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Tadnoll Brook; Final Report

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1. 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 1990s 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. In 2006 a suitable easement was constructed on the Mill and in the winter following successful spawning occurred upstream. It is expected that this easement will allow free passage upstream even in years with lower than average winter flows.

Introductions of salmon parr in 2003 and swim-up fry during 2006 and 2007 together with the easement should facilitate the return of adult salmon to the best salmon rearing habitat above Tadnoll Mill. The swim-up fry introduced during 2006 led to densities of parr in the autumn that were comparable to densities found on the river Frome; and these parr further produced smolts emigrating the river during spring 2007. This suggests that the flow conditions during 2006 were adequate to support a healthy salmon population should successful spawning take place. A similar comment can be made about 2007, when considering survival of the naturally spawned fish to the autumn parr stage.

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 no long-term data on the salmon populations or flow levels that enable a direct assessment of the impact of summer flows on those populations. This is a major gap in knowledge in the review of the Empool abstraction. Currently, it is only possible to repeat the above statement that the flow conditions of 2006 and 2007 during the summer appear to be adequate to support a population density of salmon to that found on the River Frome.

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.

2. 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).

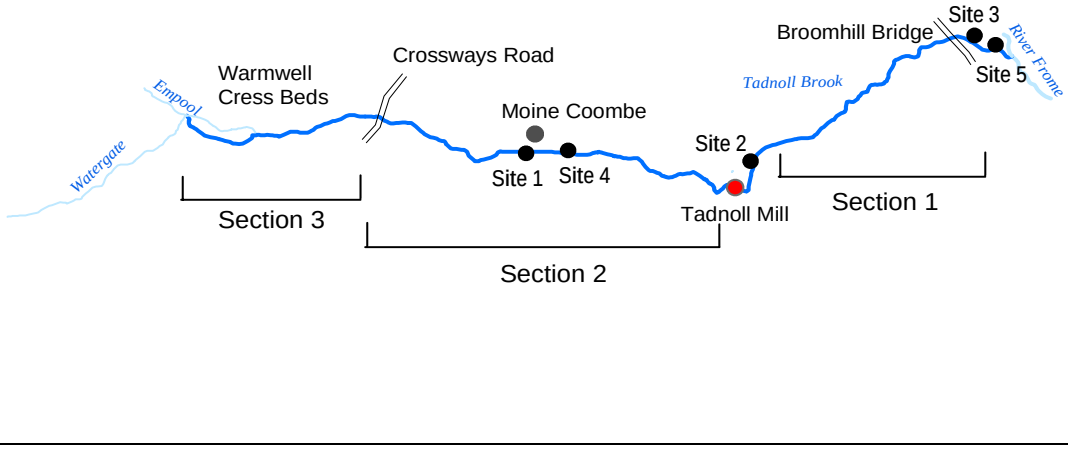


Figure 1 Schematic diagram of the Tadnoll Brook showing fish survey sites

It is thought that by the late 1990s the salmon population above Tadnoll Mill had become extinct. The most likely cause of this extinction was a series of low winter flows in the late 1980s interacting with a partially impassable barrier at Tadnoll Mill (Ibbotson, 2006a). Since 2003 efforts have been made to reintroduce salmon by adding 200 parr moved from the lower Frome in September 2003 and latterly using fish stocked as swim-up fry from stream-side egg incubation boxes (2006 & 2007). In 2006, an easement was installed at Tadnoll Mill, to facilitate upstream migration of adult salmon upstream.

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 2 NERC grants to study the effects of perturbations (introduction of salmon and removal of tree canopy) on 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.

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

This final report:

- Collates and 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, describes and discusses the easement to the obstacle at Tadnoll Mill
- Reports on those areas of the Tadnoll Brook with suitable habitats for salmon.

3. BARRIERS TO UPSTREAM MIGRATION OF SALMON ADULTS

In 2005 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 was identified at Tadnoll Mill (Figure 2). Assessment of the seriousness of this barrier was 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 was built.

With the flow at Tadnoll Mill split between effectively four channels it is probable that it represented 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 has admitted in the past 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 create another pipe 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.

An easement to upstream passage partially funded by the Environment Agency was completed in 2006 on the step structure to make this more passable (Figure 2). Initial reports from the migration of adults during the winter 2006/2007 suggest that adults are now migrating upstream over the structure without assistance. In addition, juvenile salmon have been observed during the 2007 surveys (see below), in regions where they were not stocked, for the first time since the late 1990s. Thus it is thought that whilst no conditions for the operation of the fish pass have been set in regard to the amount of water flowing over it, minimal flow over the pass will make this structure passable, and since salmon migrate upstream during flood events it is likely that Tadnoll Mill is no longer a significant barrier to upstream migration.

In 2006, antennae were installed on the easement and around the flood relief channel for detecting both downstream and upstream fish tagged with passive integrated transponder (PIT) tags.

Figure 2 **Photographs of the step structure at Tadnoll Mill before and after installation of the easement in 2006.**

4. REVIEW OF HISTORIC AND CURRENT SALMON POPULATIONS

4.1 Historic 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 groundwater 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 and between 2005 and 2007 under contract to Wessex Water (Table 1). All the surveys completed by CEH prior to 2005 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 data are often only exhibited in pictorial form with graph axes that 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
2006	3.4	7.9		Site 3 & 5	CEH & Agency - Q
2007	9.0	4.5		Site 3 & 5	CEH & Agency - 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.

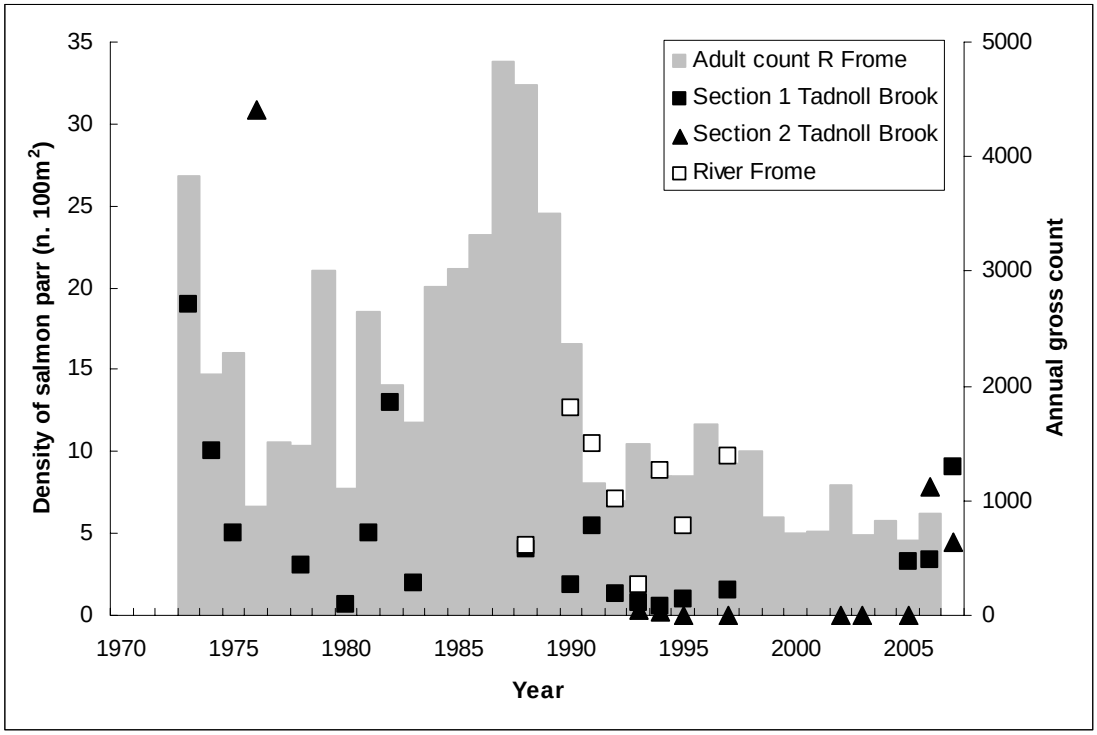


Figure 3 **Estimated densities of salmon parr in the River Frome, Section 1 and 2 of the Tadnoll Brook over time together with annual gross counts of adult salmon.**

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 historic data for Section 2 is so poor it is difficult to draw many conclusions. However, it is clear from the 1976 survey that local 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). More recently in 2006 and 2007, densities in Section 2 increased to levels that are comparable to the River Frome salmon parr densities. In 2006 this was the result of stocking with swim-up fry and in 2007 it was probably the result of limited natural spawning.

4.2 Re-introduction of salmon

In both 2006 and 2007 swim-up salmon fry were stocked into the Tadnoll Brook. In both years, the swim-up fry were reared in salmon egg incubation boxes located at Watergates Fish Farm. The source of the eggs was wild adult salmon collected from

the River Frome during the preceding spawning period. In 2006, Tadnoll Brook was stocked in three reaches, but in 2007 only Watergates Stream was stocked (Table 2).

Table 2 Numbers and location of swim-up salmon fry stocked in the Tadnoll Brook in 2006 & 2007

Site Name	Grid Reference	2006	2007
Watergates	SY 744 873	6228	3569
Site 3 (Figs. 4 & %)	SY 778 872	6000	0
Ford u/s Tadnoll Mill	SY 785 869	500	0

4.3 2006 & 2007 Parr Densities

Surveys were undertaken during August/September 2006 (Ibbotson et al 2006b) & 2007. Five discrete sites were surveyed (Table 3; Figure 4). All salmon captured in these surveys were PIT tagged in order to monitor their migration out of Tadnoll Brook; their contribution to the River Frome smolt population; their subsequent contribution to the River Frome adult salmon population and their return or otherwise to the Tadnoll Brook.

In addition, in July 2006, the whole river between Site 4 (immediately downstream of Tadnoll Mill) and Site 2 (upstream of Moigne Coombe) (Figure 5) was surveyed to investigate the distribution of stocked salmon parr a few months after the introduction.

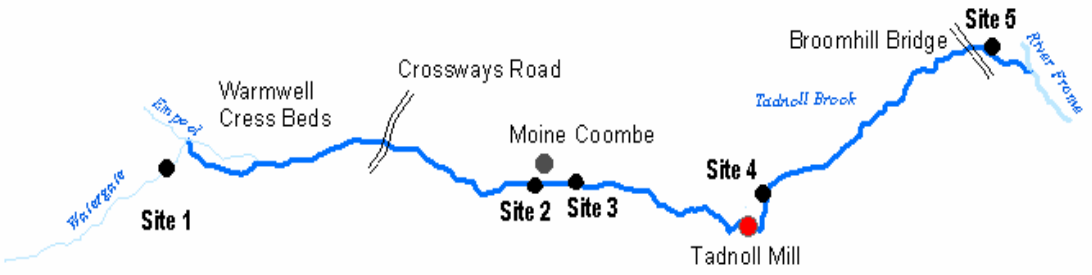


Figure 4 Location of salmon parr survey sites in August/September 2006 & 2007

Table 3 Densities of salmon parr at five survey sites on the Tadnoll Brook in August/ September 2006 & 2007

Site Number (see Figure 2)	Grid Reference	Density of salmon parr 2006 (n 100m^{-2})	Density of salmon parr 2007 (n 100m^{-2})
1 (Watergates)	SY 746 873	7.6	2.2

2 (U/S Moigne Coombe)	SY 771 871	0	2.5
3 (D/S Moigne Coombe)	SY 779 872	7.9	4.5
4 (Tadnoll Mill)	SY 794 871	0.5	0.9
5 (Broomhill Bridge)	SY 813 881	3.4	9.0

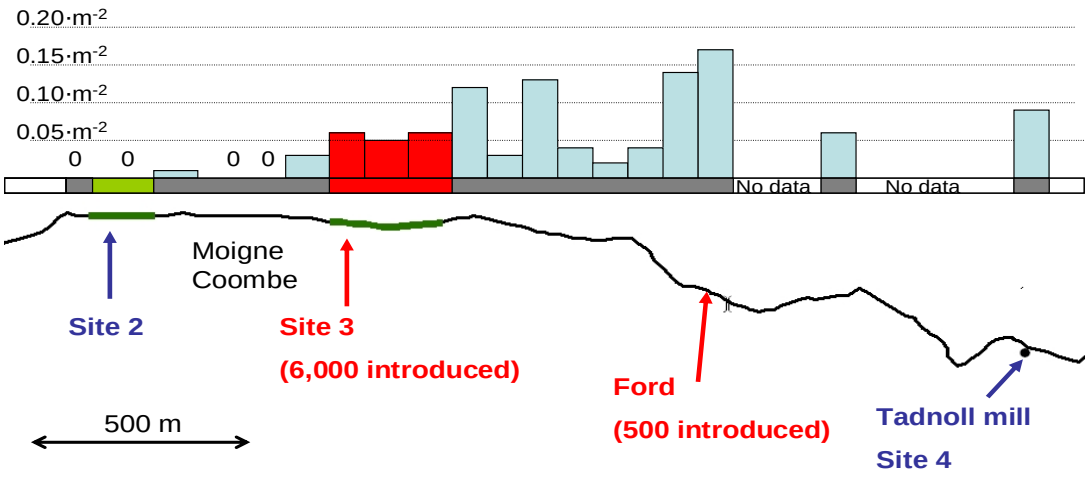


Figure 5 **Densities of salmon parr in July 2006 within 100 m sections between Moigne Coombe and Tadnoll Mill**

In 2006, when swim-up fry were stocked out from incubation boxes, densities of salmon parr at the site of stocking and downstream showed densities ranging from 5 per 100m^2 to 17 per 100 m^2. These are very comparable to densities of salmon parr found at sites on the River Frome, suggesting that the Tadnoll Brook is capable of supporting salmon parr as and when successful spawning takes place.

The July 2006 survey clearly showed that salmon parr had distributed several hundred metres downstream from the original stocking site below Moigne Coombe (Site 3), but that upstream distribution was minimal, such that no salmon were found 500 metres above the stocking site. Average densities of approximately eight fish per 100 m^2 are similar to average densities found in the River Frome during annual parr surveys, although care should be taken in making this comparison as parr surveys of the Frome are usually done later in the year.

In the area of river upstream of Tadnoll Mill the autumn surveys in 2006 (Table 3) showed similar densities of fish at the sites where swim up fry had been stocked, but zero to low densities in regions where they had not been stocked. Below Tadnoll Mill, densities of approximately three fish per 100 m^2 were found which is consistent with densities found in recent years in that part of the river (Figure 3). This is lower than the densities found in the stocked sites, and it is suggested that these fish represent immigration from natural spawning that occurs in the main river rather than spawning that has occurred in the Tadnoll Brook.

In 2007, the presence of salmon parr at both Sites 2 & 3 above Tadnoll Mill, probably represent the first natural successful spawning of salmon since the early 1990s. The source of the adult female/s is not known. It is conceivable these were 2 sea-winter

adult females from the movement of parr into the Tadnoll in 2003. However, this important observation demonstrates that the easement at Tadnoll Mill works and combined with the reasonable densities achieved with stocking, it suggests that over time the Tadnoll Brook could support a population of salmon comparable to the River Frome.

4.4 River Frome and Tadnoll Brook Redd Counts

Years where counts of the entire catchment 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 entire catchment was surveyed (2005) indicated 42 redds in the Tadnoll Brook (~13% of the Frome number) (Figure 6).

In 2006 a further redd survey of the Tadnoll Brook was completed with 26 redds found but no survey was done on the River Frome due to funding restrictions. Most of the large redds on the Tadnoll Brook in 2005 & 2006 are found upstream of Tadnoll Mill and downstream of Crossways Bridge (Section 2) (Figure 7) confirming the view of the habitat surveys that this section provides the best habitat for spawning (Ibbotson 2006a).

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 successfully in Section 2, this seems very unlikely until 2006 when juveniles were found for the first time in 2007 since the late 1990s.

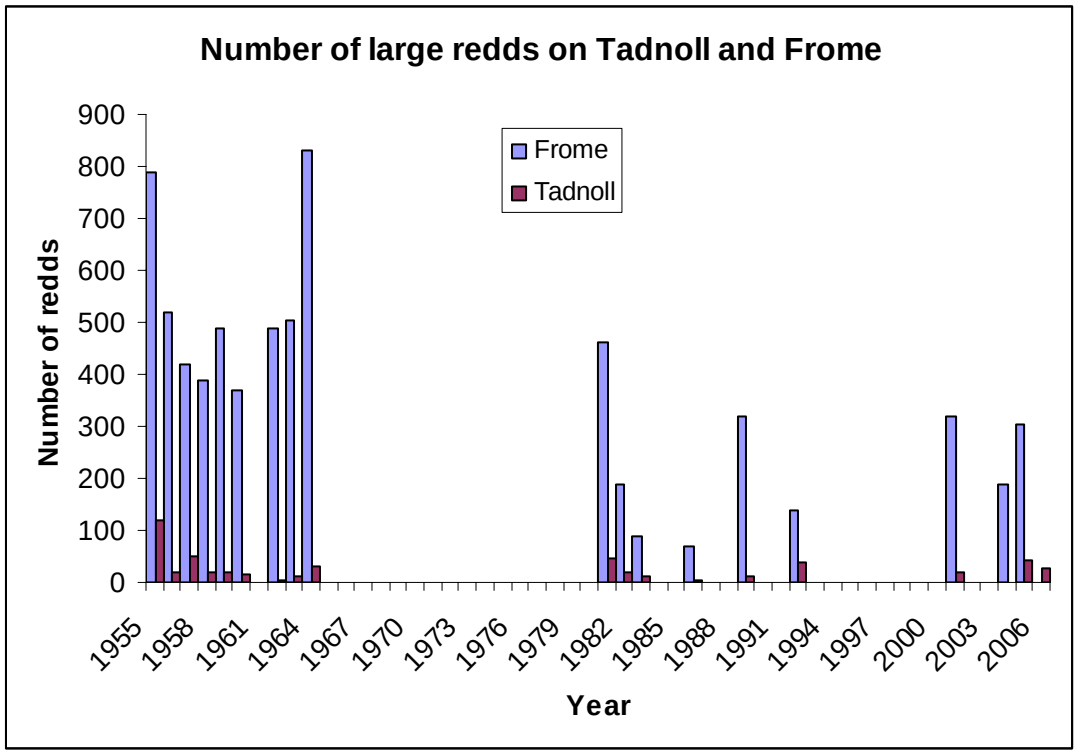
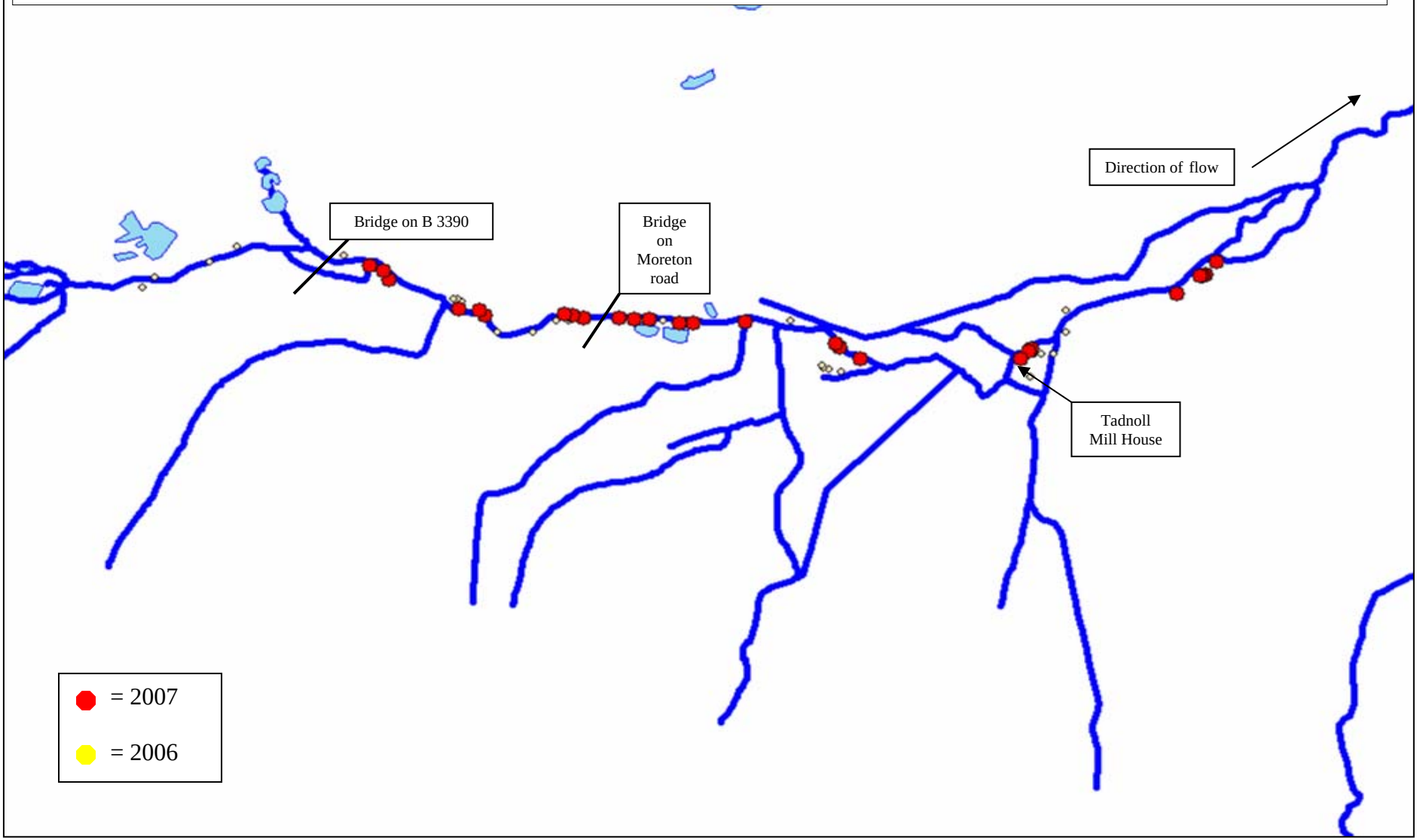


Figure 6 Large redd numbers on Tadnoll Brook. Zero values indicate survey not carried out

Figure 7 Location of large redds in Tadnoll Brook in winter 2005/2006 and 2006/2007



5. SMOLT PRODUCTION

It is possible from the data collected to make an approximate estimate of the number of 1 year old spring smolts that emigrated from the Tadnoll Brook past the East Stoke smolt counter.

In 2006, from the main River Frome, it was estimated that approximately 15.2% of autumn parr emigrate from the river as 1 year old smolts. The comparative figure for the Tadnoll Brook was 16.2%. From the number of fish tagged in the main river we estimate that the total smolt run was ~16,000 smolts in spring 2007. From the population densities, of the extensive survey completed in July 2006 we estimate a total population of ~1000 autumn parr above Tadnoll Mill, with 16.2% of these emigrating as spring smolts. That is ~162 smolts. These figures have to be regarded with a great deal of caution as they are dependent on the true efficiency of the smolt counter, which is not known until the adults return.

In previous studies it has been estimated that the Tadnoll Brook could produce between 1000-1500 smolts if it were fully populated by salmon. Evidence from this study suggests that the Tadnoll Brook can support populations at the same level as the main river Frome and that conversion to spring smolt might be at a slightly higher percentage. Therefore the conclusion is that once a naturally spawning population becomes fully established this may be a reasonable estimate.

6. 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 4). 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 4 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 5). 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 5 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.

7. 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 8 & 9).

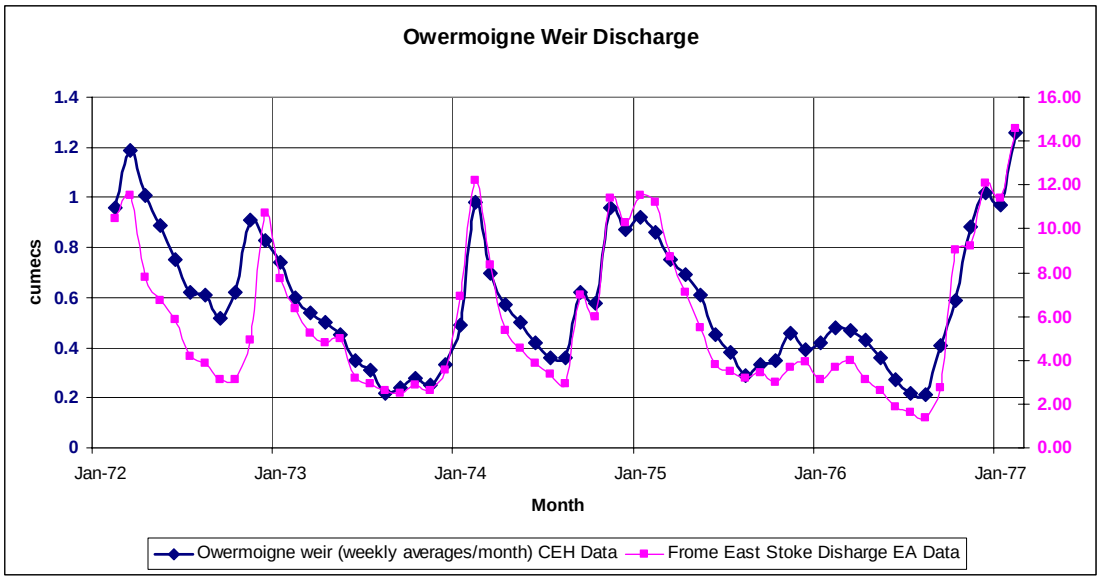


Figure 8 Temporal comparison of Tadnoll and Frome discharge

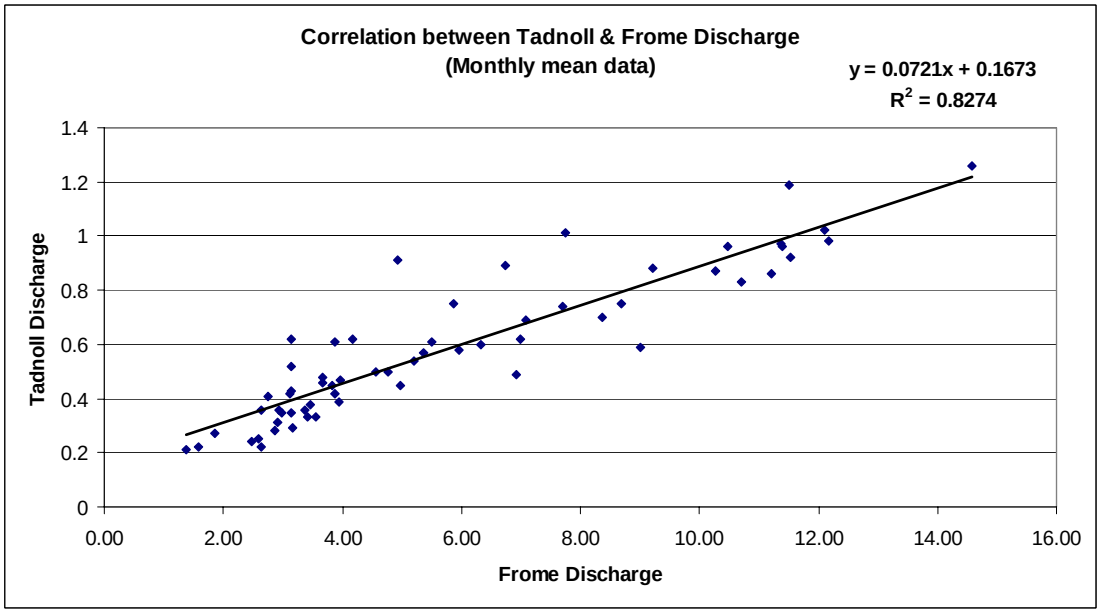


Figure 9 Correlation between R Frome East stoke discharge and Tadnoll Brook discharge

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

Tadnoll discharge = 0.072* Frome discharge + 0.17 $r^2 = 0.83$

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 historic impact of flow on the River Tadnoll salmon population may be its interaction with the partially impassable obstruction at Tadnoll Mill. Unfortunately, prior to the installation of the easement 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 prior to the installation of the easement. This is further complicated by alterations in the management of the hatches and channels that will change the interaction between flow and passage. However, the easement seems to have had its intended effect with at least one successful spawning recorded in the Tadnoll Brook last year. Since migration into the Brook occurs in November/December, during flood events it is likely that Tadnoll Mill will now no longer represent a barrier to upstream migration.

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 1970s the fish population density was probably supplemented by spawning from upstream of the Mill and this no longer happens.

The successful survival of the swim-up fry introduced to the Tadnoll Brook in 2006, with resultant densities (7.9 $100m^2$) of parr in the late autumn that compare favourably with those observed in the Frome; suggests that the flow conditions in the Tadnoll Brook during 2007 were sufficient to support a salmon population, once successful spawning takes place. The successful spawning that is now known to have taken place in the winter of 2006/2007 has also produced a reasonable density of salmon parr (4.5 $100m^2$). Although this was lower than the density produced by the stocking in 2006 we may expect this to increase in future years as more fish home back to the Tadnoll Brook.

Given the higher winter flows 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 long-term data to base any reliable assessment of how fish populations have responded to variable inter-annual 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 licensed to take the equivalent of 0.1 m^3 per sec. At the top of the Tadnoll Brook below the Empool abstraction and above the cress farm at Warmwell 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 3

(Figure 1), roughly in the centre of the best salmon habitat the flow has been measured at 0.25 cumecs (11/05/05), 0.31 cumecs (5/07/05), 0.32 cumecs (5/07/06), 0.20 cumecs (16/08/06), 0.25 cumecs (31/07/07), 0.225 cumecs (06/08/07). The presence of salmon during these flows would suggest that these flows will support a juvenile salmon population.

8. REFERENCES

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