro-fishing passes are made over wide areas) make comparisons between years difficult. The data produced in the semi-quantitative 'Agency' reports are difficult to interpret as the reports are poorly produced and data are often only exhibited in pictorial form with graph axis that are make location and fish density almost impossible to extract usefully.

The earliest survey for which records can be found was in 1973. Prior to this date there are no known records of fish surveys. However, local knowledge would suggest that salmon were present in the Tadnoll Brook at least up to the top of Section 2 for decades prior to 1973. There is an unconfirmed view that up to the 1930s Tadnoll Mill presented a total barrier to upstream migration of adult salmon.

Table 1 Details of locations, ownership and survey methods (Q = quantitative; SQ = semi-quantitative) of fishing surveys of the Tadnoll Brook

Year	Section 1 Est. Densities n/100 m^2	Section 2 Est Densities n/100 m^2	River Frome Est Densities n/100 m^2	Site Number (see Figure 1)	Owned by and method
1973	19			All Section 1	CEH - Q
1974	10			All Section 1	CEH - Q
1975	5			All Section 1	CEH - Q
1976		30.9		Site 1	CEH - Q
1978	3			All Section 1	CEH - Q
1980	0.7			All Section 1	CEH - Q
1981	5			All Section 1	CEH - Q
1982	13			All Section 1	CEH - Q
1983	2			All Section 1	CEH - Q
1988	4		4.2	Site 2&3	'Agency' Q
1990	1.8		12.6	Site 2&3	'Agency' Q
1991	5.4		10.5	Site 2&3	'Agency' Q
1992	1.3		7.1	Site 2&3	'Agency' Q
1993	0.75	0.3	1.8	Part Sect1&2	'Agency' SQ
1994	0.5	0.2	8.8	Part Sect1&2	'Agency' SQ
1995	1	0.01	5.5	Part Sect1&2	'Agency' SQ
1997	1.5	0	9.7	Part Sect1&2	'Agency' SQ
2002		0		Site 4	CEH - Q
2003		0		Site 4	CEH - Q
2005	3.3	0		Site 1,3,4& 5	CEH - Q

There is more data on the salmon population of Section 1 than for Section 2 where the earliest record is 1976 and the next record 1993.

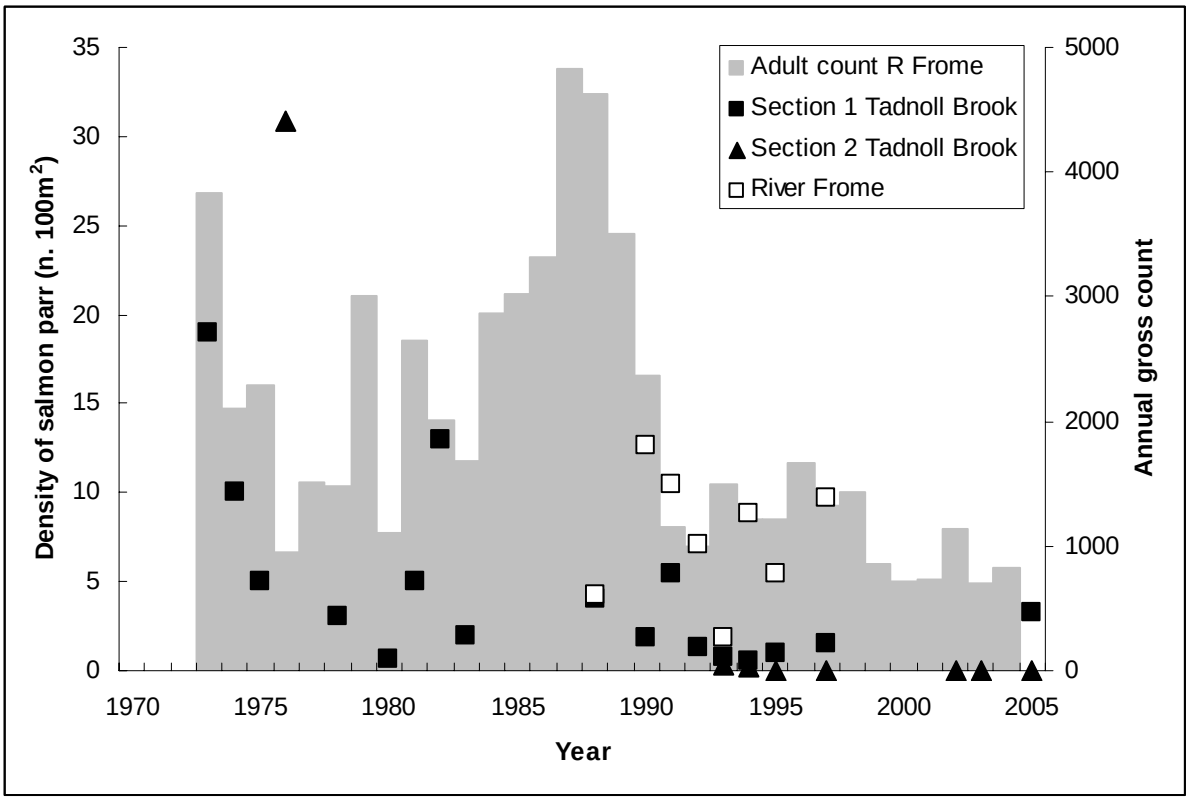

Figure 3 **Estimated densities of salmon parr in the River Frome, Section 1 and 2 of the Tadnoll Brook over time together with annual gross counts of adult salmon.**

The density of salmon in Section 1 shows high levels of variation between years (Figure 3). If the three years with high density recorded in 1973, 1974 and 1982 are ignored then it looks as though densities in Section 1 have remained fairly stable but at low levels, considerably below typical densities found on the river Frome (Table 1, Figure 3). Unfortunately the data for Section 2 is so poor it is difficult to draw many conclusions. However, it is clear from the 1976 survey that densities can be very high, but that by 1993 densities were at a very low level and fell to zero by 1997 (Table 1; Figure 3). Although there are no densities of salmon parr recorded for the River Frome prior to 1988, densities of salmon parr since then are comparable to densities recorded from Section 1 of the Tadnoll Brook prior to that date.

One interesting observation is that the Tadnoll Brook salmon population has historically had a higher composition of 1+ parr than the main river. In the 1976 survey at Owermoigne 40% of the parr caught were 1+, compared with a typical figure of 5% for River Frome fish. Whilst direct comparisons are difficult because of the timings of surveys this has important implications for the subsequent age structure of the returning adults and may increase the importance of the Tadnoll Brook to the river Frome system as a salmon rearing area for the larger multi-sea winter adults.

3.2 Redd Counts

Years where counts have taken place are sporadic but records as far back as 1955 have been found where over 100 large redds were found on the Tadnoll (~ 16% of the large redds counted in the Frome system). The most recent year the Brook was surveyed (2001) indicated

21 redds (~6% of the Frome number) (Figure 4). Discrimination between salmon and sea-trout redds has traditionally used redd size, with redds having a gravel pile width of more than 110cm being considered to be salmon. However this is a very poor mechanism for determining the presence of salmon redds in streams such as the Tadnoll Brook which has a population of large sea-trout. Whilst recent counts of large redds in the Tadnoll Brook would imply that salmon have spawned in Section 2, this seems very unlikely given the low to zero densities of parr reported above.

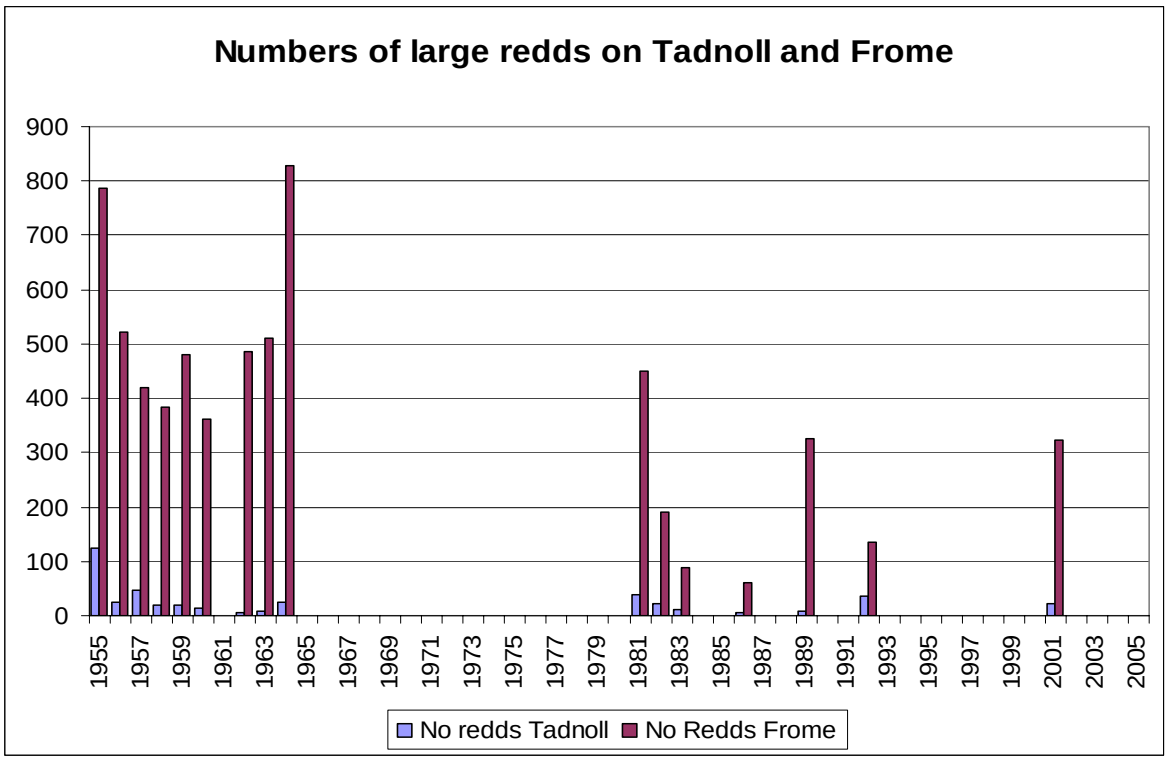

Figure 4 **Large redd numbers on Tadnoll Brook. Zero values indicate survey not carried out**

4. HABITAT SURVEY OF THE TADNOLL BROOK

During August and September 2005 the entire Tadnoll Brook was habitat mapped at base flow with purpose of identifying those habitats that were suitable for the different life-stages of salmon and for laying a basic foundation for any future work which may consider changes in physical habitat with streamflow. This survey recorded the proportions of the different mesohabitats present in the Tadnoll Brook and can be used to identify representative reaches of river suitable for the placement of PHABSIM study sites.

We used a standard list of mesohabitats that CEH has previously used in other surveys of lowland rivers including the River Wylye (Table 3). This makes use of 7 mesohabitats, that can be easily translated into their relative usefulness for the different salmon life-history stages. By mapping in this way we provide a level of precision that is greater than subjective intuitive assessment.

Table 3 Definition of mesohabitats and the life-history stage relevance of each

Mesohabitat	Depth Features	Velocity Features	Description
RIFFLE	shallow	fast flowing	Relatively steep water surface gradient, coarser bed material than local vicinity, some broken water. Usually of limited extent with deeper water evident both upstream and downstream. **This is good juvenile habitat, where gravel is abundant it is also considered good for spawning**
SHALLOW GLIDE	< 0.5	visible flow	Relatively smooth, low gradient water surface compared to riffle. Differentiated from deep glides by max. depth value. Visible flow clearly evident. **This is good juvenile habitat, where gravel is abundant it is also considered good for spawning**
DEEP GLIDE	>0.5	visible flow	Relatively smooth, low gradient water surface differentiated from shallow glide by depth >0.5 m. **Suitable for parr**
SHALLOW SLACK	<0.5	little or no visible flow	All associated with multiple thread channels. Shallow with little visible flow. **Not considered suitable for salmon**
DEEP SLACK	>0.5	little or no visible flow	Smooth, low gradient water surface. Deep with little visible flow. **Suitable for parr**
VERY DEEP AND SLOW	>1.3	little or no visible flow	Depths greater than 1.3 m. Mainly associated with reaches upstream from impoundments. 'Canal-like' with little or no visible flow. **Suitable for parr and adults**
POOL	deep, often >1.3	little or no visible flow	Deep wide pool with shallows at upstream and downstream ends, mainly found downstream from weir/sluice. **Suitable for parr and adults**

In total 160 transects were surveyed and of the seven mesohabitats only 5 were observed with slack water being absent with the exception of areas above impoundments (Table 4). Although, much of its habitat was suitable for young of the year and older parr, Section 1 was characterised by its lack of spawning habitat, in general this habitat has mostly sand or silt substrate and less than 1% was suitable for spawning. Almost all the spawning habitat occurred immediately below the plunge pool below Tadnoll Mill. Clearly, for the Tadnoll Brook between Tadnoll Mill and the confluence with the Frome, to support salmon parr they must come from spawning elsewhere.

Conversely Section 2 had an abundance of both spawning gravels and excellent habitats for young of the year and parr. Nearly 20% of the habitat was judged as being suitable for spawning and 80% suitable for rearing young of the year. The generally higher gradient of this section is borne out by the higher percentage of riffles being present. This section should be capable of supporting large numbers of salmon parr, spawned directly in the section.

Section 3 does have spawning habitat for salmonids generally together with habitats that support young of the year. However, this has been separated from Section 2 because the river starts to get smaller here and it is less likely that sea-run salmonid adults would migrate to this area of the river to spawn. It is more likely used as rearing areas for river resident brown trout. Although occasional salmon may be able to migrate to Warmwell cress beds, our opinion is that this would be an exception rather than common.

Table 4 Percentage of each mesohabitat type found in each of 3 sections of the Tadnoll Brook together with percentage of habitat useful for each salmon life-stage

Habitat type	Section 1	Section 2	Section 3
Riffle	3.3	12.2	7.8
Shallow Glide	54.9	63.1	90.4
Deep Glide	37.9	22.6	1.2
Deep Slack	0	1.1	
Pool	3.9	0.9	0.6
Spawning	0.6	19.3	7.8
Young of year	57.7	78.6	98.2
Parr	41.7	24.3	1.8
Adult	3.9	2	0.6

One important observation was that the channel of the Tadnoll Brook upstream of the Warmwell cress beds was entirely dry.

5. RELATIONSHIP BETWEEN SALMON POPULATION AND FLOW

There is no constantly monitored gauging station on the Tadnoll Brook and therefore very little detailed information exists about the Tadnoll flow. Some good quality historic data exists from February 1972 to February 1977 taken at Owermoigne at site 1, but these do not coincide with many measures of salmon density. However, it has been correlated with data obtained for the East Stoke gauging weir on the main river Frome (Figures 5 and 6).

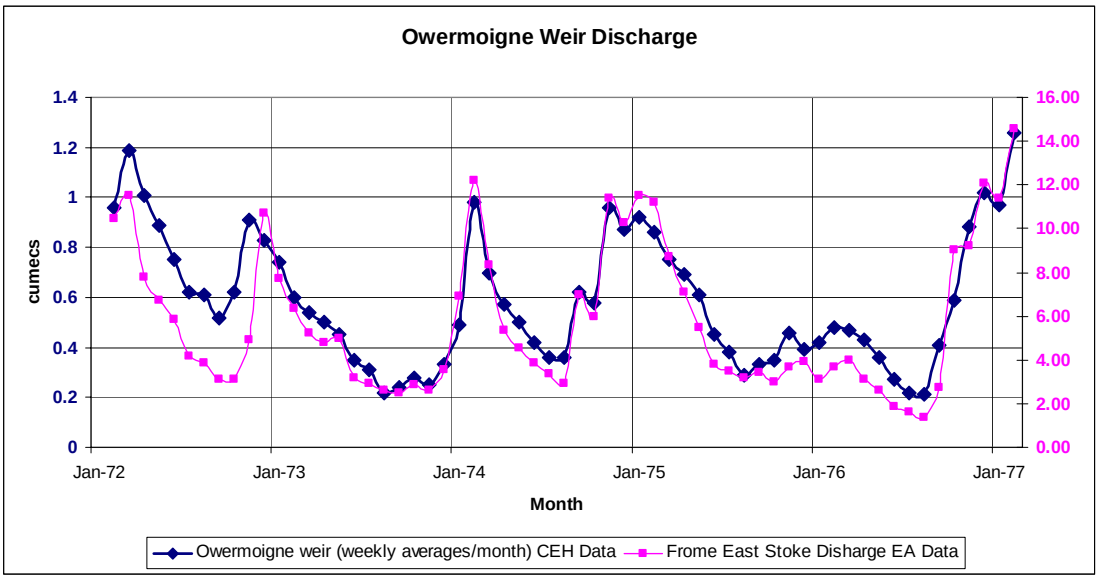

Figure 5 Temporal comparison of Tadnoll and Frome discharge

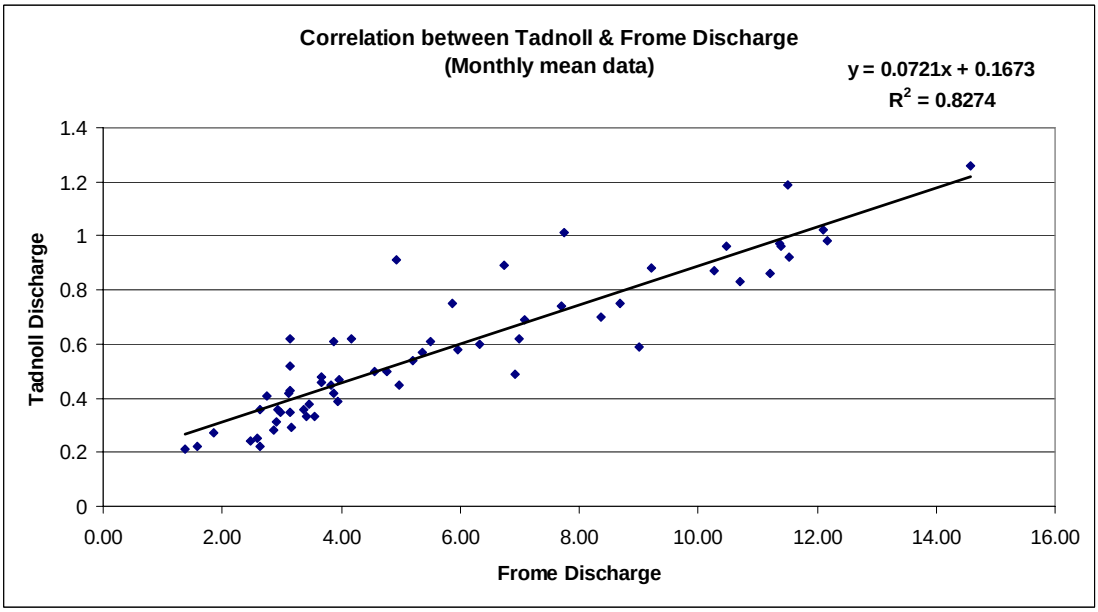

Figure 6 Correlation between R Frome East stoke discharge and Tadnoll Brook discharge

Overall a good correlation was found between the monthly means of Tadnoll discharge and Frome discharge.

$$\text{Tadnoll discharge} = 0.072 * \text{Frome discharge} + 0.17 \quad r^2 = 0.83$$

On average the Tadnoll discharge was ~11% of the Frome discharge, but it is not known whether this relationship still holds currently and there is not any monthly average data from the Tadnoll Brook available to test this.

The most notable impact of flow on the River Tadnoll salmon population may be its interaction with the partially impassable obstruction at Tadnoll Mill. Unfortunately we only have one data point (1976) for the population above the Mill and therefore it is not possible to draw any conclusions about the level of flow that would allow the Mill to be passed. This is further complicated by alterations in the management of the hatches and channels that will change the interaction between flow and passage.

Where there are more frequent measures of salmon population levels downstream of the Mill, the fish are more likely to have originated from other parts of the catchment and the relevance of these fish densities to flow rates are unclear. Whilst there have been a number of spot measurements in this area, without more knowledge of real-time flows it is difficult to understand the significance of a flow on one day for a population that has been affected by variable flow rates for months. This is further complicated when it is considered that in the 70's the fish population density was probably supplemented by spawning from upstream of the Mill and this no longer happens.

Now that salmon are to be re-introduced upstream and a pass installed at Tadnoll Mill a good question for the future is how will flows and abstractions impact the future naturally spawning population. Given the flashy nature of Tadnoll Brook current abstractions are less likely to impact winter flood events. They are most likely to have an impact during the late spring to autumn period. Since there is no data to base any reliable assessment of how fish populations have responded to flow rates in the Tadnoll Brook, the only recourse is to view the potential of each of the major abstractions on current flow rates to see if they are likely to be significant or not.

Empool is licenced to take the equivalent of 0.1 m^3 per sec. It is not known how much of this would find its way into the river. At the top of the Tadnoll Brook below the Empool abstraction the river channel is dry. This channel may not be important for salmon, given it is quite a small channel, but it will probably be important as a brown trout rearing habitat. By the time the Brook reaches Site 4, roughly in the centre of the best salmon habitat the flow has been measured at 0.25 cumecs (11/05/05) and 0.31 cumecs (5/07/05). Thus the Empool abstraction represents about a third of the current at that site. However, there are other abstractions as well and an accretion study recently completed by Wessex Water demonstrated that on occasions the equivalent of about 0.08 cumec was being lost in the vicinity of Warmwell gravel company leat, although on other occasions no water was lost in this region.

6. FUTURE WORK

The reality is that given the current paucity of data on salmon populations and good long-term time series of flow data, it is not possible to draw any conclusions about the impact of flow on the salmon population, other than that already stated with regard to the partially impassable structure at Tadnoll Mill.

Ideally, to study the response of the salmon population to flow one would like long term data on the smolt output of the Tadnoll Brook along with gauged data on river flows. Whilst CEH is setting up a system for measuring the smolt production, there is currently no reliable gauged data from an area relevant to the salmon population. Installation of such a gauge would be useful for longer term assessments.

Since it is not possible that such a data set could be compiled within the timescale of this review, the only other choice is resort to an indirect assessment of the impacts of flow on habitat. The PHABSIM model can be used to quantify the relationship between physical habitat and flow. This includes habitat in the downstream part occupied by salmon, and in the upstream reaches that appear more heavily affected by abstraction. PHABSIM requires field calibration data, and the spatial extent of the data collection would depend on the habitat heterogeneity (whether a single representative reach is possible) and the heterogeneity of the abstraction impacts as one goes downstream. Ideally, one would use PHABSIM, fed by inputs from a hydrological model, to simulate the effects of different abstraction regimes on the habitat, against a baseline naturalised scenario, going back up to 30 years, to cover climate variability.

7. DISCUSSION

Most of the historic data, on the fish population has been collected below Tadnoll Mill. Since there is so little spawning habitat in this area it seems likely that most of the juveniles recorded here were either spawned in the main river and migrated upstream into the Tadnoll Brook, upstream of Tadnoll Mill and drifted downstream or both.

The single survey of the salmon population in Section 2 above Tadnoll Mill provides enough evidence that salmon have made use of the habitat above Tadnoll Mill and the higher densities in Section 1 in this period may be representative of a supply of salmon parr drifting downstream from Section 1 as well as parr migrating upstream from the main river. Since the mid 90s when we know that the salmon population upstream of Tadnoll Mill was virtually extinct it can reasonably assumed that all the salmon parr observed in Section 1 would have migrated in from the main river.

It is not possible to know for certain why the salmon adults no longer migrate into the Tadnoll Brook and upstream of Tadnoll Mill. Even if the Mill could only be passed in winters with exceptional high flows, we would expect the homing nature of salmon to bring adults up the base of the Mill. However, in the last 3 years, regular observations by CEH staff in the plunge pool below the Mill have only found sea trout, implying that there is no longer a salmon population to home back to that tributary.

Since salmon are relatively short lived in the River Frome (3-4 years), such an extinction of the population could occur if the spawning grounds above Tadnoll Mill were not accessible for 3-4 years consecutively. In other words if there were 3-4 years of relatively dry winters then the Mill would not be passable in any of those years and the Tadnoll Brook salmon population would die out. Although there are no records for the Tadnoll Brook, examination of the river Frome flow records does show a period between 1988 and 1991 when winter flows were consistently below average (Figure 7). There is a possibility that this reduced the population to a very low level. Sea trout live much longer than salmon and would be able to survive these events, which possibly explains why sea-trout still exist whilst salmon do not.

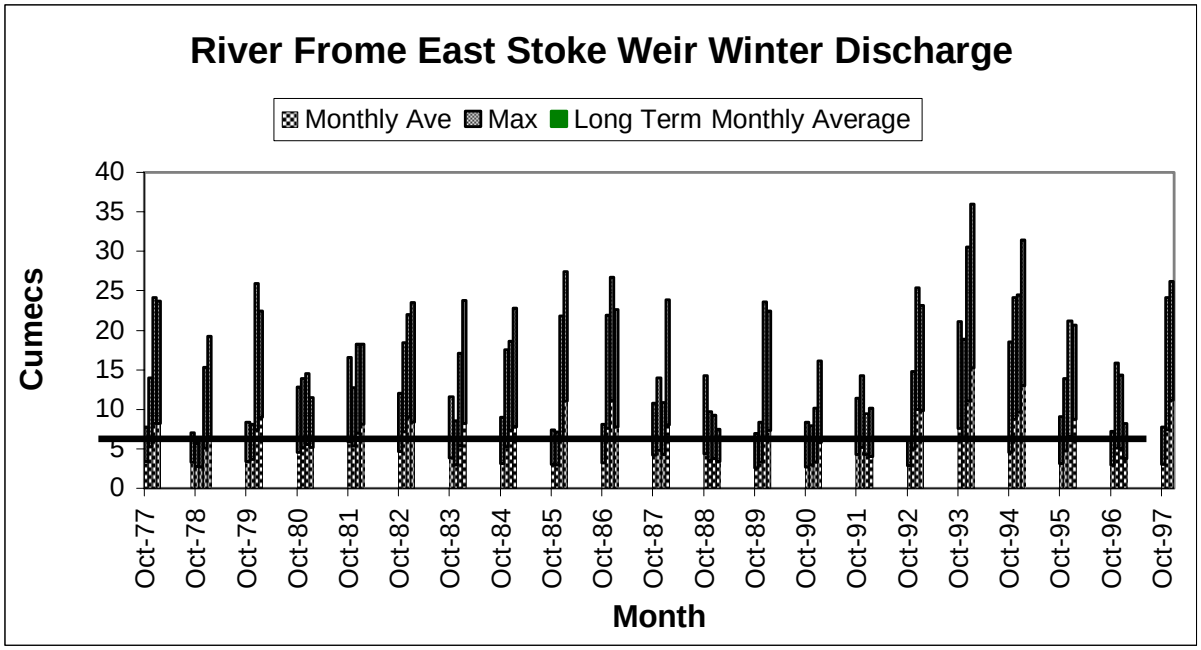

Figure 7 Long-term winter discharge at East Stoke weir 1977 – 1997

Losing the salmon population of the Tadnoll Brook will have a significant impact on the River Frome smolt output and adult returns. To estimate this impact we have taken the only measure of parr densities we have for the Tadnoll Brook above Tadnoll Mill and multiplied it up to fill the suitable habitat that is currently unused. This equates to 15,750 m^2 x .309 salmon per m^2 = 4870 late summer parr. To convert this into smolt output we have used a figure of 20% survival from late summer parr to smolt survival that we have found from other sites on the Frome, which gives a value of 974 smolts. To put this in perspective, the total smolt run for the Frome is about 6-8,000 smolts per year. The Tadnoll Brook could therefore represent 12-15% of the future River Frome smolt production.

CEH will this winter (December 2005) attempt to re-introduce salmon to the Tadnoll Brook with the use of stream-side egg incubation boxes. Assuming that this will be successful and that the pass on the Mill is completed, this should result in the re-establishment of a natural salmon population above Tadnoll Mill.

The impact of flow and abstraction on this future population is not known. However, the rate of abstraction at Empool represents approximately a third of current summer flow rates in the important salmon habitats, if it assumed that all water abstracted would enter the Tadnoll Brook. A ground water model would be useful here to gain better data on the flow impact of this abstraction.

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