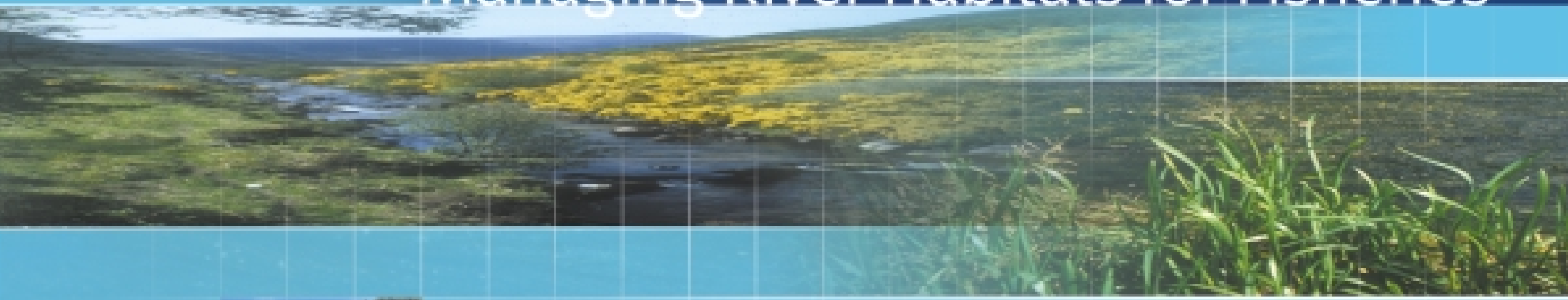
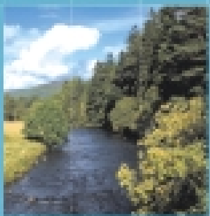
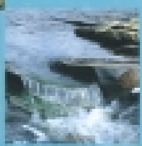
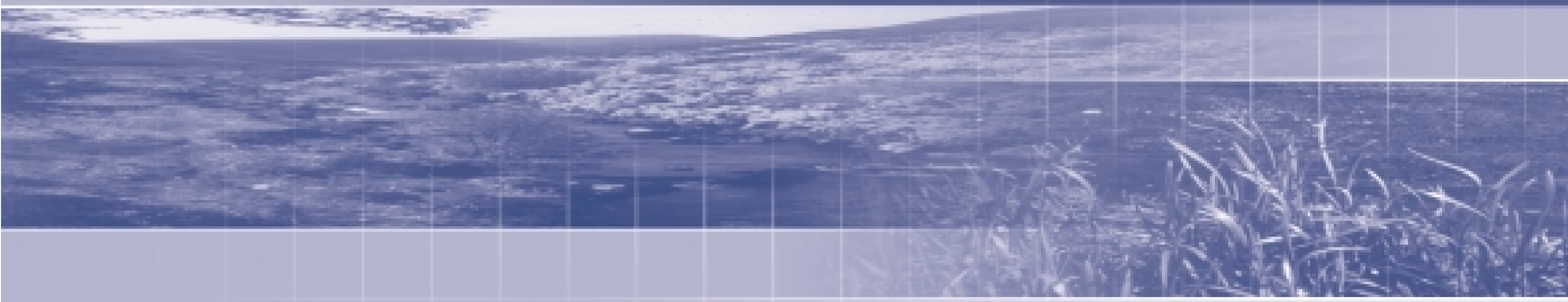
Managing River Habitats for Fisheries







a guide to best practice



Managing River Habitats for Fisheries

This document was prepared on behalf of the four partners by Professor Chris Soulsby of the Department of Geography and Environment, University of Aberdeen.
The document benefited from extensive consultation over this and previous drafts.
The partners are grateful for the input of all contributors.

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Scottish Executive

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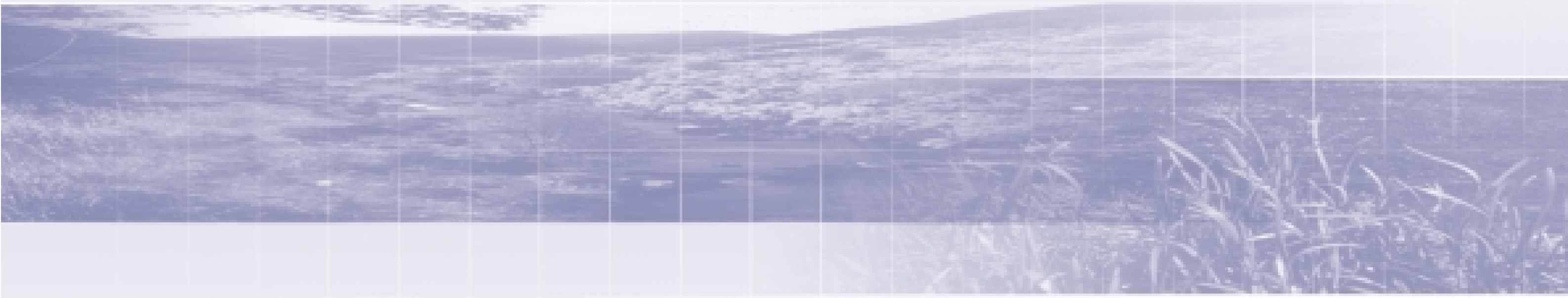


Introduction

Scotland's rivers are renowned the world over for their clean water, natural beauty and the quality of fishing. In particular, salmon fishing on Scotland's rivers has a long history and is a major part of the culture in many rural areas.

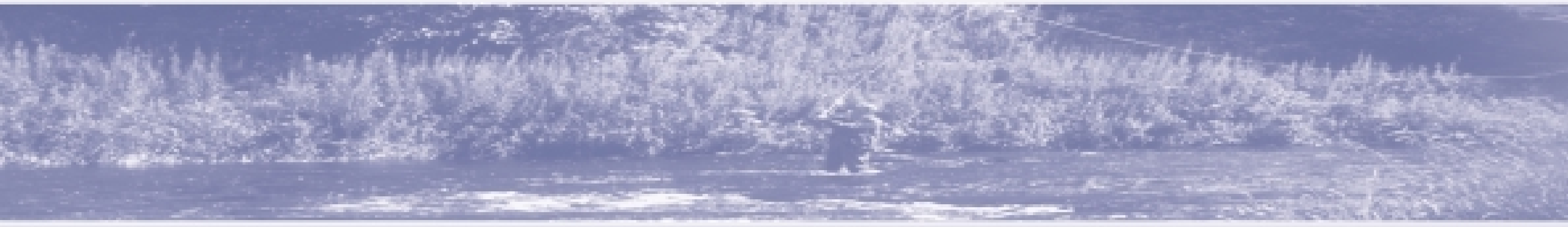
Angling for salmon and other freshwater fish also provides a major source of income to remote rural economies and is a highly significant component of local employment patterns, both directly and in related tourist industries.

As with salmon rivers elsewhere in Europe and North America, recent decades have seen a decline in salmon catches on many Scottish rivers. These declines appear to be associated with a range of factors, including increased mortality during the marine phase of the salmon life cycle. However, changes have also occurred in water and land management practices in the catchments of many salmon rivers. These include changed flow and sediment regimes in rivers affected by intensified agriculture, commercial forestry and flow regulation for hydro-electric power production.

Scotland's freshwater fish and fisheries are not restricted to salmon, however. There are important fisheries for trout, grayling and, increasingly, species of coarse fish. Fisheries managers are becoming increasingly aware of the value of these resources and the conscious need to enhance their potential.

There is a long history of river engineering by fishery managers. Many of the schemes were attempts to increase the fish holding capacity of pools, or to create easier access for anglers. A number were designed to ease the passage of fish past obstructions. In more recent times, in order to address declines in salmon numbers, some fisheries managers have undertaken proactive management to try to improve the quality of habitat and conserve existing stocks, whilst at the same time attempting to enhance fishing opportunities for anglers. In some cases, this has involved carefully planned, coordinated and catchment-wide initiatives aimed at promoting sustainable fisheries. In other cases, management initiatives are more localised and may involve individual managers addressing very specific problems, such as an eroding bank or the local degradation of spawning habitat.

This document is designed to help managers assess whether intervention is required and if, after careful consideration, they decide it is, to encourage best practice in the planning, design and implementation of river management schemes.



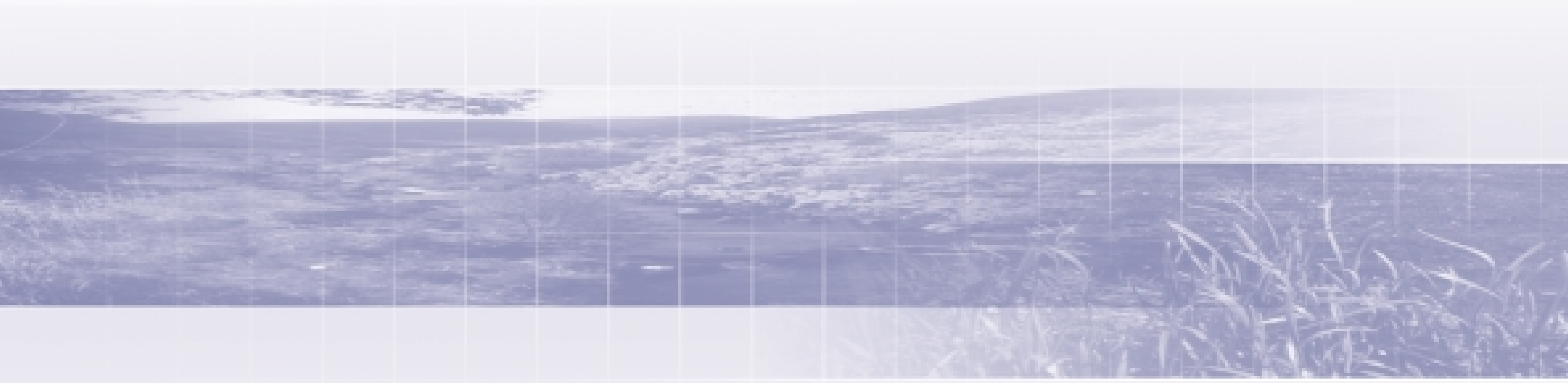
2. Managing river habitats for fisheries: the changing context

Key Points

- Fisheries managers often try to modify river channels to restore and enhance degraded fisheries and improve fishing opportunities. Such manipulation can have negative impacts as well as positive results.
- In the future, river basin planning will require such modifications to be carried out in a way that avoids negative impacts, leading to the more sustainable management of Scotland's rivers, for salmonids, other fish and other freshwater species.

There is increasing awareness of the nature and complexity of the processes influencing river channels and the maintenance of fish habitats. Increased understanding highlights the sensitivity of these processes and the way in which they also underpin the biodiversity and amenity value of rivers. It shows the need for careful planning and design if management is to be sustainable and is to achieve its objectives without producing unanticipated and detrimental impacts. There is a clear need to consider carefully the consequences of management intervention in river channels. This requires careful appraisal of whether or not to intervene and the need to distinguish between good and bad practice in such schemes.

Although the document offers some guidelines to facilitate best practice in river management for fisheries, it does not seek to be a detailed manual of different management techniques or a manual of engineering design. (Some sources of such information are provided in Appendix B). Rather, it emphasises a number of key issues that need to be recognised and appraised in order to ensure that rivers are managed sustainably and in a way that recognises and addresses the concerns of other stakeholders with interests in the river environment.



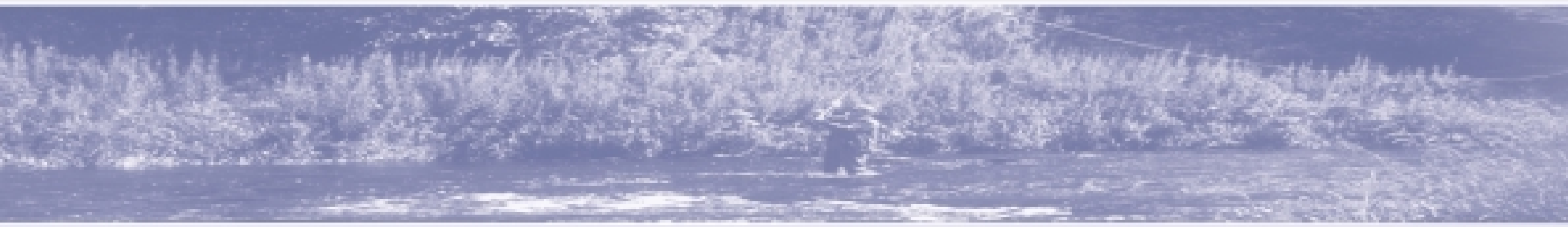
Historically, fisheries managers, mainly on salmon and trout rivers, have modified river channels for a wide range of purposes. These can generally by characterised by two key objectives:

- *Restoration and enhancement of fish habitats in degraded streams to increase fish abundance*
- *Improvement of fishing opportunities*

The success of such schemes can be varied. In some cases objectives have been achieved, in others they have not. Even when successful in terms of their original objectives, some schemes can have adverse and unforeseen impacts. These include severe deterioration of the landscape and conservation value of river channels, primarily as a result of unsympathetic engineering. In some cases, river channels can become unstable with altered patterns of erosion and deposition causing serious problems both for the original proponent of the scheme as well as other up- and/or down-stream interests. The resolution of such problems may require costly additional channel works and could possibly result in legal action being taken against the instigator.

Increasingly, the concept of integrated management is being advocated for rivers and their catchments. To a certain extent this represents a common-sense approach to reconciling the potentially conflicting demands that society places on rivers. Increasingly this approach is being formalised within statutory and regulatory frameworks. Perhaps the most significant development in this respect is the new EC Water Framework Directive (WFD). The Directive will be implemented in Scotland by means of the Water Environment and Water Services Bill, planned for 2002. This will require, for the first time, the development of strategic scale river basin management plans for all catchments in Scotland. It will also require that the ecological status of rivers be defined, protected and, where necessary, improved. In the past, the quality of rivers has largely been defined on the basis of water chemistry and levels of pollution. Now, new definitions of ecological quality will be also be based on the flow regime of a river and the physical features (or hydromorphology) of the channel which contribute to habitat diversity. It is likely that this will result in greater concern over protecting the physical characteristics of river channels. The Bill will introduce controls over river engineering activities that could have a significant impact on ecological quality. This could include any management activity which physically impacts on the river channel and riparian zone (the land adjacent to the river).

It is expected that many of Scotland's rivers will prove to have a high ecological status, not only because pollution levels are low and flow regimes are relatively undisturbed, but because many river channels are largely unmodified. Consequently, many rivers already have a diverse range of natural features, and provide excellent habitat for fish, as well as other important legally protected species such as otters and freshwater pearl mussels. Management which seeks to alter channel characteristics such as width, depth, flow velocities and sediment characteristics, or modify the structure of the riparian corridor, will need to ensure that the ecological status of a river is maintained and that protected species are not damaged.



These changes will have profound impacts on how we view and manage our rivers in Scotland, and the objective will ultimately result in significant environmental improvements, landscape protection and the development of more sustainable approaches to the management of river channels. This will, in turn, protect and enhance the biodiversity of river systems helping safeguard populations of salmonids and other fish species, as well as other freshwater plants and animals.

Fisheries managers will need to be increasingly careful in planning and considering the potential effects of the sorts of activities that they have traditionally undertaken in order to enhance fish habitat or improve fishing conditions. They may also have to consider alternative approaches to river management that require less reliance on some of the more traditional, engineering or intervention-orientated techniques.

This move towards more sustainable approaches to river channel management will require managers to become increasingly familiar with how rivers function as an integrated system within the landscape, and to maintain the range of habitats that different fish and other freshwater species have evolved to use. Managers often have detailed knowledge of the behaviour of particular stretches of river channels, such as a particular beat under their jurisdiction. That behaviour needs to be understood within the context of the timescales over which river channels evolve. It also needs to recognise the large catchment areas which contribute water and sediments to the channel network of a particular river system.

3. Scotland's rivers

Key Points

- Most of Scotland's rivers are dynamic, high energy systems.
- Large flood flows and naturally high erosion rates result in a diverse range of physical habitats created by the processes of erosion and deposition. These habitats are used by fish (in different ways at different lifestages) and other freshwater animals and plants.
- These habitat-forming processes in river systems are linked by flows of water and sediments from the entire catchment. As a result, intervention or change in one part of the system is likely to produce effects elsewhere.

Basic characteristics

Scotland is predominantly an upland country underlain by hard, relatively impermeable rocks, with around 60% of the land surface having an altitude greater than 250m. The majority of Scottish river systems have their headwaters in upland areas where rainfall and rates of snowmelt are highest. In addition, much of the Scottish landscape has been modified as a result of past glaciation and most Scottish river valleys originate in glaciated mountains with steep slopes and high valley gradients. Many rivers flowing through low-lying agricultural land also have their headwaters in such upland areas. The river valleys are often covered by loose, erodible deposits (such as sand and gravel) left behind by glaciers.

These physical catchment characteristics determine river behaviour with rapid responses to high levels of rainfall and snowmelt causing frequent periods of high flows and floods. This leads to high flow velocities and high energy levels which, coupled with the erodible nature of many river banks, can cause rapid and high rates of erosion. It is important to understand that some degree of erosion is natural and provides a way in which rivers dissipate their additional energy during high flows. Consequently, most Scottish river systems are highly dynamic and prone to change as rivers move water, together with sediments, from their catchment area, along channel networks and eventually towards the oceans (Figure 1).

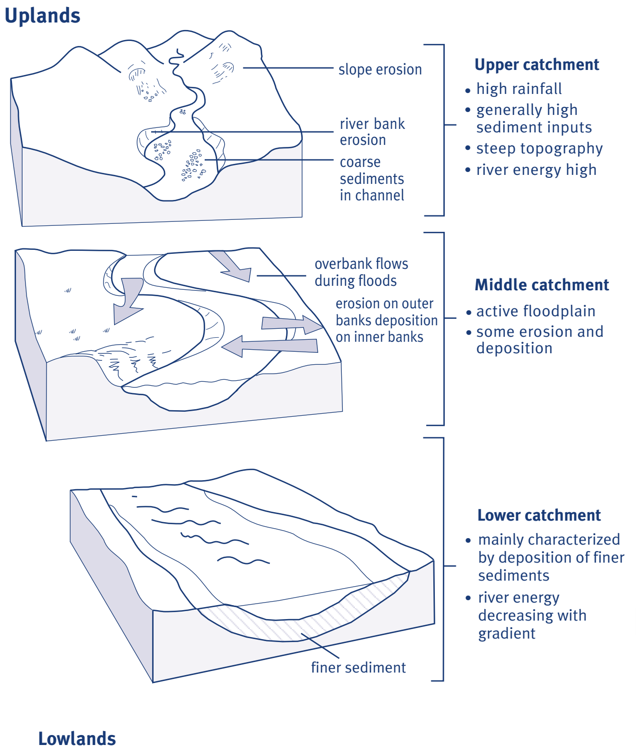


Figure 1: Idealised view of a river catchment, showing how water and sediment flows are linked, and provide different habitats in different parts of the catchment (after Ward et al,1994).

Rivers and their catchments are connected by flows of water and sediments. This creates a continuity, and intervention in one part of the system has the potential to alter conditions elsewhere. In other words, action in one location will almost inevitably cause a reaction somewhere else. Management of part of a river channel has, therefore, the potential to cause both upstream and downstream effects which may often be unexpected. Land management within a catchment also has the potential to impact on the processes operating in the river channel.

Rivers are dynamic features of the landscape, although large-scale changes tend to occur over relatively long time periods (decades – centuries); much longer than the average human lifespan. Small parts of the river network (particular stretches or specific bends) can, nevertheless, change very quickly, often in response to one or more extreme flood events. In such instances, rapid rates of erosion and/or deposition may occur and the channel characteristics of particular stretches of rivers may change abruptly as a result. In many cases, this is natural behaviour in Scottish high energy rivers.

Influences on river channels and the river corridor

The processes of erosion and deposition are of fundamental importance in the creation of diverse river channels, making a range of physical features that can be used as habitat by different freshwater animals and plants. Scotland has had a long history of human occupation and today's landscape and vegetation cover has been strongly influenced by human activity. These activities, such as changes in land use, represent key, catchment-scale influences on river systems (along with climate, geology and topography), and are perhaps the factors most likely to affect river channels on short timescales. Many of the land use changes that have occurred in Scotland affect river channels, sometimes directly, at other times indirectly. Forest clearance, high levels of grazing, cultivation for arable agriculture and commercial forestry, together with land drainage all have their impacts on rivers.

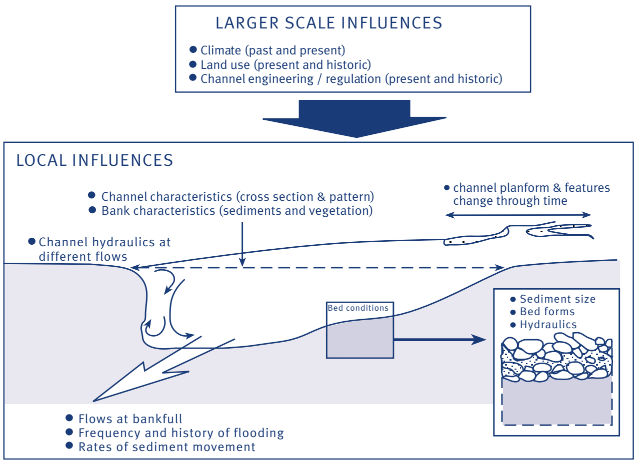
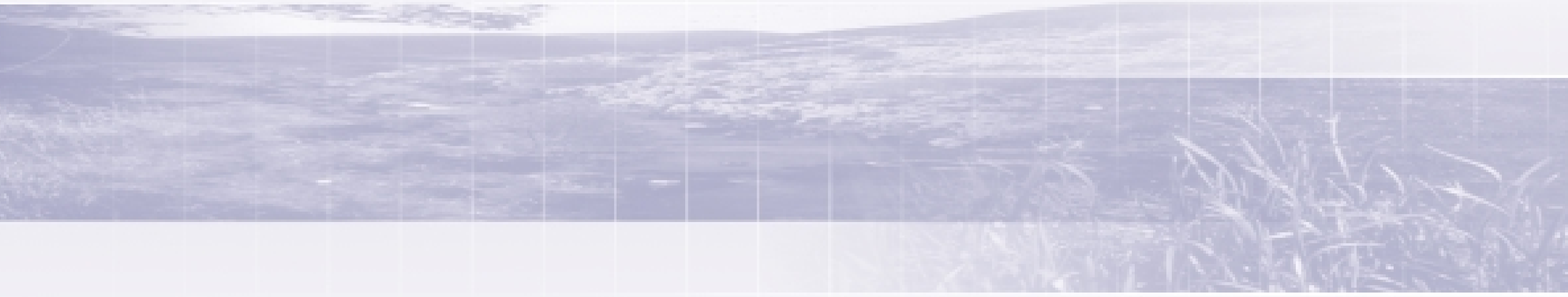


Figure 2: Idealised diagram showing how larger scale catchment factors combine with local channel characteristics to influence river processes (after Thorne et al, 1997).

With increasingly intensive and mechanised cultivation practices, the delivery rates of both water and sediments into river channels have generally increased during the twentieth century.

At a more local scale, the pattern of river flows and nature of the sediment load exert a strong influence on the channel characteristics. These operate along with the channel slope or gradient, the nature of the river bed and bank material and riparian vegetation to influence channel features (Figure 2).

The behaviour of a particular river channel usually reflects the quantities of water and sediment that are transported during floods. In some cases, this may involve a channel actively meandering and slowly moving across a floodplain, in others, the channel may split into several branches and begin to divide or braid. River channel behaviour reflects the complex interplay between large catchment-scale factors with the local character of a particular reach, over both long and short timescales. This complexity, underpinning the creation of freshwater habitats, forms part of the natural capital of river systems. However, it also means that it is difficult to understand and predict river channel behaviour and its likely response to management without expert advice and detailed investigation.



River channels as habitats for salmon and other species

Aquatic organisms use the physical habitat that is created by river channel processes. The complex life cycle of the Atlantic salmon, for example, reflects the close interaction between the species and the different features of river channels where salmon have evolved (Figure 3). For example, gravel bars form where in-stream accumulation of sediments (eroded from river banks) occur. These can form riffles with fast water flows, and are used by spawning salmon in the construction of redds (where eggs are deposited during the autumn and winter). When the eggs hatch and juvenile fish emerge, they use the cover afforded by stones and rocks on the river bed to avoid the faster flowing parts of the channel and conserve energy as they feed on insects and other animals delivered by the current. After one or more years, the salmon smolt and leave their native river systems for the marine phase of their life cycle. This may last one or more years before adult fish return, usually to their native river system. They gradually move upstream, sometimes over a period of several months, to spawn, often close to the area from where they originated. During this adult freshwater phase, the fish conserve energy by spending long periods resting in deeper, cooler pools interspersed by rapid movements upstream following spates.

These resting pools are scoured by the river, often on the outer side of river bends, as a result of the high volume of water and sediment transported at high flows (Figure 3). Such pools often provide excellent angling opportunities and are often features that fisheries managers are keen to maintain, along with other important habitats such as spawning gravels and in-stream cover.

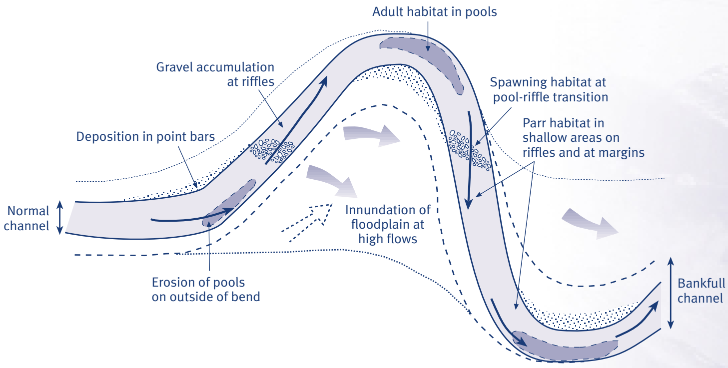
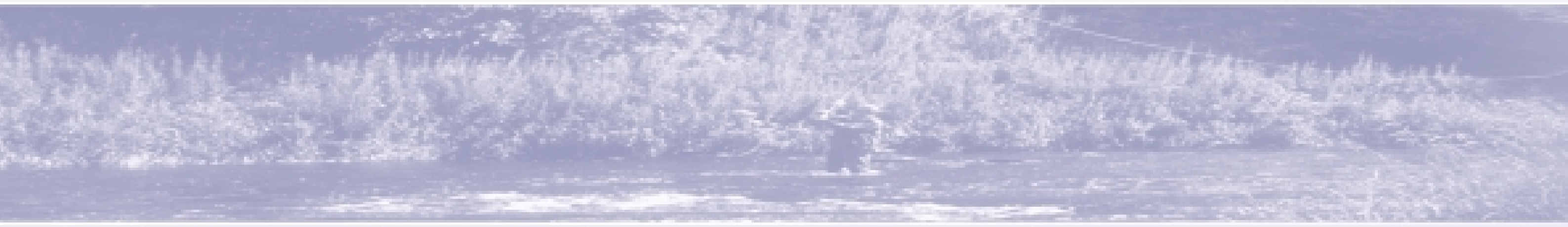


Figure 3: Idealised diagram showing how patterns of erosion and deposition along a meandering stretch of a river create a mosaic of habitat features. It also shows at a local scale how the processes of erosion and deposition are linked.



Although much fisheries management focuses on Atlantic salmon, other fish species are also important in many areas. Brown trout are found in almost every Scottish stream and river, and share many habitat requirements with Atlantic salmon, including use of spawning habitat and pools. They tend to be more common in smaller streams and are particularly dependent on terrestrial invertebrates from overhanging vegetation as a food source. Grayling are also common in many Scottish rivers south of the River Tay, and tend to spawn in finer gravels than salmon and trout, often at the tail of pools. Eels are also widespread in Scottish rivers though cold water temperatures often dictate that they spend much of the year buried in river gravels. Neverthless, they form an important part of the ecology of many rivers and are a significant food source for predators such as otters.

Aside from fisheries interests, riverine habitats are also used by other species. The habitats of these other freshwater species, particularly those that are legally protected, such as freshwater pearl mussels and otters need to be conserved. In some cases it is illegal to disturb the species or its habitat. Consequently, it is extremely important that rivers managed for salmonids or other fish are not manipulated in such a way that the habitats of other important species are lost. For example, the flow of clean, well-oxygenated water through river gravels is an important habitat for freshwater pearl mussels, whilst exposed gravels are used by many protected Red List invertebrates and more silted bars are colonised by aquatic macrophytes and invertebrates. As different species use different habitats, maintaining a full range of natural channel features is the most appropriate way of sustaining fish populations and protecting the biodiversity of the river and its riparian corridor. For example, macroinvertebrates provide important food sources for juvenile fish, and bankside trees provide summer shade from their canopies and cover under their roots.

4. River channels and management issues

Key Points

- In some cases catchment-scale change in land and water management has contributed to the degradation of fish habitats.
- Sustainable restoration management often involves concerted action at the catchment scale.
- More localised management needs a catchment context to ensure that the causes of problems, rather than their symptoms, are being addressed.

Studies in remote parts of North America and northern Europe show that in relatively undisturbed catchments, where river systems are relatively stable, the range of habitats available to fish will usually be extensive and of high quality. However, in countries like Scotland, historic land management often means that river channels are often gradually adjusting to changing environmental conditions as flow regimes and sediment loads have altered.

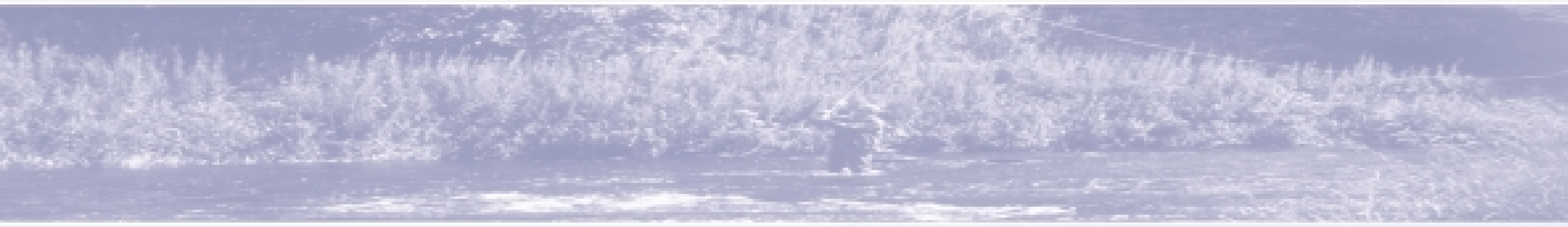
Patterns of land ownership and the distribution of individual fishery management units often do not reflect the integrated nature of rivers and their catchments. This makes responses to management issues at the appropriate spatial and temporal scales somewhat difficult. Consequently, management is often piecemeal and can relate to localised manifestation of a problem with more widespread causes. Management decisions and actions are therefore often based on particular beats or reaches belonging to individual proprietors. This means that care is needed to avoid adverse effects on neighbouring stretches of rivers and it can mean that the symptoms of problems are tackled rather than causes.

A number of initiatives involving different stakeholder groups are attempting to coordinate activities more effectively for the benefit of habitats and fish populations within particular rivers or tributaries. In the future, such plans might be integrated into the river basin management planning system as sub basin plans, as they are likely to be aimed at achieving the same environmental objectives as the river basin management plans. The recognition that salmon and other fish populations in particular rivers are a shared resource is an important prerequisite to more coordinated habitat management initiatives. This is analogous to the more coordinated approaches to pollution control that have been undertaken over recent decades, where the dilution capacity of rivers for various effluents has been shared in a coordinated and fair manner, to bring about real improvements in environmental quality, to the benefit of all river users.

5. Intervening in river systems: key principles for best practice

Key Points

- As river channel behaviour is complex and any intervention in natural processes may result in unexpected, adverse impacts, management needs careful judgement.
- The motivation for any planned intervention requires clear identification of the problem or issue to be addressed and its underlying causes.
- The options for intervention need to be carefully considered, often with professional assistance, and the possible risk of adverse impacts needs to be assessed. The implications for other river users needs to be considered and they need to be consulted.
- In many cases, intervention should be a last resort or may not be required at all.



Given the complex nature of river processes, any attempt to manage problems in river channels must ensure that the causes of the problems – and not the symptoms - are being addressed. Before attempting to try to intervene in river processes, managers need to consider carefully whether or not intervention is necessary or desirable. This requires careful planning, often with inputs of expert advice, and the development of a clear set of achievable objectives, which recognise the real cause of the problem.

5.1 Key questions in decision making

Before any management intervention occurs, for any reason, the following questions should be given careful consideration:

- What is the problem or issue of concern?
- What are the causes of the problem?
- What are the aims of the planned intervention?
- Are they realistic?
- Are they legal?
- Have they been approved by the appropriate bodies?
- What are the likely negative impacts of the proposed intervention?
- What are the chances of the aims being successfully achieved with minimal additional impacts?
- After consideration of the above questions, is the intervention still necessary and/or desirable?
- If so, how can management maximise benefits to other river users?

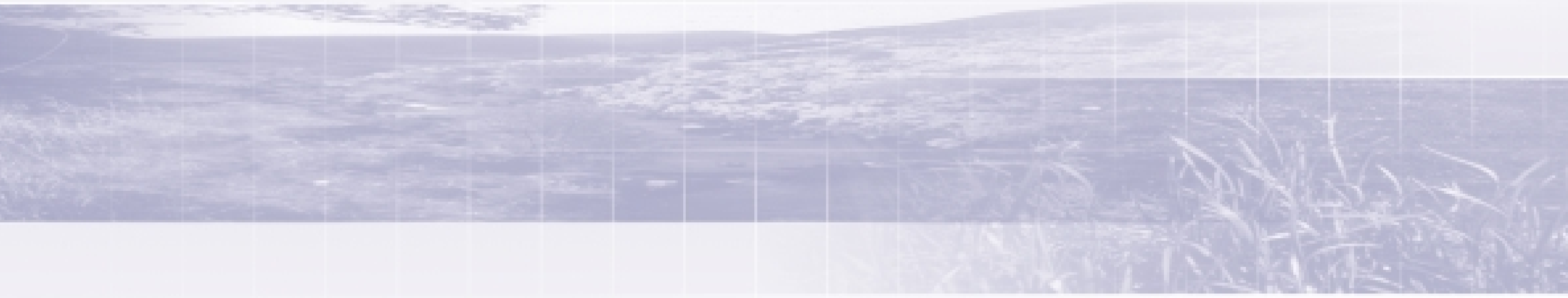
By careful consideration of these points, managers can often avoid large expenditure on projects that may fail to yield the anticipated benefits and/or avoid unanticipated adverse impacts on the river system and other river users.

What is the problem or issue of concern?

Clear identification of a particular problem or issue is a prerequisite to any management intervention.

What are the causes of the problem?

Given the integrated nature of river systems described above, the causes of a problem may be outwith the control of the manager of a particular river reach. In some cases this may mean that attempts to treat the ongoing symptoms of a problem without addressing its causes will result in an expensive, repetitive commitment that is both unsustainable and unsuccessful. For example, restoration work on spawning gravels may involve raking or treatment with compressed air to flush out accumulated fine sediments. Ultimately these fine sediments are likely to be derived from areas of intensive cultivation or over-grazed land upstream. Consequently whilst the gravel restoration may have some short term benefits, it is likely that the next flood will, once again, cause fine sediment infiltration into the gravels and the cleared silt will deposit within gravels downstream. It follows that management should always try to address the causes of a problem.



What are the aims of the planned intervention and are they realistic?

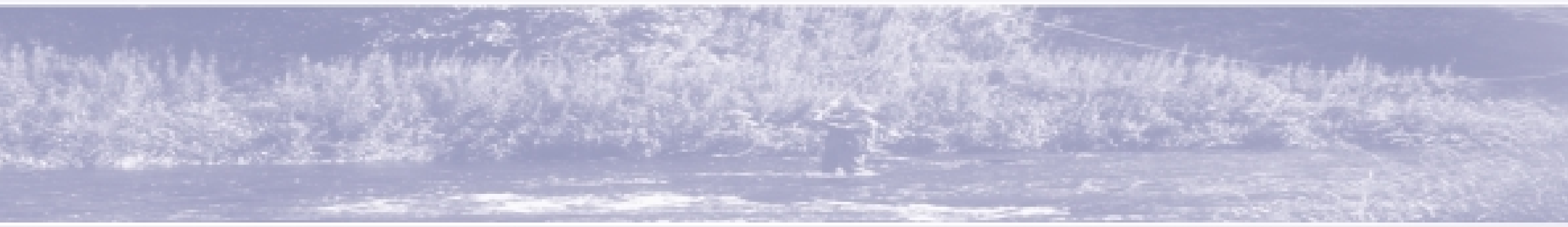
Successful river management schemes require clear, well-justified aims. In some cases, the manager may consider this to be obvious, but it is surprising how often schemes do not have clear aims or have aims that are not realistic. Consequently large sums of money may be spent on works that will fail to bring demonstrable benefits.

Are the planned works legal and approved by the appropriate bodies?

Early and extensive consultation with relevant regulatory authorities, interest groups and individuals is crucial to the development and successful implementation of any river management scheme. In the following section guidance is given on who to approach as part of consultation procedures. Failure to consult may, at best, result in adverse reaction from other river users. In the worst cases, however, it may result in failure to comply with statutory requirements and could possibly result in legal action being taken against the instigator. As described previously, the Water Environment and Water Services Bill will introduce controls over engineering works and activities that affect the integrity of the water environment. In the future, such works will need to be notified to SEPA and may be subject to binding codes of practice or even licensing. These and other recent regulatory changes mean that the river manager is increasingly having to pay close attention to ensuring they have the proper authorisations and have carried out adequate consultation before they embark on a project.

What are the likely negative impacts of the proposed intervention?

The continual movement of water and sediment in river systems means that intervention in one location usually has impacts elsewhere that may be difficult to predict. In the spawning gravel restoration example cited above, it is most likely that fine sediments flushed from a particular spawning site will be transferred downstream where they will contribute to the degradation of other spawning areas. Also, attempts to prevent erosion on a river bank may solve the problem at that particular location but transfer the problem to the opposite bank or a length of river downstream. Often activities have wider implications for aquatic species and the wider landscape than the manager realises. Expert advice, often involving fish biologists, fluvial geomorphologists and river engineers may be required to help understand and predict what these impacts might be.



What are the chances of the aims being successfully achieved with minimal additional impacts?

After carefully defining the aims of a particular scheme and assessing, with professional guidance, that the aims are realistic and likely to be achieved, the benefits need to be judged against the levels of risk of adverse impacts. Managers and their advisors should be fully convinced that their proposals are likely to be successful and sustainable. This requires that a simple assessment of the risks associated with the nature and scale of the problem being tackled takes place before management occurs. Particular care should be taken to time any management so as to avoid sensitive periods for fish and other organisms.

Following the consideration of the above, is the intervention still necessary and/or desirable?

If a scheme is likely to achieve its aims, have minimal or no adverse impacts and satisfy relevant statutory requirements then the design and implementation of a scheme can progress.

How can management maximise benefits to other river users?

It is often possible for channel management to achieve a number of different objectives, of which fisheries management may be only one. Consequently there are often benefits to fisheries managers in exploring how other objectives can be incorporated into management schemes. In some cases doing this may, for example, provide access to various grant aid that would not be available for fisheries schemes alone. Awareness of these wider issues during consultation will help identify such opportunities and potential partners.

6. Consultation: statutory and regulatory requirements

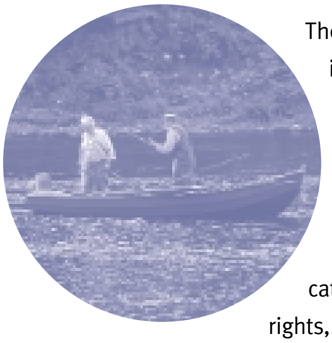
Key Points

- Interventions which affect the physical characteristics of river channels will require extensive consultation, in many cases involving statutory consultation with regulatory bodies.
- Consultation with other stakeholders involved with a particular stretch of river is good practice.
- Early consultation can avoid more serious problems later on.

Many of the river management practices of interest to fisheries managers are subject to a number of formal legal requirements. Awareness of these and adherence to them is clearly an essential element of any activity. In many management schemes a number of agencies will be able to provide advice; in some cases they may be statutory consultees. The names and addresses of some organisations who are likely to be helpful in this respect are listed in Appendix C.

Key consultees include:

The **Fisheries Research Services Freshwater Laboratory (FRSFL)** and the **Freshwater Fisheries Branch of the Scottish Executive Environment and Rural Affairs Department** should be consulted if the movement of freshwater fish may be affected.



The **Scottish Environment Protection Agency (SEPA)** needs to be consulted over any water quality impacts (e.g. mobilisation of fine sediments, or use of herbicides) resulting from management schemes. However, SEPA also has a duty to promote conservation of plants and animals dependent upon the aquatic environment and is empowered to advise river users over how this may be achieved. The Water Environment and Water Services Bill will, in future, require regulatory authorities, principally SEPA, to control significant adverse impacts on ecological status. Hydromorphological quality is a key component part of ecological status.

Scottish Natural Heritage (SNH) has a duty to secure the conservation and enhancement of the natural heritage of Scotland and so should be consulted where effects of river management on the landscape and/or species (all species, not just protected, rare or endangered species) may be important. Consultation with SNH is becoming increasingly important because numerous rivers are designated as Special Areas of Conservation (SAC) for salmon and other freshwater species, or are protected as Sites of Special Scientific Interest (SSSI) for habitat, species and earth science interest. Additionally, many good rivers are within National Scenic Areas and there is a growing emphasis on issues of sustainability in relation to development and resource management.

The relevant **District Salmon Fishery Board,** if the work is related to, or could have an impact on, salmon or salmon fisheries.

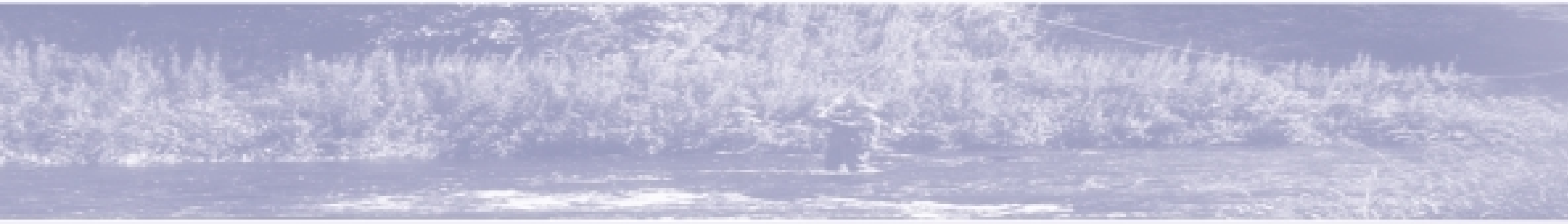
The **Local Authority** which may require an application for planning permission.

Riparian owners elsewhere in the catchment, including those who own fishing rights, and particularly those on neighbouring stretches of the river.

Scottish Water, if operations are liable to affect water quality (eg by increasing fine sediment mobilisation) upstream of public water supply intakes.

It may also be helpful to consult with local community groups (particularly **Community Councils**), and recreational groups (such as canoe clubs) especially if the area is well used for informal access.

Extensive consultation with regulatory bodies and other stakeholders is good practice in all river management schemes. Early consultation can avoid many serious problems that can later emerge.



7. Channel management practices for fisheries

River management initiatives by fisheries interests are varied with respect to the perceived need, and the scale of the operations required. However, most activities relate to the following broad categories.

Fish habitat restoration

- Management of spawning habitat
- Enhancing fish cover
- Removal of artificial barriers to upstream migration
- Bank stabilisation

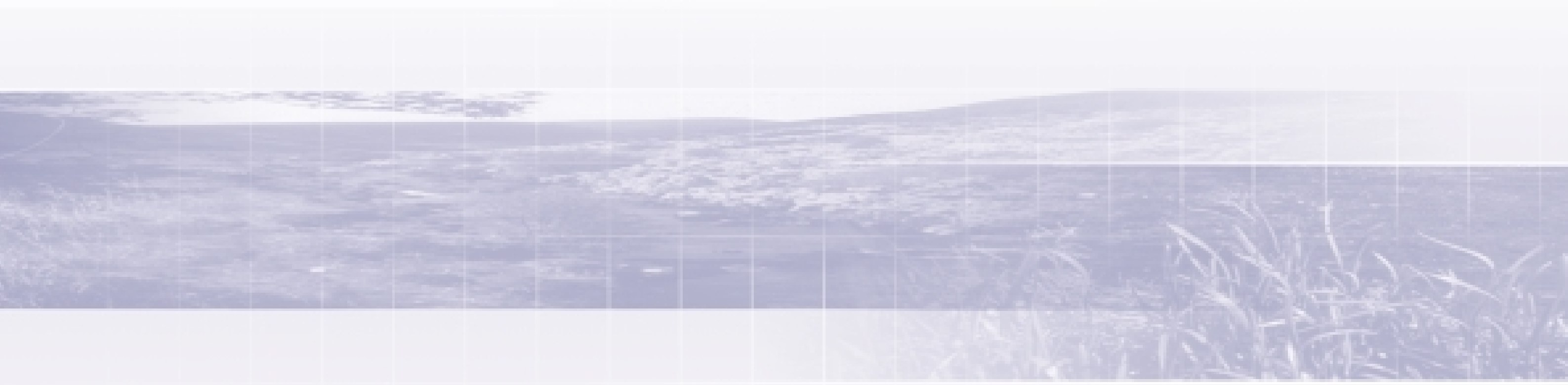
Fishing improvements

- Pool management (including use of deflectors and croys etc)
- Management of riparian vegetation
- Management of channel vegetation
- Construction of fishing platforms

These operations range from relatively routine procedures that can be undertaken by fisheries staff (eg management of riparian vegetation), to major operations that are expensive and involve external consultants and contractors (e.g, some bank stabilisation operations). In all cases, however, it is important that the management has achievable objectives and is sustainable.

The following sections provide some guidance on approaching such issues and outlines some of the problems that can arise. Such problems generally relate to points made earlier in relation to the functioning of river channels. In some cases, fishery managers will undertake the work with their own staff, and it is important that the staff involved have a basic understanding of river processes. When external consultants and contractors are undertaking river works, it is important that they too are familiar with sustainable approaches to river management.

In recent years a number of books and manuals on more sustainable approaches to river management have been produced. These provide much more detail than can be given here and should be referred to by managers and their consultants (these are listed in the bibliography in Appendix B).



7.1 Restoration of spawning habitat

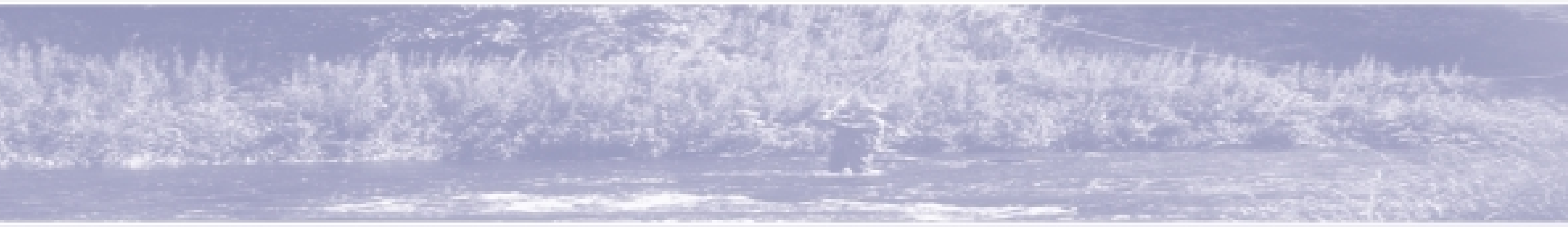
Key Points

- Distribution of spawning habitat is naturally variable in river catchments.
- In some cases, often where catchments and/or channels have been heavily modified, lack of spawning habitat may be a limiting factor on fish populations and professional opinion may indicate that restoration is needed.
- It should be established that restoration work in a degraded catchment is a realistic goal and not a treatment of symptoms. Restoration should also only be sought where a demonstrable decline in habitat has occurred, not where poor habitat is the natural state.
- The negative impacts associated with restoration works (eg de-silting operations) need to be carefully considered.

Spawning habitat is usually unevenly spread throughout a catchment area and is found where suitably sized gravels accumulate. Often spawning habitat is not limiting, and other factors may be a greater constraint on overall fish abundance.

The restoration and/or creation of spawning habitat are often key objectives of fisheries managers, particularly in river systems where fish numbers are perceived to be low or thought to be declining. In such cases, assessment by a qualified fisheries biologist may suggest that lack of spawning habitat is restricting population recruitment. Fish can spawn in a variety of situations, though they tend to prefer areas of flow acceleration, typically at the downstream ends of pools where riffles or gravel bars are present. In spawning locations fish require appropriately sized gravels that are permeable, with sufficient water depths and velocities to allow female fish to excavate redds.

A lack of spawning habitat may reflect past channel management in areas where, for example, canalisation of rivers has occurred to improve land drainage. The most frequent problem is that of fine sediment infiltration into spawning gravels. Fine sediments reduce the flow of well-oxygenated river water to developing salmon embryos and in some cases can cause mortalities through suffocation. In addition, fine sediments can become compacted and can entomb young alevins and prevent emergence. Increased fine sediment loads in rivers are commonly associated with long-term intensive land management practices such as agriculture and forestry, which may have eroding drainage ditches, runoff from compacted soils and/or eroding river banks. Consequently, only catchment-scale initiatives will solve the causes of such problems rather than treat their symptoms.



Restoration of spawning habitat

Where the enhancement or restoration of spawning gravels is the main objective, (i.e. where an area was used for spawning historically but the habitat is now significantly degraded), it is important that a holistic approach is adopted to the problem. As noted earlier, where fine sediment infiltration is the main problem, simply raking or flushing the gravels with compressed air or high velocity water jets is unlikely to be anything other than a short-term measure if fine sediment inputs upstream remain high, and may also exacerbate problems further downstream.

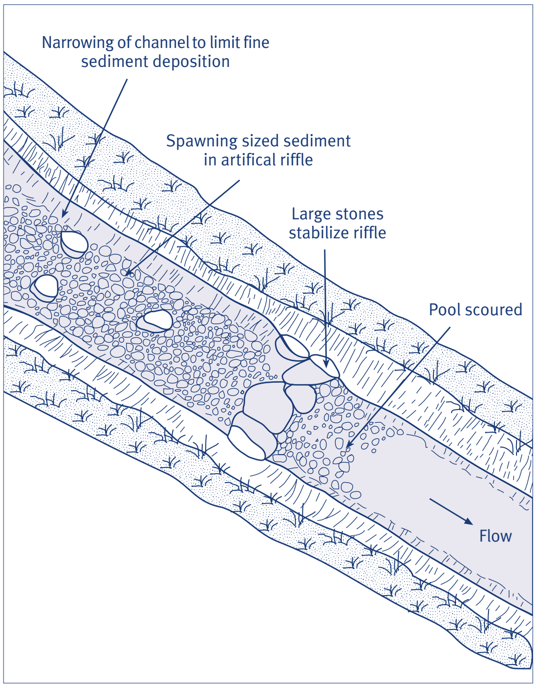


Figure 4: Example of creation of spawning habitat which may be appropriate in a small canalised stream. Large boulders stabilise riffle but are submerged below the water level. Sediments of local origin should be used (after Cowx and Welcomme, 1998).

A range of techniques are available which may, if designed and implemented sensitively, allow flows over river gravels to reduce the probability of fine sediment deposition. This might involve narrowing the channel close to spawning gravels to increase flow velocities and reduce sedimentation rates. Channel narrowing may involve the use of instream structures such as deflectors, boulder placements or use of submerged weirs. In most cases, however, such intervention needs expert advice to ensure that objectives can be achieved and that impact on other river interests can be minimised. In many situations such intervention will only pass fine sediments downstream and not address the cause of the problem.

Creation of spawning habitat

Creation of spawning habitat may be considered where a river system has been so seriously degraded that spawning habitat has largely disappeared. Usually, the sediment accumulations that fish use for spawning occur in locations that can be anticipated on the basis of other geomorphological features in the river channel. Creating new spawning habitat is expensive; it requires careful design of what sized sediments are required and where and how they should be placed if they are to remain stable (Figure 4). This is a task that needs professional advice and design and may not be suitable in high energy streams where gravels can be washed out during floods, failing to provide any long-term benefits.

7.2 Increasing fish cover

Key Points

- As part of more extensive restoration programmes, fish cover in degraded rivers can be increased by boulder emplacements.
- Boulders need to be carefully sited to avoid bank erosion or excessive bed scour.
- Woody debris and bankside planting can also be used to increase cover.

In degraded streams with poor bankside vegetation, fish cover may be limiting. As part of wider restoration schemes, cover can be provided by a range of other techniques such as placing boulders or woody debris in the river channel. Boulder placements can increase habitat complexity and create new microhabitats providing refugia for macroinvertebrates as well as both juvenile and adult fish (Figure 5). Small pools are often created on the downstream side of boulders and if used sensitively, these techniques can significantly enhance habitat diversity in degraded streams and may be less visually obtrusive than some of the more complex in-stream structures described below. Care is required; if located too close to the river bank, boulders may deflect flows towards the bank and accelerate erosion rates creating significant problems. Conversely, if judiciously sited, boulder placements can deflect flows away from vulnerable banks and in some cases can help dissipate energy levels through reaches prone to erosion. Usually however, expert geomorphological advice will be needed to assess how boulders will affect flow patterns at a range of discharges. Once in place, larger boulders can be very difficult to remove should adverse impacts occur.

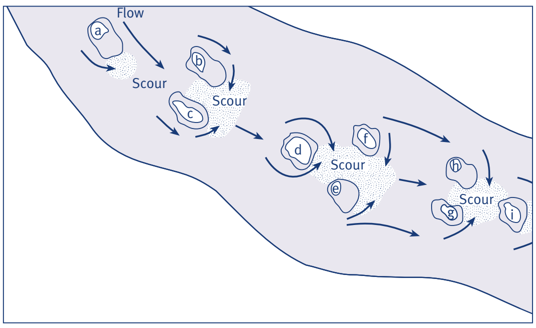


Figure 5: Use of different boulder configurations which may help create fish cover in certain types of stream. The examples show how single boulders (a), boulder pairs (b,c) or boulder clusters (d,e,f and g,h,i) can be used to encourage scour. Note boulders should be set well clear of the stream banks as not to accelerate bank erosion (after Cowx and Welcomme, 1998).

Boulders of a suitable size to resist the highest flows can be placed selectively, whether individually or in small groups (Figure 5). The selection of location will require careful judgment based upon a knowledge of the reach of river under consideration and the management objectives. In general, boulders are best installed during periods of low flows, avoiding the period between spawning and emergence, and should project just above the low water surface and have their longest axis parallel to the current. The boulder should be partially embedded within the stream bed to enhance stability. In streams with high sediment loads the usefulness of boulders may be limited by increased sediment deposition.

7.3 Removal of artificial barriers to migration

Key Points

- Fish migration within river systems may be limited as a result of artificial obstructions, areas of sediment accumulation and by natural barriers such as waterfalls.
- Removal of artificial barriers, or the installation of fish passes around them, may help increase access to upstream habitat.
- Natural barriers such as sediment accumulation at confluences and waterfalls will often only be impassable at low flows, with fish passage possible at higher flows.
- Waterfalls often have intrinsic landscape and ecological value, and they may isolate genetically rare fish populations upstream. Any proposed physical change to waterfalls will require extensive consultation with FRSFL, the District Salmon Fishery Board, the relevant local planning authority, SNH and SEPA.

Along many rivers it is possible to find locations where fish passage is impeded due to a range of human interventions in the river. Bridge aprons, culverts, and mill weirs are all examples of features that may impede fish movement or prevent it completely. In some cases, major engineering would be required to overcome these problems (such as the removal of old mill weirs or bridge aprons); in other instances fish passes may consist of formal or informal structures (Figure 6). Detailed guidance on techniques available for dealing with bridging points is given in *River Crossings and Migratory Fish: Design Guidance* (2000) published by the Scottish Executive Rural Affairs Department.

Waterfalls are common on Scotland's river systems and fisheries managers are sometimes interested in trying to increase fish habitat by allowing upstream passage. However, waterfalls have intrinsic landscape and ecological value themselves and may isolate genetically rare fish populations upstream. Any physical change to waterfalls is a major undertaking and would require extensive consultation with FRSFL,

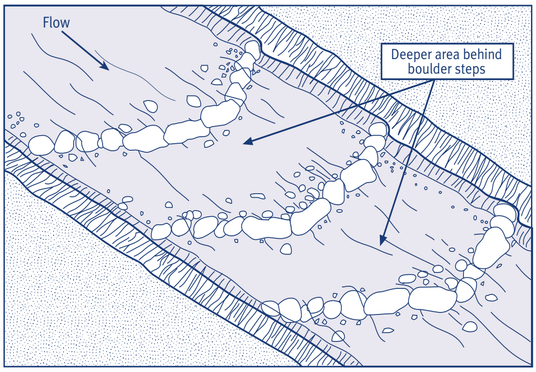


Figure 6: Example of boulder steps in a degraded channel that has been over widened and would be too shallow to allow fish passage. The submerged boulders create deeper areas upstream for fish to move into (after Cowx and Welcomme, 1998).

the District Salmon Fishery Board, SNH, SEPA and the relevant local planning authority.

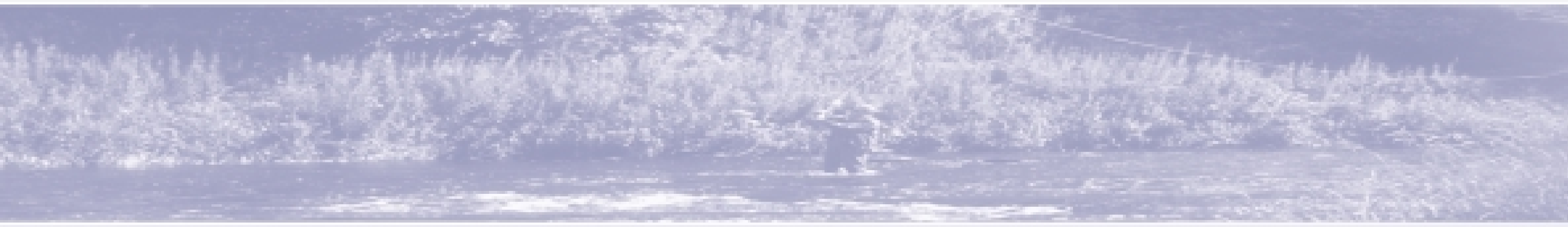
A particular type of problem can occur where tributary streams have their confluence with main river channels. A loss of energy occurs when a tributary enters a larger channel due to the usual decrease in gradient and reduced hydraulic efficiency as two flows converge. As a result, sediment deposition is common and in some instances, particularly in degraded catchments where sediment delivery rates are high, the resulting gravel accumulation may restrict the passage of migratory fish at low flows.

Traditional management responses have tended to focus on regular dredging to retain fish access, though this tends to treat the symptoms of the problem, rather than the cause. Large gravel accumulations occur when the tributary enters the main river at a near perpendicular angle. In such cases realignment of the confluence to reduce the angle of stream entry may help create a self-scouring confluence, though this will require very careful design and usually needs expensive engineering works to stabilise the river banks. Again such works should avoid the period between spawning and emergence (October – May). In many cases, however, gravel accumulations will be submerged at higher flows allowing access at the times when migration tends to occur.

7.4 Bank stabilisation

Key Points

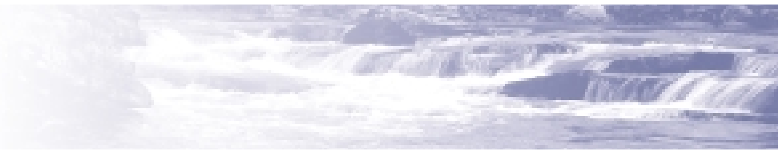
- Erosion is a natural and complex process in river channels; accelerated erosion rates often relate to changes in catchment land use. Bank stabilisation is often carried out by fisheries managers to protect fishing beats, reduce sediment inputs and allow access.
- Bank stabilisation requires the correct identification of causes and careful planning of solutions.
- Many of the traditional engineering techniques used by fisheries managers (e.g. heavy use of rock revetment) are no longer acceptable and more environmentally sensitive engineering is required. Often reducing grazing pressures can do much to limit erosion rates.



River bank erosion frequently causes problems for fisheries managers. This can result in loss of land adjacent to the bank, increased sediment inputs into rivers (sometimes with associated habitat degradation) and access difficulties for anglers attempting to enter the river. As noted above, bank erosion is a natural process and is important to the maintenance of diverse habitats, such as the provision of spawning gravels. However, where bank erosion rates are high and serious damage to habitats is occurring (eg fine sediment inputs to spawning gravels, infilling of downstream pools etc.) management intervention may be appropriate.

An important issue in such cases is to consider what is causing the bank erosion and what the appropriate response should be. Rapid rates of erosion may very often relate to human impacts such as over-grazing as a result of high livestock densities. This may reduce vegetation cover and expose riparian soils, rendering them susceptible to erosion. Such problems can be addressed by erecting stock fencing. In other cases the problem may be more difficult to solve, where, for example, erosion is being accelerated by aggressive land drainage in the upstream catchment. In such cases coordinated and integrated catchment management responses may achieve progress.

In essence there are three responses to bank erosion problems which should be discussed with expert advisors: do nothing; enhance natural vegetation; or use of environmentally sensitive engineering. Whatever the eventual management response, it is important that managers avoid the temptation to over-react to new occurrences of bank instability. The timescale over which erosion has occurred needs to be considered, along with the actual erosion rates and the consequences, if any, of the erosion. Newly eroded banks often settle down to a new profile which adds diversity to the river corridor. Observing the instability under both high and low flow periods gives an opportunity to understand the processes causing it.



Do nothing

Although the do nothing approach to an eroding river bank may appear paradoxical, observations and/or expert opinion may suggest that intervention could exacerbate the problem or transfer it elsewhere. Rivers expend energy in eroding river banks, and protecting one stretch of bank commonly causes erosion to start or accelerate elsewhere. In some situations this may create an even more

serious problem. In some cases erosion rates may be self-limiting. Although eroding river banks can look alarming, it is not uncommon to find that large rocks falling into the river protect the foot of the bank and restrict further erosion rates, thus creating a new quasi-stable profile. Some freshwater species will utilise the habitat created by eroding river banks (e.g. kingfishers and sand martins).

Enhancing natural bank protection through re-vegetation

Over-grazing, cultivation and/or unsympathetic management of bank side vegetation often reduces the natural resistance of river banks to erosion. The recovery of eroding channels when well designed and well-placed stock fencing is used to exclude livestock and facilitate revegetation can be remarkable (Figure 7). Erosion rates can be minimised, fine sediment inputs to the channel reduced, bank side cover increased and river channels can be reduced in width and increased in depth. All of these factors can have significant positive impacts on fish populations, other freshwater species and the wider landscape. Where possible, working with natural processes in such a way often offers the most sustainable approach to bank protection.

Care needs to be taken when siting stock fencing, as large floods can rapidly erode banks and undercut fences if they are not placed outwith the active zone of channel migrations (Figure 7). Expert advice and observation of river behaviour prior to management intervention is, therefore, important when designing the scheme. In some situations (eg open moorland) there may also be sensitivities over the appearance of rectilinear fencing features and alternative water sources for livestock might need to be considered.

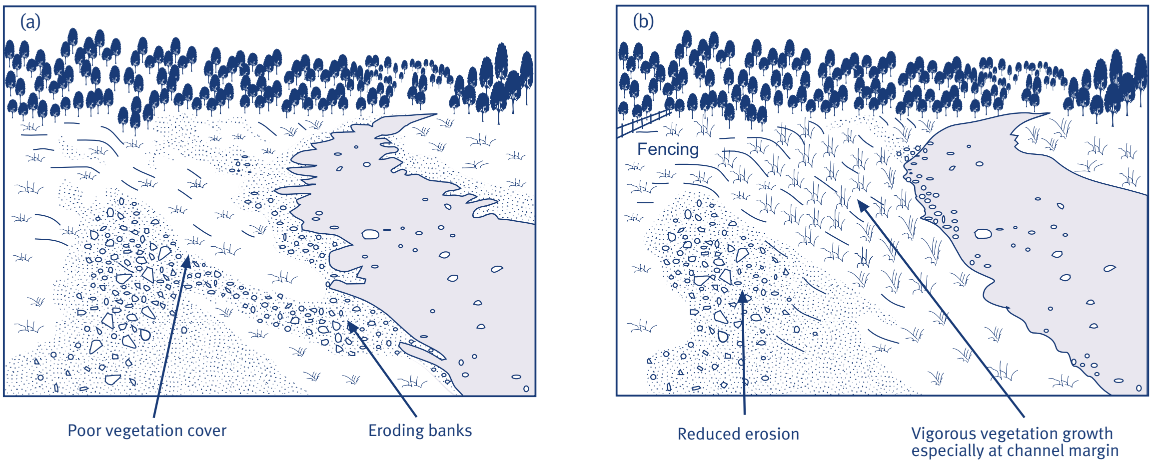
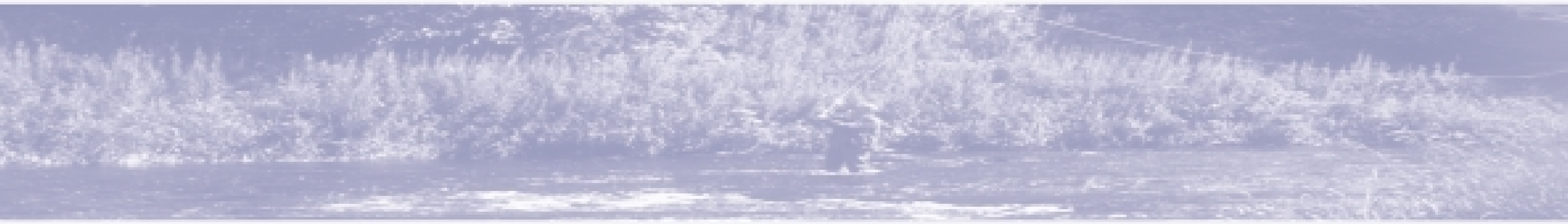


Figure 7: Idealised comparison of a river bank a) under an intense grazing regime and b) five years after stock fencing was put in place. (a) shows degraded riparian area, eroding river margin and extensive sediment inputs to the channel; (b) shows riparian revegetation, more stable channel margin and reduced sediment inputs.



Bank protection through environmentally-sensitive engineering works

In extreme cases, engineering works may be required if erosion is to be halted. In the past, this has commonly involved relatively crude rock armouring or gabions (stone filled baskets) which reduce the amenity and conservation value of river channels. It is often also unsuccessful, as rivers usually begin to erode the bank immediately upstream or downstream of the protected area. In extreme floods, the works may become submerged and the river begins to erode behind and below the armouring (Figure 8).

Fortunately, new techniques are being developed which involve the use of more natural materials which, with careful landscaping and professional design, offer more sustainable approaches. Reprofiling banks and encouraging re-vegetation, with the use of geotextiles, for example, may provide similar levels of protection to rock armouring, incur similar costs and avoid the aesthetic and ecological problems associated with rock armouring.

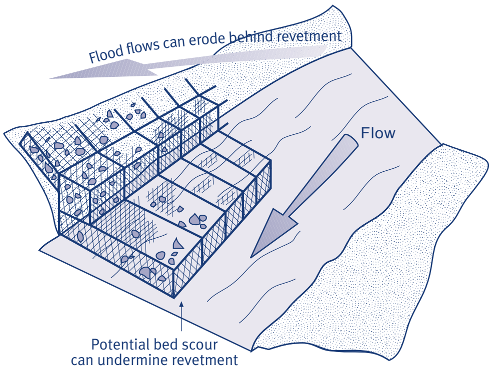


Figure 8: How Revements such as gabions may protect banks from erosion under normal flows, but are prone to scour on the river bed or erosion of the bank behind in large floods. Careful design and maintenance are needed to avoid major problems and intrusive aesthetic impacts.

Where more traditional revetment techniques (such as the use of rock armouring and gabion baskets) are needed, these can now be used as parts of a more sustainable channel design. The River Restoration Centre has recently published a manual detailing examples of environmentally-sensitive engineering techniques successfully applied on two restoration schemes in England (River Restoration Centre, 1999). These can include planting within gabions or armouring to soften the visual impact and enhance the diversity of instream and riparian

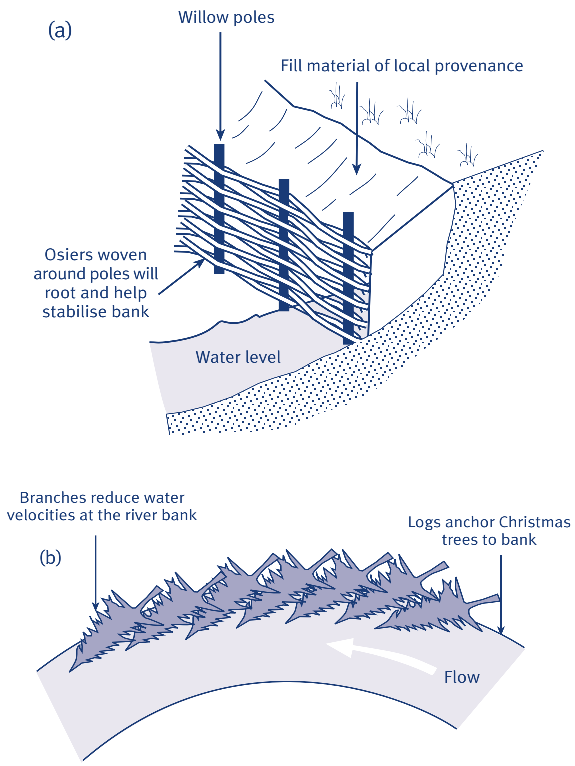


Figure 9: In certain circumstances use of willow spiling (a) or old Christmas trees in log revetment (b) may stabilise an eroding river bank. This is an example of providing bank protection using more environmentally sensitive techniques.

habitats. Alternatively, willow spiling or log revetment are techniques that can be used both to increase the strength of the bank material and reduce the erosion pressures (Figure 9).

An important point to bear in mind about bank protection is that river erosion is a necessary process and will always occur. On-going maintenance and expenditure will therefore usually result from management intervention.

7.5 Pool Management

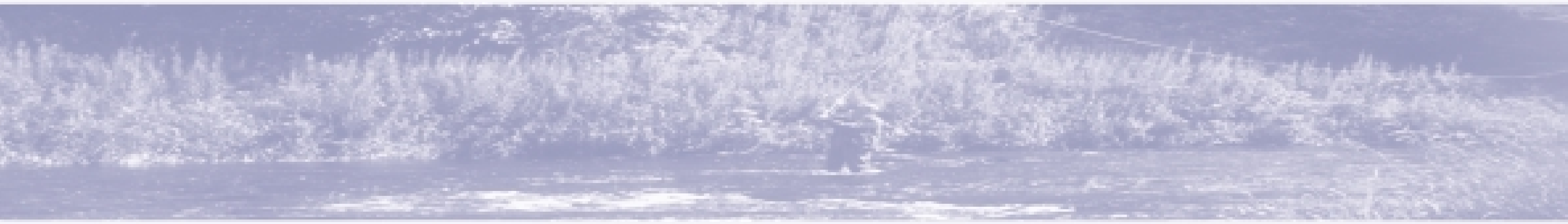
Key Points

- Deep pools are natural features in river channels that are used by adult fish and often provide important areas for angling.
- Pools are dynamic features in rivers and respond to patterns of erosion and deposition, often over long timescales. It is natural for them to infill or move position over time.
- Individual fisheries managers may often look to maintain or create pools to maintain or improve fishing. Use of direct excavation or in-channel structures such as croys are common management techniques. In some cases this management can have adverse effects on other habitat types.
- Pool management needs careful planning and expert advice; in some cases it may involve a long-term commitment to maintenance, in others it may destabilise the river channels and accelerate erosion rates.

Pools are often a prime concern for fisheries managers as they provide a key habitat where adult fish reside. As such, pools form areas where anglers will focus their activity.

Fisheries managers are keen to retain and maintain these channel features and thus the attractiveness and economic success of their fishing beat. In some cases pools are relatively stable features of the river system; in other cases pools may be infilling with deposited gravel, either in response to increased levels of erosion upstream or following particularly heavy floods. Over a sufficient length of river channel, the numbers of pools and riffles are likely to be relatively constant, though the exact areas of erosion and deposition may vary over decades or in response to large floods. Along a given stretch of river, the distribution of pools and riffles may vary between particular beats or proprietors.

Pool management involves occasional excavation of infilling gravel or the construction of weirs or croys to try and maintain a quasi-permanent area of bed scour. Such management must recognise how the deposition of sediments in pools is part of the normal functioning of a river system in response to both catchment and localised influences. Operations must be carefully considered if adverse impacts are to be avoided whilst fisheries management objectives are satisfied.



Pool maintenance by excavation

Excavation of infilling sediment from pools is an intuitively attractive and apparently simple approach to maintaining pool habitat. It is however, much more complex than might initially appear and excavation of the river bed can potentially accelerate erosion rates and increase channel instability. This is because the bed of a typical Scottish river is usually considered to be armoured. This means that it is covered by a layer of large, stable cobbles that only become mobile in the largest floods. This layer prevents frequent scour of the river bed and protects the finer sediments beneath. Removal of this armour layer, together with alterations to the bed topography can cause bed scour to occur and, in extreme cases, cause the river channel to become unstable. As a result, any excavation work needs to replace this armour layer and should not affect a significant proportion of channel width if potential instability is to be avoided. The excavation should be restricted to pre-existing pools that are known to have been stable for prolonged periods.

Further issues to be considered in pool excavation include the frequency of maintenance which, in active gravel bed rivers, may require frequent repetition at intervals of less than every three years. Additionally, it is important that the spoil removed from the river is disposed of appropriately and not simply dumped on river banks creating a visual impact and reducing the habitat quality of the river corridor. Over excavation of pools may result in loss of channel and marginal habitat if the flow is over-concentrated in the excavated area, which may additionally lower surrounding water tables. Any such operations should avoid the sensitive time between spawning and emergence.

Pool maintenance using croys and weirs

Croys (sometimes called deflectors or groynes) are in-stream structures that partially cross the channel and seek to divert flows into a particular area. These are often constructed to facilitate scour of the river bed by concentrating flows at a particular location (Figure 10). Traditionally croys or deflectors have been constructed from blockstones, large quarried boulders, or gabions. In some cases the resulting pool becomes a fish lie and the pattern of flows around the croys can create a diverse range of fishing conditions. In some severely degraded rivers, croys can help introduce diversity into highly canalised stream channels. In many high energy rivers in Scotland, however, croys are inappropriate or, if installed, need to be carefully designed and sited to avoid adverse impacts. A particular problem that can occur if croys are aligned pointing downstream is accelerated bank erosion.

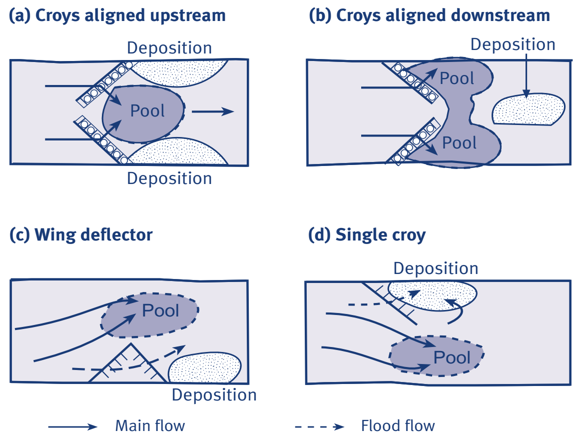


Figure 10: Use of croys and deflectors to affect patterns of erosion and deposition (a) croys pointing upstream will scour in the central channel, whilst (b) croys aligned downstream will scour towards channel margins. (c) wing deflectors and (d) single croys can have more localised effects. The diagram shows idealised effects; the height, width and angle of alignment of the structures together with the river channel characteristics will determine the precise impact.

In the past fisheries managers have often constructed croys without recourse to detailed engineering design, or geomorphological survey. The length, height and angle of croy design needs to be carefully selected to be sympathetic to the processes affecting a river channel. In some cases, croys can be very intrusive to the riverine environment, inhibit the upstream movement of fish and adversely affect other aquatic species. As croys are designed to stimulate scour, the mobilised sediment will inevitably be deposited downstream, which may have undesirable consequences.

Weirs function in a similar way to croys, with the difference being that weir structures are entirely submerged and extend across the full width of a river. They tend to be used in preference to deflectors on smaller lowland rivers (less than 10m wide) where stream channels are relatively stable and lack habitat diversity.

7.6 Management of bank side vegetation

Key Points

- Careful management of riparian vegetation has many benefits including minimising erosion rates and provide fish cover and food sources.
- Removal of bank side trees to improve casting and providing access needs to be carefully considered in light of the loss of these other benefits.

Riparian vegetation, especially when involving native trees, can bring many benefits. These include provision of natural protection from erosion, casting of shade and maintenance of cool water temperatures, in-stream cover beneath tree roots, and sources of nutrients from the in-falling leaves and insects (Figure 11). Using areas of riparian land as buffer strips (often fenced off areas between the river channel and cultivated land) is increasingly popular and it may be possible to obtain grant aid for this.

Different freshwater species are affected in different ways by riparian tree cover, and maintaining a diverse range of conditions is of particular importance. Dappled shade, affecting around half the channel surface, provides a useful rule of thumb for maintaining such diversity for different species.

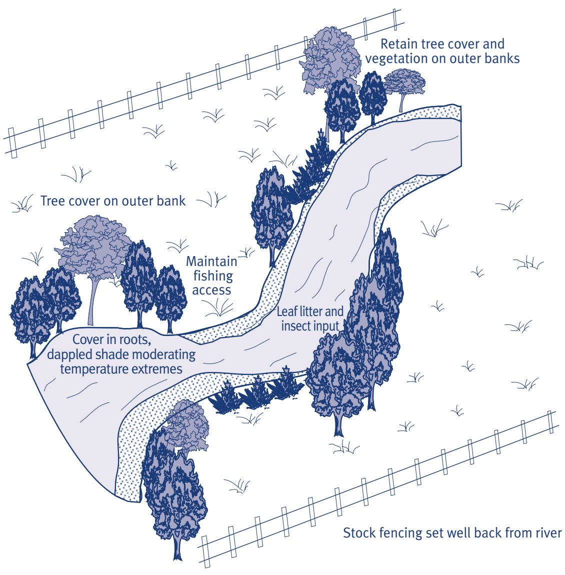
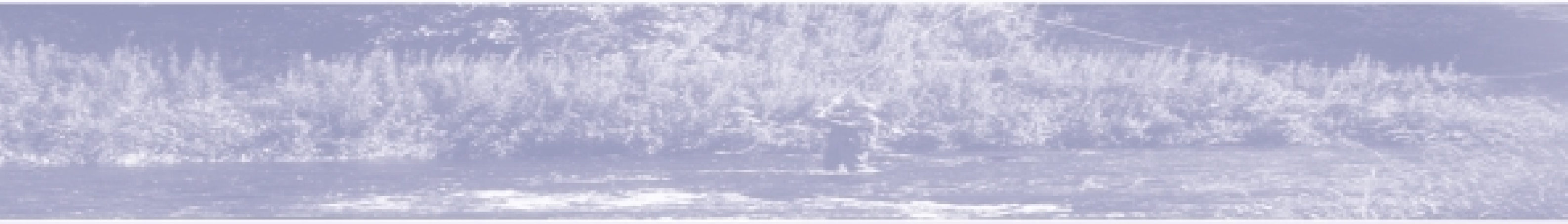


Figure 11:
Example of advantages associated with good, diverse riparian vegetation.



Along many fishing beats these benefits are, however, balanced against the need to gain access to the river and provide adequate space for casting. If cutting is taken to the extreme, fishing beats become highly manicured and lose a large degree of naturalness, resulting in a loss of amenity and other benefits.

In general, removal of trees on unconsolidated river banks will lead to a loss of bank strength when the roots die, increasing erosion risks. Where possible, trees should be retained and obstructive branches removed, perhaps by pollarding or coppicing. Where bankside vegetation is mown, this should be restricted to areas where access is required, and thus retain some cover and shading.

7.7 Management of channel vegetation

Key Points

- If in-channel vegetation is to be managed careful consideration is required to ensure legal requirements are met; notably in relation to herbicide application and removal of cut vegetation.
- Consultation must be undertaken with SEPA if herbicide use is proposed.

In-channel vegetation is an important component of aquatic ecosystems, providing habitat and energy for a range of aquatic organisms. In some cases, often where nutrient levels have been increased due to fertiliser runoff from agricultural land, vegetation growth can become excessive, and some form of management may be necessary.

In many such cases, in-channel vegetation can be managed by judicious removal by hand from problem areas. Mechanical cutting may cause downstream accumulation of cuttings and/or colonisation and establishment in new areas. The decomposition of cut material can also cause de-oxygenation if it accumulates downstream. Consequently, it is an offence under the Control of Pollution Act 1974 to leave cut weed in a river channel. On smaller streams, use of riparian trees and the shade that they cast can be used to limit the growth of in-channel vegetation. If chemical removal of vegetation is planned SEPA must be consulted before application of herbicides in or near watercourses. Scottish Water should also be consulted in watercourses used for public water supply.

7.8 Construction of fishing platforms

Key Points

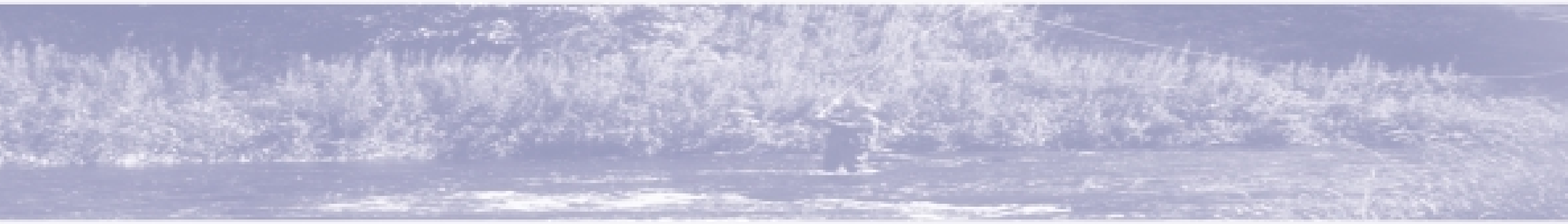
- Fishing platforms may be significant intrusions on river systems.
- Careful design and planning will minimise adverse environmental impacts. In particular, creation of erosion problems upstream or downstream need to be avoided.

Along some rivers, structures have been developed to provide improved platforms for fishing activity. These are sometimes constructed from gravel extracted from the river bed, a practice that is likely to reduce habitat diversity and possibly result in adverse impacts such as increased channel instability. The resulting structure can have an adverse visual impact and reduce the naturalness and amenity of the river corridor. Other, smaller platforms constructed of wood and concrete may be less damaging to the channel habitat but more visually intrusive, and need to be carefully integrated into the river bank to prevent erosion occurring on the upstream and downstream edges.

8. Summary and conclusions

The management of channels and river corridors for fisheries and fishing should always be based on an understanding of river processes. In Scotland, many river systems, particularly many of those with good fisheries, are dynamic and have high energy levels. Channel management therefore needs to be considered carefully and the associated risks thoroughly assessed if it is to be sustainable and avoid unanticipated, adverse impacts. It is particularly important to consult relevant authorities and consider the views of other relevant stakeholders at an early stage in planning.

When assessing the possible options for a particular channel management project, it is important that a wide range of possibilities are considered. River Basin Management Planning will introduce a new level of hydromorphological protection to physical features in Scottish rivers and water bodies. This means that there will have to be a more formal consideration of the way that traditional river management activities are undertaken in order to protect ecological objectives and maintain biodiversity.



Appendix A: Glossary of technical terms used

Armouring: The predominance of stable large cobbles on the bed of rivers which protect or armour the finer sediments beneath.

Bank stabilisation: prevention of river bank erosion or retreat by increasing the strength of the bank by natural materials (e.g. promoting re-vegetation) or engineering.

Bar: a general term referring to depositional features, usually formed of gravel, deposited in rivers after high flows.

Biodiversity: biological richness, including species, genetic and ecosystem variety.

Blockstones: large boulders used in river engineering structures.

Braided river: A river that splits around sediment accumulations into two or more channels

Buffer strip: an area of land between the river channel and cultivated land that is uncultivated and often fenced off.

Canalisation: generic term for management of river channels that results in a combination of straightening, widening and deepening, which usually severely damages in-stream habitat.

Catchment: The topographically defined area which drains into a particular river.

Channel: A variable area that is occupied by a river. It can extend greatly in flood flows compared to normal flows. Channels are often described according to their width and depth, cross-sectional shape and pattern (plan form – ie when viewed from above).

Cobbles: sediment of intermediate size between gravel and boulders.

Competence: The ability of a river to transport sediment. Generally competence will increase as flows and velocities increase.

Confluence: The merging of two river channels into a single one. Usually a smaller river (tributary) joining a larger one.

Croys: Partially submerged structures, often in pairs, which are constructed in river channels to influence patterns of water flow and affect patterns of bed scour and sediment deposition.

Deflectors: Similar to croys, but usually smaller structures on one bank of the river.

Degraded river: A state which occurs when river or catchment management has resulted in a serious deterioration in the quality of river habitats.

Deposition: The process by which sediment being transported by a river comes to rest.

Dynamic rivers: Rivers, generally with high energy levels, which are prone to change their channel characteristics relatively rapidly.

Ecological status: A new concept arising from the EU Water Framework Directive that seeks to define the quality of rivers and other water bodies by according to their ecological characteristics and their degree of naturalness.

Engineering: Generally large-scale intervention in river channels, usually involving physical structures.

Environmentally sensitive river engineering: engineering that seeks to apply engineering techniques within a context of understanding the ecological functioning of river systems and is less-reliant on hard engineering structures.

Erosion: The process by which sediments are mobilised and transported by rivers.

Fine sediments: Small sediments, usually less than 2mm in diameter, including sands, silts and clays.

Flood: A high river flow following rainfall or snowmelt where a river flows out of its channel, sometimes affecting human activity.

Floodplain: The valley bottom area inundated by water when a river floods.

Flow: the volume of water passing along a river in a specific period of time. Usually measured in cubic meters of water passing a point in one second (unit – cumec).

Flow regime: description of how the flow in a river varies over time and how frequently and for how long high flows (floods) and low flows (during droughts) occur.

Flow velocity: The speed that water is flowing at (usually measured in metres per second).

Fluvial geomorphology: the branch of geomorphology that describes the characteristics of river systems and examines the processes sustaining them.

Gabions: metal or polymer baskets, filled with large stones, which are often used in river engineering structures such as croys or bank revetments.

Geomorphology: the earth science that examines features at, or close to, the earth's surface, describes them and investigates the processes forming them.

Geotextile: fabric membrane used for bank stabilisation, usually to aid re-vegetation.

Glaciation: Colder climatic period resulting in the extension of the polar ice caps and the formation of valley glaciers in mountain areas. The last glaciation to affect Scotland ended about 10,000 years ago.

Gravel: a general term for accumulations of loosely compacted, coarse stoney river bed sediments. Technically, it is sediment that has a diameter ranging between 2 and 60mm.

Gravel-bed river: a river, usually dynamic, that is mainly characterised by gravel-sized bed sediments.

Hard engineering: river engineering primarily reliant on traditional artificial materials and methods such as concrete, gabions, steel and rock revetment.

High energy river: rivers with steep valley gradients, and frequent high flows and velocities that have the potential to transport sediments and change channel characteristics.

Hydromorphology: a term that describes the interaction between river flows (hydrology) and river channel features (geomorphology) that creates freshwater habitats.

Hydraulic efficiency: The flow characteristics that determine a river's ability to transport its sediment load.

Intervention: management that seeks to manipulate or alter river channel processes.

Load: the amount of sediment that is being carried by the river.

Low energy river: rivers with gentler valley gradients that are stable, with limited dynamic features.

Meandering: the sinuous characteristic of many river channels.

Modification: channel features that have been created by management interventions and often involve river engineering.

Over-grazing: condition where livestock numbers are high, resulting in reduced vegetation cover and increasing susceptibility of soils to erosion.

Pools: deeper stretches of rivers that are generally characterised by low flow velocities, but scour during floods. Commonly used by adult fish.

Reach: a stretch of a river displaying the same broad combination of features.

Red List: list of species that are rare and endangered and are published in Red Data Books.

Re-profiling: Modifying a river bank – usually by reducing the angle and trying to increase bank stability.

Re-vegetate: encouraging vegetation growth on river banks. Often involves re-planting and fencing to reduce grazing pressures.

Revetment: an engineering procedure which seeks to increase the strength of river banks by facing. Often relies on traditional engineering structures such as gabions, quarried rocks and boulders or concrete.

Riffles: elevated parts of the stream bed where gravel bars cause flows to accelerate and become turbulent.

Riparian: pertaining to land at the side of the river channel.

Riparian corridor: transitional area between the river and its surrounding catchment which former a corridor along the entire channel network.

Scour: localised erosion of the river bed.

Sediments: the unconsolidated material transported by a river, a mixture of particles ranging from clays to boulders.

Soft engineering: river engineering which involves more reliance on environmentally sensitive methods and highly limited use of hard engineering solutions.

Sustainable: contemporary use and management of a resource that does not compromise its management and use in the future.

System: an aggregation of components that displays self-organising structure and function. A useful way of viewing the movement of water and sediments through catchments and river systems.

Tributary: a smaller stream flowing into a larger river channel.

Water Framework Directive: a new EC Directive that seeks to promote the ecological health of the water environment across Europe. It came into force in December 2000. It unifies and replaces a number of existing water-related Directives with a new, coherent water management system for Europe. For more information, see the European Commission or Scottish Executive websites.

Appendix B: Useful references

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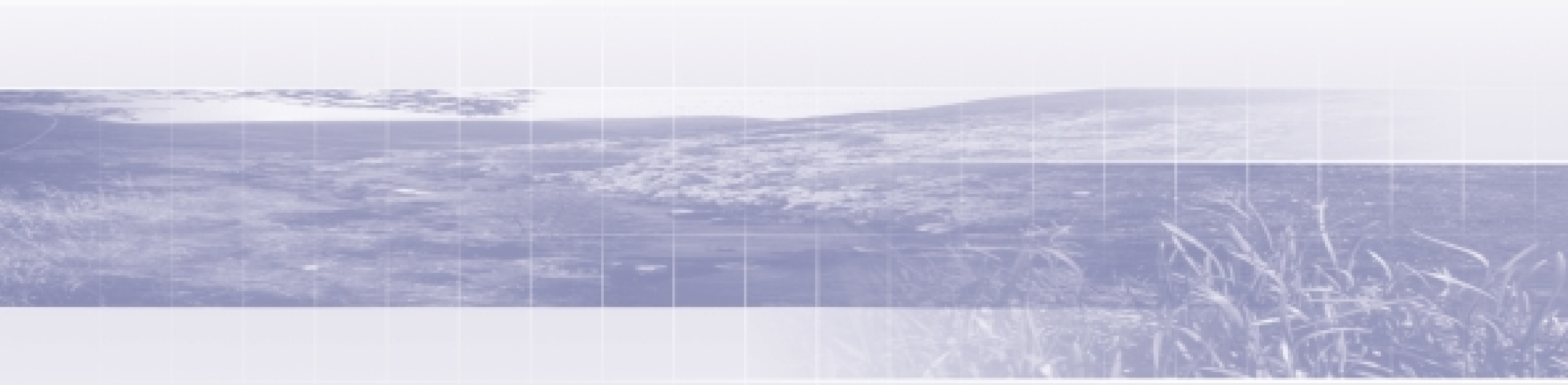


Appendix C: Sources of further information

Association of Salmon Fishery Boards
5A Lennox Street
Edinburgh EH4 1QB
Tel: 0131 343 2433
www.asfb.org.uk

Atlantic Salmon Trust
Moulin, Pitlochry,
Perthshire PH16 5JQ
Tel: 01796 473439
www.atlanticsalmontrust.org

Council for Scottish Local Authorities
Rosebery House
9 Haymarket Terrace
Rosebery House, Edinburgh
EH12 5XZ
Tel: 0131 474 9200
www.cosla.gov.uk

Farming and Wildlife Advisory Group
FWAG Scotland
The Rural Centre
West Mains, Ingliston
Newbridge, Midlothian EH28 8NZ
Tel: 0131 4724080
www.fwag.org.uk

Fisheries Research Services
Freshwater Laboratory
Faskally
Pitlochry
Perthshire
PH16 5LB
Tel: 01796 472060
www.marlab.ac.uk

Game Conservancy Trust
Fordingbridge
Hampshire SP6 1EF
Tel: 01425 652381
www.gct.org.uk

River Restoration Centre
Silsoe Campus
Silsoe
Bedfordshire MK45 4DT
Tel: 01525 863341
www.aecw.demon.co.uk/rrc/rrc.htm

Scottish Anglers National Association
The Caledonian Club
32 Abercromby Place
Edinburgh
EH3 6QE
Tel: 0131 5583644
www.sana.org.uk

Scottish Canoe Association
Caledonia House
South Gyle, Edinburgh
EH12 9DQ
Tel: 0131-317-7314
www.scot-canoe.org/index2.htm

Scottish Environment Protection Agency
Corporate Office
Erskine Court
Castle Business Park
Stirling FK9 4TR
Tel: 01786 457700
www.sepa.org.uk

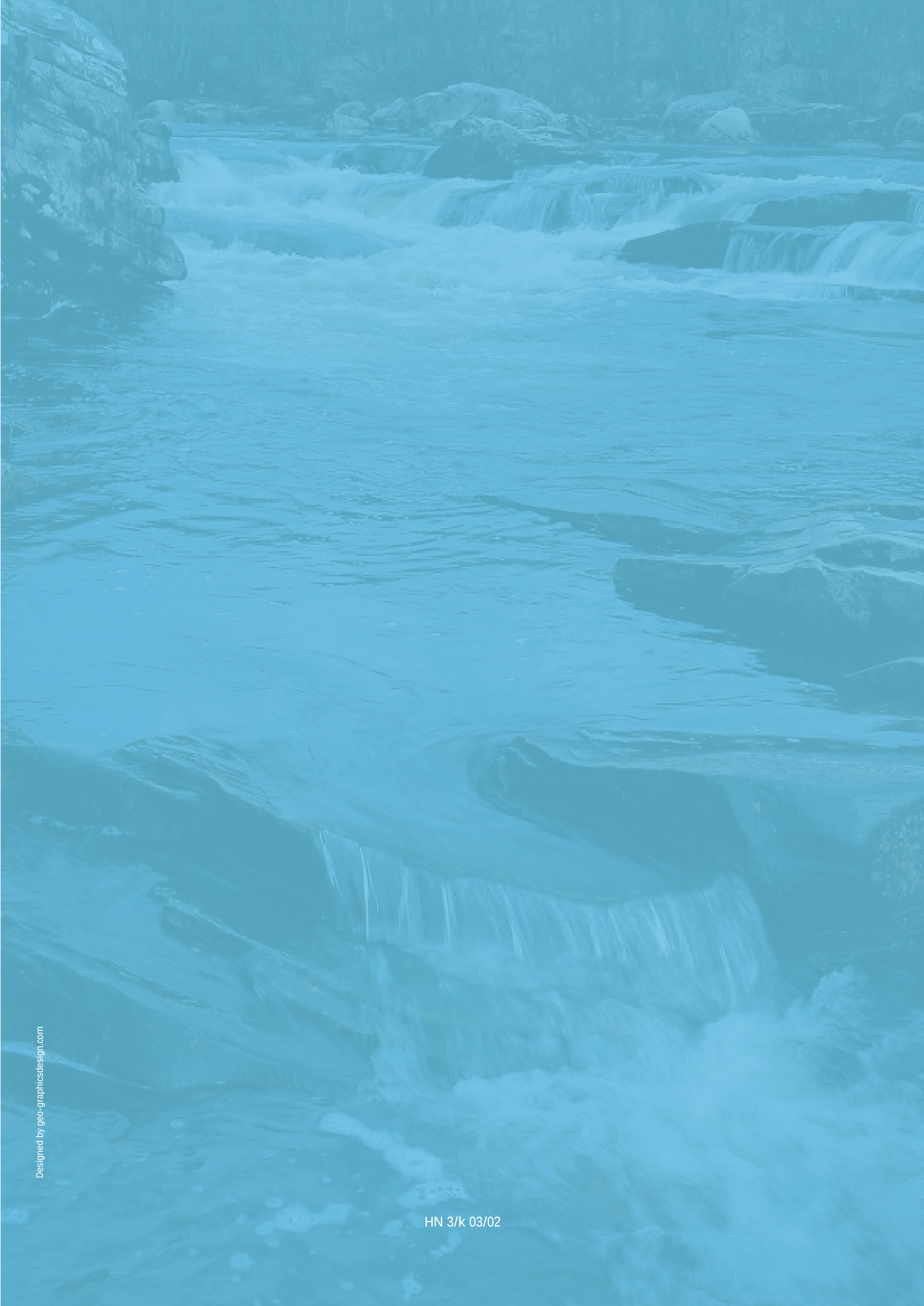
Scottish Executive Rural Affairs Department:
Freshwater Fisheries Branch
Pentland House
47 Robb's Loan
Edinburgh EH14 1TY
Tel: 0131 244 6229
www.scotland.gov.uk

Scottish Natural Heritage
12 Hope Terrace
Edinburgh EH9 2AS
Tel: 0131 447 4784
www.snh.gov.uk

Scottish Water
Castle House
6 Castle Drive
Carnegie Campus
Dunfermline
Fife KY11 8GG
Tel: 01383 848200

Scottish Wildlife Trust
Cramond House
Kirk Cramond
Cramond Glebe Road
Edinburgh EH4 2NS
Tel: 0131 312 7765
www.swt.org.uk

WWF Scotland
8 The Square
Aberfeldy
Perthshire
PH15 2DD
Tel: 01887 820449
www.wwfscotland.org.uk



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