# Some thoughts on channelized streams, salmonid fish and their management in arable eastern Scotland.

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## Introduction

The idea for this note arose from consideration of issues raised in a consultation on *Improving the physical condition of Scotland's water environment* which SEPA issued at the end of 2012. It is intended to suggest how channelized streams in arable areas of eastern Scotland might best be managed for the benefit of salmonid fish populations.

It considers the following issues.

1) Straightened streams and erosion
2) Sediments in channelized streams
3) Straightened channels as fish habitat
4) Riparian vegetation along channelized streams
5) The need to avoid maintenance dredging
6) Overall conclusions
7) Appendix 1. The stability of historically channelized streams in eastern Scotland
8) Appendix 2. Why does maintenance dredging occur?
9) Appendix 3. What might channelized streams in lowland eastern Scotland have looked like before the agricultural revolution and what has been the effect of channelization on them?
10) Appendix 4. Elements of lowland stream habitats that are important to salmonids.
11) Appendix 5. – Effects of shading from riparian trees on fish "cover" in lowland streams.
12) Appendix 6. An example of low cost improvement to salmonid habitat in a steepened channelized stream
13) Appendix 7. Channelized streams in lowland Scotland and "climate proofing"

## 1) Straightened streams and erosion

At various points, the SEPA consultation document referred to erosion problems caused by straightened streams. For example, on page 19, under Agriculture, it says that "this means that on-going maintenance such as dredging....is needed". The first scenario in the consultation's Table 3 also implied that rivers on high value agricultural land may have problems with "erosion and siltation" and that a key objective is to "find mechanisms to stabilise river and reduce management requirements".

Table 3 also implied that re-meandering such streams might be a desirable thing, though perhaps unachievable in high value land. Of moderate and low value land, Table 3 mentioned "re-engineering some sections of river to ensure more sinuous and stable channels".

One implication from the consultation document appears therefore to be that channelization, in itself, leads to channel instability, although no distinction was made between grazed channels and ungrazed channels. (It would have been helpful if a distinction was made between arable and grazing land.)

I question this generalisation, at least on arable land in eastern Scotland.

For example, much of the channelization in the arable areas of eastern Scotland was performed a long time ago – certainly before the publication of the first Ordnance Survey maps (i.e. before *circa* 1870). While it is likely that some catchments may have experienced significant in-channel erosion immediately following the initial diversion works (probably downcutting rather than lateral erosion as channels adjusted to new base levels), these have long reached some form of quasi-equilibrium and no longer erode to any great degree, if left alone. In many arable catchments in eastern Scotland, the banksides of channelized streams have been colonised by thick growths of reedy grasses such as reed canary-grass (*Phalaris arundinacea*) which very effectively protect them from erosion, provided they are not subject to heavy grazing. Numerous examples supporting this conclusion are described in Appendix 1.

## 2) Sediments in channelized streams

It is true, however, that lowland arable streams can be affected by sedimentation. The deposition of fine sediment in such channels and its subsequent stabilisation and assimilation into the banks or marginal berms by the sturdy grasses referred to, causes a loss of channel capacity and unfortunately often results in a need or perceived need for maintenance dredging (see Appendix 2). That can have disastrous ecological consequences, in the short term at least.

The problem, in such circumstances, is caused by sediment that has been generated further upstream, often by direct run-off from the land surface rather than from eroding stream banks. An example of this type of effect, in a predominantly arable catchment in southern England, is described in Walling & Amos (1999).

The only real way to cure this issue, and therefore to reduce the necessity for the highly damaging practice of maintenance dredging, is to reduce soil erosion in the wider catchment. The sinuosity of the channel will have little bearing. Indeed, if anything, re-meandering may make sedimentation effects worse. This is because one effect of historic channel straightening was to increase the gradient of channels, due to channel shortening and re-alignment along the steepest axes of floodplains. The reinstatement of sinuous channels will reduce gradients and therefore current velocities. "Restoring" sections of channelized streams which have high sediment loads will cause increased deposition rates in the "restored" areas making them more prone to flooding and requiring a greater necessity for dredging (see photos on page 23, Appendix 3). Indeed, one of the stated aims of the restoration of the Savoch Burn (one of the first examples in Scotland where re-meandering was done) appears to be to encourage the deposition of sediment before it reaches the Loch of Strathbeg, albeit in an in-channel impoundment.

Therefore, rather than curing sedimentation problems, channel "restoration" without effective soil erosion control in the wider catchment may actually exacerbate them.

### 3) Straightened channels as fish habitat

The consultation document also suggested that straightened channels represent a degraded habitat for fish.

I agree that channelization can sometimes be a problem for fish, but not always, particularly for salmon. This is now explained.

#### *Habitat requirements of salmonids*

Juvenile salmon are widely known to favour riffle type habitats with coarse substrates in which they hide, although there is a significant degree of latitude around optimum habitats.

Trout, particularly juvenile trout, may also use similar habitats to those preferred by juvenile salmon, but as they grow, trout are classically considered to prefer pool habitats. While trout also benefit from physical cover in mid channel, they are well known to like to hide beneath undercut banks / marginal vegetation.

Salmon are, therefore, a species typically associated with rivers of significant gradient, whereas trout are more successful than salmon in lower gradient channels, but can occur in steep streams too. As trout are often associated with the bank, they are often proportionally more numerous in smaller streams.

This difference in distribution is significant with regard to channelized streams, as now explained. (A further summary of juvenile salmon and trout habitats is provided in Appendix 4.)

***Implications of historic channelization in eastern Scotland on salmonids***

In the arable areas of eastern Scotland, it is clear from the mid $18^{th}$ century Roy Map, that the great majority of currently straight channels were once meandering. This is true even in catchments with very low gradients. It is likely, therefore, that many lowland streams were "naturally" dominated by pool habitat. Substrates would also have been relatively fine – gravels, sands and silts. The effect of historic channelization would not have been to remove coarse substrates. Boulders, for example, would not have been present in such reaches. (Some examples of what lowland streams in eastern Scotland may have looked like immediately prior to the agricultural revolution are provided in Appendix 3.)

The widespread channelization of the early $19^{th}$ century would have created shorter but steeper channels with coarser substrates. Where valley gradients were very low, pool type habitats may have remained dominant, but in other areas riffle type habitats became dominant (Appendix 3).

Historically, the meandering streams of lowland Scotland may therefore have been more of a habitat for trout rather than juvenile salmon. The most important habitat for salmon would have been the mainstems of steeper rivers. Channelization may have improved prospects for riffle loving juvenile salmon in many cases, particularly where channels have been allowed to naturalise to some degree. Adult resident brown trout are likely to have been the biggest loser. It is certainly the case that some historically channelized streams are very productive of salmon.

For example, in the 2011 RAFTS led site condition monitoring of Scottish SAC salmon rivers (not yet available publicly?), the top two fully quantitative Tay district sites for juvenile salmon were in channelized streams, the Keithick (Coupar) Burn and the Kerbet Burn (see page 36 for site photo). The best timed electrofishing site was on the channelized Glamis Burn. Those two top quantitative sites had no equals in any other Scottish SAC except for two sites in the Tweed catchment, one of which is clearly also a channelized stream, the Heriot Water. The Glamis Burn timed CPUE was only beaten by two sites in Scotland, one on the River Almond and one on the Tweed. An even higher abundance of juvenile salmon was since found in the channelized Dunning Burn, a tributary of the River Earn, in 2012 (see photo on page 27).

***Implications of salmonid habitat preferences for the "restoration" of channelized streams***

In cases where old channelized streams are productive for salmon, the process of re-meandering could potentially have negative consequences for them. Even in lower gradient valleys, migratory (sea) trout could lose out to resident (brown) trout as slow deep pool habitats increase at the expense of shallow spawning riffles giving rise to less dense populations of faster growing fish.

In England, one of the drivers of interest in re-meandering rivers and creating off channel ponds etc is that habitat may be improved for some species of cyprinid fish. However, as no cyprinids are indigenous to Scotland, this concern does not apply here.

While it is appreciated that there may be other reasons for seeking to re-meander rivers in some instances, it should not be assumed that re-meandering will automatically be of benefit to salmon fisheries, although this often seems to be assumed to be the case. If improving habitat for juvenile salmon is the goal, it might be more successful and much more cost-effective simply to accelerate natural processes within an existing channelized watercourse, taking advantage of the higher gradient of channelized streams (see Appendix 6).

***A case for reclassification?***

From the foregoing, I would suggest that, just because a stream has been channelized in the past, it should not be assumed that the population of migratory salmonids, at least, will be poor. In some streams the opposite will certainly be true.

It is my understanding that when the ecological status of waterbodies was classified, it may have been assumed that straightened channels were at less than good status simply because they had been modified rather than on the basis of biological data, particularly for fish. If so, such streams should be ground truthed with fish data and reclassified if necessary.

Where biological data do support a downgrade of channelized streams, I would again suggest that care needs to be taken to disentangle the effects of "morphology" from diffuse pollution (including sedimentation) which commonly occurs in the same streams. As I have explained, diffuse pollution / sedimentation is not a consequence of channelization in itself. The real focus for restoration in lowland areas should be on wider diffuse pollution, as opposed to channel morphology. The latter will take care of itself if the former can be cured, ending the requirement for maintenance dredging (see Appendix 2).

## 4) Riparian vegetation along channelized streams

On several occasions the SEPA consultation document appeared to promote the planting of trees in riparian areas. There was also reference to "damaged" bank side vegetation. However, on page 19, in the Forestry Section, the document also stated, with reference to forestry plantations, that "shading prevented the growth of bankside vegetation". In fact the same problem can also occur with deciduous trees. I offer some clarification on issues surrounding riparian vegetation below.

### *4.1 What is the best type of riparian vegetation for salmonid fish in arable lowland catchments?*

#### *4.1.1 The value of riparian vegetation as fish cover*

As previously explained, juvenile salmonids require some form of physical cover in streams, e.g. a coarse substrate or, indeed, "woody debris". However, submerged macrophytes can also provide this, particularly in lower gradient streams where coarse substrates are lacking. Salmonids also benefit from cover along the stream margin. I stress this is physical cover in the actual water. Physical marginal cover can be provided by undercut banks or coarse marginal substrate (yes, even rip-rap can be a wonderful habitat for fish in certain circumstances). It can also be provided by emergent vegetation or terrestrial vegetation which drapes through the water surface. In lowland arable areas, for example, dense growths of species like reed canary-grass or reed sweet-grass, which encroach on the channel, can provide excellent cover (see photos page 32). In addition the encroachment of such plants in summer helps to cause channel narrowing and flow concentration during low flow periods. However, boughs which drape over the water surface, but not in it, may create shade but that is not the same as cover.

In steeper streams where coarser substrates like cobbles or boulders dominate, bankside vegetation is less critical or even irrelevant as cover. But, as the consultation was principally about streams with altered morphologies, the main concern must be about the lowlands.

#### *4.1.2 Impact of shading from trees on fish habitat in lowland streams*

When trees dominate the riparian zones of lowland streams, their shade suppresses algae, submerged macrophytes and low marginal vegetation. Consequently, channels with low calibre substrates widen and erode out into the bases of the tree roots. Depths, current speeds and cover are reduced. Invertebrate production can also be reduced. A number of studies have demonstrated that, where such effects occur, fish production can decline (e.g. O'Grady 1993). For examples of the effects see Appendix 5.

Therefore, rather than promoting the planting of trees along lowland streams, from a fish perspective, it may in fact be preferable in many cases to promote exactly the sort of reedy vegetation that is already widespread. Thus, many streams on arable land may actually be perfectly fine for fish as they are in terms of bankside vegetation (see examples in Appendix 1 as well as Appendix 5).

*4.1.3 Riparian shading – climate change issues*

Another issue which the consultation hinted at is the promotion of riparian tree shading to mitigate possible temperature rise in future. This issue is already gaining ground and even attracting grant funding for implementation.

However, I have been of the opinion that it may be premature to recommend the blanket establishment of such a policy. Hardly any detailed research has been conducted on the subject in Scotland. This deficiency must be addressed first.

There are many questions that require investigation. For example:

- What is the risk that streams / rivers really will really suffer from overheating? Which types are most at risk and are there any that are not at risk?
- Is the risk of overheating offset by other benefits of warmer temperatures? The optimum temperature for juvenile salmon growth is 16 degrees after all.
- How effective will shading be in reducing temperatures anyway? How much shading is required and with what? How does shade relate to stream type etc?

I first wrote this several weeks ago and, in the interim, we have experienced the warmest summer weather in eastern Scotland for a number of years. Consequently I was able, to a limited extent, to try to answer some of these questions. On several hot afternoons in July 2013 spot temperature readings were taken using simple garden centre thermometers, mostly in streams close to our office at Almondbank. Some pertinent results are presented in Appendix 7.

As detailed in Appendix 7, the conclusion of that exercise is that narrow incised channelized streams are actually well proofed against high temperatures if they have dense marginal vegetation. In fact one stream which had been recently dredged and had yet to re-establish good vegetation cover was warmer than others that had good cover.

### *4.2 Conclusions on Riparian Vegetation*

On the basis of the above, it would seem to be the case that, as far as salmonid fish are concerned, the best type of vegetation to encourage alongside lowland streams may be dense grassy / reedy vegetation, which is exactly what you get along arable channelized streams anyway. In smaller channelized streams, at least, this vegetation may also effectively protect them from any future temperature extremes. Therefore, rather than encouraging the planting of trees, perhaps we should instead seek to maintain coarse reedy vegetation. However, this has its own challenges, as described below.

## 5) The need to avoid maintenance dredging

In lowland streams, as stated, encroaching marginal vegetation can be very important in providing fish cover. By encroaching in the channel such vegetation creates variation in water velocities, depths and sediment sorting, providing even greater ecological benefits. However, it is precisely this recovery process that farmers do not like and leads to the desire for maintenance dredging (Appendix 2).

Maintenance dredging operations remove vital cover for fish and other valuable features such as sorted gravels which are used for spawning. Given time, the habitat quality will improve again, the time and extent depending on local circumstances. Vegetation will return and sediment sorting may occur. Habitat variation will develop, until that is, it is dredged again.

The practice of periodic dredging is therefore the biggest concern for fish in many channelized streams.

As outlined already, if good fish habitat is to be maintained or to be allowed to develop, this problem has to be reduced by removing the sediment problem, i.e. controlling land erosion at source, or perhaps, where possible, trapping and removing the sediment from watercourses (e.g. see Hansen, Alexander & Dunn 1983).

## 6) Overall Conclusions

From the foregoing arguments I conclude that, at least as far as migratory salmonid fish are concerned (bearing in mind many channelized burns are SACs for salmon), the historic straightening of many streams may not be the issue it is often assumed to be. Indeed, if appropriate habitats can be maintained within these channels, many might be better for salmon than they would be with a natural planform, particularly with modern sediment loads, because of their more appropriate gradients and substrates. Therefore, expensive re-meandering exercises may not bring about benefits for such fish. Indeed, in some cases, they may even have negative impacts.

Channelized streams might therefore be best left alone, apart from some instream modifications, if appropriate. The big issue is to cure wider land erosion, if sedimentation / maintenance dredging is a problem. However, there may be a need to develop management regimes for preventing overshading by trees where that is likely to occur.

**References**


Hansen, E A, G A Alexander and W H Dunn (1983) Sand sediment in a Michigan trout stream. Part I. A technique for removing sand bedload from streams. *North American Journal of Fisheries Management,*3, 355-364.

O’ Grady M.F. (1993) Initial observations on the effects of varying levels of deciduous vegetation on salmonid stocks in Irish waters. *Aquaculture and Fisheries Managemen*t, 24, 563-573

Walling D E & C M Amos (1999) Source, storage and mobilisation of fine sediment in a chalk stream system. *Hydrological Processes*, 13, 323 – 340.

# Appendix 1

**The stability of historically channelized streams in eastern Scotland**

This section contains examples illustrating the stability of historically channelized streams in eastern Scotland. They are based on photographs largely taken around 1990 in NE Scotland, often taken shortly after some maintenance dredging had taken place. By using recent Google Street View images, where available (many of the photos were taken from road bridges), a comparison over time can be made.

**Figure 1.1.** Adziel Burn, tributary of North Ugie Water, Aberdeenshire. Photo on left taken *ca* 1990 relatively soon after maintenance dredging of historically straightened channel. Despite having recently been dredged, the banks had effectively re-vegetated. Note the riffle nature of stream and clean gravel substrate. Recent photo on right from Google Street View. It is not really possible to see the stream, but there has been a major growth of planted trees on south side and establishment of dense grassy vegetation on the north bank which appears to be part of some buffer strip scheme. In 1991, densities of 0.04 salmon fry and 1.05 trout fry per square metre were found here on a semi quantitative electrofishing survey. In 2001 the figures were 0.44 and 0.89 respectively.

**Figure 1.2** Faichfield Burn, tributary of River Ugie, Aberdeenshire. Left and centre photos taken *ca.* 1990 in different seasons. Left photo was taken just after some maintenance dredging. Right photo, recent image from Google Street View. Note dense grassy vegetation and stable channel which has not significantly changed over the period.

**Figure 1.3** Faichfield Burn, tributary of the River Ugie, Aberdeenshire. Photo on left taken *ca*. 1990, right photo recent from Google Street View. This channel again appears highly stable over this period.

**Figure 1.4** The Quhomery Burn, (tributary of the South Ugie Water, Aberdeenshire). Photo on left late spring *circa* 1990. Middle photo, late summer *ca.* 1990, right photo late spring recent Google Street View image. After around 20 years there has clearly been no change in this very stable channel. Note also, there is some degree of riffle / pool variation in this channel. Semi quantitative electrofishing surveys found trout fry densities to be 0.32 per square metre in 1991, 0.92 in 1992, 2.22 in 2001 and 0.91 in 2002. One year old trout densities were 0.38, 0.49, 0.47 and 0.21 respectively.

**Figure 1.5** Auchreddie Burn, tributary of South Ugie Water, Aberdeenshire. Photo on left taken *ca.* 1990 and, on right, recent image from Google Street View. Note the degree of flow speed / depth variation, dense bankside vegetation and stability which has been maintained. Semi quantitative electrofishing surveys found trout fry densities to be 2.11 per square metre in 1991, 0.6 in 2001 and 0.75 in 2002. One year old trout densities were 0.34, 0.36 and 0.5 respectively.

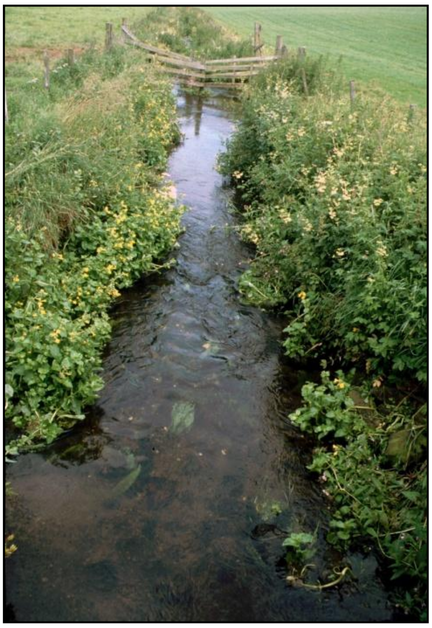



**Figure 1.6** Redbog Burn, tributary of North Ugie Water, Aberdeenshire. Photo on left taken *ca*. 1990 shortly after burn was subject to maintenance dredging of historically straightened channel. Note the generally riffly / stony nature of the stream after dredging, indicative of its gradient. The dense growth of summer grasses etc apparent in recent Google Street View photograph clearly show this stream to be stable in the absence of human intervention. No doubt encroachment of grasses resulted originally in the dredging shown.

**Figure 1.7**. Cuttyhill Burn, tributary of North Ugie Water, Aberdeenshire. Photo on left was taken *ca*. 1990, immediately after maintenance dredging. Banks are bare and eroding following the dredging. Recent photograph on right from Google Street View, shows stream has been fenced and is now densely vegetated, clearly very stable and unlikely to be eroding.

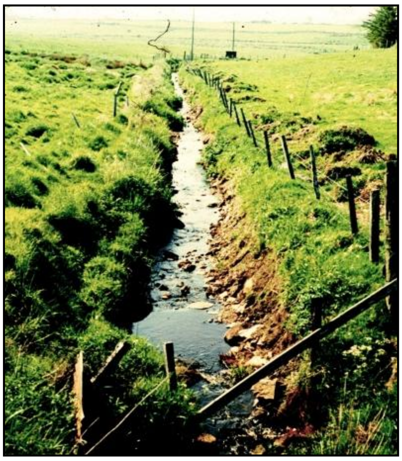


**Figure 1.8** Fedderate Water, tributary of the South Ugie Water, Aberdeenshire. Photo on left *ca*. 1990 immediately following maintenance dredging. Centre photograph was taken in the summer following the first photograph showing the limited extent to which vegetation recovered in six months. Right photo, recent photo from Google Street View shows how vegetation has encroached on the channel. Again, this channel is clearly stable and does not erode, except when freshly dredged.

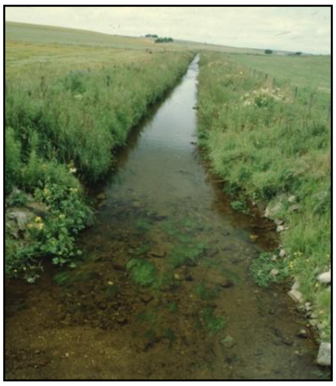


**Figure 1.9** Fedderate Water, tributary of South Ugie Water, Aberdeenshire, just downstream of Figure 1.8.

Left photo taken *ca.* 1990 following maintenance dredging. Right photo, recent image from Google Street View, facing opposite direction. Note type of substrate, gradient and velocities in early photo. Note also degree of encroachment by vegetation in recent photograph. Clearly a very stable channel in the absence of dredging.

**Figure 1.10**. Tributary of North Ugie Water, Aberdeenshire.

Left photo taken *ca*. 1990 following maintenance dredging. Right photo recent image from Google Street View. Again this channel appears highly stable in the absence of maintenance dredging.

**Figure 1.11.** South Ugie Water at Maud, Aberdeenshire. Two photos on left, taken *ca*. 1990, downstream and upstream views. Bottom right photo is of the substrate *ca*. 1990. Top right photo, recent Google Street View image. Again this is a very stable channel. The substrate is coarse and there is no evidence of channel erosion. Semi quantitative electrofishing surveys found trout fry densities to be 1.09 per square metre in 1991, 1.14 in 1992, 0.22 in 2001 and 0.93 in 2002. One year old trout densities were 0.05, 0.07, 0.13 and 0.25 respectively. Salmon fry densities were 0 per square metre in 1991, 0 in 1992, 0.14 in 2001 and 0.3 in 2002. One year old salmon densities were 0, 0.11, 0.15 and 0.10 respectively.

**Figure 1.12.** Tributary of North Ugie, Aberdeenshire. The photo on the left taken *ca* 1990 immediately after maintenance dredging. Right photo, recent Google Street View image. Again a clearly stable channel.

**Figure 1.13**. Loan Burn, tributary of North Ugie Water, Aberdeenshire.

The photo on left taken *ca*. 1990. Photo on right recent image from Google Street View. Stream has been fenced in interim. Banks clearly very stable and not eroding. A semi quantitative electrofishing survey found the trout fry density to be 0.422 per square metre in 1991 and the one year old trout density to be 0.633.


**Figure 1.14**. Greenspeck Burn, tributary of North Ugie Water, Aberdeenshire.

Photo on left taken *ca*. 1990, following maintenance dredging. Right photo, recent image from Google Street View. Again, in the absence of dredging, clearly a stable channel. Semi quantitative electrofishing surveys found trout fry densities to be 0 per square metre in 1992, 0.34 in 2001 and 0.26 in 2002. One year old trout densities were 0, 0.08 and 0.17 respectively.


**Figure 1.15.** Little Water, tributary of River Ythan, Aberdeenshire.

Photo on left taken *ca*. 1992. Right photo, recent image from Google Street View. Again, clearly a stable channel.

**Figure 1.16.** Little Water, tributary of River Ythan, Aberdeenshire.

Photo on left taken *ca*. 1992. Right photo, recent image from Google Street View. Again, clearly a stable channel, but benefit of fencing clearly demonstrated.

**Figure 1.17.** Cruick Water, tributary of River North Esk.

Photo on left taken *ca*. 1992. Right photo, recent image from Google Street View. Again, clearly a stable channel.

**Figure 1.18.** River Ythan, Fyvie, Aberdeenshire.

Photo on left taken *ca*. 1992. Right photo, recent image from Google Street View. Again, clearly a stable channel.

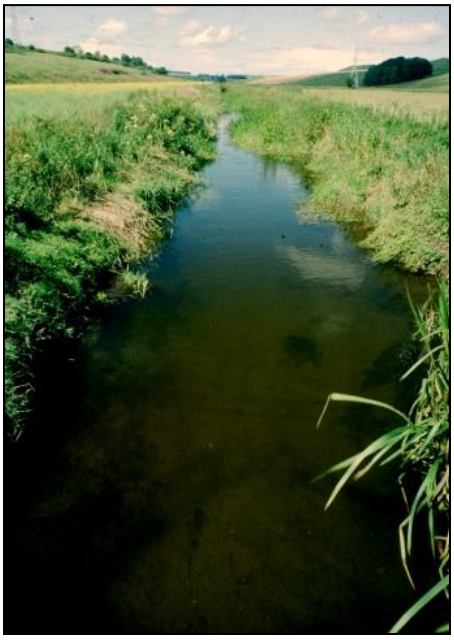
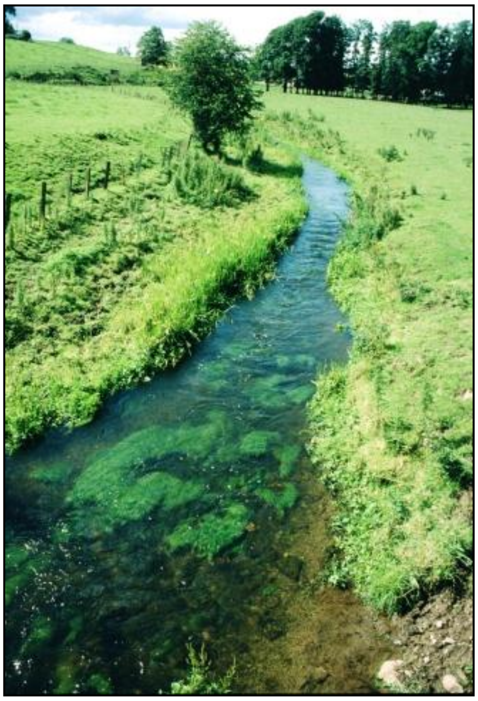


**Figure 1.19**. River Ythan, Fyvie, Aberdeenshire.

Photo on left taken *ca*. 1992. Right photo, recent image from Google Street View. Again, clearly a stable channel.

**Figure 1.20**. River Ythan, Fyvie, Aberdeenshire.

Photo on left taken *ca*. 1992. Right photo, recent image from Google Street View. Again, clearly a stable channel. Note clear benefit of fencing.



# Appendix 2

**Why does maintenance dredging occur?**

The illustrations in Appendix 1 clearly show that, in the absence of maintenance dredging, historically channelized streams in lowland eastern Scotland that are protected from grazing animals are stable and their banks and beds are not likely to be much of a source of fine sediment.

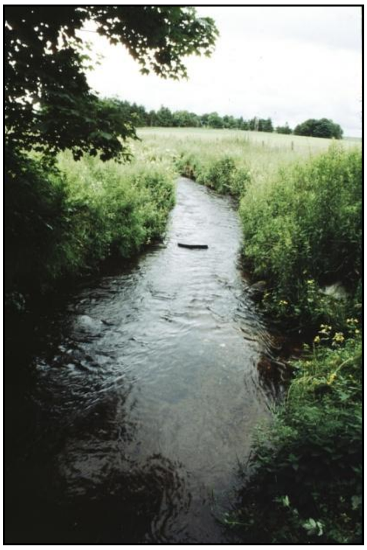
So why does maintenance dredging occur?

One of the reasons is the desirable encroachment of emergent and reedy vegetation and instream macrophytes. The other is the undesirable presence of sediment load.

As shown in the two photos below, sediment gets deposited among and around macrophytes and emergent vegetation. This can then be a self reinforcing process. As more sediment accumulates, more plants grow trapping more sediment and so on. Eventually this results in a reduction in channel capacity which creates a desire for dredging to restore the level of channel capacity farmers believe they need.

**What damage does maintenance dredging do?**

Maintenance dredging has several effects. It can result in sediment release which then affects downstream reaches, as is shown in the following example. The left photo overleaf shows the Fedderate Water, Aberdeenshire, *ca*. 1990 in a reach where velocities generally preclude deposition of fines. However, at the same location, one year later, following maintenance dredging that took place upstream (see Figs 1.8 and 1.9), sandy sediment is clearly visible on the bed, dislodged by the dredging work. The sediment deposited on the bed in this example, though 1 km+ downstream from its source, would have had negative ecological consequences.




In dredged reaches themselves, there is a much more dramatic impact on the ecology. This is shown by the following example on a small tributary of the Shochie Burn, near Moneydie, Perthshire.

This is a Google Street View image taken a few years ago. The stream appears to have been part of an environmental scheme. It is well buffered etc with grass encroaching and no local erosion likely. Comparing with the small burn in 4.1.6 (p. 30), it is quite possible this stream, albeit small, might have been a trout nursery.

This photo shows that in early 2013, the stream was dredged, presumably because the encroaching vegetation was deemed to be reducing channel capacity. The recovering habitat has clearly been destroyed

By July 2013 there was some recovery of vegetation but the stream was still very open, lacking in cover, depth of water, variety of substrate etc. It was also more prone to heating (see Appendix 7). In time, if left alone, the stream will improve until dredged again. Ironically since the rules were relaxed there has been a lot of this recently.

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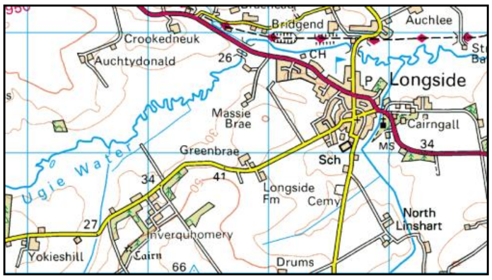
# Appendix 3

**What might channelized streams in lowland eastern Scotland have looked like before the agricultural revolution and what has been the effect of channelization on them?**

Analysis of historic maps, e.g. the Roy Maps of the 1750s, shows that many now straight channels were formerly meandering. However, there are few original examples of smaller meandering streams in lowland areas to provide a baseline for comparison.

One example, though relatively large, is the South Ugie Water, near Longside, Aberdeenshire. It is a rare example of a low gradient watercourse which is just large enough not to have been channelized. The area was in fact used as a water meadow in the 19th century, which were rare in Scotland. (For more information click here). It is an area of tortuous meanders, which were shown on the Roy Map of the 1750s and the present OS map shown below.

Some other parts of the Ugie catchment were similarly meandering in the 1750s, but no longer are. I suggest that this river might provide an example as to what similar streams on similar gradients might have looked like.




The general character of the area can be seen from the photo below of the South Ugie Water at Longside *ca*. 1990.

Close detail of the channel can be seen in the four photos overleaf. The two upper photos show the South Ugie water just upstream of Longside *ca*. 1987. The stream is narrow, tortuous, and relatively deep with steady smooth flow. Banks are cohesive silt/clay. Note incipient formation of cut-off and oxbow (the dried oxbow can be seen on recent aerial photos). No classic pools and gravel riffles exist in this reach. The gradient is simply too low.

The lower two photos are of the South Ugie just downstream of Longside, *ca*. 1990, taken in clear water conditions.

Sand / finer sediments clearly cover the bed, forming ripples and dunes. The gradient / current velocity is too low to prevent the temporary deposition of sediment during its passage downstream.

I imagine that, historically, there would have been less sand, which is a product of land erosion upstream. While probably never a prime habitat for the youngest stages of salmonids – particularly salmon – I would hypothesise the presence of all this sand has made it even worse.

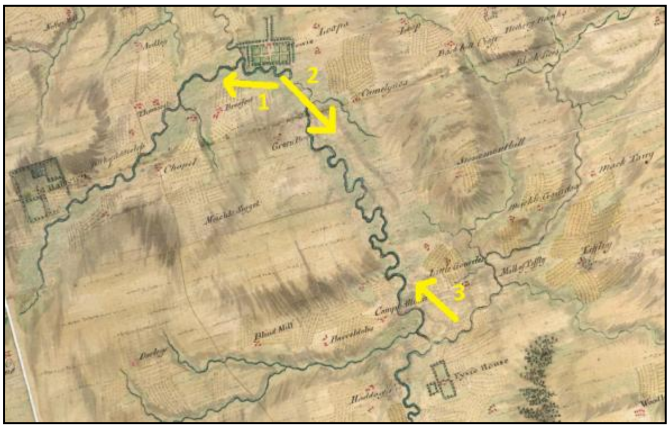



The impact of channelization on streams that were formerly meandering varies, but some of the changes are illustrated by the following examples.

**Example 1. River Ythan, Fyvie, Aberdeenshire**.

The River Ythan upstream of Fyvie flows through a low gradient flood plain. The Roy Map of the 1750s indicates the river had tortuous meanders (top left photo below). Arrows on the Roy Map show approximate positions of photographs taken in 1992. 1 is the top right photo, 2 is the bottom left photo and 3 is the bottom right photo.

These photos show that the river has been totally straightened. In the top right photo, the river is now relatively shallow with run / riffle and coarse substrate. The bottom left photo also indicates a relatively fast current, but by the bottom right, the valley gradient is so low that even, with meanders removed, current velocities are still low and a fine substrate dominates.

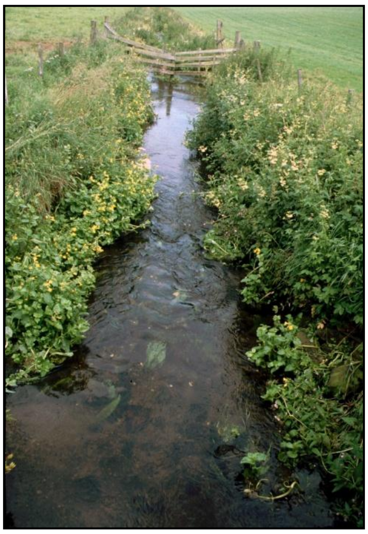


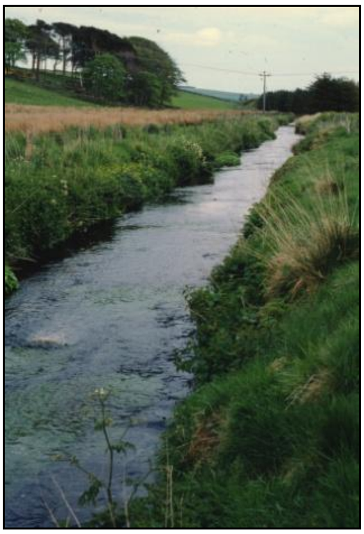

**Example 2. South Ugie Water, Maud, Aberdeenshire**.

The Roy Map of the 1750s (top left photo below) indicates that the South Ugie Water in the vicinity of the present village of Maud had areas of tortuous meanders, similar to the lower South Ugie at present. The top right photo, location indicated by arrow 1 on the Roy Map, was probably always in a steeper zone with less meandering. However, it has been clearly channelized and deepened. The main flow type now is riffle / run, mainly relatively shallow with a cobble substrate. Good numbers of trout (sea trout) fry particularly were found here in the past at least (up to 2.61 per $m^2$).

The stream indicated by arrow 2 is shown in the bottom left photo. It is clearly straight and currently is a mix of pool habitats and shallower faster riffles with coarser substrates. Good densities of juvenile trout were found here in the past too (see Figure 1.5). The bottom right photograph is typical of the area where there were tortuous meanders (arrow 3). The river is now straight, relatively shallow and has a reasonable velocity with a predominantly gravel substrate (see Figure 1.11). Note also the growth of *Ranunculus* which does not grow in slow water. Electrofishing has revealed reasonable salmonid densities here in the past.

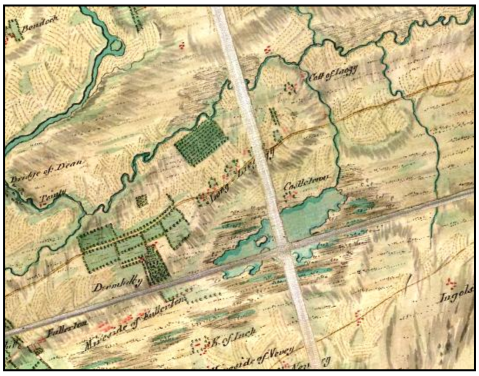
Based on both the look of the habitat and actual fish data, these three sections, though not perfect, are much more suitable as habitats for juvenile salmonids, particularly spawning and early stages, than the habitat in the lower South Ugie where it is still meandering.

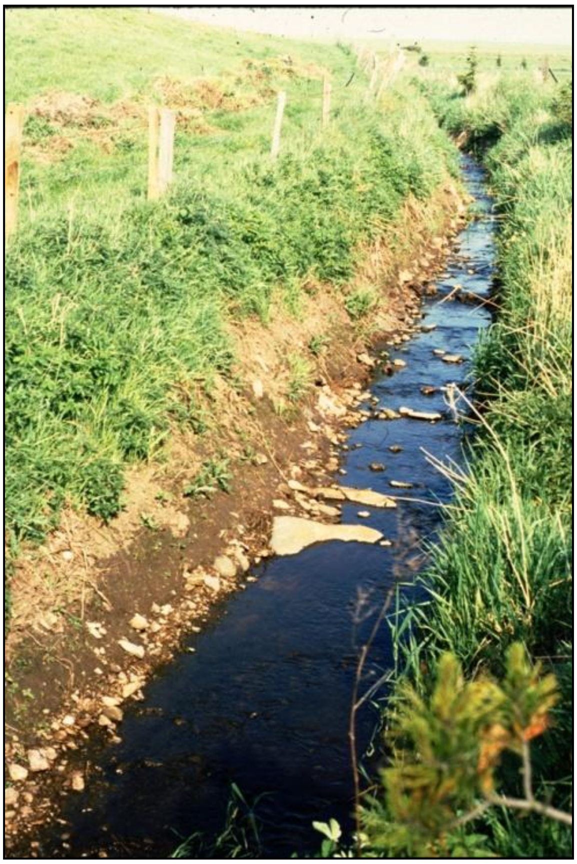


**Example 3. Castleton Burn, tributary of River Isla, Perthshire**.

In this instance, the burn, despite being channelized, has a low gradient and is relatively slow and silty (left photo below). On electrofishing, a low density of salmonids was found. However, on investigation it turns out this stream was actually a loch 250 years ago (right photo below). Thus, where even after channelization, streams still are slow and pooly, there must just be no valley gradient.



**Summary of some of the main effects of channelization on streams**



The photo opposite encapsulates some of the main features of channelization.

The stream gradient has increased. In this instance the gradient is such that the stream has basically been turned into a shallow riffle.

As the dredging has gone down into the underlying subsoil or regolith, the substrate is no longer water sorted sediments and contains mixed (including coarser) material.

The stream is also more incised, i.e. has a deeper and narrower channel.

# Appendix 4

## Elements of lowland stream habitats that are important to salmonids

### 4.1 Habitat preferences of juvenile salmon and trout.

#### 4.1.1 Salmon spawning habitat

Salmon spawn by laying eggs in gravel of a size that they can move. Gravel bars in riffle reaches, such as that shown (left photo below) are classic habitat. However, they will also spawn in gravel pockets among other substrate if that is all that is available (right photo below). Key requirements are gravel of sufficient calibre to be loosened and sufficient current velocity.

#### 4.1.2 Salmon fry habitat

Typically, salmon fry like shallow riffle habitat with coarse gravel / small cobbles. The riffle on the left photo below in the River Almond, Perthshire, is a known prime salmon fry habitat. The riffle in the foreground in the right photo below of the channelized Dunning Burn, Perthshire, held an extremely high salmon fry density in 2012. The pool in the middle distance, did not, however.

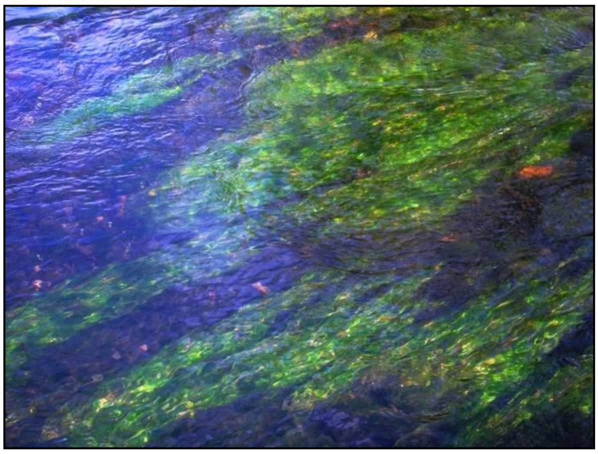
**4.1.3 Salmon parr habitat**

In this part of the world, salmon parr are classically associated with coarse substrate, cobbles / boulders with significant current velocity. The fish use the substrate as cover as protection from predators and fast flows. Good examples of classic salmon parr habitat are shown below.

**4.1.4 Salmon habitats used in lowland streams**

While the previous photos show classic habitat, juvenile salmon will use slightly different habitats in lowland streams. It may be that in the presence of higher food abundance in lowland streams, sub-optimal physical habitats are tolerated to a greater degree than in upland rivers.

In the left photo below (Kerbet Water, Angus), a high density of large salmon fry / small parr was found despite a substrate that offers little cover. The fish were found to take refuge under the undercut emergent vegetation where the current bored under the grasses. Juvenile salmon can also be found in high abundance where submerged macrophytes provide the cover, provided there is a good current velocity (right photo below).



Juvenile salmon will also take refuge amongst fallen woody debris such as the fallen tree in the photo below, where these lie in areas of significant current.

**4.1.5 Trout spawning habitat**

Trout spawning habitat is hydraulically similar to salmon – i.e. spawning in gravel riffle habitats, though substrate size / velocities may be lower than that preferred by salmon. Furthermore, while salmon will spawn both in streams and the main stems of large rivers, trout (both sea trout and brown trout) mainly spawn in smaller streams, often even little more than ditches.

The sort of substrate calibre and water depths used are illustrated by this sea trout “redd” on gravel in the Cruick Water, Angus (left photo below). In the right photo, another sea trout “redd” has been cut in gravel in a small, low gradient (channelized) tributary of the Cruick Water, Angus. Much trout spawning occurs in streams of this size, or even smaller.

**4.1.6 Trout Fry Habitat**

Trout fry habitat has many similarities to salmon fry habitat - a coarse gravel or coarser substrate with shallow riffling water, though trout cannot use such fast flows as salmon can. Therefore, trout fry tend to occur mainly in smaller streams not larger rivers.

This type of habitat is well illustrated by the left photo below of the Cloan Burn near Auchterarder, where we found a very high density of trout (sea trout) fry in the reach photographed.

Trout fry will also use much smaller streams, however. I once found a very high density of trout fry in the small burn in the right photo, where grasses had to be peeled back even to get in to electrofish. This stream has a gravel substrate, shallow, riffling. Emergent vegetation may have significantly contributed to the habitat.

**4.1.7 Trout Parr Habitat**

Trout parr can be found in a range of habitat types. However, weedy burns, so long as there is a current with much marginal vegetation, as in the left photo below, can be very productive and hold high densities. Trout parr prefer deeper water – glides and pools – than do fry or juvenile salmon.

It is important that the trout have cover. Where this is not provided by undercut banks or vegetation it can be provided by rocks or woody debris where that occurs. Pooly habitat, with rocks, even like this artificial habitat in the right photo below would be a habitat preferred by trout over say salmon.

#### 4.1.8 Adult Trout Habitat

Adult brown trout require deeper water than juvenile trout and are typically associated with pool habitats in smaller watercourses, or pool or glide habitats in larger rivers. They also have a liking for being close to bankside cover, e.g. undercuts, or other protection.

Adult brown trout might be found in deeper water with cover in smaller watercourses, as in the photo below left. They may also drop out of tributaries into larger main stem rivers, like the right photo below.

While adult trout like cover such as undercut banks, boulders or wood they can also use submerged macrophytes as in the case opposite.

#### 4.1.9 Bankside cover for salmonid fish

In appreciating the importance of lowland burns for salmonids, it is worth expanding on what constitutes bankside cover as this is a very important element of the habitat in these streams that can be affected by human activities.

The examples below show good and bad examples of what might constitute such cover. However, what all good cover types do have in common is that cover will only be of value if the current bores against the bank. Salmonid fish tend to avoid silty backwater areas.

As already stated, good cover can be provided by an undercut bank (upper left photo below). It can also be provided by marginal vegetation like grasses which flop onto the water surface from the bank (upper right photo below), or emergent vegetation where water is deep enough (bottom left), or even better, where an undercut bank and flopping vegetation exist together (bottom right).




As an example of what emergent vegetation and reedy grass cover can do, the example below is of a project I was previously involved with on a Dorset chalkstream. Following the erection of fencing (right photo below), a grazed stream (left) experienced a dramatic increase in trout use. For more information on that project click here.


In addition to reedy vegetation, other forms of vegetation can also provide marginal cover. Tree roots, where they extend out into a channel as in the left photo below, provide excellent cover, although they tend to provide spots of cover rather than continuous expanses of cover as reedy grasses can. The same is true of trees and branches which have fallen into the water, particularly where they extend into the current as in the right photo below. However, fallen trees also only tend to produce spots of cover as opposed to continuous cover.

However, it must also be understood that bankside shade from overhanging trees should not be confused with physical cover in the water. To a considerable extent, reedy cover and fallen woody cover are mutually exclusive, as explained in Appendix 5.

Where there may be good and suitable vegetation on the banks, but this does not extend down to the water surface, there is little cover value, as in the photo below.

## Appendix 5

**Effects of shading from riparian trees on fish "cover" in lowland streams**

Shading by trees along the banks of lowland streams, irrespective of whether deciduous or conifers, can have detrimental effects on low fish cover.

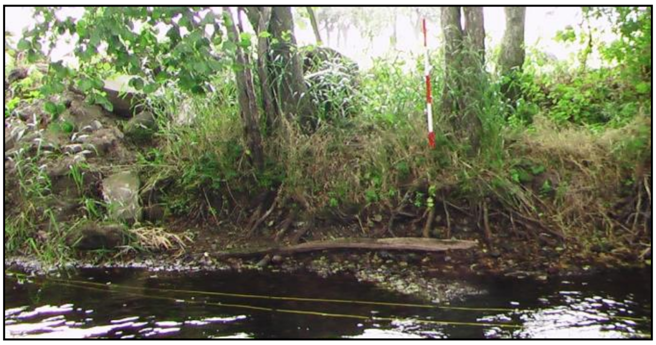
This issue is described by means of examples.

### 5.1 Lunan Burn

The Lunan Burn is a tributary of the River Isla, Perthshire. It has been channelized at some point and over a significant length has developed a dense growth of trees, predominantly alder. Within living memory, it was more open that it is now.

It can be seen from the photo below that where there are trees, there is no reedy grass growth. However, in the short section on the left which is kept open below a power line, reed canary grass is growing. Elsewhere, reed canary grass has been shaded out. In the absence of trees, reed canary grass would flourish along this stream.

The photos below show that under the tree canopy, there is little in the way of low growing marginal vegetation because of the level of shade. Nor are there any submerged macrophytes. Because of the lack of marginal vegetation in the shaded reach, the bank has eroded back to expose the roots of the trees at a winter flow level. When flows recede in summer the roots are exposed on dry land. If the shade was not present, reedy and emergent vegetation would encroach into the channel to compensate for reducing flow. Instead, the channel margin is shallow, bare and offers very little value for salmonid fish.



The left photo below further emphasises that there is a lack of marginal cover for fish. The right photo below shows that on another short section of the Lunan Water where the trees have been suppressed to protect another power line, a very different vegetation dominates. In the absence of trees this stream would be wholly fringed by reed canary-grass and would be narrower and deeper.

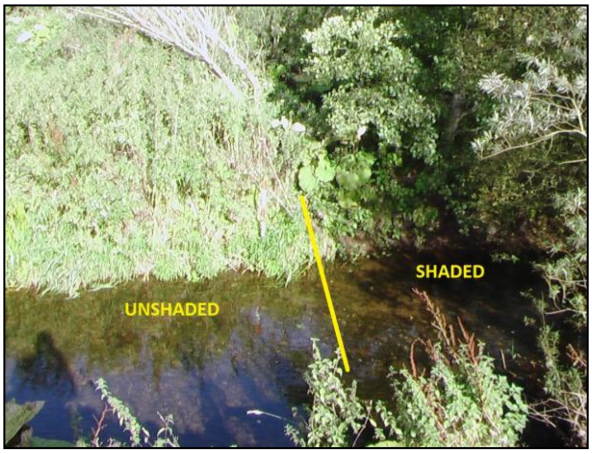
We have found that over years of annual electrofishing surveys at precisely this shaded location, the mean size of salmon fry particularly has been consistently considerably smaller than other lowland Tay tributaries (see Figure 7.4 in the attached report). Perhaps this reflects a reduced abundance of invertebrates.

**5.2 Kerbet Water, tributary of River Isla, Perthshire.**

The Kerbet Water is a channelized stream draining a largely arable catchment near Forfar. The section of stream shown below has been electrofished several times. In each year a very high density of juvenile salmon, principally 0+, has been found (see pages 50 – 52 of attached report). Despite the high density of juvenile salmon, their growth rate in this generally unshaded stream is much greater than in the shaded Lunan (see 5.1). With a relatively poor substrate, the salmon mainly took refuge under the trailing reed canary-grass mat, which was undercut by up to one metre.

Another photo of the electrofishing site, taken in 2011, is shown below left. Note the large willow tree in the middle distance. It is located just upstream of the upper boundary of the electrofishing site.

It can be seen, below right, that immediately under the trees' branches, the grasses are suppressed and a bare soil bank is visible. Therefore the encroaching marginal cover provided by the reed canary-grass is completely lost under the trees' shade.



**5.3 River Lambourne, Berkshire**

The photographs below are of two contiguous sections of the River Lambourne, a chalkstream in southern England. The top photograph was taken just upstream of the lower photograph. The top site is wooded and there is a complete lack of an understory.

However, in the lower photo, most of the river is unshaded and has a lush growth of emergent / bank vegetation and in-channel macrophytes, though the latter probably also benefit from a slightly higher gradient in the open section. The lower photograph shows a much better habitat for juvenile salmonids. While this is in southern England, the same type of effect is just as apparent in arable areas in eastern Scotland.

### 5.4 Conclusions on the effects of shading by trees

Dense shading by deciduous trees can have a negative impact on fertile lowland streams by suppressing marginal and instream vegetation. This results in a loss of the cover value and summer low flow narrowing that low vegetation can provide in low gradient streams. It also reduces the food supply for fish.

However, tree roots and fallen branches can compensate for some of these effects, particularly when the trees get old. “Woody debris” does increase cover for fish compared to a clean tunnel of trees. Encouraging the addition of such material has recently become another river restoration paradigm. However, it is not clear whether such material dropping into otherwise shaded streams might sufficiently replace what would be there if there were no trees at all. That is a key question.

I suggest that where lowland streams have already got good cover from reedy vegetation and are productive of fish, as many are, they should be protected unless good evidence can be presented to the contrary.

# Appendix 6

**An example of low cost improvement to salmonid habitat in a steepened channelized stream.**

As has been outlined, by increasing the gradient, historic channelization may, in some cases at least, have made streams more suitable for some stages of juvenile salmonids than they might have been with a meandering channel, particularly with modern sediment loads.

However, one problem with some channelized streams is that their homogeneous shallow riffle habitats may only be suitable for very young salmonids but not older fish (e.g. fry as opposed to parr).

In such instances a much cheaper and perhaps more effective alternative to costly re-meandering, which might not be of any benefit anyway, might just be to perform modifications within the existing channel to increase heterogeneity of substrate and depth without reducing the gradient.

While I make no comment on the sustainability of this example, I now show some photos of an enhancement scheme in a channelized stream in Ireland that I saw in 1998. It is useful at least to illustrate the concept.

The stream in the photo below is a tributary of the River Moy, Co. Mayo. It was subject to an arterial drainage scheme some decades ago. It was deepened and turned into continuous riffle. Bearing in mind the photo was taken during slightly elevated flows, I would certainly say this stream is excellent summer habitat for salmon fry at least.

The stream was modified in order to improve the habitat for juvenile salmon. One of the facets of this was to narrow in the bank using a brushwood revetment.

However, in order to create more variation in the in-channel habitat, transverse boulder bars were placed at intervals in the channel, extending 2/3 the way across. These had the effect of creating pockets of deeper water and providing a substrate that would be suitable for salmon parr. The end product looks for all the world like a good mixed age salmon stream. It would be interesting to know how this performed in the longer term.

# Appendix 7

**Channelized streams in lowland Scotland and “climate proofing”**

Recently, interest has arisen into increasing shade from trees to mitigate potential future climate change.

Should this be done along lowland streams, there is a danger that there could be negative side effects on fisheries, e.g. if the quality of bankside cover deteriorates.

It is essential therefore that the necessity for such shade is demonstrated to outweigh other considerations. In order to inform this issue, some water temperature data were collected from River Tay tributaries during the recent hot weather. Some of the results are presented in the Table on page 43.

The temperature readings were all taken in the late afternoon, the time when water temperatures reach their daily maxima. As well as providing locations and times of readings, the Table also provides the air temperature reading published by the Met Office for the Strathallan Weather Station (near Crieff) to the nearest hour. Photos are intended to convey an impression of the physical nature of each stream.

It can be seen from the Table that there is some variation in the temperatures recorded. The highest temperature (26 degrees) was recorded in the upper Shochie Burn at Little Glenshee on 9 July, the hottest day of the year at Strathallan. However, on the same day some other burns had lower temperatures.

What is quite clear is that the highest temperatures occured in open unshaded burns where there is a high width to depth ratio, shallow water and very little current. Higher flows / velocities seemed to equate to lower temperatures, other things being equal. This effect was demonstrated on the River Almond in the Sma’ Glen on 11 July where the temperature in a shallow backwater was 1.5 degrees warmer than in the main river channel.

Another good example concerns the upper Shee Water on 12 July. A tiny tributary which had very little flow and was unshaded by being open to grazing by cattle and sheep, recorded a temperature of 24.5 degrees while the main river a mile or so downstream was only at 21 degrees though equally exposed or even more so. Further down the valley, another very open tributary (Drimmie Burn) weaving slowly through exposed stones was also much warmer.

However, what is equally clear is that temperatures taken in channelized burns were generally the lowest. A good example is the Logiebride Burn where temperatures were taken on two occasions. It is narrow and incised, with some trees, but mainly low vegetation. The same was true of the East Pow or burns in the Coupar Burn / Burrelton Burn system. On 12 July, the Burrelton Burn was only at 14 degrees and a field drain discharge only 11 degrees. Deeply incised burns with encroaching reedy vegetation would seem to be well “climate proofed” therefore.

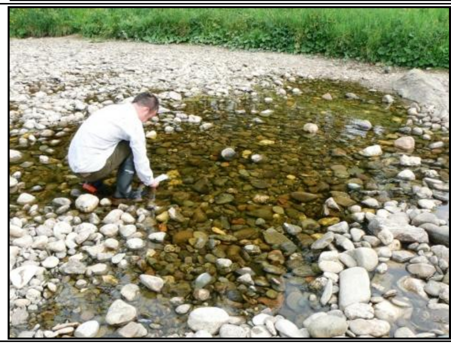
Another interesting example was a small tributary of the Shochie Burn near Moneydie. This is the burn that was dredged last winter and shown in Appendix 2. I was surprised to find a reading of 24 degrees on the first visit on 9 July. Therefore a reading was also taken further upstream at Moneydie Roger on 11 July which also proved quite high. However, it was apparent that this stream had been dredged over a long distance and that the vegetation had not recovered enough to cover the burn. In addition the stream had a high width / depth ratio and was slow and ponded. There was in fact very little flow (see photos page 21). This circumstance made this stream very prone to heating therefore. Had it not been dredged, it would presumably have been cooler.

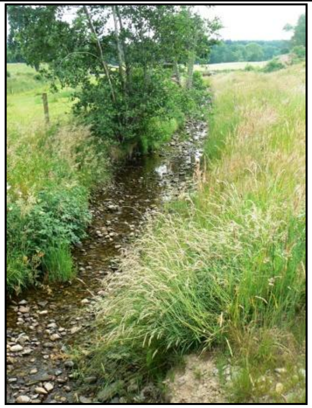
Thus, particularly on smaller streams, by a combination of being incised and having a covering of reedy vegetation, channelized burns might actually be some of the best adapted to fending off any future significant temperature rise.

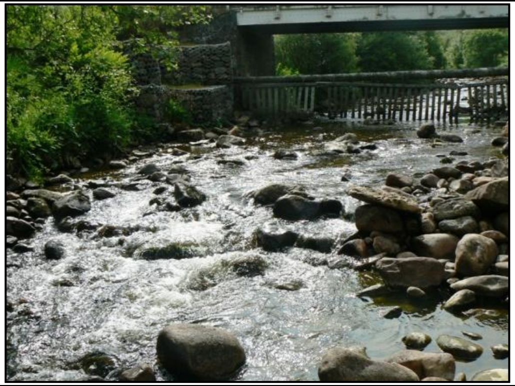
Indeed, another unforeseen consequence of channel “restoration” might make streams more prone to heating. The two photographs below are of the Savoch Burn, Aberdeenshire. The left photo shows the burn prior to “restoration”. It was a typical incised stream with dense encroaching grasses. Following the remeandering work that was done a few years ago, the stream channel has a much greater width to depth ratio and has lost the shading from the bank. Such a channel configuration would clearly be more prone to heating. In addition, by lengthening the channel, the surface area exposed to the sun has increased and the mean water velocity decreased, another two factors which could lead to more heating.

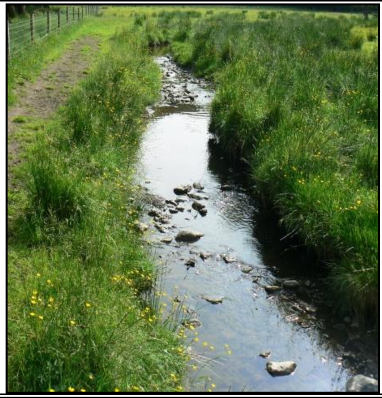
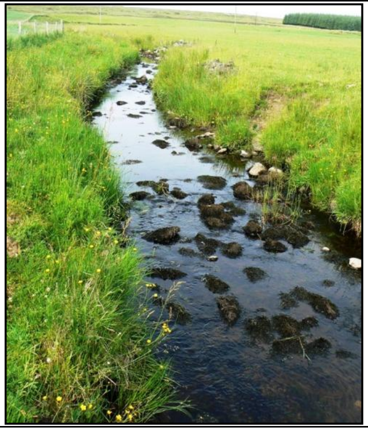
| Waterbody | Location | Grid ref | Date | Time | Water temp | Strathallan air temp. | Photo |
|---|---|---|---|---|---|---|---|
| Shochie Burn | Little Glenshee Ford | NN 988 340 | 9/7 | 17:00 | 26 | 28.2 |  |
| Logiebride Burn | Balmacolly | NO 052 344 | 9/7 | 17:25 | 18.5 | 28.2 |  |
| Ordie Burn | Balmacolly | NO 053 342 | 9/7 | 17:25 | 20 | 28.2 |  |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Shochie Burn | Moneydie | NO 072 293 | 9/7 | 17:50 | 21.5 | 28.1 |  |
| Shochie Burn | Little Glenshee Ford | NN 988 340 | 9/7 | 18:05 | 25 | 28.1 |  |
| Moneydie Burn | Moneydie House | NO 064 288 | 9/7 | 18:20 | 24 | 28.1 |   |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| River Almond | Almondbank | NO 067 259 | 9/7 | 18:30 | 22 | 28.1 | NO PHOTO |
| East Pow Burn | Lochty | NO 066 254 | 9/7 | 18:35 | 17 | 24.8 |  |
| | | | | | | | |
| River Almond | Sma’ Glen | NN 899 300 | 11/7 | 17:00 | 23.5 | 25.3 |  |
| River Almond backwater off main channel | Sma’ Glen | NN 899 300 | 11/7 | 17:00 | 25 | 25.3 |  |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Moneydie Burn | Moneydie Roger | NO 058 290 | 11/7 | 17:51 | 23.5 | 25 |  |
| Moneydie Burn | Moneydie House | NO 064 288 | 11/7 | 18:00 | 24.5 | 25 |   |
| | | | | | | | |
| Shee Water | Corrydon | NO 136 667 | 12/7 | 15:45 | 21 | 27.1 |  |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Glen Beg Burn | Spittal of Glenshee | NO 113 704 | 12/7 | 15:55 | 21.5 | 27.1 | |  |
| Lochsie Burn | Dalmunzie | NO 093 711 | 12/7 | 16:05 | 22.5 | 27.1 | |  |
| Thaitneich Burn | Dalmunzie | NO 094 711 | 12/7 | 16:05 | 22.5 | 27.1 | |  |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Small Burn | Spittal of Glenshee | NO 098 707 | 12/7 | 16:15 | 24.5 | 27.1 |  |
| Shee Water | Slochnacraig | NO 128 687 | 12/7 | 16:25 | 21 | 27.1 |  |
| Drimmie Burn | Rannagulzion | NO 179 512 | 12/7 | 16:50 | 24.5 | 27.1 |  |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Coupar Burn | A94 Bridge | NO 208 383 | 12/7 | 17:15 | 17.5 | 27.1 | No photo |
| Burrelton Burn | Burrelton STW | NO 208 378 | 12/7 | 17:25 | 18.5 | 27.1 |  |
| Burrelton Burn | Redstone | NO 182 346 | 12/7 | 18:00 | 14 | 26.5 |  |
| Drain pipe, Burrelton Bun | Redstone | NO 182 346 | 12/7 | 18:00 | 11 | 26.5 |  |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Shochie Burn | Little Glenshee Ford | NN 988 340 | 19/7 | 17:45 | 24 | 25.2 |  |
| Logiebride Burn | Balmacolly | NO 052 344 | 19/7 | 18:00 | 18 | 25.2 |  |
| Ordie Burn | Balmacolly | NO 053 342 | 19/7 | 18:10 | 19.5 | 25.2 |  |