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The Management of Forest Streams

D H Mills

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PLATE 1 *(Front Cover).* The reinforcement of the river bank with large boulders on flat-faced stones to prevent undermining is linked to a small stone weir providing an attractive holding pool. Note the wide clear strip between woodland and stream.

THE MANAGEMENT OF FOREST STREAMS

Derek Mills

Department of Forestry & Natural Resources
University of Edinburgh

INTRODUCTION

Whilst the production of timber is likely to be the principal objective in most woodlands, any water features, whether stream, river, pond, lake or loch, are important assets deserving the forester's attention. Angling, whether for game or coarse fish, is a popular recreation from which the increased income will help justify the measures recommended in the following pages. Additional attractive and valuable benefits accrue, to be seen in the visual impact of richer and more varied herbaceous and woody vegetation at the water's edge, supporting and sheltering terrestrial and winged wildlife living in association with creatures in a healthier aquatic habitat.

The upland areas of the British Isles have been extensively afforested and it is in these areas that many of our salmon and trout rivers begin, arising from an extensive network of small, fast-flowing tributaries which serve as the spawning and nursery areas of these important fish species. These upland streams are invaluable to the river system and the degradation of their abundant, clean, cool, well-aerated and silt-free waters would lead to the loss of much of the area upon which the Atlantic salmon *(Salmo salar* L.) and trout *(S. trutta)* depend for the survival of their young. It is not always realised that even the smallest of these streams, some little more than a metre wide, can be important and even salmon and large sea trout, as well as the smaller brown trout, will penetrate these channels to deposit their eggs in the gravel in the early winter months. It is therefore important to appreciate how delicate the natural balance is when considering various forest management practices which could affect the aquatic environment.

A HEALTHY STREAM AND THE NEEDS OF ITS FISH

A stream environment has to have certain physical, chemical and biological characteristics if it is to be healthy and maintain a good stock of fish and other freshwater organisms upon which the fish feed, such as insect larvae, snails and freshwater shrimps.

A good, steady *flow of water* is of more value to fish than extremes of drought and flood. Flash-floods resulting from the rapid run-off from well-drained land, may cause serious erosion and are of little value for fish migration. Furthermore, they do not keep the stream bed-load in suspension for any length of time. In drought years, with some streams having low minimum flows as a result of land drainage, there is a tendency for pools to become shallower, the gravel more compacted and the streams more silted.[1] Changes in the flow regime may also be accentuated by higher water use by a forest through transpiration and it has been shown that trees can, under certain conditions, intercept substantially more water than open moorland in areas of high rainfall.[2]

Oxygen is an obvious requirement, as without a sufficient oxygen concentration dissolved in the water fish will be unable to breathe. Certain species of fish, such as salmon and trout, which are the dominant species in forest streams, require dissolved oxygen concentrations greater than 5mg per litre. *Water temperature* affects the level of oxygen in the water, warmer water having less dissolved oxygen. The temperature of the water must be less than 10°C before salmon and trout will spawn, while the optimum temperature for the growth of trout is in the region of 13-14°C and above 28°C both these species will die. A stream that

PLACE 2 All vegetation has been lost due to the dense canopy resulting from trees planted too close to the banks of this stream. Erosion is evident, the stability of some trees is much in doubt and there is a poor habitat for wildlife and fish.

is shaded will obviously remain cooler than one that is exposed to the direct rays of the sun, and shade can be provided by overhanging banks, thick ground vegetation or a dense tree canopy, and all of these will protect fish from predators and supply them with a source of terrestrial insects for food. However, *sunlight* is necessary if the green algae, upon which fish food organisms feed, are to grow and therefore a natural balance has to be struck between shade and light. A dense tree canopy can result in a reduction in stream productivity[3, 4, 5, 38]. Furthermore, the ground vegetation disappears and the stream banks become unstable and easily eroded, leading to lack of *cover* for the fish, silting up of the pools and a reduction in the terrestrial food component of the fish's diet (Plate 2). Sunlight can be excluded in other ways than by trees, and water made turbid by high levels of *suspended solids* reduces sunlight penetration. This suspended matter can also be damaging if it settles out on the gravel bed of the stream, as it may suffocate the developing eggs in the gravel and smother the insect larvae living between the stones. This is particularly true if the suspended solids consist of sediment washed into the stream through erosion of hill drains. If this suspended material is of organic origin it will be broken down by the action of bacteria and fungi and the resulting nutrients will be recirculated. Bacterial activity is high in alkaline water and low in acid conditions. Some streams running over rocks such as gneiss, schist and granite are poor in nutrients and have an acid reaction, while those flowing over carboniferous limestone and old red sandstone are nutrient-rich, have a good calcium content and high amounts of nitrates and phosphates.

Certain chemicals which find their way into water through being used on neighbouring land without suitable precautions can be injurious to the freshwater fauna. Some, such as DDT, dieldrin and the ester formulation of

2, 4, 5-T are directly toxic to fish while others affect fish indirectly by destroying their food organisms. Fenitrothion is one such chemical which can have this effect.

A stream has not only to have the correct water quality to support fish life but it has also to have a suitable *substrate* of silt-free gravel in which fish can lay their eggs. It also needs a sufficient *depth of water* to allow adult fish to ascend the stream at spawning time with security, as well as providing holding pools in which the fish can lie sheltered until it is time to lay their eggs in the gravel beds in the fast, shallow water at the tail of a pool. However, even suitable spawning areas will remain unvisited if fish cannot reach them through lack of water due to too rapid a run-off after rain, or if their upstream passage is barred by *barriers* of branches and logs that have fallen into the stream.

The absence of any one of the above requirements may make all the difference between success and failure in the completion of the fish's life cycle. Foresters can therefore influence the survival of salmon and trout in these upland streams in many ways.

FOREST MANAGEMENT AND STREAM CONSERVATION

Ploughing and Drainage

Sedimentation, resulting in silting of fish spawning and nursery areas and in-filling of holding pools, can occur from erosion of plough furrows and drainage channels on steep hillsides. Alignment of ploughing along the contour was once favoured and is still occasionally practised. It is now felt that this is inappropriate in wetland situations, since each furrow tends to 'pond' surface run-off and gives rise to lines of stagnant conditions. Alignments are now made to run roughly up and down the slope to improve run-off and to provide lines for downhill seepage when the furrows become filled with plant litter. The risk of severe erosion has been shown to be small, *provided cut-off drains* are used and individual down-hill furrows are *not* used to carry water draining from large areas lying above. The current policy of varying the lines of ploughing for landscape reasons or interrupting them on fragile areas further diminishes the risk from erosion. The alignment of the deep drains intended to collect water from the superficial furrows and from the subsoil should be nearly parallel with the contour, consistent with maintaining a suitable drain gradient.[7] A drain with a gentle gradient of no more than 2° is ideal and generally accords with normal forest practice. Except at the start of the drain, gradients steeper than 3° should be avoided to prevent severe erosion. The alignment of the drain should be designed to achieve the maximum interception effect with the minimum drain length. In order to catch silt where drains are leading to streams or small watercourses they should either be tapered in depth and stopped 15 to 20 metres short in order that the water discharging from these drains has to filter through the ground vegetation or, in areas of higher rainfall, a sump should be taken out just before the drain opens into the watercourse. On the very steep slopes where it is not possible to put in the cut-off drain, it is suggested that a large V-type sump drain should be cut along the bottom of the slope to trap debris which is carried down the plough furrows.[8]

From time to time it may be necessary to clean out certain drains within the forest if waterlogging is evident. This operation should be very carefully timed so that little silt enters the watercourses to affect the stream bed and bank habitats. For this reason, it is important not to clean out drains during the period mid-October to mid-May, if possible, as during this time the eggs, and latterly the alevins, are in the gravel and would be suffocated by the silt. The time of the early autumn floods would be the most suitable for cleaning drains, but care should be taken to remove as much of the silt and leaf litter as possible from the drain and deposit it on dry land some distance away from any watercourse.

Planting and Stream Bank Protection

Basically, the *protection of stream banks requires the establishment of permanent reserve* *strips of vegetation.* Valley topography, soil and aesthetic factors will usually help to define the area and shape of reserve strip required. Before considering the scale and the nature of the bank vegetation the importance of streamside vegetation should be stressed, as it:

a. shades water, stream bed and stream bank from the sun's heat,
b. provides energy to the stream through leaf fall, terrestrial insect drop and dissolved nutrients,
c. gives protective cover for fish,
d. protects the stream banks from channel erosion, erosion from overland run-off and the erosive effects of precipitation impact,
e. acts as a buffer against debris from overland run-off, and
f. intercepts toxic materials from spraying.[9]

Removal of streamside vegetation can facilitate stream temperature increases which may reach a lethal point for salmon and trout[10, 11].

Terrestrial insects have been shown to make up 5 to 65 per cent of the diet of trout and salmon in some streams. Most of these insects come from streamside vegetation and its removal reduces the number of insects available to trout and salmon, birds and some other animals.

Cover is important in providing hiding places for fish and it has been shown that the removal of bank vegetation and other shelter can destroy trout streams[12]. It has been found that larger brown trout were 27 per cent more numerous and weighed 44 per cent more in a sheltered section of stream than in a non-sheltered section[13], while trout were found to be 78 per cent more abundant in well-covered mountain streams than in an area where cover had been removed.

Stream bank vegetation also helps to maintain deep pools by preventing lateral erosion which results in a wider but shallower stream channel[14].

Reserve areas

The widths of the reserve areas of vegetation will vary with the landform but as a rough guide the overall width (both sides) could be 10 times the width of the stream, up to a maximum of 30 metres overall.

Within the reserve areas tree planting should be kept to the minimum required for landscape reasons; in addition heavy machinery should be confined, as far as possible, to using defined roads and tracks.

These areas may seem unnecessarily large but they will also help to counteract the effects of precipitation interception. Furthermore, they give easy access for anglers, walkers and staff.

Streamside vegetation

This can consist of ordinary ground vegetation and small deciduous tree species such as birch (*Betula* spp.), willow (*Salix* spp), rowan (*Sorbus aucuparia* L.) or alder (*Alnus* spp). Alders may also contribute substantial amounts of dissolved nutrients such as nitrates to the stream and it has been found that leaf fall from alders contained four times as much nitrogen as other deciduous species[15]. Alder grows vigorously on most stream sides and, to prevent excessive shading and to allow access for recreation and stream management, it should be used in well-scattered groups especially along streams less than 12 metres wide. If willows are used they require regular basal pruning. Their root systems are effective in preventing bank erosion. A variety of other species suitable for water margins has also been suggested[16], including common ash (*Fraxinus excelsior* L.) and aspen (*Populus tremula* L.)

Bank reinforcement

Where stream banks show signs of erosion, protection from further damage can be given by reinforcing the bank with mattress gabions, large stones, brushwood staked in with fence posts, tree trunks or boarding secured with piling, or by diverting the current with croys or groynes, or with boards secured to stakes. Once the banks are stabilised the character of the stream may be slightly altered and deeper pools may be formed (Front cover). Where there has been reinforcement, particularly on a sharp bend, it is advisable to ensure that the bank on the inside of the bend allows even a

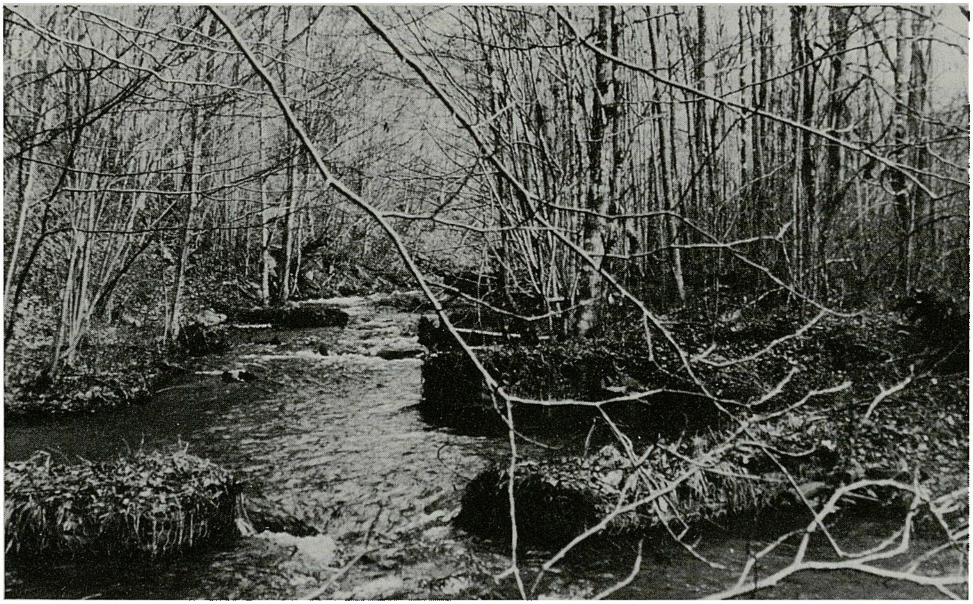

PLATE 3 A series of gabions increase the number of holding pools and help to stabilise the stream bed.

moderate flood to flow over it so as to take the pressure off the reinforcements.

One type of structure which is proving very useful in countering erosion is the gabion (Plate 3). These are large, steel wiremesh baskets, rectangular in shape, variable in size, and galvanised to ensure long life in and around water; for added protection they can be obtained with a plastic coating. These baskets are filled while in tension with hand-size (larger than the mesh openings), clean boulders. These gabions are permanent, flexible and maintenance free. Being wire baskets they are easily transported to the site and can be filled with stones from the river or from nearby areas. The gaps between the stones in the gabions may also increase the aquatic insect life in the stream. A natural appearance can easily be achieved by covering them with vegetation. They can also be used to check the erosion which occurs near weirs on torrential streams. Where the river runs through wide and often multiple channels gabion groynes can play a useful role in controlling the watercourse. The groynes are usually required on concave bends and in straight channels, rarely on convex bends.

All reinforcing structures must, of course, be carefully designed to maintain the aesthetic quality of the stream.

Fencing

Where fences are needed they should be erected well back from the stream bank and above the flood channel so that they will not catch debris or be washed out during high flows. The fences should be far enough back to allow vegetation control and stream improvements and not to interfere with angling. It must be remembered that some grazing animals can stretch their heads through a fence and graze bare the other side to a distance of about a metre. For this reason too, fences should be well back from the outside banks of the bends as the stream may soon undermine the fence unless bank protection devices have been constructed.

Barbed wire may be required on stock fences but, in any event, stiles should be erected at suitable places. Where livestock must have access to the water their access should be on gently sloping ground where the stream substrate is hard and the water shallow. Their approach paths, which should be wide enough to prevent bunching up and panic, should be fenced on either side[17].

Where boundary or accommodation fences or drystone walls cross a water course, a water-gate is often necessary to prevent stock passage. Water-gates will vary in design but must always be independent of the fence. They should be examined for damage after spate to ensure removal of debris of any kind which hinders stream flow and the passage of fish and, also in periods of drought, to see that they are effective barriers to stock.

Road Construction

Road building may initially cause erosion until the exposed soil and tracks have become stabilized, and badly positioned culverts may hinder or prohibit fish ascent. Proper drainage should be incorporated into road construction to minimize erosion on the road surface, on the slopes and in the ditches. In order to achieve this the following steps are usually necessary:

a. Water from roadside drains should be discharged into water courses at frequent intervals, culverts being provided where necessary.
b. Drainage structures should be of a sufficient size to accommodate run-off from the drainage area.
c. Where ditches drain directly into permanent watercourses, a sump to trap silt and debris may be necessary.
d. Special erosion control measures may be required on roadside banks including such measures as intercepting trenches or terracing. Bare earth embankments and cuttings should be left at the natural angle of repose to encourage the establishment of vegetation.
e. Culverts should be rip-rapped as necessary, to prevent erosion at both inflow and outflow ends. This is done by reinforcing the substrate at each end and reducing flow velocities.
f. The outflow ends of hanging culverts should be provided with down flumes or other suitable drains where necessary. Rock or concrete aprons should be provided as stilling areas to decrease water velocity and prevent stream-bed erosion.
g. Culverts or other drainage devices should be placed so as to attain a maximum drainage efficiency.
h. Whenever possible culverts should be installed so as to allow passage of fish on all watercourses frequented by them.
i. The inverts of culverts should be laid to be self-cleansing and properly bedded to avoid settlement. The size of the culvert will depend on the characteristics of the catchment area and the natural watercourses.

Fords for heavy vehicles and forest machinery should not be used at high flows and care must always be taken to avoid oil spillage. Fords are sometimes used as spawning grounds by salmon.

Where it is necessary to extract gravel from a watercourse it is essential that this is done in amounts and at a period which will minimize damage to fish, especially migratory fish. Consultation with the river authority, the riparian owner and tenants are advisable. It is essential that the stability of the stream bed is subsequently restored.

Spraying

The effects on fish and stream insect populations of improperly controlled forest spraying have been well documented[18, 19, 20, 21]. It is common knowledge that spraying over watercourses should be avoided if at all possible and that the correct spray dosages should be used to minimize the damage to fish and wildlife. When agricultural chemicals are used at recommended rates and with due care the risk to fisheries is relatively small and limited to certain types of chemicals[22]. In the event of accidental spillage or careless disposal of concentrated chemicals, however, the problem is more serious. Exposure of fish for only a few minutes to high concentrations can result in a rapid absorption of the toxicant via the gills and death follows quickly[22]. For this reason *no spraying equipment or empty, or partially empty tins or drums of chemical should be washed out in or near any watercourse, however small, nor should empty containers be punctured and buried.* Advice should be sought from the appropriate authority (i.e. the relevant water authority in England and Wales and the local river purification board in Scotland) on the safe disposal of unwanted chemicals.

Application of Fertilisers

Leaching of fertilisers into streams in forested catchments after the forests have been fertilised has been well recorded[23, 24, 25]. In some cases, this leaching has had little effect on water quality and in other instances it has been suggested that it could increase stream productivity and so be beneficial. However, leaching into streams running into closed areas of water, such as lakes and reservoirs, could produce undesirable conditions of eutrophication and for this reason fertiliser programmes should be considered with water authorities if domestic supply reservoirs are likely to be affected.

Fire

In order to provide a ready supply of water for fire-fighting purposes it is sometimes the practice where the land configuration is suitable to impound small streams and form what are known as 'fire dams'. It can be achieved with less damage to the stream environment if water is diverted into an excavated pond to one side of the stream channel. In this way the stream is kept open along its length and the passage of fish is consequently not hindered. Furthermore, the silt load in the stream is not trapped in the 'fire dam' to lower the dam's capacity and value.

Thinning, Felling and Extraction

There has been considerable research on the effects of these operations on fish and their stream environment, and probably the effects of logging on stream quality and salmon and trout populations in North America have received the most attention[26, 27, 28, 29]. The major effects of these activities can be changes in streamflow and water temperature, sedimentation, loss of nutrients, damage to spawning grounds, blockage of streams, prevention of the movement of migratory fish and bacterial decomposition of any bark and wood debris smothering the stream bed.

Preventing the fall of lop and top into streams is the best way to control the last three mentioned effects. *Trees should be felled away from streams* wherever possible. If tree tops and branches do enter a stream they should be removed as soon as possible, certainly no later than when the logs are extracted. Before felling teams move away the stream should be checked to ensure that the lop and top is neither in the stream nor likely to enter the stream on high flows.

When logs are to be moved care should be taken not to break the soil surface of the forest floor unduly, resulting in stream sedimentation. This can be done by:

a. avoiding the use of long skid-roads on steep slopes,
b. stacking logs well away from watercourses,
c. not operating heavy equipment in or near streams.

STREAM IMPROVEMENT

Whilst the forester's objective should be to conserve the environment of streams for landscape benefits and as stable habitats for aquatic and other wildlife, he should consider where recreational potential, particularly for angling, can be increased and how the improvement of fish stocks can be achieved. This can be done by providing more cover to protect fish from predation, consequently ensuring better survival. By increasing the volume of water, the fish can attain a greater size.

A deep channel gives good protection to fish, and deep areas in the stream bed, or pools, occur naturally as parts of the meandered channel pattern of even slow-flowing streams as well as in faster streams where there is the usual alternating sequence of pools and shallow, fast-flowing riffles. In many streams, however, the total volume of the channel far exceeds that portion which either salmon or trout can effectively use. Much of the channel may be too shallow for large fish to rest in prior to spawning, and other parts of insufficient depth to provide protection.

Three ways of overcoming these deficiencies and providing better living space and more fishable water for anglers is by the use of wing-deflectors, bank covers and low weirs.

Wing Deflectors

Useful for modifying stream channels, they are built out from the bank of the stream to deflect the water flow. They are best constructed in a roughly triangular shape and filled with rocks and soil. Many deflectors are badly designed and consist simply of single logs or sheet piling. Since water spills off an obstruction at right angles to the last surface it touches, downstream edges of triangular structures conduct high water back into the stream while single logs protruding out from the bank cause high water to plunge toward the stream bank and erode holes between the log wings and the bank. Deflectors should guide the current into a self-deepening, scouring action rather than dam it, and they should have no protrusions on which drifting debris can accumulate. They should not be built at the top of riffles but preferably part way down, at its tail or in the slack water beyond. They should be low enough to allow the bulk of high stream flows to pass over the top. High deflectors concentrate floodwater and so tend to erode the stream bed. It is suggested that deflectors should not protrude more than 25 centimetres above normal summer water level[17].

Bank Covers

As artificial overhanging ledges at the outside of bends in the stream, they consist of a platform built out from the side of the stream and covered with boulders, earth and vegetation to make the structure appear as natural as possible. In certain instances where these have been installed they have resulted in a 52 per cent increase in the number of pools, a 50 per cent increase in the biomass of trout and a 196 per cent increase in the yield of trout to anglers[30].

The procedure for the construction of these covers is illustrated in Figure 1 (opposite) and consists of:

a. Sinking pairs of 2-metre long (preferably oak or elm) pilings into the stream bed to a depth that leaves their tops below water.
b. Nailing 7.5 centimetre thick boards (stringers) to each pair of pilings at a right angle to the stream.
c. Nailing 7.5 centimetre thick oak planks to the stringer boards and parallel to the stream bank. These wooden substructures, completely under water, provide platforms one-third to one metre out from the natural stream bank.
d. Covering the substructure platforms with rocks and filling in a wall of rocks between the inner edge of the platforms and the old stream bank.
e. Covering the protruding wood and rock structure with grassy sod to stabilise the devices and restore the aesthetic appearance of the stream.

Low Weirs

These or dams can be used on streams with a fairly steep gradient both to deepen existing pools and create pools from stretches of uniformly shallow water. The main point to watch in pool construction is that spawning areas are not flooded out and that pool formation does not result in flooding of surrounding land at high flows. Gabions are ideal structures for making weirs but care must be taken to ensure that they are securely anchored into the stream bed and are not likely to be washed out in exceptional floods. It is always advisable to continue each end of the weir well into the banks so as to give it additional anchorage. It is sometimes an advantage to step the weir by

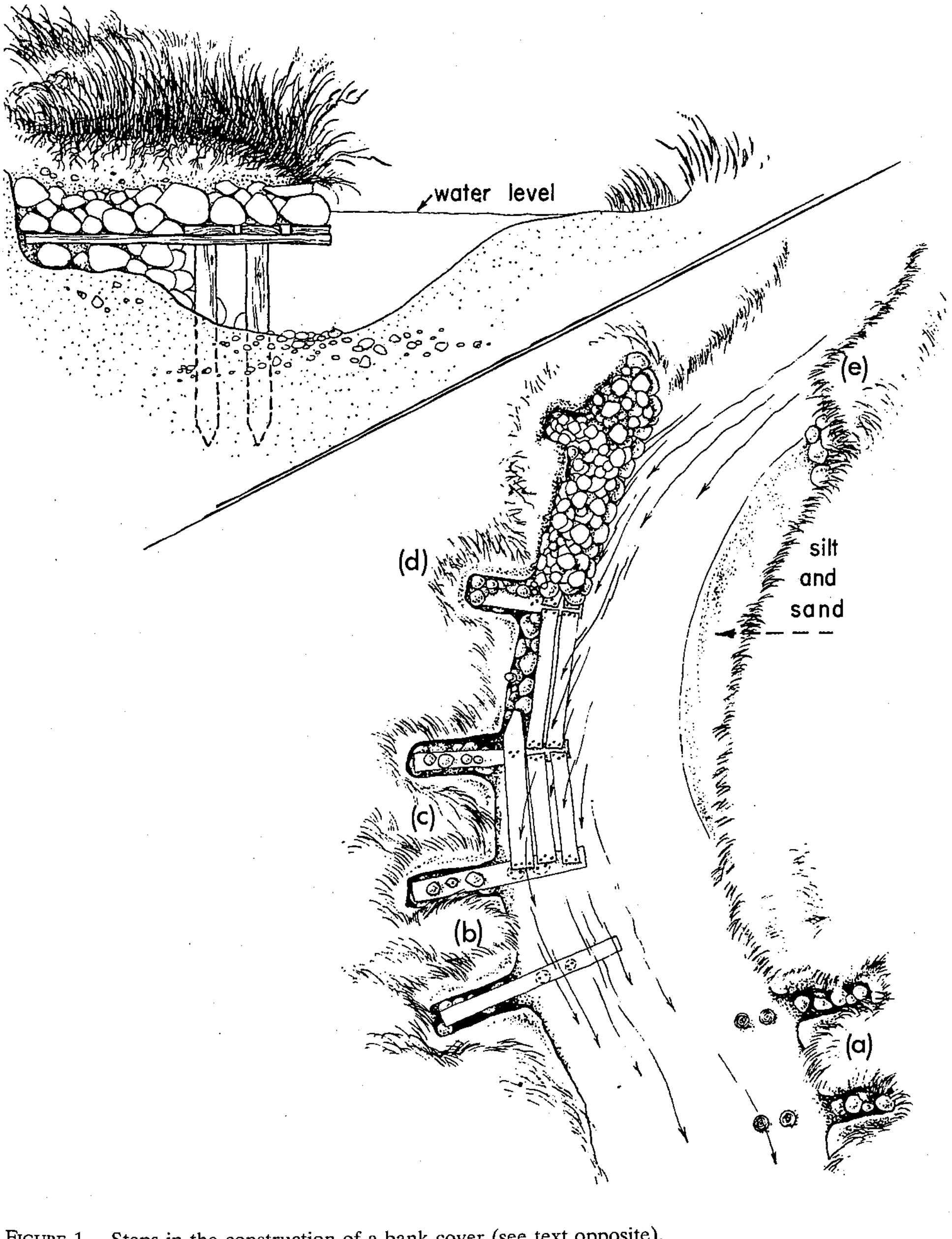

FIGURE 1. Steps in the construction of a bank cover (see text opposite).

placing in, say, three rows of gabions, each row one layer higher than the next in an upstream direction, thus giving the weir added strength. Care must be taken to see that the ascent of migratory fish is not affected, and a gap in the centre of the weir is usually sufficient to allow the passage of fish.

Occasionally, pools can be deepened by placing a log across the stream channel and anchoring it in position with iron stakes. The upstream side of the log is filled up with boulders so that the stream bed upstream of the log slopes up to the log dam. Scouring on the downstream side can be prevented by placing large flat boulders close in to the log to take the impact of the water cascading over. This type of log dam is sometimes useful in arresting or slowing up the downstream movement of gravel, the absence of which could influence the spawning success of salmon and trout.

There are many miles of stream in the British Isles which would make suitable spawning areas for salmon and sea trout that, for one reason or another, are barred to these fish. In opening up such spawning areas to migratory fish it may be necessary to ease insurmountable falls. Frequently this can be done by judicious blasting, but this is a skilled operation and if not carried out correctly can lead to further problems due to fracturing of neighbouring rock and may lead only to a temporary easement before the falls are again insurmountable due to breaking off of fractured rock through flood or frost action or blocking of the river channel by dislodged boulders. It is often wiser to circumvent falls by excavating a by-pass channel and installing a fish pass[31, 32, 33].

STREAM SURVEY

The fishing potential of a stream, and even its ability to hold fish, can be assessed by sampling the stream habitat characteristics. Sampling is done by taking measurements along selected transects across a stream. The frequency of sampling should be every 200 metres. At every 200 metres a group of 5 transects is made, and the spacing between each transect is 2 metres. The results can give good estimates of stream width, surface area, pool and riffle area, depth and stream bed composition as well as the stability and vegetative cover of the stream banks and the quality of the pools for their fish-holding capacity[34].

The characteristics to measure which are recorded on the form depicted (Table 1) are:

Width

The width of the water surface is measured to the nearest half-metre. Protruding rocks, stumps or logs are included as part of the total width. Note whether the channel is at high- or low-water level.

Depth

Depth is measured to the nearest centimetre at three points (A, B, C) along each transect at intervals of one quarter, one half and three-quarters of the distance across each channel.

Pools

Five pool-quality classes are given in Table 2. These have been designed on the basis of pool size, water depth and fish shelter. The deeper and larger pools are considered better fish habitat than the smaller, shallower and more exposed pools.

Bottom Composition

Five types of bottom material are indicated by initials and defined as follows:

Boulder (B) — Rocks over 300 mm in diameter

Rubble (R) — Rocks 50 to 300 mm in diameter

Gravel (G) — Rocks 3 to 50 mm in diameter

Sand-silt (S-S) — Particles less than 3 mm in diameter

Other (O) — Other matter (sunken logs or other debris).

Bank Stability

Bank conditions at each end of a transect are rated either as 'stable' (S) or 'unstable' (U). An unstable rating is given if there is any evidence of soil sloughing within the past year. The number of stable banks for each transect is recorded as 0, 1 or 2. On multiple channels, only the two outermost banks are rated.

Streamside vegetation
Three types of streamside vegetation are recognised: 'forest', 'shrub', and 'open'. Forest is defined as stands of trees. Other woody vegetation is defined as 'shrub' and banks without woody types of vegetation are defined as 'open'.

Aquatic vegetation
At the time of recording the above features a note should also be made of the presence and abundance of aquatic plants. An example of the results which will be obtained is given in Table 3 which summarises the habitat characteristics of a small forest stream in Peeblesshire.

Flows
These can be measured in a number of ways. The simplest is by multiplying the cross-sectional area by the speed of flow as measured by a floating object. Frequently an orange has been used as a float, as it is conspicuous and travels along almost entirely submerged. The following formula can also be used:

$$D = W \alpha d \, l/t$$

when D = discharge (in cubic metres per second), W = width (in metres) d = mean depth (in metres) and l = distance (in metres) over which the float travels in time, t (in seconds). The term α is a coefficient which varies from 0.8 if the stream bed is rough, to 0.9 if it is smooth (mud, sand, bedrock).

Water Chemistry
Water quality data (pH, alkalinity, suspended solids, etc) may be available from the appropriate regional water authority or river purification board.

Table 1 Stream sampling record

Drainage Unit No. ....

Sample No. ....

Field Crew ....

Date ....

Photo No. ....

Transect No.	Channel No.	Total width	Riffle width	Pool width	Width										Vegetative bank cover			Bank stability		Stream channel depth				Average gradient
					Pool quality[1]					Bottom material														
					1	2	3	4	5	B	R	G	S-S	O	F	Sh	O	S	U	A	B	C	Av.	
		metres			metres										No. of banks					centimetres				Per cent
Total																								

[1] See Table 2.

Table 2 Pool quality recognition guide.

	Pool		
Quality class no	*Length or width*	*Depth*	*Shelter*[1]
1	Greater than a.c.w.[2]	60 cm or deeper	Abundant[3]
	Greater than a.c.w.	90 cm or deeper	Exposed[4]
2	Greater than a.c.w.	60 cm or deeper	Exposed
	Greater than a.c.w.	<60 cm	Intermediate[5]
	Greater than a.c.w.	<60 cm	Abundant
3	Equal to a.c.w.	<60 cm	Intermediate
	Equal to a.c.w.	<60 cm	Abundant
4	Equal to a.c.w.	Shallow[6]	Exposed
	Less than a.c.w.	Shallow	Abundant
	Less than a.c.w.	Shallow	Intermediate
	Less than a.c.w.	<60 cm	Intermediate
	Less than a.c.w.	60 cm or deeper	Abundant
5	Less than a.c.w.	Shallow	Exposed

[1] *Logs, stumps, boulders and vegetation in or overhanging pool, or overhanging banks.*
[2] *Average channel width.*
[3] *More than ½ perimeter of pool has cover.*
[4] *Less than ¼ of pool perimeter has cover.*
[5] *¼ to ½ perimeter of pool has cover.*
[6] *Approximately equal to average stream depth.*

Table 3 Summary of stream drainage characteristics for the Kirk Burn, Peebles-shire.

		Total			*Coniferous forest*			*Pasture and deciduous woodland*		
		No.	*%*	*Area (ha)*	*No.*	*%*	*Area (ha)*	*No.*	*%*	*Area (ha)*
Transects		40			21			19		
Adjusted stream lengths (km)		4.9			3.4	68.5		1.5	31.5	
Average width (metres)		2.3			2.2			2.3		
Surface area				1.14			0.74			0.40
Riffle area			50.4	0.56		47.7	0.35		54.7	0.21
Pool area			49.6	0.58		52.3	0.39		45.3	0.19
Bank stability			60.0			45.2			76.3	
Proportion of pool area by quality	Class 1		0			0			0	
	Class 2		41.4			35.3			50.0	
	Class 3		0			0			0	
	Class 4		37.9			41.2			33.4	
	Class 5		20.7			23.5			16.6	
Proportion of bottom area by material	Boulder		22.7			24.0			19.6	
	Rubble		57.2			54.3			65.7	
	Gravel		7.9			9.5			3.4	
	Sand/silt		11.8			12.2			11.2	
	Other		0			0			0	
Proportion of stream bank vegetation type	Forest		50			80.9			15.8	
	Shrub		12.5			7.1			18.4	
	Open		37.5			11.9			65.8	
Average depth (cm)		18.5			17.4			19.7		
Average gradient			4.7							

FISH STOCKING POLICIES

The subject of stocking streams is a large one. In many situations, a great deal of money has been wasted in introducing fish either to waters where their chances of survival have been poor, or where there was no need to supplement the existing natural stock of fish.

Supplementing natural reproduction by artificial propagation is usually necessary when:

a. there is a deficiency in natural reproduction;

b. where the species has in the past been reduced or eliminated or

c. where the species, for one reason or another, has not existed previously. It is also carried out in sport fisheries on a 'put and take' basis where the aim is to introduce fish of takeable (legal-sized) or near takeable size with a view to catching them within a very short time.

Some of the questions to be asked before considering artificial propagation are: will stocking work in this situation, is the population regulated by density-dependent factors or limited by density-independent factors, and what is the carrying capacity of the stream? The carrying capacity is usually considered to be the ability of the environment to support a population in good conditions indefinitely and not the number of animals it can hold for a short time.

The stocking of a river should be done in the first place by means which make use of the river's own production capacity, whenever it can be restored, or when lost production areas can be replaced by stream improvement or by opening up new grounds to the fish. Where natural spawning occurs there is little advantage gained by introducing eggs or young fish. Unless the number of spawners is obviously too low for the area to be adequately occupied by their progeny, the number of young resulting from natural spawning will 'in most cases' very soon adjust itself to a level corresponding to the amount of space and food available. If more fish are added the competition is increased and many of either the introduced fish or those already present will die, the equilibrium will be restored and little or nothing will be gained.

Salmon stocking can be done at either the egg, fry, parr or smolt stage and the merits and results of such plantings have been well documented and reviewed[35, 36].

Stocking rivers and streams already holding a natural stock of *brown trout* and having good spawning tributaries is not worthwhile unless there has been severe mortality from pollution or from the various effects of afforestation or where angling activity is very intense and some stocking on a 'put and take' basis is required. Disturbance from intense angling activity is often the reason for low catches rather than lack of fish.

Stocking on a 'put and take' basis in running waters is successful, but the amount of benefit that the riparian owner or angling club that does the stocking will get from such an operation depends on the extent of their fishings. For example, it was found[37] that of five hundred 25cm tagged hatchery-reared brown trout released into the River Tweed at the end of March, a total of 206 (41 per cent) were recaptured by 75 anglers between the opening of the fishing season on 1st April and 1st September, but 97 per cent of the recaptures were made in the first three months after release and 95 per cent were taken within 5 km of the release site. The club into whose waters these trout had been liberated have more than 50 km of river under their control and so the venture was a success, but a club that has smaller stretches of water may find that neighbouring owners benefit more from the introduction, particularly those owning water lower down the river. For example, in the above exercise, it was found that while similar numbers of trout were recaptured upstream and downstream of the release site, the distance (29 km) travelled downstream by some fish was greater than that covered upstream (2.6 km).

Timing is also important in stocking as, if releases are made some time before the start of the angling season, fish may become too well dispersed.

From the results of the Tweed experiment it was found that the majority of the introduced fish were caught during the first few weeks of the season, after which progressively fewer were caught. To overcome this, the 'once-a-season' stocking can be replaced by 'topping-up' with small numbers of fish at intervals throughout the season.

LIAISON

Our forests and fisheries are both important natural resources and there is no reason why these resources, with wise management, should not be compatible. The most certain way of achieving such compatibility is through liaison between forest, fishery and river personnel. In England and Wales this involves contact with the relevant river division of the appropriate regional water authority. On matters of water quality the water quality officer should be approached. For example, it might be that information on fertilisation programmes would be useful to the resource planning division in case there are water supply reservoirs or proposed reservoirs in the area whose water quality could be affected. On purely fisheries matters (e.g. spraying programmes, road building or felling) the divisional fishery officer should be contacted. As the administrative structure varies in each regional water authority it is advisable to obtain information on the various divisions from the publication *Who's Who in the Water Industry* published by the National Water Council, Queen Anne's Gate, London.

The position in Scotland is very different. The water quality of rivers is the concern of the river purification boards of which there are seven — the Tweed, Solway, Clyde, Forth, Tay, North-East and Highland. Migratory fish, salmon and sea trout, are the concern of the salmon district fishery boards, of which there are a large number. Details of these can be obtained from the Inspector of Salmon and Freshwater Fisheries for Scotland, Chesser House, Gorgie Road, Edinburgh. On most matters it is also a courtesy to keep the local landowners informed of developments.

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Enquiries relating to this publication should be addressed to the Publications Officer, Forestry Commission Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, GU10 4LH

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